INTERNATIONAL STANDARD

ISO 17409

First edition
2015-11-01

Corrected version
2015-12-15

Electrically propelled road vehicles — Connection to an external electric power supply — Safety requirements

Véhicules routiers à propulsion électrique — Connexion à une borne d'alimentation électrique externe — Exigences de sécurité

Reference number
ISO 17409:2015(E)

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Foreword

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

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information.

The committee responsible for this document is ISO/TC 22, *Road vehicles*, Subcommittee SC 37, *Electrically propelled vehicles*.

This corrected version of ISO 17409:2015 incorporates the following corrections.

6.1.2 and 6.1.3: The phrase 'overload protection' has been replaced with 'short-circuit protection' in four places.

Electrically propelled road vehicles — Connection to an external electric power supply — Safety requirements

1 Scope

This International Standard specifies electric safety requirements for conductive connections of electrically propelled road vehicles to an external electric power supply using a plug or vehicle inlet.

It applies to electrically propelled road vehicles with voltage class B electric circuits. In general, it may apply to motorcycles and mopeds if no dedicated standards for these vehicles exist.

It applies only to vehicle power supply circuits. It applies also to dedicated power supply control functions used for the connection of the vehicle to an external electric power supply.

It does not provide requirements regarding the connection to a non-isolated d.c. charging station.

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

The requirements when the vehicle is not connected to the external electric power supply are specified in ISO 6469-3.

NOTE 1 This International Standard does not contain requirements for vehicle power supply circuits using protection by class II or double/reinforced insulation but it is not the intention to exclude such vehicle applications.

NOTE 2 Requirements for EV supply equipment are specified in IEC 61851.

2 Normative references

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

ISO 6469-1, *Electrically propelled road vehicles — Safety specifications — Part 1: On-board rechargeable energy storage system (RESS)*

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

ISO 13849 (all parts), *Safety of machinery — Safety-related parts of control systems*

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

ISO 26262 (all parts), *Road vehicles — Functional safety*

IEC 60309-1, *Plugs, socket-outlets and couplers for industrial purposes — Part 1: General requirements*

IEC 60309-2, *Plugs, socket-outlets and couplers for industrial purposes — Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories*

IEC 60364-4-43, *Electrical installations of buildings — Part 4-43: Protection for safety — Protection against overcurrent*

IEC 60364-5-54, *Low-voltage electrical installations — Part 5-54: Selection and erection of electrical equipment — Earthing arrangements and protective conductors*

IEC 60364-6, *Low-voltage electrical installations — Part 6: Verification*

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

IEC 60884-1, *Plugs, socket-outlets and couplers for household and similar purposes — Part 1: General requirements*

IEC 61851-1, *Electric vehicle conductive charging system — Part 1: General requirements*

IEC 61851-23, *Electric vehicle conductive charging system — Part 23: D.C. electric vehicle charging station*

IEC 62196-1, *Plugs, socket-outlets, vehicle connectors and vehicle inlets — Conductive charging of electric vehicles — Part 1: General requirements*

IEC 62196-2, *Plugs, socket-outlets, vehicle connectors and vehicle inlets — Conductive charging of electric vehicles — Part 2: Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories*

IEC 62196-3, *Plugs, socket-outlets, vehicle connectors and vehicle inlets — conductive charging of electric vehicles — Part 3: Dimensional compatibility and interchangeability requirements for dedicated d.c. and combined a.c./d.c. pin and contact-tube vehicle couplers*

ISO/IEC 15118 (all parts), *Road vehicles — Vehicle to grid communication interface*

3 Terms and definitions

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

3.1
balance of electric power system
remaining portion of a voltage class B electric circuit when all RESS and fuel cell stacks are disconnected

3.2
barrier
part providing protection against direct contact from any usual direction of access

3.3
basic insulation
insulation of hazardous-live-parts which provides basic protection

3.4
case A
connection of an EV to the a.c. supply network (mains) utilizing a supply cable and plug permanently attached to the EV

3.5
case B
connection of an EV to the a.c. supply network (mains) utilizing a detachable cable assembly with a vehicle connector and a.c. EV supply equipment

3.6
case C
connection of an EV to the a.c. supply network (mains) utilizing a supply cable and vehicle connector permanently attached to the EV supply equipment.

Note 1 to entry: Only case C is applicable for mode 4 (see IEC 61851–1).

