



**International
Standard**

ISO 5474-3

**Electrically propelled road
vehicles — Functional and safety
requirements for power transfer
between vehicle and external
electric circuit —**

**Part 3:
DC power transfer**

*Véhicules routiers à propulsion électrique — Exigences
fonctionnelles et exigences de sécurité pour le transfert de
puissance entre le véhicule et le circuit électrique externe —*

Partie 3: Transfert de puissance DC

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

A list of all parts in the ISO 5474 series can be found on the ISO website.

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Electrically propelled road vehicles — Functional and safety requirements for power transfer between vehicle and external electric circuit —

Part 3: DC power transfer

1 Scope

This document in combination with ISO 5474-1 specifies requirements for conductive power transfer using direct current (DC) with a voltage up to 1 500 V d.c. between electrically propelled road vehicles and external electric circuits.

This document provides requirements for conductive charging in mode 4 according to IEC 61851-1. For mode 4, this document provides requirements regarding the power transfer only with isolated DC EV supply equipment according to IEC 61851-23.

The requirements in this document are applicable to vehicle power supply circuits.

An outlook of requirements for megawatt charging applications is given in [Annex B](#).

This document does not provide:

- requirements for simultaneous operation of multiple power transfer interfaces and
- requirements for power transfer while driving (electric road systems)

but they are under consideration.

This document does not provide:

- requirements for mopeds and motorcycles (which are specified in ISO 18246);
- comprehensive safety information for manufacturing, maintenance and repair personnel.

2 Normative references

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

ISO 5474-1:2024, *Electrically propelled road vehicles — Functional requirements and safety requirements for power transfer — Part 1: General requirements for conductive power transfer*

ISO 6469-3:2021, *Electrically propelled road vehicles — Safety specifications — Part 3: Electrical safety*

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

IEC 60364-4-43, *Low-voltage electrical installations — Part 4-43: Protection for safety — Protection against overcurrent (relevant parts will be specified during the project)*

IEC 61000-4-5, *Electromagnetic compatibility (EMC) — Part 4-5: Testing and measurement techniques - Surge immunity test*

IEC 61180, *High-voltage test techniques for low-voltage equipment — Definitions, test and procedure requirements, test equipment*

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

IEC 61851-23:2023, *Electric vehicle conductive charging system — Part 23: DC electric vehicle charging station*

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

IEC TS 62196-3-1, *Plugs, socket-outlets, vehicle connectors and vehicle inlets — Conductive charging of electric vehicles — Part 3-1: Vehicle connector, vehicle inlet and cable assembly for DC charging intended to be used with a thermal management system*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5474-1 and the following apply.

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

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

3.1

cut-off current

let-through current

maximum instantaneous value of current attained during the breaking operation of a switching device or a fuse

Note 1 to entry: This concept is of particular importance when the switching device or the fuse operates in such a manner that the prospective peak current of the circuit is not reached.

[SOURCE: IEC 60050-441:1984, 441-17-12, modified — “is” added to the Note to entry.]

3.2

insulation monitoring device

IMD

device which permanently monitors the insulation resistance to earth of unearthed AC IT systems, AC IT systems with galvanically connected DC circuits having nominal voltages up to 1 000 V a.c., as well as monitoring the insulation resistance of unearthed DC IT systems with voltages up to 1 500 V d.c., independent from the method of measuring

[SOURCE: IEC 61557-8:2014, 3.1.14]

3.3

insulation resistance monitoring system

system that periodically or continuously monitors the insulation resistance between live parts and the electric chassis

[SOURCE: ISO 6469-3:2021, 3.24, modified — “isolation” has been replaced by “insulation”.]

3.4

thermal cut-out

temperature sensing control device intended to switch-off automatically under abnormal operating conditions and which has no provision for adjustment by the user

[SOURCE: IEC 60050-442:1998, 442-01-43]

3.5

thermal sensing

means for providing temperature data of accessories, cable assemblies or parts thereof

[SOURCE: IEC 61851-23:2023, 3.3.109]

3.6

RESS SOC

rechargeable energy storage system state of charge
residual capacity of RESS available to be discharged

Note 1 to entry: RESS state of charge is normally expressed as a percentage of full charge.

[SOURCE: ISO/TR 11954:2008, 2.2]

3.7

leakage current monitoring device

passive electrical device for monitoring insulation resistance of separated DC system by measuring leakage current between live parts and exposed conductive parts or the protective conductor

[SOURCE: IEC 61851-23:2023, 3.2.104, modified — Deprecated term removed.]

3.8

SPD

surge protective device

device that contains at least one non-linear component that is intended to limit surge voltages and divert surge currents

[SOURCE: IEC 61643-11:2011, 3.1.1]

4 System architecture

ISO 5474-1:2024, Clause 4 applies.

5 Environmental and operational conditions

ISO 5474-1:2024, Clause 5 applies.

6 Safety requirements

6.1 General

ISO 5474-1:2024, 6.1 applies except as follows.

Protection against electric shock for the vehicle power supply circuit shall comprise a provision for basic protection and a provision for fault protection according to the requirements in [6.2](#).

Unless specified otherwise, "Alternative protection measures" according to ISO 6469-3:2021, 6.3.5 shall be applied directly between live parts of the vehicle power supply circuit and an ordinary person.

For all safety related functions, the vehicle shall carry out its own measurement of current and voltage, and shall not solely rely on values communicated via digital communication by the EV supply equipment.

NOTE Digital communication is considered to be not reliable in terms of safety.

6.2 Protection of persons against electric shock

6.2.1 General

ISO 5474-1:2024, 6.2.1 applies.

6.2.2 Compatibility with external safety devices

6.2.2.1 Insulation resistance monitoring system

The operation of the insulation monitoring device or/and the leakage current monitoring device of the external electric circuit, as specified in IEC 61851-23, shall not be affected. The vehicle should deactivate or disconnect its insulation resistance monitoring system to avoid such interference.

6.2.2.2 Compatibility of a 1 000 V vehicle with 500 V EV supply equipment

If the vehicle contains circuits with a maximum working voltage between DC+ and DC- above 500 V and it is intended to be connected to DC EV supply equipment with a rated maximum DC output voltage below or equal to 500 V d.c., there is a risk that the voltage between the live conductors and protective conductor in the EV supply equipment exceeds 500 V. It can be caused by, but is not limited to, an insulation fault, see [Figure 1](#), or asymmetric distribution of the insulation resistance between DC+/DC- and the protective conductor in the section of the vehicle with a working voltage above 500 V d.c.

The temporary overvoltage can trip SPDs in the EV supply equipment or damage components in the EV supply equipment.

The current caused by those effects can subsequently:

- cause a touch voltage between earth and vehicle chassis, and/or
- damage the protective conductor connection between the vehicle and the DC supply equipment as a secondary effect.

