BS ISO 13063:2012

BSI Standards Publication

Electrically propelled mopeds and motorcycles — Safety specifications

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee AUE/14, Motor cycles and mopeds.

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

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ISBN 978 0 580 71421 4

ICS 43.140

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 September 2012.

Amendments issued since publication

Date	Text affected

BS ISO 13063:2012

INTERNATIONAL STANDARD

ISO 13063

First edition
2012-09-15

Electrically propelled mopeds and motorcycles — Safety specifications

Cyclomoteurs et motocycles à propulsion électrique — Spécifications de sécurité

Reference number
ISO 13063:2012(E)

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Foreword

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ISO 13063 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 23, *Mopeds*.

Electrically propelled mopeds and motorcycles — Safety specifications

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1 Scope

This International Standard specifies requirements for functional safety means, protection against electric shock and the on-board rechargeable energy storage systems intended for the propulsion of any kind of electrically propelled mopeds and motorcycles when used in normal conditions.

It is applicable only if maximum working voltage of the on-board electrical circuit does not exceed 1000 V a.c. or 1500 V d.c.

This International Standard does not provide comprehensive safety information for manufacturing, maintenance and repair personnel.

2 Normative references

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

ISO 3864-1, *Graphical symbols — Safety colours and safety signs — Part 1: Design principles for safety signs and safety markings*

ISO 6469-3, *Electrically propelled road vehicles — Safety specifications — Part 3: Protection of persons against electric shock*

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 60479-1:2005, *Effects of current on human beings and livestock — Part 1: General aspects*

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

IEC 60950-1, *Information technology equipment — Safety — Part 1: General requirements*

3 Terms and definitions

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

3.1
auxiliary electric system
on-board vehicle system, other than for vehicle propulsion, which operates on electric energy

3.2
balance of electric power system
remaining portion of an electric power system when the power sources (e.g. fuel cell stacks, batteries) are disconnected

3.3
barrier
part providing protection against direct contact from any usual direction of access

3.4
basic insulation
insulation applied to live parts for protection against direct contact under fault-free conditions

NOTE Basic insulation does not necessarily include isolations used exclusively for functional purposes.

3.5
basic protection
protection against direct contact with live parts under fault-free conditions

3.6
battery-electric vehicle
BEV
electric vehicle with only a traction battery as the power source for vehicle propulsion

NOTE The abbreviation BEV is often shortened to EV.

3.7
battery pack
single mechanical assembly comprising battery cells and retaining frames or trays and possibly components for battery management

3.8
BEV operating mode
in operating mode of an HEV, in which only the RESS is used for energy supply for vehicle propulsion and possibly auxiliary electric systems

3.9
conductive part
conductor
part capable of conducting electric current

3.10
creepage distance
shortest distance along a surface of a solid insulating material between two conductive parts

3.11
direct contact
contact of persons with live parts

3.12
double insulation
insulation system comprising both basic insulation and supplementary insulation

3.13
drive direction control
device physically actuated by the rider for selecting the driving direction of the road vehicle (forward or backward)

EXAMPLE Lever or push-button switch.

3.14
driving-enabled mode
only operating mode in which the vehicle can be moved by its own propulsion system

3.15
electric chassis
conductive parts of a vehicle that are electrically connected and whose potential is taken as reference

3.16
electric drive
combination of an electric motor and associated power electronics for the conversion of electric to mechanical power and vice versa

3.17
electric power system
electric circuit, containing electric power sources (e.g. fuel cell stacks, batteries)

3.18
electric shock
physiological effect resulting from an electric current passing through a human body

3.19
electrically propelled vehicle
EPV
vehicle with one or more electric drive(s) for vehicle propulsion

3.20
enclosure
part providing protection of equipment against direct contact from any direction

3.21
exposed conductive part
conductive part of the electric equipment that can be touched by a test finger according to IPXXB after removing barriers/enclosures that can be removed without using tools and that is not normally live, but which may become live under fault conditions

NOTE Protection degrees (e.g. IPXXB) are defined in ISO 20653.

3.22
hybrid electric vehicle
HEV
vehicle with at least one RESS and one fuelled power source for vehicle propulsion

EXAMPLE ICE or fuel-cell systems are typically types of fuelled power sources.

3.23
isolation-resistance monitoring system
system which periodically or continuously monitors the isolation resistance between live parts and the electric chassis or exposed conductive parts

3.24
isolation resistance
resistance between live parts of voltage class B electric circuit and the electric chassis or exposed conductive parts as well as the voltage class A system

3.25
live part
conductor or conductive part intended to be electrically energized in normal use

3.26
maximum working voltage
highest value of a.c. voltage (rms) or of d.c. voltage which may occur in an electric system under any normal operating conditions according to manufacturers' specifications, disregarding transients

3.27
potential equalization
electric connections of exposed conductive parts of the electric equipment to minimize differences in potential between these parts

3.28
protection degree
protection provided by a barrier/enclosure related to the contact with live parts by a test probe, such as a test finger (IPXXB), a test rod (IPXXC), or a test wire (IPXXD)

NOTE Protection degrees (e.g. IPXXB, IPXXC or IPXXD) are defined in ISO 20653.