3.7
charger
power converter at the vehicle power supply circuit which supplies electric power, e.g. for charging a RESS

3.8
conductive part
part capable of conducting electric current

3.9
control pilot circuit
circuit designed for the transmission of signals and/or communication between an EV and an EV supply equipment

3.10
control pilot conductor
insulated conductor incorporated in an EV cable assembly that creates, together with the protective conductor, the control pilot circuit

3.11
control pilot function
functionality used to monitor and control the interaction between the electric vehicle and the supply equipment

3.12
d.c. EV charging station
EV supply equipment intended to supply d.c. current to an EV

3.13
direct contact
contact of persons with live parts

3.14
distortion power factor
product of the displacement power factor and the total harmonic distortion up to the 40th harmonics of the load current

3.15
displacement power factor
power factor due to the phase shift between voltage and current at the fundamental line frequency

3.16
double insulation
insulation comprising both basic insulation and supplementary insulation

3.17
electric chassis
conductive parts of a vehicle that are electrically connected and whose potential is taken as reference

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

3.19
electric vehicle
electric road vehicle
EV
any vehicle propelled by an electric motor drawing current from a RESS intended primarily for use on public roads

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

3.21
EV supply equipment
equipment or combined equipment providing dedicated functions for an electric power supply from a fixed installation to an EV for the purpose of charging for all dedicated charging modes and cases of connection

3.22
exposed conductive part
conductive part of the electric equipment, which can be touched by a test finger according to IPXXB (see ISO 20653) after removing barriers/enclosures which can be removed without using tools and which is not normally live, but which can become live under fault conditions

3.23
external electric power supply
electric power source that is not part of the vehicle for supplying electric energy to an EV using an EV supply equipment

3.24
hazard
potential source of harm

3.25
isolation resistance
resistance between live parts of voltage class B electric circuit and the electric chassis, as well as the voltage class A system

3.26
live conductor (line and neutral)
conductor which is energized in normal operation and capable of contributing to the transmission or distribution of electric energy

3.27
live part
conductor or conductive part intended to be electrically energized in normal operation

3.28
maximum working voltage
highest value of a.c. voltage (rms) or of d.c. voltage which can occur in an electric system under any normal operating conditions according to manufacturer's specifications, disregarding transients

3.29
mode 1
connection of the EV to the a.c. supply network (mains) utilizing a cable and plug, that is not fitted with any supplementary pilot or auxiliary contacts, and connects to a standard socket-outlet

3.30
mode 2
connection of the EV to the a.c. supply network (mains) utilizing a cable and plug connected to a standard socket-outlet, with a control pilot function and system for personal protection against electric shock placed between the EV and the socket outlet

3.31
mode 3
connection of the EV utilizing EV supply equipment permanently connected to the a.c. supply network (mains) and where the control pilot function extends to control equipment in the EV supply equipment

Note 1 to entry: Mode 3 includes the use of cable assembly not permanently connected to the a.c supply network (case A and case B).

3.32
mode 4
connection of the EV to the a.c. or d.c. supply network (mains) utilizing a d.c. EV supply equipment or d.c. EV charging station using a control pilot function

3.33
non-isolated d.c. EV charging station
d.c. EV charging station with d.c. circuit on output side which is not electrically separated by at least basic insulation from the supply system

3.34
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

3.35
protective conductor (PE)
conductor provided for purposes of safety, for example protection against electric shock

3.36
rechargeable energy storage system
RESS
system that stores energy for delivery of electric energy and which is rechargeable

EXAMPLE Batteries and capacitors.

3.37
reinforced insulation
insulation of hazardous-live-parts which provides a degree of protection against electric shock equivalent to double insulation

Note 1 to entry: Reinforced insulation may comprise several layers which cannot be tested singly as basic insulation or supplementary insulation.

3.38
residual current device
RCD
mechanical switching device or association of devices designed to make, carry and break currents under normal service conditions and to cause the opening of the contacts when the residual current attains a given value under specified conditions

Note 1 to entry: A residual current device can be a combination of various separate elements designed to detect and evaluate the residual current and to make and break current.

3.39
socket-outlet
accessory having socket-contacts designed to engage with the contacts of a plug and having terminals for the connection of cables or cords

3.40
standard plug and socket-outlet
plug and socket-outlet which meets the requirements of any IEC and/or national standard that provides interchangeability by standard sheets, excluding the specific EV accessories as defined in the IEC 62196 series

Note 1 to entry: The standards IEC 60309–1, IEC 60309–2, and IEC 60884–1 define standard plugs and socket-outlets.

3.41
supplementary insulation
independent insulation applied in addition to basic insulation for fault protection

3.42
touch current
electric current passing through a human body or through an animal body when it touches one or more accessible parts of an electrical installation or electrical equipment

3.43
vehicle connector
part of a vehicle coupler integral with or intended to be attached to the cable assembly

3.44
vehicle coupler
means of enabling the manual connection of a flexible cable to an EV for the purpose of supplying electric energy to an EV

Note 1 to entry: It consists of two parts: a vehicle connector and a vehicle inlet.