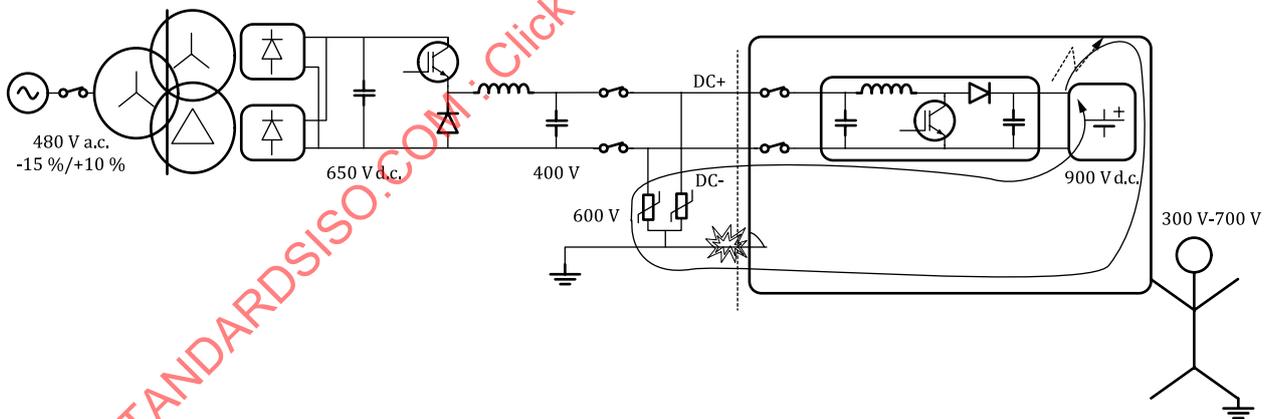


Figure 1 — Single fault scenario of a 1 000 V vehicle with 500 V EV supply equipment

The vehicle manufacturer shall perform a safety analysis to minimize the risk of a hazardous electric shock caused by the effects above. The protection measures are, but not limited to:

- the vehicle shall disconnect the vehicle power supply circuit from the EV supply equipment in less than 5 s if the voltage between the live conductors and protective conductor exceeds 500 V in the section of the vehicle power supply circuit with a working voltage of less than or equal to 500 V;
- the vehicle shall fulfil at least one of the following:

- a) have a vehicle power supply circuit with a maximum working voltage up to 500 V and provide simple separation between the vehicle power supply circuit and any circuit which has a working voltage above 500 V;
- b) implement double or reinforced insulation between the live parts of the vehicle power supply circuit (including the RESS) with a working voltage above 500 V and electric chassis/voltage class A circuit;
- c) limit the operating joule integral I^2t in consideration of IEC 60364-5-54 and limit the duration of touch voltage between electric chassis and earth or EV supply equipment housing in consideration of IEC 60479 series.

6.2.2.3 Y-capacitance coordination

The total y-capacitance of the vehicle power supply circuit shall not exceed 4 μF .

For a vehicle equipped with a vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3 configuration AA with a maximum working voltage up to 500 V d.c., the y-capacitance of the vehicle power supply circuit shall not exceed 1,1 μF per live conductor and 2,2 μF in total y-capacitance.

For a vehicle with a vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3 configuration AA, configuration EE or configuration FF and a maximum working voltage above 500 V d.c., the total y-capacitance of the vehicle power supply circuit shall not exceed the limits according to [Formula \(1\)](#).

$$C_y = \frac{1,6}{1000 * U} \quad (1)$$

where

C_y is the total y-capacitance, expressed in Farad (F);

U is the maximum working voltage, expressed in Volt (V).

NOTE The formula assumes a measurement current of the IMD of 1 mA and limits the time to perform a single measurement for one live conductor to 8 s. This supports a total time for a complete measurement cycle for the vehicle of 30 s without consideration of the added y-capacitance of the external electric circuit.

For a vehicle with a vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3 configuration BB the Y-capacitance of the EV supply equipment shall be considered.

The y-capacitance per live conductor should be balanced by choosing appropriate design values.

Conformance is checked by inspection and by test. An example for a test is given in [Annex A](#).

6.2.2.4 Compatibility with the special protection of the DC EV supply equipment

To support the special protection of the DC EV supply equipment, the total y-capacitance of the vehicle power supply circuit shall not exceed the limits according to [6.2.2.3](#).

NOTE 1 The special protection is provided by the DC EV supply equipment according to IEC 61851-23:2023, 8.105.1.

NOTE 2 The Y capacitance threshold from [6.2.2.3](#) by itself does not provide additional protection for vehicles with a maximum working voltage above 500 V d.c. when the vehicle is disconnected from the DC EV supply equipment. For protection of persons against electric shock when not connected to an external electric circuit, see ISO 6469-3.

6.2.3 Insulation resistance

ISO 5474-1:2024, 6.2.3 applies.

6.2.4 Touch current

ISO 5474-1:2024, 6.2.4 applies except as follows.

Conformance shall be tested in accordance with [12.5](#).

6.2.5 Insulation coordination

The vehicle shall provide one of the following provisions between voltage class B live parts of the vehicle power supply circuit and an accessible voltage class A circuit:

- protective separation;
- basic insulation and, under single fault condition, limitation of the voltage at the accessible voltage class A terminals of a voltage class B component to below 60 V d.c. (or 30 V a.c.). Voltage transients exceeding 60 V shall be limited with an adequate margin from ventricular fibrillation in accordance with IEC 60479 series. The margin shall be specified by the vehicle manufacturer;

Conformance shall be checked by either design review or conformance test as specified by the vehicle manufacturer. An example is given in [C.1](#).

- basic insulation and, under single fault condition, limitation of:
 - a) steady-state touch current between the accessible voltage class A terminals of a voltage class B component and accessible conductive parts to 3,5 mA a.c. and 10 mA d.c.;
 - b) touch energy below a value with an adequate margin from the limit of ventricular fibrillation in accordance with IEC 60479 series; the margin shall be specified by the vehicle manufacturer.

Conformance shall be checked by either design review or conformance test as specified by the vehicle manufacturer. An example is given in [C.2](#).

The insulation between DC+ and protective conductor as well as DC- and protective conductor of the vehicle power supply circuit shall be designed to withstand:

- impulse withstand voltage of at least 2 500 V;
- short-term temporary overvoltage of 1 980 V d.c. with durations up to 5 s;
- long-term temporary overvoltage of 550 V d.c. with durations longer than 5 s if the vehicle power supply circuit has a maximum working voltage between DC+ and DC- up to 500 V d.c.;
- long-term temporary overvoltage of 110 % of the maximum working voltage between DC+ and DC- with durations longer than 5 s if the vehicle power supply circuit has a maximum working voltage between DC+ and DC- above 500 V d.c.

NOTE 1 The value of 1 980 V is based on the equation $(U_n + 1\ 200) \cdot \sqrt{2}$ from IEC 61851-23:2014 with an assumed value of $U_n = 200$ V.

NOTE 2 IEC 61851-23:2023 specifies a short-term temporary overvoltage of 1 800 V.

NOTE 3 These requirements are derived from IEC 61851-23. See also IEC 60664-1:2020, Clause 5.

Conformance shall be tested in accordance with [12.4.1](#).

For normal operation the vehicle power supply circuit shall be designed for a maximum voltage between DC+ and protective conductor as well as between DC- and protective conductor of at least the maximum DC working voltage.

Additional voltages of the insulation monitoring device (IMD) of the external electric circuit (see IEC 61851-23) shall be considered.