3.29
rechargeable energy storage system
RESS
system that stores energy for delivery of electric energy and which is rechargeable

EXAMPLE Batteries, capacitors.

3.30
reinforced insulation
insulation of live parts for protection against electric shock equivalent to double insulation

NOTE Reinforced insulation does not imply that the insulation shall be a homogeneous piece. The reinforced insulation may comprise several layers which cannot be tested individually as supplementary or basic insulation.

3.31
supplementary insulation
independent insulation applied in addition to basic insulation for protection against electric shock in the event of a failure of the basic insulation

3.32
traction battery
propulsion battery
battery
collection of all battery packs, which are electrically connected, for the supply of electric power to the electric drive and conductively connected auxiliary system, if any

3.33
voltage class A
classification of an electric component or circuit as belonging to voltage class A, if its maximum working voltage is ≤ 30 V a.c. or ≤ 60 V d.c., respectively

3.34
voltage class B
classification of an electric component or circuit as belonging to voltage class B, if its maximum working voltage is (> 30 and ≤ 1000) V a.c. or (> 60 and ≤ 1500) V d.c., respectively

3.35
wiring
a system of wires providing electric circuits and including cables and connectors

4 Environmental and operational conditions

The requirements given in this International Standard 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 ISO 16750 for guidance.

5 Voltage classes

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

Table 1 — Voltage classes

Dimensions in volts

Voltage class	Maximum working voltage	
	d.c.	a.c.
A	0 < U ≤ 60	0 < U ≤ 30
B	60 < U ≤ 1500	30 < U ≤ 1000
NOTE The values 60 V d.c. and 30 V a.c. are selected taking into account humid weather conditions.		

6 Marking

6.1 Marking of voltage class B electric components

The symbol shown in Figure 1 shall appear on (preferably) or near voltage class B electric energy storage systems as RESS and fuel cell stacks. The same symbol shall be visible on barriers and enclosures, which, when removed expose live parts of voltage class B circuits. Accessibility and removability of barriers/enclosures should be considered for the necessity of the symbol. The symbol background shall be yellow, the bordering and the arrow shall be black in accordance with ISO 3864-1.

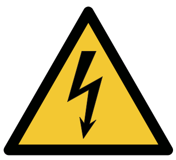


Figure 1 — Symbol of voltage class B electric components

6.2 Marking of voltage class B wiring

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

NOTE 1 Voltage class B connectors can be identified by the harnesses to which the connector is attached.

NOTE 2 Specifications of orange colour are given, e.g., 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 and measures of voltage class A electric components

7.1 Requirements of voltage class A electric components

7.1.1 General requirements of voltage class A electric components

The electrical control system shall be designed so that, should it malfunction in a hazardous manner, it shall switch off power to the electric motor.

Safety and compatibility of the combination between RESS and any auxiliary electric energy supplies shall be ensured, according to the manufacturer's specifications.

7.1.2 General requirements of barrier/enclosures of voltage class A electric components

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

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

7.1.3 Requirements of voltage class A electric cables and connections

Cable and plug temperature shall be lower than that specified by the manufacturer of the cables and plugs. There shall be no corrosion on plug pins and no damage to cable and plug insulation.

Compliance shall be checked by the test described in 7.2.1.

7.1.4 Requirements of voltage class A wiring

The following provisions apply to voltage class A wiring:

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.

Separate parts of the RESS that can move in normal use or during user maintenance relative to each other, shall not cause undue stress to electrical connections and internal conductors, including those providing earthing continuity.

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. If flexing occurs in normal use, the appliance is placed in its normal operational position and is supplied at rated voltage under normal operation.

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 7.2.2.

f) The insulation of internal wiring shall withstand the electrical stress likely to occur in normal use.

Compliance with f) shall be checked by the test described in 7.2.2. 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.

7.1.5 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 protection measures adopted by the manufacturer. Compliance is checked by inspection.

7.2 Test procedures for the protection measures of voltage class A electric components

7.2.1 Test method of voltage class A electric cables and connections

Cable and plug temperature shall be checked by the following test method.

Discharge the fully charged RESS to the discharging limit at the maximum allowable current specified by the vehicle manufacturer and record the current.

Measure the cable and plug temperatures and ensure that they are lower than the levels specified by the manufacturer.

7.2.2 Test method of voltage class A wiring

7.2.2.1 Test method for the movable part of the voltage class A wiring

The flexibility of movable part of the wires shall be checked by the following test method.

The wires shall maintain to flex the largest angle specified by manufacturer or permitted by the construction after the test.

The wires shall be flexed with the largest angle specified by the manufacturer or permitted by the construction for 10.000 cycles with the test frequency of 0,5 Hz at (20 ± 5) °C.

After the above flexibility test, the wire shall be tested for the electrical strength as described in 7.2.2.2.