3.45
vehicle inlet
part of a vehicle coupler incorporated in, or fixed to, an electric vehicle

3.46
vehicle isolation resistance monitoring system
system which periodically or continuously monitors the isolation resistance between live parts of voltage class B electric circuits and the electric chassis

3.47
vehicle power supply circuit
voltage class B electric circuit which includes all parts that are galvanically connected to the vehicle inlet (case B, case C) or the plug (case A) and that is operational when connected to an external electric power supply

3.48
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. (rms) or ≤60 V d.c., respectively

3.49
voltage class B
classification of an electric component or circuit as belonging to voltage class B, if its maximum working voltage is (>30 V and ≤1 000) V a.c. (rms) or (>60 V and ≤1 500) V d.c., respectively

4 Environmental conditions

The requirements given in this International Standard shall be met across the range of environmental conditions for which the electric vehicle is designed to operate when connected to an external electric power supply, as specified by the vehicle manufacturer.

NOTE See ISO 16750-4 for guidance.

5 Requirements for protection of persons against electric shock

5.1 Basic protection

In this Clause, requirements for protection against direct contact at the vehicle inlet (case B and C) and at the plug (case A) are specified.

Standard plug mated with standard socket-outlet (case A) shall comply with the requirements of relevant standards and the national requirements of the country where the product is placed on the market.

Plug according to IEC 62196 mated with socket-outlet according to IEC 62196 (case A) shall comply with the degree of protection IPXXD at minimum in accordance with ISO 20653.

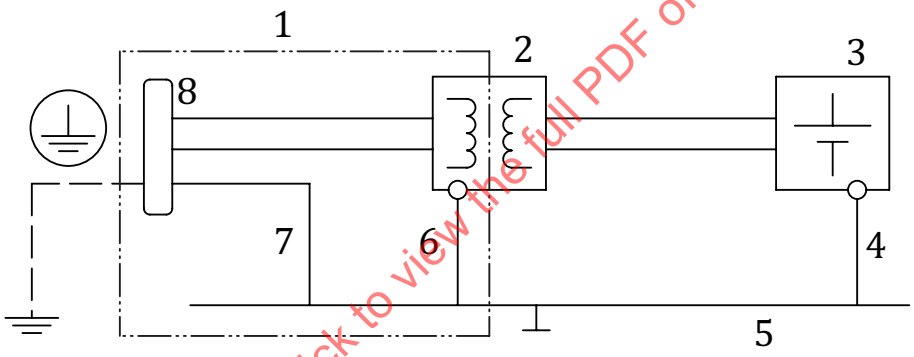
Mated portion of the vehicle inlet mated with vehicle connector (case B and case C) shall comply with IPXXD at minimum in accordance with ISO 20653. The requirements for unmated contacts of such a vehicle inlet are specified in 5.4.

5.2 Protection under single failure conditions

For mode 1, 2, 3, and 4, the plug (case A) or the vehicle inlet (case B and case C) shall have a contact for connecting the vehicle electric chassis to the protective conductor of an external electric power supply.

To provide protection under single failure conditions, at least one of the following requirements shall be fulfilled.

— The protective conductor terminal of the plug (case A) or the vehicle inlet (case B and case C) shall be connected to the vehicle electric chassis fulfilling the requirements for protective conductor connection. All exposed conductive parts of the vehicle power supply circuit shall be connected to the vehicle electric chassis fulfilling the requirements for the protective conductor connection. An example for this option is given in Figure 1.

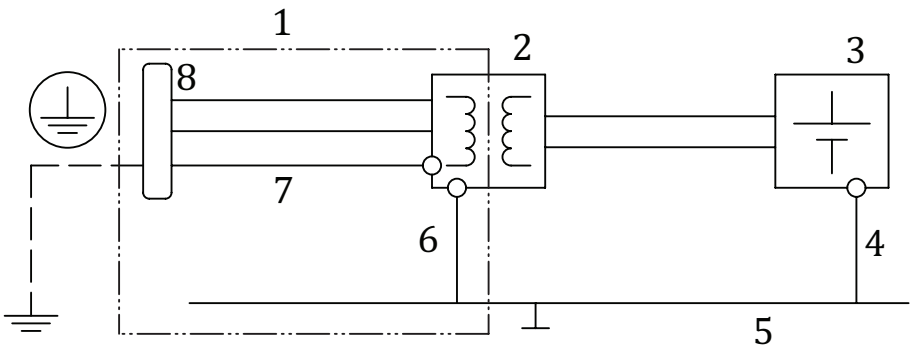


Key

1	vehicle power supply circuit	5	electric chassis
2	charger with galvanic separation	6	protective conductor
3	RESS	7	protective conductor
4	potential equalization according to ISO 6469	8	vehicle inlet

Figure 1 — Connection between protective conductor and electric chassis (example for Option 1)

— The protective conductor terminal of the plug (case A) or the vehicle inlet (case B and case C) shall be connected to exposed conductive parts of the vehicle power supply circuit fulfilling the requirements for protective conductor connection. All exposed conductive parts of the vehicle power supply circuit shall be connected to the vehicle electric chassis fulfilling the requirements for protective conductor connection. An example for this option is given in Figure 2.