6.2.6 Protective conductor

ISO 5474-1:2024, 6.2.6 applies except as follows.

For cross-sectional area of the protective conductor, see also IEC 61851-23:2023, 8.105.11.

6.2.7 Basic protection when connected to an external electric circuit

ISO 5474-1:2024, 6.2.7 applies.

6.2.8 Requirements for unmated vehicle contacts

ISO 5474-1:2024, 6.2.8 applies.

6.2.9 Withstand capability during insulation resistance check before charging

The vehicle shall withstand the voltage applied during insulation resistance check before charging, as specified in IEC 61851-23. If the vehicle detects an unexpected or reversed voltage it shall not close its disconnection devices and shall stop the charging process.

Conformance shall be tested in accordance with [12.4.3](#).

6.2.10 Monitoring continuity of protective conductor

For a vehicle equipped with a vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3 configuration AA, when an unintended transition from CP state 'ON' to 'OFF' or any other unknown state occurs during energy transfer phase according to IEC 61851-23:2023, AA.4.3.1, the vehicle shall fulfil the criteria for the 'maximum time to reach safe voltage from fault occurrence' as specified in IEC 61851-23:2023, Table AA.8 and trigger a normal or error shutdown within 3 s.

NOTE 1 The discontinuity of PE or CP3 triggers the transition of CP state from 'ON' to 'OFF' and the opening EV disconnection device Sv1 by hardware, see IEC 61851-23:2023, Figure AA.1.

In order to prevent the unintentional current flow through CP3 in case of PE conductor discontinuity (i.e. CP bypassing) during the energy transfer phase, the vehicle shall open CS after the permission of insulation resistance check in the initialization 1 phase and until the opening of the EV disconnection device Sv1 in the shutdown 1 phase according to IEC 61851-23:2023, AA.4.3.1.

NOTE 2 CS can be opened by a disconnection device such as relay and transistor. Refer to 'unintentional current flow prevention circuit' in IEC 61851-23:2023, Figure AA.1.

For a vehicle equipped with a vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3 configuration BB, when an unintended transition from CC2 state 'low' to 'high' or any other unknown state occurs during charging phase according to IEC 61851-23:2023, BB.4.4, the vehicle shall trigger an emergency shutdown, send "vehicle stopping command" by digital communication according to IEC 61851-24:2023, Clause B.4 to the EV supply equipment and open the EV disconnection device Sv1 within 300 ms.

For a vehicle equipped with a vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3 configuration EE or configuration FF, monitoring of the continuity of the protective conductor shall be implemented in accordance with IEC 61851-23:2023, CC.4.3 and CC.4.7.

Conformance shall be checked by either design review or conformance test in accordance with [12.7](#).

6.2.11 Insulation resistance monitoring system

The vehicle shall monitor the vehicle power supply circuit with an insulation resistance monitoring system according to ISO 6469-3.

If the insulation resistance of the vehicle power supply circuit divided by its maximum working voltage is less than 100 Ω/V , the vehicle shall not close its disconnection device.

The section between the disconnection device and the vehicle inlet may be omitted in the measurement.

For a vehicle equipped with a vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3 configuration AA, the vehicle shall monitor the insulation resistance from the beginning of the initialization 1 phase and until the end of the initialization 3 phase according to IEC 61851-23:2023, AA.4.3.1. The vehicle may reactivate the insulation resistance monitoring after opening the EV disconnection device in the shutdown 1 phase.

For a vehicle equipped with a vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3 configuration BB the insulation monitoring system of the vehicle shall remain active in accordance with IEC 61851-23.

For a vehicle equipped with a vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3 configuration EE and FF, the vehicle shall monitor the insulation resistance in accordance with the timings specified in IEC 61851-23:2023, CC.3.

6.3 Protection against thermal incident

6.3.1 Requirements for normal operation

ISO 5474-1:2024, 6.3.1 applies except as follows.

The cross-sectional area of the live conductors may be reduced as long as temperature limits according to 6.3.6 are not exceeded. In this case, protection against thermal incidents of the vehicle power supply circuit shall be provided. The maximum ambient temperature of the vehicle shall be considered.

The vehicle may allow a current exceeding the rated current of the vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3 as long as the temperature requirement for the voltage class B contacts of the vehicle inlet according to 6.3.6 is fulfilled.

6.3.2 Overcurrent protection

6.3.2.1 General

ISO 5474-1:2024, 6.3.2.1 applies except as follows.

NOTE 1 When determining the necessary breaking capability of the vehicle overcurrent protection device, also consider the impedance of the external electric circuit. Measures to mitigate short circuit energy by the EV supply equipment are under consideration.

NOTE 2 Requirements for impedance of the external electric circuit are under consideration in IEC 61851-23:2023, 101.1.8.

6.3.2.2 Overload protection

ISO 5474-1:2024, 6.3.2.2 applies.

6.3.2.3 Short-circuit protection

ISO 5474-1:2024, 6.3.2.3 applies except as follows.

6.3.2.3.1 Short-circuit energy supplied by external electric circuit

In case of a short circuit, the vehicle shall be capable of withstanding a peak current, including transient effects, according to the IEC 61851-23:2023, 13.101.

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

- a) The vehicle power supply circuit shall have a I^2t value of at least the following values:
- 1 000 000 A^2s , if a vehicle is equipped with a vehicle inlet of configuration AA, configuration BB, configuration EE, configuration FF according to IEC TS 62196-3-1 or IEC 62196-3, or
 - an I^2t value to be coordinated for any other DC charging system.

The minimum cross-sectional area of the live conductors shall be calculated in accordance with IEC 60364-4-43:2008, Equation (3).

NOTE This I^2t value corresponds to the characteristics of the overcurrent protection of the external electric power supply. The given I^2t values are coordinated with IEC 61851-23.

- b) An overcurrent protection (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 shall be designed according to the short-circuit interrupt rating of this overcurrent protection. The cross-sectional area of the live conductors between the vehicle inlet and this overcurrent protection shall conform to the requirement of [6.3.2.3.1 a\)](#).

6.3.2.3.2 Short-circuit energy supplied by the vehicle

To limit the short-circuit energy supplied from the vehicle to the external electric circuit, the vehicle power supply circuit shall provide overcurrent protection with the following characteristics:

- the cut-off current supplied by vehicle sources does not exceed 30 kA at the voltage class B contacts of the vehicle inlet, and
- the supply to the external electric circuit is switched off within 1 s after start of the short-circuit condition, and
- the maximum I^2t value at the voltage class B contacts of the vehicle inlet:
 - of 2 500 000 A²s, if the vehicle is equipped with an inlet of configuration AA according to IEC TS 62196-3-1 or IEC 62196-3, or
 - of 5 000 000 A²s, if the vehicle is equipped with a vehicle inlet of configuration BB, EE or configuration FF according to IEC TS 62196-3-1 or IEC 62196-3,
- an I^2t value to be coordinated for any other DC charging system.

NOTE 1 The I^2t value requirement for vehicles equipped with a configuration EE or configuration FF vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3 (System C according to IEC 61851-23) was 12 000 000 A²s in ISO 17409:2015.