7.2.2.2 Test method for the voltage withstanding electrical strength

The wiring and the connectors shall be checked by the electrical strength test.

The test voltage, expressed in volts, shall be equal to (500 + 2 x V_r) for 2 min and applied between live parts and other metal parts only.

NOTE V_r is the rated voltage.

Or, the safety and compatibility of the wires for the voltage withstanding electrical strength, shall be ensured by the vehicle manufacturer.

To perform the test of the voltage withstanding electrical strength, the vehicle need to be prepared as follows:

a) traction batteries shall be disconnected at their terminals from the power system;

b) electric power sources of the voltage class A power systems other than the traction batteries (fuel cell stacks, capacitors) may be disconnected at their terminals from the power system; if they remain connected power generation shall be deactivated;

c) all live parts of the balance of the voltage class A power systems shall be connected to each other;

d) all exposed conductive parts of the voltage class A power systems shall be connected to the electric chassis.

8 Measures and requirements for protection of persons against electric shock of voltage class B electric components

8.1 General requirements of voltage class B electric components and RESS

Protection against electric shock shall be comprised of

a) basic protection measures against direct contact with live parts (basic protection), and

b) measures for protection under first failure conditions.

The protection measures shall meet the requirements as described in 8.2 and 8.3 and compliance shall be tested according to test methods specified in Clause 9.

8.2 Basic protection measures of voltage class B electric components and RESS

Persons shall be protected against direct contact with the live parts of the voltage class B electrical circuits.

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

a) basic insulation of the live parts;

b) barriers/enclosures, preventing access to the live parts.

The barriers/enclosures may be electrically conductive or non-conductive.

8.3 Protection under first failure conditions of voltage class B electric components and RESS

8.3.1 General

The voltage class B circuits shall have sufficient isolation resistance according to requirements in 8.7.

If the minimum isolation resistance requirement (see 8.7) cannot be maintained under all operational conditions and over the entire service life, one of the following measures shall be applied:

a) monitoring of the isolation resistance periodically or continuously. An appropriate warning shall be provided if loss of isolation resistance is detected. The voltage class B system may be deactivated depending on the operational state of the vehicle or the ability to activate the voltage class B system may be limited;

b) double insulation or reinforced insulation;

c) an additional layer of barriers/enclosures over the basic protection.

NOTE Isolation resistances below the required minimum values may occur due to deterioration of FC systems cooling liquids or of certain battery types.

Exposed conductive parts of voltage class B electric equipment including exposed conductive barriers/enclosures shall be bonded to the electric chassis and/or exposed conductive parts for potential equalization.

8.3.2 Voltage class B d.c. circuits

If a credible first failure condition which may be specified by the vehicle manufacturer may render direct contact to live parts of voltage class B d.c. circuits, protection shall be achieved for capacitances which are directly or indirectly connected between terminal of class B voltage and chassis by fulfilling at least one of the following options:

— the energy of the total capacitance between any energized voltage class B live part and the electric chassis and/or exposed conductive parts shall be < 0,2 J at its maximum working voltage. Total capacitance should be calculated based on designed values of related parts and components;

— the potential d.c. body current shall meet zone DC-2 in Figure 22 of IEC 60479-1:2005 including the requirement of 10 mA;

— alternative electrical or mechanical measures for d.c. voltage class B electric circuits; see 8.3.4.

8.3.3 Voltage class B a.c. circuits

If a credible first failure condition which may be specified by the vehicle manufacturer may render direct contact to live parts of voltage class B a.c. circuits, protection shall be achieved for capacitances which are directly or indirectly connected between terminal of class B voltage and chassis by fulfilling at least one of the following options:

— the potential a.c. body current shall not exceed 5 mA when measured in accordance with IEC 60950-1;

— alternative electrical or mechanical measures for a.c. voltage class B electric circuits; see 8.3.4.

8.3.4 Alternative electrical or mechanical measures

Alternative electrical or mechanical measures include the following:

— double or reinforced insulation instead of basic insulation;

— one or more layers of insulation, barriers and/or enclosures in addition to the basic protection;

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

8.4 Alternative approach for protection against electric shock of voltage class B electric components and RESS

As an alternative to 8.2 and 8.3, the following approach may be applied to establish sufficient protection for persons against electric shock.

The vehicle manufacturer shall conduct an appropriate hazard analysis with respect to electric shock and establish a set of measures which give sufficient protection against electric shock

8.5 Creepage distance of voltage class B electric components and RESS

This clause deals with an additional leakage current hazard along with the surface between the connection terminals of voltage class B electrical circuit and RESS, including any conductive fittings attached to them and any conductive parts, due to the risk of electrolyte or dielectric medium spillage from leakage under normal operating conditions

If electrolytic leakage does not occur, the RESS should be designed according to IEC 60664-1. The pollution degree shall be suitable for the range of application. If electrolyte leakage can occur it is recommended that the creepage distance be as follows (see Figure 2):

a) In the case of a creepage distance between two connection terminals of the electric circuit and/or the RESS connection terminals:

$$d \geq 0{,}25U + 5 \quad (1)$$

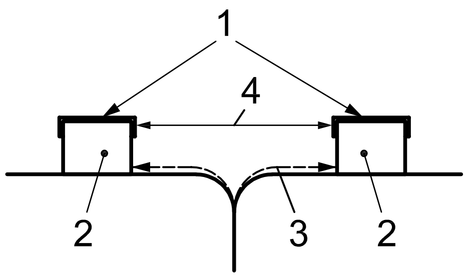
b) In the case of a creepage distance between live parts and the electric chassis:

$$d \geq 0{,}125U + 5 \quad (2)$$

where

d is the creepage distance measured on the tested RESS, in millimetres;

U is the maximum working voltage between the two RESS connection terminals, in volts.