Key

1	vehicle power supply circuit	5	electric chassis
2	charger with galvanic separation	6	protective conductor
3	RESS	7	protective conductor
4	potential equalization according to ISO 6469	8	vehicle inlet

Figure 2 — Connection between protective conductor and electric chassis (example for Option 2)

The cross-sectional area of the protective conductor shall be designed in accordance with IEC 60364-5-54.

For the specification of the protective conductor of a vehicle power supply circuit used for a d.c. connection, a fault current and the disconnecting time in case of a fault current in accordance with IEC 61851-23 shall be considered.

The resistance of the protective conductor connection between the protective conductor contact of the plug (case A) or the vehicle inlet (case B, case C) and the vehicle electrical chassis, as well as all exposed conductive parts of the vehicle power supply circuit shall be less than 0,1 Ω. All paths used for protective conductor connection shall be considered.

The resistance of protective conductor shall be tested in accordance with 12.2.

NOTE Protective conductor requirement for double/reinforced insulation is under consideration.

5.3 Isolation resistance

5.3.1 A.C. connection (Mode 1, 2, and 3)

The total isolation resistance of the vehicle power supply circuit shall be at least 500 Ω/V when the vehicle is not connected to an external electric power supply. The reference shall be the maximum working voltage of the relevant electric circuit.

Compliance shall be tested in accordance with 12.3.

5.3.2 D.C. connection (Mode 4)

The isolation resistance of the vehicle power supply circuit shall comply with the requirements in ISO 6469-3 when the vehicle connector is not mated with the vehicle inlet.

Compliance shall be tested in accordance with 12.3.

5.4 Protection from unintended voltage

5.4.1 Mode 1

The plug (case A) or vehicle inlet (case B and case C) shall comply with at least one of the following requirements:

— the charge between any contacts shall be below 50 µC within 1 s after cut off of the external electric power supply;

— the voltage between any contacts shall be below or equal to 60 V d.c. and 30 V a.c. (rms) within 1 s after cut off of the external electric power supply.

For compliance, cut off of external electric power supply can be simulated by unmating the plug (case A) or the vehicle connector (case B and case C).

NOTE Cut off of external electric power supply means loss of supply voltage, including disconnection and voltage outage on the supply.

5.4.2 Mode 2 and mode 3

The plug (case A) or vehicle inlet (case B and case C) shall comply with at least one of the following requirements if their voltage class B live parts are not protected at least by IPXXB in accordance with ISO 20653:

— the charge between any contacts shall be below 50 µC within 1 s after disconnection of the vehicle from external electric power supply;

— the voltage between any contacts shall be below or equal to 60 V d.c. and 30 V a.c. (rms) within 1 s after disconnection of the vehicle from external electric power supply.

The plug (case A) or vehicle inlet (case B and case C) shall comply with at least one of the following requirements if their voltage class B live parts are protected at least by IPXXB in accordance with ISO 20653:

— the energy between any contacts shall be below 0,2 J within 10 s after disconnection of the vehicle from external electric power supply;

— the voltage between any contacts shall be below or equal to 60 V d.c. and 30 V a.c. (rms) within 10 s after disconnection of the vehicle from external electric power supply.

For case B and case C, the voltage or energy shall be measured at the unmated vehicle inlet.

5.4.3 Mode 4

The vehicle inlet shall comply with at least one of the following requirements if its voltage class B live parts are not protected at least by IPXXB in accordance with ISO 20653:

— the charge between any contacts shall be below 50 µC within 1 s after disconnection of the vehicle from external electric power supply;

— the voltage between any contacts shall be below or equal to 60 V d.c. and 30 V a.c. (rms) within 1 s after disconnection of the vehicle connector from external electric power supply.

The vehicle inlet shall comply with at least one of the following requirements if its voltage class B live parts are protected at least by IPXXB in accordance with ISO 20653:

— the energy between any contacts shall be below 0,2 J within 10 s after disconnection of the vehicle from external electric power supply;

— the voltage between any contacts shall be below or equal to 60 V d.c. and 30 V a.c. (rms) within 10 s after disconnection of the vehicle from external electric power supply.

The voltage or energy shall be measured at the unmated vehicle inlet

5.4.4 Contacts of unmated portion of vehicle inlet

The contacts of an unmated portion of the vehicle inlet shall fulfil at least one of the following requirements, when the other contacts of this vehicle inlet are mated with a vehicle connector (e.g. d.c. contacts of a combined vehicle inlet unmated and other contacts mated with a type 1 or type 2 vehicle connector according to IEC 62196 series):

— the energy between any unmated contacts shall be below 0,2 J if live parts are protected at least by IPXXB in accordance with ISO 20653;

— the voltage between any unmated contacts shall be below or equal to 60 V d.c. and 30 V a.c. (rms) if live parts are protected at least by IPXXB in accordance with ISO 20653;

— the charge between any contacts shall be below 50 μC if live parts are not protected at least by IPXXB in accordance with ISO 20653.

5.5 Insulation coordination

5.5.1 General

The vehicle power supply circuit shall fulfil the applicable sections of IEC 60664 series on insulation coordination and meet the withstand voltage capability according to the details in 5.5.2 or 5.5.3.