Conformance is checked:

- by inspection, assuming a fault resistance of $R_{\text{fault}} = 5 \text{ m}\Omega$ and a fault inductance of $L_{\text{fault}} = 2 \text{ }\mu\text{H}$, or
- by test, applying a fault resistance of $R_{\text{fault}} \leq 5 \text{ m}\Omega$ and a fault inductance of $L_{\text{fault}} \leq 2 \text{ }\mu\text{H}$ for the short circuit condition external to the vehicle.

The cross-sectional area of the live conductors between the vehicle inlet and the overcurrent protection shall be designed according to the characteristics of the overcurrent protection.

The cross-sectional area of the live conductors shall be calculated from IEC 60364-4-43:2008, Equation (3).

NOTE 2 The short-circuit withstand capabilities of the external electric circuit (see IEC 61851-23) correspond to these characteristics of the overcurrent protection of the vehicle power supply circuit.

Requirements for external impedance are under consideration in IEC 61851-23:2023, 101.1.8.

Conformance is checked by inspection.

6.3.3 Residual energy after disconnection related to thermal incident

ISO 5474-1:2024, 6.3.3 applies.

6.3.4 Arc protection

ISO 5474-1:2024, 6.3.4 applies except as follows.

Arc protection shall be covered by the requirement of control of the latching device of the vehicle coupler. For a vehicle equipped with a configuration EE or configuration FF vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3, the following requirements shall be met:

- the vehicle shall engage the latching device of the vehicle inlet at the beginning of the power transfer process, before the vehicle changes the system state to state C in accordance with IEC 61851-1;
- the vehicle shall check the proper engagement of the latching device and shall only close S2 if the latching device is properly engaged;

NOTE 1 The proper engagement of the latching device is typically checked by the detection of the end position of the actuator of the latching device.

- if the latching device disengages falsely, the vehicle shall change the system state of the control pilot function to state B, in accordance with the sequence diagrams as specified in IEC 61851-23:2023, CC.3, in order to trigger an emergency shutdown;
- the vehicle shall only disengage the latching device if the vehicle power supply circuit is in a condition that does not cause hazardous arcing.

In case of a malfunction, a means for disconnection specified by vehicle manufacturer is allowed to be provided.

The vehicle manufacturer shall analyse the system design including the EV supply equipment to specify the thresholds to prevent from hazardous arcing.

EXAMPLE

- the voltage and the current of the vehicle power supply circuit are below values specified by the vehicle manufacturer (e.g. 60 V and 5 A);
- disconnection device detected open.

NOTE 2 For a vehicle equipped with a configuration AA or configuration BB vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3, the latching device of the vehicle coupler is provided by the DC EV supply equipment.

Furthermore, a vehicle equipped with a configuration EE or configuration FF vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3 shall detect the loss of electric continuity of the control pilot conductor and shall react in accordance with IEC 61851-23:2023, CC.4.3.

6.3.5 Voltage withstand capability

The vehicle power supply circuit from vehicle inlet up to and including the disconnection device, shall be designed according to an impulse withstand voltage of at least the maximum working voltage of the vehicle power supply circuit plus 500 V between DC+ and DC- according to IEC 61851-23:2023, 12.7.101.

The relevant parts of the voltage class B electric circuit shall withstand a temporary overvoltage caused by load dump in accordance with the system specific requirements of IEC 61851-23:2023, 101.1.7.

The output inductance of the EV supply equipment shall be considered.

NOTE The maximum value of the output inductance of the EV supply equipment is under consideration in IEC 61851-23.

Conformance shall be tested in accordance with [12.4.2](#).

6.3.6 Voltage class B contact temperature

The temperature of the voltage class B contacts of the vehicle inlet shall not exceed the temperature limit as specified by the manufacturer of the vehicle inlet.

For an ambient temperature up to 40 °C, if the contact temperature of the voltage class B contacts of the vehicle inlet exceeds 90 °C for 8 consecutive seconds, the vehicle shall trigger an error shutdown according to IEC 61851-23 within 1 s.

Conformance is checked by inspection and test [12.6](#).

For an ambient temperature up to 40 °C, if the contact temperature of the voltage class B contacts of the vehicle inlet exceeds 95 °C for 1 s, the vehicle shall trigger an error shutdown according to IEC 61851-23 within 1 s.

Conformance is checked by inspection.

NOTE 1 The temperature limits are derived from the IEC 62196 series and IEC 61851-23.

For vehicles equipped with a vehicle inlet according to IEC TS 62196-3-1 one of the following requirements applies.

- a) The vehicle shall implement thermal sensing for each DC power contact. The vehicle shall control the current by evaluating the measured temperature values. The vehicle shall periodically check the plausibility of thermal sensing and provide an appropriate warning if the check fails.

NOTE 2 Plausibility check of thermal sensing can be implemented by comparing the ambient temperature of the vehicle with the temperature of the power contacts while the vehicle inlet or the automated coupler is not used.

- b) The vehicle shall provide a thermal cut-out for each DC power contact.

6.4 Vehicle movement

ISO 5474-1:2024, 6.4 applies.

6.5 AC or DC electric power at the same contacts

The disconnection device (see [9.2](#)) shall interrupt all live conductors of the vehicle power supply circuit according to this document. The relevant parts of the vehicle power supply circuits shall fulfil the requirements for AC electric power transfer and for DC electric power transfer, or they shall be disconnected by a disconnection device which provides simple separation between the circuits.

If the vehicle is using contacts for DC electric power transfer at the vehicle inlet, which also can be used for AC electric power transfer, the vehicle shall connect its vehicle power supply circuit according to this document only to an external DC electric circuit if the following requirements are fulfilled:

- a communication between the external DC electric circuit and the vehicle that is required to start DC electric power transfer is established;
- voltage at the vehicle inlet shall be measured and the vehicle shall only close its disconnection device, if a DC voltage which complies with the requirement in [9.2](#) is detected;
- the voltage measurement circuit shall be monitored by plausibility check of measured voltages during operation.

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

When connected to an external electric circuit, provisions shall be taken that unintentional reverse DC current flow does not occur from vehicle power supply circuit according to this document through the vehicle inlet under single failure conditions in the vehicle power supply circuit according to this document (e.g. disconnection device) and in the vehicle power supply circuit according to ISO 5474-2 (e.g. charger).

The following are examples of possible measures for vehicle power 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 the ISO 13849 series;
- use of charger which provides basic insulation by galvanic separation.

The analysis and design shall be in accordance with the ISO 26262 series.

The vehicle manufacturer shall include the following into the analysis:

- possible hazards in the infrastructure or external electric circuit resulting from DC 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 AC voltage supplied by the infrastructure or external electric circuit to the vehicle; and
- other possible hazards.

7 Electromagnetic compatibility (EMC)

ISO 5474-1:2024, Clause 7 applies.

8 Protection in case of unintended power transfer

ISO 5474-1:2024, Clause 8 applies.

9 Functional requirements

9.1 General

IEC 61851-23:2023, Annexes AA, BB and CC specify functional requirements for both, EV supply equipment and vehicle.

Vehicles equipped with a configuration AA vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3 shall fulfill the functional requirements in IEC 61851-23:2023, Annex AA.