Key

1 conductive surface
2 connector terminal (RESS pack or RESS)
3 creepage distance
4 clearance

Figure 2 — Creepage distance and clearance

8.6 Clearance of voltage class B electric components and RESS

This clause deals with an additional leakage current hazard through the minimum distance between the connection terminals of voltage class B electrical circuit and RESS, including any conductive fittings attached to them and any conductive parts, due to the risk of electrolyte or dielectric medium spillage from leakage under normal operating conditions.

If electrolytic leakage may not occur the RESS should be designed according to IEC 60664-1. The pollution degree shall be suitable for the range of application. If electrolyte leakage may occur it is recommended that the clearance d be shown in Table 2.

Table 2 — Minimum clearance of voltage class B electric components and RESS

Maximum working voltage, *U* V		Minimum clearance, *d* [a] mm			
		Current ≤ 63 A		Current > 63 A	
d.c.	a.c.	L-L [b]	L-A [c]	L-L [b]	L-A [c]
60 < *U* ≤ 125	30 < *U* ≤ 125	3	5	5	6
125 < *U* ≤ 250		3	5	5	6
250 < *U* ≤ 380		4	6	6	8
380 < *U* ≤ 500		6	8	8	10
500 < *U* ≤ 660		6	8	8	10
660 < *U* ≤ 800	660 < *U* ≤ 750	10	14	10	14
800 < *U* ≤ 1500	750 < *U* ≤ 1000	14	20	14	20

a See Figure 2.
b Distance between two of electric circuit and/or RESS connection terminals.
c Distance between the live part and the electric chassis.

8.7 Requirements of barrier/enclosures of voltage class B electric components

8.7.1 General

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

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

If barriers/enclosures are accessible directly they shall be opened or removed only by use of tools or maintenance keys or they shall have means to deactivate live parts with class B voltage, e.g. interlock.

NOTE See 6.1 for marking of barriers/enclosures.

8.7.2 Protection degrees

8.7.2.1 Protection degrees for barriers/enclosures

Barriers/enclosures shall comply with the protection degree IPXXB at minimum (see 3.28).

In case the barriers/enclosures can be intentionally or unintentionally accessed under normal conditions of use and without any tool by the rider, barrier/enclosures shall comply with the protection degree IPXXD at minimum. (see 3.28).

8.7.2.2 Protection degrees for connectors

If connector parts can be disconnected without tools, the connector shall comply with IPXXB at minimum in unmated condition, for the contacts that can have class B voltage.

Requirements for charging inlet are defined in 8.13.

8.8 Requirements for insulation of voltage class B electric components and RESS

If protection is provided by insulation, the live parts of the electric system, electric circuit and RESS 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 components and RESS

The insulation shall have sufficient withstand voltage capability. Compliance shall be tested according to 9.4.

8.9 Insulation requirements of the voltage class B RESS

For a RESS not embedded in a whole circuit, the minimum requirement for the isolation resistance, R_i, divided by its maximum working voltage shall be at least 100 Ω/V, if not containing a.c., or at least 500 Ω/V, if containing a.c. without additional a.c. protection throughout the entire lifetime of the RESS.

When the RESS is integrated in a whole electric circuit, a higher resistance value for the RESS may be necessary.

NOTE 1 For details on the integration of RESS and for additional a.c. protection. See 8.10.2.

NOTE 2 Resistances lower than the required minimum isolation resistances can occur due to the deterioration of certain battery types.

If the isolation resistance of the whole power circuit, measured with an on-board isolation resistance monitoring system, meets the requirements in ISO 6469-3, the isolation resistance measurement of the RESS as a single component in 8.9 is not required.

8.10 Isolation resistance requirements of the electric system and electric circuit

8.10.1 General

If the protection measures chosen (see 8.3) require a minimum isolation resistance, it shall be at least 100 Ω/V for d.c. circuits and at least 500 Ω/V for a.c. circuits. The reference shall be the maximum working voltage.

NOTE Depending on value and duration, hazard of electric shock occurs when electric currents pass through the human body. Harmful effects can be avoided if the current is within zone DC-2 in Figure 22 for d.c. or zone AC-2 in Figure 20 for a.c. of IEC 60479-1:2005, respectively. The relation of harmful body currents and other wave forms and frequencies is described in IEC 60479-2. The isolation resistance requirements of 100 Ω/V for d.c. or 500 Ω/V for a.c. allow body currents of 10 mA and 2 mA respectively.