Neither dielectric breakdown nor flashover shall occur during the withstand voltage test.

Compliance shall be tested in accordance with 12.4.

5.5.2 A.C. connection (Mode 1, 2, and 3)

The vehicle power supply circuit shall be designed according to the overvoltage category II unless appropriate overvoltage reduction in accordance with IEC 60664-1 is provided in the vehicle power supply circuit.

5.5.3 D.C. connection (Mode 4)

The vehicle power supply circuit shall be designed according to a rated impulse voltage of at least 2 500 V.

NOTE IEC 61851-23 has adopted this fixed value of the rated impulse voltage independent of input voltage of d.c. charging station.

6 Protection against thermal incident

6.1 Overcurrent protection

6.1.1 Overload protection

The cross-sectional area of the live conductors of the vehicle power supply circuit, as well as the rated current of the plug (case A) or vehicle inlet (case B and case C), shall be according to the maximum load current of the vehicle unless parts of this circuit are separately protected by an overcurrent protection device in the vehicle. (e.g. fuse, circuit breaker, etc.).

6.1.2 Short-circuit protection for a.c. connection

For short-circuit current supplied by external power supply, the requirements in a), b), or c) shall be fulfilled.

a) The cross-sectional area of the live conductors of the vehicle power supply circuit shall have a short-circuit current withstand rating (I^2t) according to the characteristics of the overcurrent protection device of the external electric power supply. For the connection to an external electric power supply with a rated current up to 80 A, the vehicle power supply circuit shall have a short-circuit current withstand rating (I^2t) of at least 80 000 A^2s. I^2t value shall be calculated according to IEC 60364-4-43.

   NOTE Breaking time for overcurrent protection device is less than 0,1 s (see IEC 60364-4-43).

b) An overcurrent protection device (e.g. fuse, circuit breaker) shall be provided in each live conductor of the vehicle power supply circuit. The cross-sectional area of the live conductor downstream this overcurrent protection device shall be designed according to the rating of this overcurrent protection device.

c) For case B and case C, all of the following requirements shall be fulfilled:

   — cross-sectional area of the vehicle power supply circuits shall be designed according to the maximum load current of the vehicle;

   — protection against mechanical damage for vehicle power supply circuit wiring between the vehicle inlet and the charger shall be provided so that single failure does not cause insulation fault between live conductors and between live conductors and electrical chassis;

   — an overcurrent protection device (e.g. fuse, circuit breaker) shall be provided inside the charger. The overcurrent protection device rating and short-circuit current interrupt rating shall be sufficient to protect the wiring of the vehicle power supply circuit between the vehicle inlet and the on-board charger.

For short-circuit current supplied by power sources of the vehicle, short-circuit protection shall be provided for the vehicle power supply circuit.

6.1.3 Short-circuit protection for d.c. connection

For short-circuit current supplied by external electric power supply, the requirements in a) or b) shall be fulfilled for short-circuit protection.

a) The cross-sectional area of the live conductors of the vehicle power supply circuit shall have a short-circuit current withstand rating (I^2t) of at least the following values:

   — 1 000 000 A^2s for System A according to IEC 61851-23;

   — 5 000 000 A^2s for System C according to IEC 61851-23;

   — a value in A^2s to be coordinated for any other d.c.-EV charging station.

   I^2t value of the live conductors shall be calculated according to IEC 60364-4-43.

   NOTE 1 This short-circuit current withstand rating (I^2t) corresponds to the characteristics of the overcurrent protection device of the external electric power supply.

b) An overcurrent protection device (e.g. fuse, circuit breaker) shall be provided in the vehicle power supply circuit. The cross-sectional area of the live conductors to be protected by this overcurrent protection device shall be designed according to the short-circuit interrupt rating of this overcurrent protection device. The cross-sectional area of the live conductors upstream from this overcurrent protection device (to vehicle inlet) shall comply with the requirement of a).

The breaking time for interruption of a short-circuit current shall be gathered from the technical data of the selected overcurrent protection device.

For short-circuit current supplied by vehicle sources, the vehicle power supply circuit shall have an overcurrent protection device with a rating not higher than following values:

— 2 500 000 A^2s for System A according to IEC 61851-23;

— 12 000 000 A^2s for System C according to IEC 61851-23;

— a value in A^2s to be coordinated for any other d.c. EV charging station.

The cross-sectional area of the live conductors of the vehicle power supply circuit upstream from this overcurrent protection device (to vehicle inlet) shall be designed according to the rating of the overcurrent protection device of the vehicle power supply circuit.

I^2t value of the live conductors shall be calculated according to IEC 60346-4-43.

NOTE 2 This characteristics of the overcurrent protection device (I^2t) corresponds to the short-circuit current withstand rating of the live conductors of an external electric power supply, if no additional overcurrent protection device is provided, see e.g. IEC 61851–23.