Vehicles equipped with a configuration BB vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3 shall fulfill the functional requirements in IEC 61851-23:2023, Annex BB.

Vehicles equipped with a configuration EE or configuration FF vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3 shall fulfill the vehicle requirements related to the process of energy transfer and related to the additional functions in accordance with IEC 61851-23:2023, Annex CC.

NOTE Vehicle requirements for safety related functions according to IEC 61851-23 are covered by the requirements of [Clause 6](#).

9.2 Disconnection device

The vehicle shall provide a disconnection device between each voltage class B contact (excluding protective conductor) of the vehicle coupler and electric power sources of the vehicle.

The disconnection device shall withstand an inrush current in accordance with system specific requirements in IEC 61851-23.

The disconnection device shall have a breaking capability to disconnect at the maximum rated current of the vehicle power supply circuit.

NOTE If the rated current of the disconnection device is lower than the rated current of the vehicle coupler, see ISO 5474-1:2024, 6.3.2.2.

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

When the disconnecting device is opened during the power transfer stage, the vehicle shall stop and may restart charging process according to IEC 61851-23.

The vehicle shall disconnect from the external electric circuit based on the control pilot function as specified in IEC 61851-1 and/or IEC 61851-23, as applicable.

For a vehicle equipped with a vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3 configuration EE or FF, or IEC TS 63379¹⁾, the voltages between DC+ and DC- on both sides of the disconnection device shall not differ more than 20 V before the vehicle closes its disconnection device.

9.3 Control pilot functions

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

9.4 Compatibility with external insulation monitoring

For functional reasons, a vehicle that is equipped with a vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3 configuration EE or configuration FF should have an insulation resistance high enough to allow the combined insulation resistance of EV supply equipment and vehicle power supply circuit to be above the threshold in accordance with IEC 61851-23.

Conformance can be tested in accordance with clause ISO 5474-1:2024 12.3.

Further insulation resistance requirements related to the protection of persons against electric shocks are given in ISO 5474-1:2024, 6.1.3.

NOTE IEC 61851-23:2023, CC.4.1.4 specifies a fixed value of 100 k Ω as the IMD threshold.

9.5 Specific requirements for the vehicle inlet

The vehicle inlet shall conform to:

- IEC 62196-3, and
- IEC TS 62196-3-1 for a DC connection with a thermal management system.

9.6 Control of the latching device of the vehicle coupler

For a vehicle equipped with a configuration EE or configuration FF vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3, the following recommendations apply:

- the vehicle should engage the latching device of the vehicle inlet as soon as CP and PP indicate that the vehicle connector is fully inserted into the vehicle inlet;
- for configuration EE, the vehicle should not engage the latching device of the vehicle inlet before PP indicates that the retaining device of the vehicle connector is in the proper position to allow latching;
- at the end of a charging session, if the vehicle allows unmating of the vehicle coupler, the vehicle should disengage the latching device after receiving the response message of session stop, in accordance with IEC 61851-23.

10 Additional requirements for reverse power transfer

ISO 5474-1:2024, Clause 10 applies except as follows.

1) Under preparation. Stage at the time of publication: IEC TS/CD 63379:2023.

Requirements for specific reverse power transfer cases are under consideration.

NOTE For a vehicle equipped with a vehicle inlet according to IEC TS 62196-3-1 or IEC 62196-3 configuration AA, the functional requirements for reverse power transfer are specified in IEC 61851-23.

11 Owner's manual and marking

ISO 5474-1:2024, Clause 11 applies.

12 Test procedure

12.1 General

ISO 5474-1:2024, 12.1 applies.

12.2 Resistance of protective conductor

ISO 5474-1:2024, 12.2 applies.

12.3 Insulation resistance

ISO 5474-1:2024, 12.3 applies.

12.4 Withstand voltage test

12.4.1 Withstand voltage test between voltage class B contacts and electric chassis / PE

The withstand voltage test shall be performed according to ISO 6469-3:2021, 10.6, with the following modifications:

- the test is performed on the vehicle power supply circuit at the contacts of vehicle inlet (case C);
- if the vehicle power supply circuit includes contactors or disconnection devices, they are closed.

The test voltage shall be derived from the requirements given in [6.2.5](#).

12.4.2 Differential mode overvoltage withstand test for vehicle power supply circuit

12.4.2.1 Differential mode overvoltage test requirements

This test is intended to verify the adequacy of the entire insulation between the voltage class B contacts of all parts and components of the vehicle power supply circuit between and including the vehicle inlet and the disconnections devices.

The test requires two test steps.

- a) Start the test with applying the maximum working voltage between DC+ and DC-. Then apply an impulse test according to one of the options below:
 - an impulse withstand voltage test in accordance with 1,2/50 μ s according to IEC 61000-4-5/IEC 61180; or
 - a DC voltage test with 3 pulses of at least 10 ms duration.

The peak amplitude of the test voltage shall equal the maximum working voltage of the vehicle power supply circuit plus 500 V according to IEC 61851-23:2023, 12.7.101.

- b) Perform a long temporary overvoltage test at 110 % of the maximum working voltage between DC+ and DC- or 550 V, whichever is higher, for 60 s. The load dump withstand capability is deemed to be fulfilled with this test as well, as it applies the same overvoltage but for a shorter duration according to the requirements in IEC 61851-23.

NOTE Rationale 60 s: 38 s of timeout duration for cable check system C with 110 % maximum voltage according to IEC 61851-23 and the ISO 15118 series (38 s).

The test may either be performed at the vehicle with open disconnection devices directly at the inlet, or alternatively at component level with all components that are galvanically connected to the vehicle power supply circuit in the respective vehicle with opened disconnection devices. If components are tested separately, the original connectors shall be used to make connections for applying the test voltage to the component.

12.4.2.2 Preconditioning and conditioning

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

- preconditioning at the temperature selected for conditioning within tolerance of $+4/-0$ K and a duration that ensures a constant temperature of the device under test;
- conditioning: for 48 h within ± 2 K at a temperature between 20 °C and 40 °C, a humidity of 93 % \pm 3 %, and an atmospheric pressure of 86 kPa to 106 kPa.

12.4.2.3 Test procedure

After preconditioning, the respective test voltage according to [12.4.2.1](#) is applied and also measured continuously directly at the component terminals or the vehicle inlet.

Impulse test criteria in accordance with IEC 61000-4-5 shall be fulfilled.

For DC test pulses and the temporary overvoltage test, the voltage shall remain at or above the required level for at least the test duration/time given in [12.4.2.1](#). and repeated accordingly. Between tests or test steps the voltage shall drop back to a range of start voltage \pm 5 V of the test.

Neither electric breakdown of the insulation nor flashover shall occur. Partial discharges shall not occur.

12.4.3 Withstand voltage test – reversed voltage during insulation resistance check

Simulate a charging session and stop at the stage of insulation resistance check.