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

If d.c. and a.c. voltage class B electric circuits are conductively connected one of the following two options shall be fulfilled:

a) Option 1: meet at least the 500 Ω/V requirement for the combined circuit, or

b) Option 2: meet at least the 100 Ω/V requirements for the entire conductively connected circuit, if at least one of the additional protection measures as defined in 8.10.2 is applied to the a.c. circuit.

8.10.2 Additional protection measures for the a.c. circuit conductively connected to the d.c. circuit

One or a combination of the following measures in addition to or instead of the basic protection measures as described in 8.2 shall be applied to provide protection against first failures to address the failures, for which it is intended:

a) Addition of one or more layers of insulation, barriers, and/or enclosures;

b) Double or reinforced insulation instead of basic insulation;

c) Rigid barriers/enclosures with sufficient mechanical robustness and durability, over the vehicle service life.

NOTE The rigid barriers/enclosures include (but are not limited to) power control enclosures, motor housings, connector casings and housings, etc. They may be used as single measure instead of basic barriers/enclosures to meet both basic and first failure protection requirements.

8.11 Requirements for withstand voltage of voltage class B electric components and RESS

The voltage class B components and wiring shall fulfil the withstand voltage capability according to the withstand voltage test in 9.4.

8.12 Requirements of potential equalization of voltage class B electric components and RESS

All components forming the potential equalization current path (conductors, connections) shall withstand the maximum first failure current in a maximum fault clearance time.

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

8.13 Requirements for vehicle charging inlet of voltage class B electric components and RESS

8.13.1 Voltage decrease requirement

One second after having disconnected the charge coupler, the voltage of the vehicle inlet shall be less than or equal to 30 V a.c. or 60 V d.c.

This condition is not necessary if vehicle inlet complies with the requirement of at least IPXXB (see 3.28).

8.13.2 Grounding and isolation resistance requirement for vehicle power inlet

8.13.2.1 vehicle power inlet conductively connected to the grid

The vehicle inlet intended to be connected conductively to the grounded external power supply (grid) shall have a terminal for connecting the vehicle exposed conductive parts to the ground of the grid.

The total isolation resistance at the charging inlet, which includes circuits conductively connected to the grid during charging, shall be at least 1 MΩ when the charge coupler is disconnected.

8.13.2.2 vehicle power inlet not conductively connected to the grid

The total isolation resistance of the charging inlet, which includes circuits conductively connected to the inlet during charging, shall comply with the requirements in 8.10 when the charge coupler is disconnected.

The vehicle inlet intended to be connected conductively to the grounded external power supply (grid) shall have a terminal connecting the vehicle with the chassis of the external charger if potential equalization is required.

8.14 RESS of voltage class B over-current interruption

If a RESS system is not short-circuit proof in itself, a RESS over-current interruption device shall open the RESS circuit under conditions specified by the vehicle and/or RESS manufacturer, to prevent dangerous effects for persons, the vehicle and the environment.

9 Test procedures for the protection measures against electric shock for voltage class B electric components and RESS

9.1 General

The tests to verify the protection measures according to Clause 8 shall in principle be performed on each voltage class B electrical circuit on the vehicle.

If the safety aspects in relation to the whole vehicle are not affected, the tests may be performed outside the vehicle on the components or parts of the voltage class B electric circuits individually instead.

It is recommended that the vehicle manufacturer perform the isolation resistance measurements (see 9.2 and 9.3) and the voltage withstand test (see 9.4) on each vehicle before its entrance into service.

9.2 Isolation resistance measurements for voltage class B electric circuits

9.2.1 Preconditioning and conditioning

Prior to the measurement the device under test shall be subjected to a preconditioning period of at least 8 hours at (5 ± 2) °C, followed by a conditioning period of 8 hours at a temperature of (23 ± 5) °C, a humidity of (90 +10/-5) %, and an atmospheric pressure 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 in a rate from which the lowest value can be determined.

9.2.2 Isolation resistance measurements of the balance of electric power systems

The test voltage shall be a d.c. voltage of at least the maximum working voltage of the voltage class B power system and be applied for a time long enough to obtain stable reading.

If the system has several voltage ranges (e.g. because of boost converter) in conductively connected circuit and some of the components cannot withstand the maximum working voltage of the entire circuit, the isolation resistances of components can be measured separately by applying their own maximum working voltages after those components 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 power systems against the vehicle electric chassis and against the live parts of the voltage class A balance of auxiliary electric systems:

a) traction batteries shall be disconnected at their terminals from the power system;

b) electric power sources of the voltage class B power systems other than the traction batteries (fuel cell stacks, capacitors) may be disconnected at their terminals from the power system; if they remain connected power generation shall be deactivated;

c) barriers and enclosures shall be included unless evaluations prove otherwise;

d) all live parts of the balance of electric power systems (voltage class B) shall be connected to each other;

e) all exposed conductive parts of the balance of electric power systems shall be connected to the electric chassis;

f) batteries of the auxiliary electric systems shall be disconnected at their terminals from the auxiliary circuits;

g) 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 power systems and the electric chassis.