6.2 Arc protection for d.c. connections

Arc protection is covered by the requirements in 9.4.

6.3 Residual energy after disconnection

One second after having disconnected the vehicle from the external electric power supply, the stored energy at the voltage class B live parts at the plug (case A) or vehicle inlet (case B and case C), which are not protected at least by IPXXB in accordance with ISO 20653, shall be less than 20 J (see IEC 60950-1).

NOTE Circuits whose voltages are safe to touch can become hazardous with respect to energy related hazards.

7 Specific requirements for the vehicle inlet, plug, and cable

7.1 Requirements for the plug and cable

For mode 1 and mode 2, the plug (case A) shall comply with IEC 60309-1, IEC 60309-2 (industrial type), IEC 60884-1 (domestic type), or relevant national standards. For mode 3, the plug (case A) shall comply with IEC 62196-1.

NOTE 1 For mode 3, the use of a plug specified in IEC 62196–2 is recommended.

NOTE 2 In some countries, specific cable types are required by national regulations: US (NFPA 70 article 400, type cable EV, EVJ families).

7.2 Requirements for the vehicle inlet

The vehicle inlet (case B and case C) shall comply with IEC 62196-1.

NOTE 1 For an a.c. connection, the use of a vehicle inlet specified in IEC 62196–2 is recommended.

NOTE 2 For a d.c. connection, the use of a vehicle inlet specified in IEC 62196–3 is recommended.

8 Additional requirements for a.c. electric power supply

8.1 Standard a.c. external electric power supply conditions for operation in service

Vehicle power supply circuits shall not exceed their rated performance within a range of (+10 and –15) % of the rated supply voltage at the connecting point. The rated value of the frequency is 50 Hz ± 1 % or 60 Hz ± 1 %.

NOTE This voltage range is derived from an application of values indicated in IEC 60038 and IEC 60364–5-52.

8.2 Current characteristics

8.2.1 Load current

For mode 1, the vehicle shall not draw a current exceeding 16 A per phase.

For mode 2 and mode 3, the vehicle shall ensure that the vehicle load current does not exceed the maximum current given by the PWM indication of the control pilot function according to IEC 61851-1.

NOTE 1 IEC/TS 62763 is available until IEC 61851–1 edition 3 is published.

If the vehicle is using a simplified control pilot function according to IEC 61851-1, it shall be limited to single phase a.c. only and the vehicle shall ensure that the vehicle load current does not exceed 10 A.

The vehicle system shall ensure that the charge current does not exceed the limit value provided by digital communication, if used, in accordance with ISO/IEC 15118 series.

NOTE 2 The EV supply equipment may cut off the power in case the EV load current exceeds the PWM indication.

NOTE 3 In some countries, the use of simplified pilot function is not allowed: US.

For a vehicle using the proximity function contact of the vehicle inlet for simultaneous current capability coding of the cable assembly specified in IEC 61851-1, the vehicle system shall ensure that the vehicle load current does not exceed the indication of current capability coding.

8.2.2 Inrush current

The inrush current shall be limited by the vehicle as follows.

— Event 1: after closing the contactor in the EV supply equipment at the peak value of the supply voltage, the current in each live conductor shall not exceed 230 A peak within the duration of 100 µs. The current shall decline and not exceed the limit of the event 2 at 100 µs.

— Event 2: during the pre-charging of the capacitor in the charger, the current in each live conductor shall not exceed 30 A (rms). The absolute value of the current peak shall not exceed ($\sqrt{2}$ × 30 A) peak. Current peak exceeding ($\sqrt{2}$ × 30 A) may occur if requirements of other relevant standards (e.g. IEC 61000-3-3 and IEC 61000-3-11) are not violated. The event 2 shall not exceed 1 s.

NOTE The inrush current is caused by the following two phenomena: During event 1, the inrush current is caused by the EMC filters upstream of the charger power-electronics. During event 2, the inrush current is caused by the capacitance of the d.c. circuit (d.c. voltage link) of the charger power electronics.

Event 2 does not necessarily follow event 1 immediately.

Compliance shall be tested in accordance with 12.5.

8.3 D.C. fault currents

For mode 1, at least one of the following requirements shall be fulfilled to ensure a proper function of a RCD in the fixed electrical installation:

— vehicle power supply circuit shall ensure by its design that a d.c. fault current of 6 mA or above this limit cannot occur in a single failure condition;

— vehicle shall detect d.c. fault currents at the vehicle power supply circuit when connected to the external electric power supply. In case of d.c. fault currents exceeding 6 mA, the circuit supplying the d.c. fault current shall be switched off. Reaction time of switching off the circuit in case of a d.c. fault exceeding 6 mA shall not exceed 10 s, exceeding 60 mA shall not exceed 0,3 s, and exceeding 300 mA shall not exceed 0,04 s. Analysis and design shall be in accordance with ISO 26262 or other applicable standards.