Perform a withstand voltage test according to ISO 6469-3 with the following modifications:

- the vehicle power supply circuit disconnection devices are open;
- the voltage class B and voltage class A circuits shall be kept as per EV design without additional connections;
- the maximum voltage is applied with reversed polarity on the vehicle power supply circuit at the contacts of vehicle inlet (case C) between DC+ and DC-; and
- the voltage is applied for a duration that is minimum the EV detection time of the wrong polarity plus additional time for EV initiated error shutdown, see IEC 61851-23 for details;

Neither dielectric breakdown nor flashover shall occur during the test. The vehicle shall not close the EV disconnection device and shall stop the charging process.

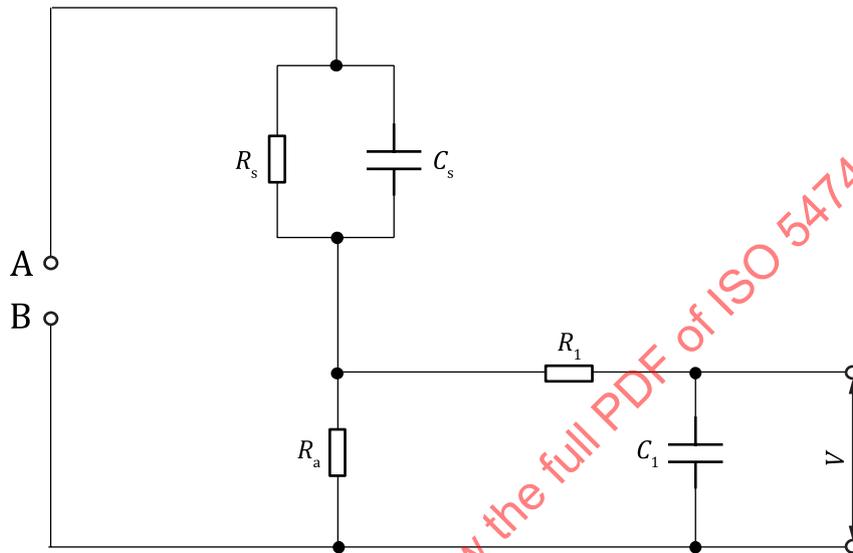
12.5 Touch current

The measurements are performed at vehicle level or at component level with the relevant parts of the vehicle power supply circuit.

The touch current is measured when the device under test is connected to a DC external electric power supply.

The test is conducted with a DC EV supply equipment conforming with IEC 61851-23 or an equivalent national standard based on recommendation by the vehicle manufacturer.

The touch current is then measured using the measurement network according to [Figure 2](#) (see also IEC 60990).



Key

- A, B terminals of measurement circuit
- $R_s = 1,5 \text{ k}\Omega \pm 5 \%$
- $R_a = 500 \Omega \pm 5 \%$
- $R_1 = 10 \text{ k}\Omega \pm 5 \%$
- $C_s = 0,22 \mu\text{F} \pm 10 \%$
- $C_1 = 0,022 \mu\text{F} \pm 10 \%$
- V measured voltage to calculate the touch current

Figure 2 — Measurement circuit

V_{rms} , which is the root mean square value of the voltage V , is measured, see [Figure 2](#). For voltage measurement, an instrument according to IEC 60990:2016, Annex G is used.

The touch current, I_{rms} , is calculated by [Formula \(2\)](#):

$$I_{\text{rms}} = \frac{V_{\text{rms}}}{500 \Omega} \quad (2)$$

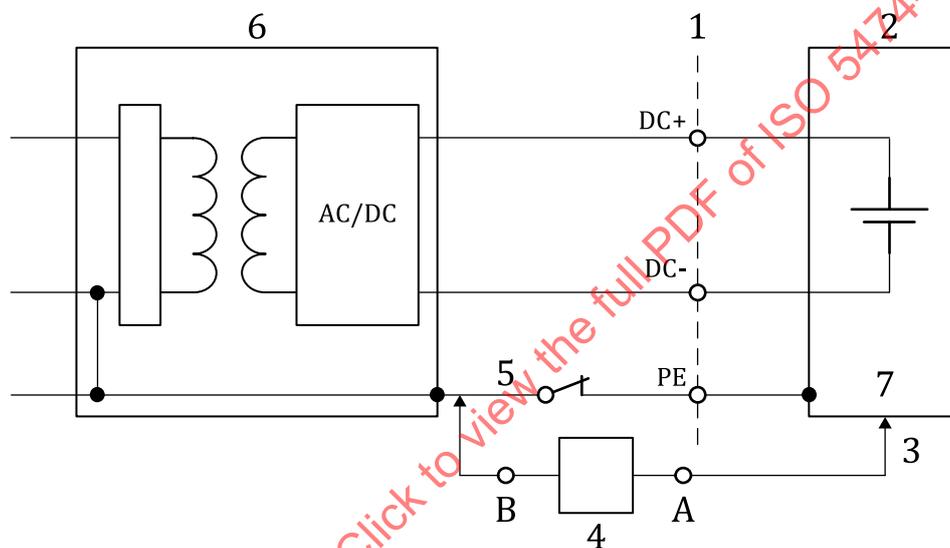
The test is passed if all touch currents measured during the test do not exceed the specified limits. The requirement is deemed fulfilled if charging stops due to monitoring of the continuity of the protective conductor by the vehicle and touch current in case of loss of continuity of protective conductor could not be measured.

Circuitry which is connected through a fixed resistance or referenced to earth for monitoring purpose which is not continuously operated, and which does not contribute to a protective conductor current during normal operation of the vehicle power supply circuit should be disconnected before this test.

The vehicle power supply circuit operates at its highest rated power. Any AC loads that are conductively connected to the vehicle power supply circuit are activated. For the test the protective conductor is disconnected. It can be disconnected on the vehicle or the switch in the protective conductor line is open (see [Figure 3](#)).

The terminal B of the measurement circuit is connected to the protective conductor of the external electric power supply. The terminal A of the measurement circuit is connected with a test probe and the test probe is used to connect the measurement circuit to the vehicles electric chassis for vehicle level measurement or the enclosure of the device under test for component level measurement. In case of measuring at the component level, the measurement is performed for the whole surface of the device under test. Non-conductive parts of the enclosure of the device under test are covered by a metal foil, which is connected to the PE terminal of the device under test and terminal A of the measurement circuit.

In order to eliminate the current of the control circuits of the DC EV supply equipment and the vehicle that flows through the protective conductor from the touch current measurement, all the control signal lines (including control pilot and proximity detection) could also be disconnected after interrupting the charging with disconnection of protective conductor.



Key

- | | | | |
|---|--|------|-----------------------------------|
| 1 | connection of vehicle or DUT | 7 | vehicle or DUT |
| 2 | vehicle electric chassis or enclosure of DUT | PE | terminal for protective conductor |
| 3 | test probe | DC+ | positive terminal |
| 4 | measurement circuit | DC- | negative terminal |
| 5 | protective conductor | A, B | terminals of measurement circuit |
| 6 | external electric power supply | | |

Figure 3 — Example test setup for touch current under DC charging

12.6 Voltage class B contact over temperature

The measurements are performed with vehicle.

This test verifies that the electrically propelled vehicle stops the DC power transfer if the voltage class B contact temperature limit according to [6.3.6](#) is exceeded.

The test is executed with a test gauge for system A according to [Figure 4](#) and for system C according to [Figure 5](#).