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

Alternatively the isolation resistance may be measured using the test procedure according to the measurement of the RESS as in Clause 9.3 with the balance of electric power system connected to an external power source.

9.2.3 Isolation resistance measurement of entire voltage class B circuits

The isolation resistance of entire conductively connected voltage class B circuits may be measured using the test procedure for the measurement of the RESS from 9.3 with the balance of power system connected to the voltage class B power sources.

Alternatively the isolation resistance of entire conductively connected voltage class B circuits may be measured using an isolation resistance monitoring system, if installed on the vehicle, provided that its accuracy is sufficiently high.

In case electric or electronic switches exist in the circuit (e.g. transistors in power electronics), those switches shall be activated. If those switches cannot be activated, the isolation resistance of the entire conductively connected circuit may be calculated using the measured resistances of the power sources and the balance of power system.

9.3 Isolation resistance measurement for the voltage class B electric power sources

9.3.1 General

The measurement of the isolation resistance of the RESS shall include auxiliary components located inside the RESS housing, e.g. monitoring or temperature-conditioning devices and liquid fluids (if any).

Both terminals of the RESS generally have different isolation resistances (R_{i1} and R_{i2} in Figure 3) against the electric chassis. For safety reasons, the lower one is regarded as the relevant RESS isolation resistance, which can be calculated using voltages measured in a procedure taking the voltage of the charged RESS as the test voltage.

9.3.2 Preconditioning and conditioning

For the measurement of the RESS isolation resistance within the vehicle, the RESS installed as for normal operation, both power terminals of the RESS shall be disconnected from the electric propulsion circuit and any other external circuit.

Terminals of the internal auxiliary systems of the RESS that are operated by power sources outside the RESS (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 activate the RESS (e.g. by connecting the battery packs inside a traction battery to the power terminals).

For the measurement of the RESS isolation resistance independently from the vehicle (stand-alone RESS) the electric chassis shall be simulated by an electric conductor, e.g. a metal plate, to which the RESS shall be attached with their standard mounting devices, as to best representing the resistances between the RESS housing and the electric chassis of the vehicle.

Prior to the measurement, the RESS shall be subjected to a preconditioning period of at least 8 hours at a temperature of (5 ± 2) °C, followed by a conditioning period of 8 hours at a temperature of (23 ± 5) °C, a humidity of (90 +10/-5) %, and an atmospheric pressure 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 specific conditions of the RESS type and usage shall be considered.

The RESS shall be charged to a state of charge as stated by the manufacturer.

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

9.3.3 Procedure

The isolation resistance shall be measured at a rate from which the lowest resistance value can be determined. The procedure for each measurement is the following [see Figure 3 and Formulae (3) and (4)]:

a) Measure the voltages between each terminal of the RESS 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 of both isolation resistances and is therefore the RESS isolation resistance R_i to be determined.

b) Add a known measuring resistance R_0 parallel to R_{i1} and measure the voltages U_2 and U'_2;

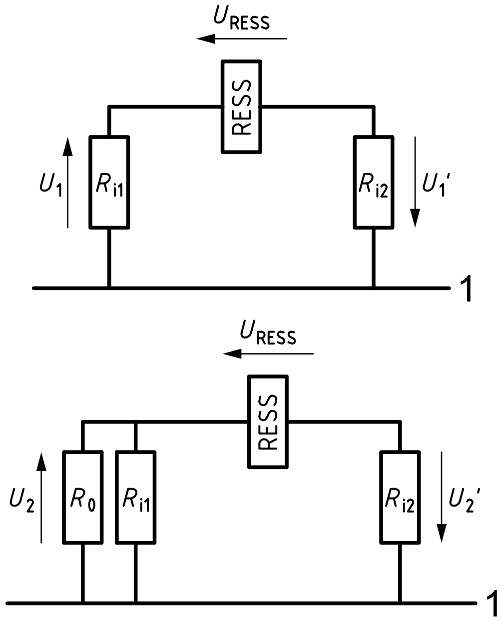
NOTE 2 Theoretically, the value of R_0 has no influence on the calculated isolation resistance. However, R_0 should be selected so as to improve the accuracy of the measured voltages on the calculated isolation resistances as much as possible. A value in the range of (100 to 500) Ω/V RESS working voltage is appropriate. The value should be known with an uncertainty of maximum 2 %.

c) Calculate the isolation resistance R_i, using R_0 and the three voltages U_1, U'_1 and U_2 with Formula (3):

$$R_i = R_0 \frac{U_1 - U_2}{U_2}\left(1 + \frac{U'_1}{U_1}\right) \qquad (3)$$

d) R_i can also be calculated, using R_0 and all four voltages U_1, U'_1, U_2 and U'_2 with Formula (4):

$$R_i = R_0\left(\frac{U'_2}{U_2} - \frac{U'_1}{U_1}\right) \qquad (4)$$



Key

1 electric chassis

Figure 3 — Measurement of isolation resistance

NOTE 3 R_{i1} and R_{i2} in Figure 3 represent the fictitious isolation resistances between the two terminals of the RESS and the chassis.