8.4 Touch current

The touch current of the vehicle shall not exceed 3,5 mA (rms) a.c. and 10 mA d.c. when the vehicle is connected to an a.c. supply network (mains).

Compliance shall be tested in accordance with 12.6.

8.5 Unintended reverse power flow

An unintended reverse power flow from the vehicle to the external electric power supply shall not be permitted under normal operation and single failure conditions.

8.6 Power factor

The distortion power factor of the vehicle power supply circuit at the rated power shall be at least 0,95.

The displacement power factor shall be at least 0,9 unless the power consumption is less than 5 % of the rated power or 300 W whichever is higher.

The compliance may be checked at the relevant component level with the resistive load connected at the operating power range of the DUT.

NOTE The operating power range can include power ranges and power steps on the vehicle.

8.7 Locking of the vehicle connector

When equipped with a vehicle inlet that is not intended for disconnection under load, the vehicle shall provide an appropriate interlock function.

When equipped with a vehicle inlet according to IEC 62196-2 that is not intended for disconnection under load, the vehicle shall provide an interlock function as described in IEC 62196-2.

— When the proximity detection circuit is used for such an interlock function, the vehicle shall stop power supply operation and reduce its load current below or equal 1 A within 100 ms after actuation of the switch in the proximity detection circuit.

— When locking is used for such an interlock function, the vehicle shall inhibit release of the vehicle connector while power supply operation or a load current exceeding 1 A.

NOTE The proximity detection circuit is specified in IEC 61851–1.

9 Additional requirements for d.c. electric power supply

9.1 Disconnection device

A disconnection device shall be provided at the d.c. vehicle power supply circuit.

This disconnection device shall withstand an inrush current according to system specific requirements of IEC 61851-23.

This disconnection device shall have a breaking capability to disconnect at a load current according to the maximum rated current of the vehicle coupler.

The disconnection device shall be controlled in accordance with the system specific sequence diagrams of IEC 61851-23.

For system C according to IEC 61851-23, the voltage difference between both sides of the disconnection device shall be lower than 20 V d.c. before the vehicle closes its disconnection device.

9.2 Control pilot functions

The vehicle shall provide control pilot functions in accordance with IEC 61851-23.

9.3 Vehicle isolation resistance monitoring system

If the vehicle is equipped with a vehicle isolation resistance monitoring system which monitors the vehicle power supply circuit, the vehicle isolation resistance monitoring system shall not interfere with an insulation monitoring device (IMD) of a d.c. EV charging station. The vehicle may deactivate the isolation resistance monitoring system to avoid such interference.

NOTE Switching off the vehicle isolation resistance monitoring system is a permitted means to avoid interference.

The contribution of the resistance of the vehicle isolation resistance monitoring system, if any, should be considered for the total isolation resistance of the vehicle power supply circuit.

9.4 Locking of the vehicle connector

For a vehicle using system A or system B according to IEC 61851-23, the locking is provided by the d.c. EV charging station.

For a vehicle using system C according to IEC 61851-23, the following requirement shall be met:

— the vehicle shall lock the connector to the vehicle inlet at the beginning of the power supply process, before the vehicle changes the system state to state C in accordance with IEC 61851-1;

— the position of the mechanical locking means shall be checked after closing;

— if the lock opens falsely, the vehicle shall change the system state of the control pilot function to state B, according to the sequence diagrams as specified in IEC 61851-23, in order to request the stop of the power supply process;

— the vehicle connector shall not be unlocked unless the voltage at the vehicle inlet is below 60 V d.c. or 30 V a.c. (rms) and vehicle load current is less than 1 A;

— in case of a charging system malfunction, a means for disconnection specified by vehicle manufacturer may be provided;

— if other options for a safe disconnect are available, information for the unlock procedure shall be stated in the owner's manual.

9.5 A.C. or D.C. electric power at the same contacts

The disconnection device (see 9.1) shall interrupt all live conductors of the d.c. vehicle power supply circuit. The relevant parts of the vehicle power supply circuits shall fulfil the requirements for a.c. and d.c. electric power supply or they shall be disconnected by a mechanical disconnection device.

If the vehicle is using contacts for d.c. electric power supply at the vehicle inlet, which also can be used for a.c. electric power supply, the vehicle shall connect its d.c. vehicle power supply circuit only to a d.c. EV charging station if the following requirements are fulfilled:

— a communication between the d.c. EV charging station and the vehicle that is required to start d.c. electric power supply is established;

— voltage at the vehicle inlet shall be measured and the vehicle shall only close its disconnection device, if a d.c. voltage which complies with the requirement in 9.1 is detected;

— the voltage measurement circuit shall be monitored by plausibility check of measured voltages during operation.

In a single failure condition of the d.c. power supply communication or d.c. voltage at the vehicle inlet measurement, the vehicle shall not allow the disconnection device to close.