For configuration AA according to IEC TS 62196-3-1 or IEC 62196-3, the test gauge is equipped with voltage class B contact pins according to IEC 62196-3(Standard Sheet 3-1a) with silver-plated voltage class B contact surfaces.

For configuration EE or configuration FF according to IEC TS 62196-3-1 or IEC 62196-3, the test gauge is equipped with voltage class B contact tubes according to IEC 62196-3 (Standard Sheet 3-IIIb or Standard Sheet 3-IVc) with silver-plated voltage class B contact surfaces.

The RESS of the vehicle is fully discharged according to the vehicle manufacturer’s specification.

The test gauge is connected to the vehicle inlet.

The test is executed at room temperature. Forced convection is avoided. The vehicle is stored at room temperature at least for two hours before the test.

The vehicle performs a DC power transfer with a current of 40 A. If the maximum current for power transfer is lower than 40 A, the test starts with the maximum current for power transfer according to the vehicle manufacturer’s specification.

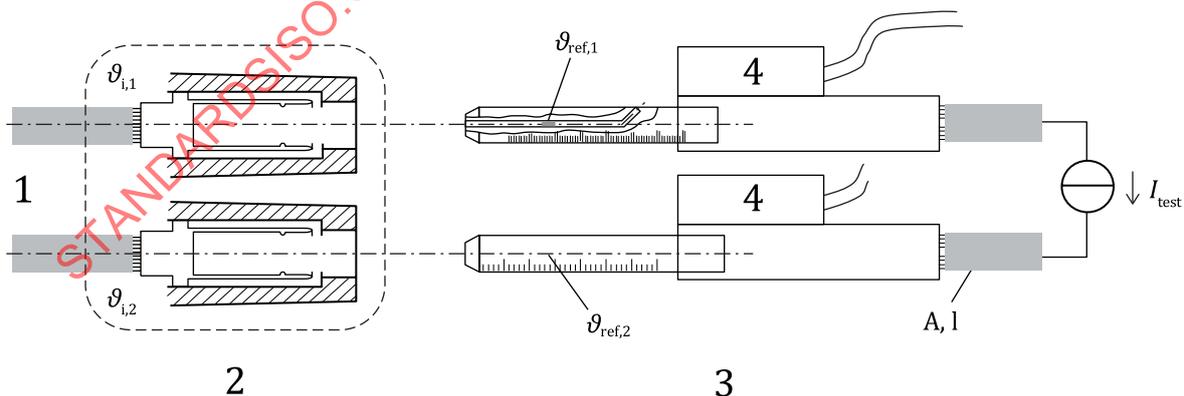
The test is executed for two different test sequences.

- Sequence a): a heating unit as shown in Figure 4 or Figure 5 is enabled until the reference temperature sensor indicates 70 °C. The injected heat power is adjusted to ensure a steady temperature of (70 ± 2) °C for 2 min. Afterwards the injected heat power is increased to reach a temperature rise of $(2 \pm 0,5)$ K/min as indicated by the reference temperature sensor.
- Sequence b): a heating unit as shown in Figure 4 or Figure 5 is enabled until the reference temperature sensor indicates 70 °C. The injected heat power is adjusted to ensure a steady temperature of (70 ± 2) °C for 2 min. Afterwards the injected heat power is increased to reach a temperature rise of $(5 \pm 0,5)$ K/min as indicated by the reference temperature sensor.

The over temperature test according to sequence a) and sequence b) is separately performed for each voltage class B contact.

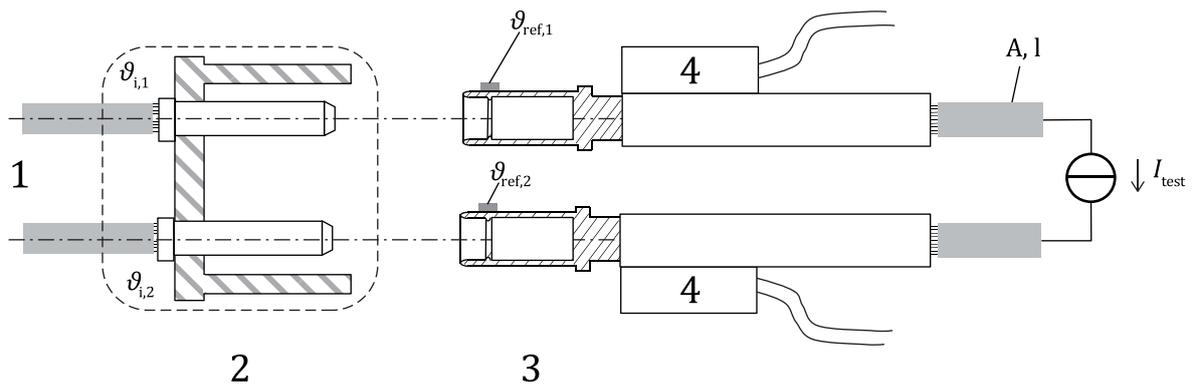
The test is passed if the vehicle stops the power transfer before or when the temperature limit for the voltage class B contacts according to 6.3.6 is exceeded as indicated by the reference temperature sensor for sequence a) and sequence b).

Stopping the power transfer includes, for example, performing a shutdown, requesting a current of 0 A, opening the contactors, or a thermal cut-out to trigger. This might be verified by measuring the current.



- Key**
- 1 wiring harness
 - 2 vehicle inlet
 - 3 gauge
 - 4 heating unit

Figure 4 — Test gauge for configuration AA



Key

- 1 wiring harness
- 2 vehicle inlet
- 3 gauge
- 4 heating unit

Figure 5 — Test gauge for configuration EE or configuration FF

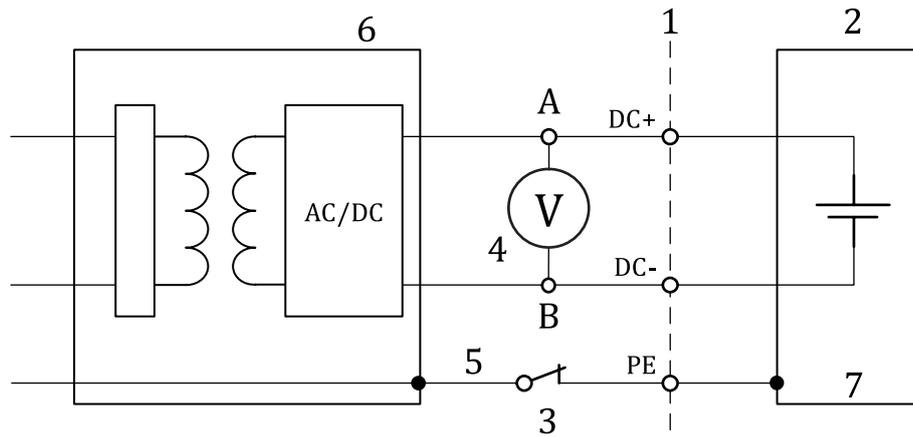
12.7 Monitoring continuity of protective conductor test

For configuration AA according to IEC TS 62196-3-1 or IEC62196-3, the test is conducted with a DC EV supply equipment or a dedicated EV supply equipment simulator conforming to the respective requirements for system A in IEC 61851-23 or an equivalent national standard based on the recommendation by the vehicle manufacturer.