NOTE 4 R_0 in Figure 3 is a measuring resistance.

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 prescribed above, e.g. by using an internal RESS isolation resistance monitoring system or an external isolation resistance monitoring system.

9.4 Withstand voltage test for the voltage class B electric components

9.4.1 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 applied for the balance of the electric power system.

The test may be performed at the component level at the discretion of the 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 it can be necessary to disconnect them during a.c. tests.

NOTE Test procedures and criteria of high voltage cables conductively connected to grid are specified in applicable sections of appropriate IEC standards (e.g. IEC 60227, IEC 60245, etc.)

9.4.2 Preconditioning and conditioning

If not otherwise specified by the vehicle manufacturer the following procedure shall apply:

a) Preconditioning: at a temperature of 30 °C ± 2 °C and a duration that ensures a constant temperature;

b) Conditioning: 48 h at a temperature of 23 °C ± 2 °C, a humidity of 93 % ± 5 %, and an atmospheric pressure between 86 kPa and 106 kPa.

9.4.3 Test procedure

This test shall include barriers/enclosures unless evaluations prove otherwise.

The following test procedure shall be applied:

a) all voltage class B live parts of the Device Under Test (DUT) shall be connected to each other;

b) for components with conductive housing all live parts of the voltage class A electric circuit of the DUT and all exposed conductive parts of the DUT shall be connected to each other;

c) for components with non-conductive housing all live parts of the voltage class A electric circuit of the DUT and electrode wrapped around the housing shall be connected to each other.

If some electronic components connected between the exposed conductive parts and the voltage class B live parts cannot withstand the test voltage, they shall be disconnected from the DUT.

At the end of the conditioning the test voltage specified in 9.4.4 or 9.4.5 shall be applied:

d) between connected live parts of voltage class B circuits and housing with electrically conductive surface;

e) between connected live parts of voltage class B circuits and an electrode wrapped around the housing in the case of non-conductive housing.

9.4.4 Test voltage for components not conductively connected to the grid

The test voltage, a.c. or d.c., shall be more than the highest voltage that can actually occur to the component. The test voltage shall be derived from the relevant over-voltages of the electric circuit to which the component is connected. Transient over-voltages that can be expected, including influences from other connections to grid, if any, shall be considered. The test voltage and its duration shall be specified, considering the applicable parts and sections of IEC 60664, by the vehicle manufacturer.

These test requirements also apply for voltage class B components connected to d.c. charging systems that are not conductively connected to the a.c. grid.

9.4.5 Test voltage for components conductively connected to the grid

The following a.c. test voltage of a frequency between 50 Hz and 60 Hz shall be applied for 1 min:

a) $(2U + 1000)$ V a.c. (rms) if basic insulation applies;

b) $(2U + 3250)$ V a.c. (rms) if double insulation and reinforced insulation applies;

where

U is the maximum working voltage of each component, in volts.

The equivalent d.c. test voltage is 1,41 times the a.c. (rms) value.

These test requirements also apply for voltage class B components connected to d.c. charging systems that are conductively connected to the a.c. grid.

9.4.6 Test criteria

Neither dielectric breakdown, nor flashover shall occur during application of the test voltage.

9.5 Continuity test for potential equalization

The potential equalization resistances shall be tested with a test current of at minimum 1 A and a voltage < 60 V d.c., which shall be passed through the potential current path between any two exposed conductive parts for at least 5 seconds. This path shall be isolated from other unintended potential paths for measurement. These conducting parts shall include voltage class B component housings, connections to exposed conductive parts and the vehicle electric chassis or barriers/enclosures respectively.

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

The voltage drop between any two exposed conductive parts which are placed at the furthest positioning in the vehicle or in a distance of 2 m, shall be measured and the resistance calculated from the current and this voltage drop.

10 Requirements for safety means and protection of persons against hazardous situations

10.1 Requirements for the emission of hazardous gases and other hazardous substances

To prevent explosion, fire or toxicity hazards, the following requirements apply when hazardous gases and other substances can be emitted by the RESS. These requirements shall consider normal operating and environmental conditions. No potentially dangerous concentration of hazardous gases and other hazardous substances shall be allowed anywhere in rider and person around the vehicle.

NOTE Refer to the latest version of applicable national/International Standards or regulations for the maximum allowed accumulated quantity of hazardous gases and other substances.

Appropriate countermeasures shall manage first failure situations.

10.2 Requirements for safety means and protection of persons against hazardous situations from RESS

10.2.1 Heat generation

Heat generation under any first failure condition which could form a hazard to persons shall be prevented by appropriate measures, e.g. based on monitoring of current or voltage or temperature.

10.2.2 Electrolyte spills

No spilled electrolyte from the RESS and its components shall reach the rider nor any person around the motorcycle and/or moped during normal condition of use and/or functional operation.