When connected to an external electric power supply, provision shall be taken that unintentional reverse d.c. current flow does not occur from d.c. vehicle supply circuit through the vehicle inlet under single failure condition. For this purpose, single failure conditions in the d.c. vehicle supply circuit (e.g. disconnection device) and in the a.c. vehicle power supply circuit (e.g. charger) shall be considered.

The following are examples of possible measures for vehicle supply circuits:

— installation of supplemental diodes at all live conductors of the vehicle power supply circuit;

— more than one independent disconnection devices with independent control system for each;

— use of safety related components in accordance with appropriate standards or combination of standards such as ISO 13849;

— use of charger which provides basic insulation by galvanic separation.

Analysis and design shall be in accordance with ISO 26262.

The vehicle manufacturer shall consider possible hazards, which include the following:

— possible hazards in the infrastructure resulting from d.c. current supplied by the vehicle to the infrastructure (e.g. fire of transformer) applying the severity level of at least S2;

— possible hazards in the vehicle resulting from a.c. voltage supplied by the infrastructure to the vehicle.

9.6 Contact temperature at vehicle inlet

The vehicle inlet that is used for system C described in IEC 61851-23 shall withstand the vehicle connector contact temperature limit of the vehicle coupler or the vehicle shall provide appropriate means to limit the temperature to the maximum value specified by the vehicle manufacturer, taking into account the coupler rating.

9.7 Overvoltage in case of a load dump

A temporary overvoltage caused by load dump in accordance with the system specific requirements of IEC 61851-23 shall be considered for the relevant parts of the voltage class B electric circuit.

NOTE Load dump describes the transient behaviour when the RESS is suddenly and unintendedly disconnected during electric power supply from the d.c. EV charging station.

9.8 Unintended reverse power flow

An unintended reverse power flow from the vehicle to the external electric power supply shall not be permitted under normal operation and single vehicle failure conditions.

9.9 Y capacitances

For system C according to IEC 61851-23, the Y capacitances of the vehicle power supply circuit shall be less than 2 µF per line conductor for supply voltage up to at 500 V d.c.

10 Operational requirements

Vehicle movement by its own propulsion system shall be impossible as long as the vehicle is physically connected to the external electric power supply (see ISO 6469-2).

11 Owner's manual and marking

11.1 Owner's manual

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

At least the following indication shall be given to the user:

— instruction for connection of the EV to an external electric power supply;

— information about the need of a proper installation of the fixed electrical installation.

11.2 Marking

The vehicle power supply circuit shall have marking in accordance with ISO 6469-3.

NOTE Marking used for voltage class B components according to ISO 6469-3 is not required and not recommended for the part of the vehicle inlet which is visible for the user.

12 Test procedure

12.1 General note on tests

All tests are type tests.

12.2 Resistance of protective conductor

The resistance of the path used for protective conductor connection shall be tested with a test current of at minimum 200 mA and a voltage <24 V d.c. The test current shall be passed through the protective conductor paths between the protective conductor terminal of the plug (case A) or vehicle inlet (case B and case C) and any connected conductive part of the vehicle power supply circuit and the electric chassis for at least 5 s. This path shall be isolated from other unintended potential paths for purpose of the test. The measured resistance shall comply with the requirement in 5.2.

12.3 Isolation resistance test

12.3.1 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 (80 to 95) % and an atmospheric pressure of (86 to 106) kPa.

Alternative preconditioning and conditioning parameters may be selected provided that 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.

12.3.2 Isolation resistance measurements at the vehicle inlet or plug

The test voltage shall be a d.c. voltage of at least the maximum supply voltage (peak) to the vehicle and be applied for a time long enough to obtain stable reading.

The following test procedure describes the measurement of the isolation resistance of the vehicle power supply circuit at the plug (case A) or vehicle inlet (case B and case C):

— RESS shall be disconnected from the vehicle power supply circuit;

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

— barriers and enclosures shall be included unless evaluations prove otherwise;

— all live parts of voltage class B electric circuit of the DUT shall be connected to each other;

— all exposed conductive parts of the DUT shall be connected to the electric chassis;

— 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 power terminal at the plug (case A) or vehicle inlet (case B and case C) and the electric chassis.

The measurements shall be performed using suitable instruments that apply the required d.c. test voltage.

Alternatively, the isolation resistance may be measured using the test procedure according to the measurement of the RESS as in ISO 6469-1 with the balance of electric power system connected to an external electric power source, if applicable.

NOTE Equipment for measuring the insulation resistance is specified in IEC 61557–2.

If the requirements for the whole vehicle are not affected, the tests may be performed outside the vehicle on the components or parts of the vehicle power supply circuit individually instead. The isolation resistance of the whole circuit may be calculated using the measured isolation resistances of the individual components.

12.4 Withstand voltage test

12.4.1 General

One of the following tests shall be applied:

— the test shall be conducted for the vehicle power supply circuit with the RESS disconnected;

— the test shall be conducted at the component level for all relevant components.

It may be necessary to disconnect components such as RFI filters during a.c. voltage test.