Electrolyte shall not spill from the vehicle when the vehicle is tilted to the ground and when the RESS is put upside-down

10.2.3 Ejection

The RESS and its components shall not be ejected during normal condition of use and/or functional operation.

The RESS and its components shall not be ejected when the vehicle is tilted to the ground and when the RESS is put upside-down.

11 Operational safety

11.1 Propulsion system, power-on/power-off procedure

11.1.1 General

For the power-on procedure of the vehicle propulsion system at least two deliberate and distinctive actions shall be performed in order to go from the power-off mode[1)] to the driving enabled mode[2)].

Only one action is required to go from driving enabled mode to power-off mode.

A main switch function shall be an integral part of the power-on/power-off procedure. If the power-on/power-off procedure of the propulsion system is activated by the vehicle key system, it shall be designed according to the operational safety design.

It shall be indicated, continuously or temporarily, to the rider, that the propulsion system of the vehicle is ready for driving.

After an intentional power-off of the vehicle, it shall only be possible to reactivate it by the power-on procedure, as described.

11.1.2 Automatic turn-off mode

An automatic turn-off mode shall be an integral part of the power-on/power-off procedure. If the automatic turn-off mode is activated, the power-off procedure of the propulsion system is activated even without any action on the main switch.

Automatic turn-off mode shall be activated when the vehicle is left alone without the rider for the period of time specified by the manufacturer, even if the main switch is being kept as turned on.

In order to avoid any unintentional power-on procedure, to go from the automatic turn-off mode to the driving enabled mode, one deliberate action shall be required to intentionally power-off the vehicle.

11.2 Connection of the vehicle to an off-board electric power supply

If the on-board RESS of the vehicle propulsion system can be externally charged by the user, vehicle movement by its own propulsion system shall be impossible as long as the RESS is physically connected to the off-board electric power supply (e.g. mains, off-board charger).

11.3 Driving partially

11.3.1 Indication of reduced power

If the electric propulsion system is equipped with a means to automatically reduce the vehicle propulsion power, significant reductions should be indicated to the rider.

NOTE Such means could limit the effects of a fault in the propulsion system or of an excessive power demand by the rider.

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1) Power-off mode: the propulsion system is off; no active driving of the vehicle is possible in this mode.

2) Driving enabled mode: only in this mode will the vehicle move when the accelerator device is applied.

11.3.2 Indication of low energy content of RESS

If a low SOC in the RESS has a relevant impact on vehicle driving performance a low energy content of the RESS shall be indicated to the rider by an obvious device, (e.g. a visual or audible signal). At the indicated low state of charge specified by the vehicle manufacturer, the vehicle shall meet the following requirements:

a) It shall be possible to move the vehicle out of the traffic area by its own propulsion system;

b) A minimum energy reserve shall still be available for the lighting system as required by national and/or International Standards or regulations, when there is no independent energy storage for the auxiliary electrical systems.

11.4 Driving backwards

If driving backwards is achieved by reversing the rotational direction of the electric motor, the following requirements shall be met to prevent unintentional switching into reverse when the vehicle is in motion.

Switching between the forward and backward (reverse) directions shall require

a) either two separate actions by the rider, or

b) if only one rider action is required, a safety device shall allow the transition only when the vehicle is stationary or moving slowly, as specified by the manufacturer.

If driving backwards is not achieved by reversing the rotational direction of the electric motor, national or International Standards or legal requirements for driving backwards for vehicles propelled by internal combustion engines shall apply.

12 Protection against failure

12.1 Fail safe design

The design of systems and components specific to electrically propelled mopeds and motorcycles shall consider fail-safe design.

NOTE For example electric drive and fuel system shall be switched off and de-energized when deactivated.

12.2 First failure response

Measures shall be implemented to manage credible single-point failures.

12.3 Unintentional vehicle behaviour

Unintentional acceleration, deceleration and reversal of direction of a vehicle caused by single-point hardware or software failures (first failures) in systems and components specific to electrically propelled vehicles shall be minimized.

13 Electromagnetic compatibility

13.1 Susceptibility

Care shall be taken to minimize electromagnetic susceptibility of the vehicle, taking into account national standards or regulations and International Standards.

13.2 Emissions

Care shall be taken to minimize electromagnetic emission from the vehicle, taking into account national standards or regulations and International Standards.

14 Emergency Response

The manufacturer of the vehicle shall have information available for safety personnel and/or emergency responders with regard to dealing with accidents involving vehicle.

NOTE For example guidance on appropriate emergency response can be found in SAE J2578.

15 Owner's guide manual

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

Bibliography

[1] ISO 3864-4, *Graphical symbols — Safety colours and safety signs — Part 4: Colorimetric and photometric properties of safety sign materials*

[2] ISO 16750 (all parts), *Road vehicles — Environmental conditions and testing for electrical and electronic equipment*

[3] IEC 60479-2, *Effects of current on human beings and livestock — Part 2: Special aspects*

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