For configuration BB according to IEC TS 62196-3-1 or IEC62196-3, the test is conducted with a DC EV supply equipment or a dedicated EV supply equipment simulator conforming to the respective requirements for system B in IEC 61851-23 or an equivalent national standard based on the recommendation by the vehicle manufacturer.

For configuration EE or FF according to IEC TS 62196-3-1 or IEC62196-3, the test is conducted with a DC EV supply equipment or a dedicated EV supply equipment simulator conforming to the respective requirements for system C in IEC 61851-23.

The voltage between DC+ and DC- and between DC+/DC- and the protective conductor are measured continuously during the test using the measurement circuit 4 according to [Figure 6](#).



Key

- 1 connection of vehicle to EV supply equipment
- 2 vehicles electric chassis or enclosure of device under test
- 3 switch inserted to the protective conductor of the cable assembly
- 4 measurement circuit
- 5 protective conductor
- 6 EV supply equipment
- 7 vehicle or device under test
- A, B terminals of measurement circuit
- PE terminal for protective conductor
- DC+ positive terminal
- DC- negative terminal

Figure 6 — Example of test setup for monitoring of the continuity of protective conductor

Connect the vehicle to an EV supply equipment or a dedicated EV supply equipment simulator.

Start power transfer session with the procedure specified by the EV supply equipment manufacturer or the EV supply equipment simulator manufacturer.

Confirm that the voltage between DC+ and DC- has reached the value specified by the vehicle manufacturer.

Open switch 3.

Confirm that the vehicle stops the power transfer and initiates shutdown sequence.

The test is passed if the voltage between DC+ and DC- has dropped to ≤ 60 V d.c. within 1 s after the opening of switch 3.

Annex A (informative)

Y capacitance measurement

A.1 General

The following test procedure describes the measurement of the y-capacitance of the vehicle power supply circuit at the plug (case A) or vehicle inlet (case B and case C).

The test procedure can be used to determine the total y-capacitance of the vehicle power supply circuit, as well as for parts (sub-system or component) of the vehicle power supply circuit.

If the test result for the whole vehicle power supply circuit is not affected, the test may be performed on parts (sub-systems or components) or sub-sections of the vehicle power supply circuit individually instead. The total y-capacitance of the vehicle power supply circuit is to be calculated as the sum of the individual measured y-capacitances.

The insulation resistance of the device under test can be determined in advance by selecting the appropriate method according to ISO 6469-3:2021, 10.3.

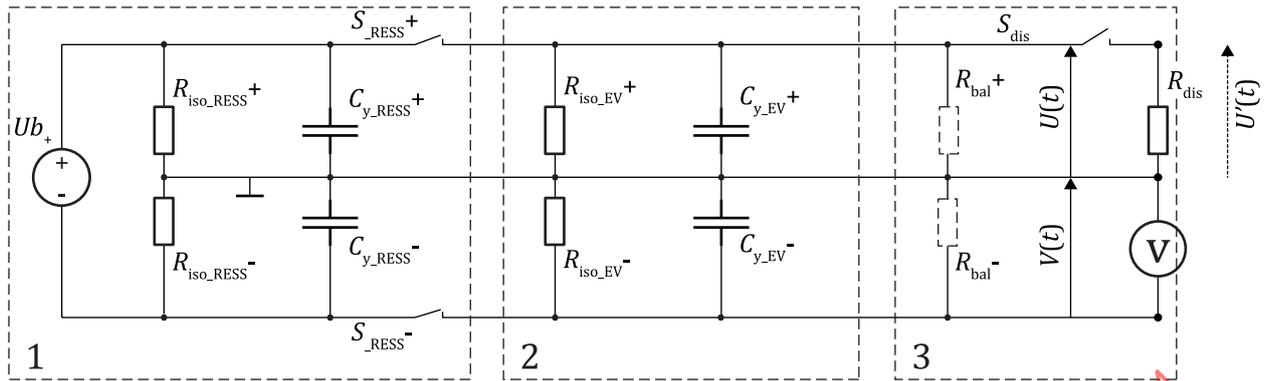
If the y-capacitance measurement is performed on a part or a sub-section of the vehicle power supply circuit, the insulation resistance of the part or the sub-section of the vehicle power supply circuit is used.

The device under test is stored for 24 h at an ambient temperature of (20 ± 10) °C.

If the device under test includes RESS using electrochemical energy conversion, the RESS SOC shall be more than 90 %, alternatively a standard cycle can be performed according to ISO 6469-1:2019, 6.1.5.

A.2 Test setup

[Figure A.1](#) shows a simplified model of an example vehicle power supply circuit with RESS and the external test setup.



Key

- 1 RESS, simplified
- 2 optional: vehicle power supply circuit excluding the RESS, simplified
- 3 measurement setup
- $R_{iso_RESS+}, R_{iso_RESS-}$ insulation resistance between the indicated live conductor of the RESS and electric chassis, in Ω
- C_{y_RESS+}, C_{y_RESS-} y-capacitance of the RESS in F
- $S_{_RESS+}, S_{_RESS-}$ disconnecting devices of the RESS
- R_{iso_EV+}, R_{iso_EV-} insulation resistance of the vehicle power supply circuit excluding the RESS in Ω
- C_{y_EV+}, C_{y_EV-} y-capacitance of the vehicle power supply circuit excluding the RESS in F
- R_{bal+}, R_{bal-} balancing resistors in Ω , when necessary
- U_b battery voltage
- $U(t)$ voltage at the side where R_{dis} will be connected
- $U'(t)$ voltage across R_{dis}
- V voltage probe
- $V(t)$ voltage at opposite side to R_{dis}
- R_{dis} discharge resistor in Ω
- S_{dis} switch to connect discharge resistor

Figure A.1 — Test setup with simplified model of an example vehicle power supply circuit

NOTE The position of V and R_{dis} can be reversed.

The setup shall maximize the amplitude of the discharge curve $U(t)$ or $V(t)$ (see [Figure A.2](#)).

Therefore, it is recommended to place R_{dis} at the side which has the highest insulation resistance, and place only one Voltage probe V at the opposite side. (The internal impedance of a differential voltage probe is usually between 3 M Ω and 10 M Ω .)

This will create an unbalanced condition before closing S_{dis} , to maximize the value of U_0 (minimize the value of V_0)

R_{bal+} or R_{bal-} shall only be used when necessary to limitate the unbalancing for a vehicle which needs it.

R_{dis} shall be chosen in order to minimize the value of U_e at end of discharge (or maximize the value of V_e):

Therefore R_{dis} shall be $<1/20$ of the insulation resistance at opposite side of R_{dis} , including R_{bal} and measurement probes.

The recommended value of R_{dis} is 1 k Ω , and not more than 100 k Ω .

The acquisition rate for the voltage measurement is recommended to be a constant and $\geq \frac{5\,000}{(R_{\text{dis}}) * C_{\text{total}}}$.

A.3 Initial conditions

Before connecting the discharge resistance R_{dis} , the initial state of the circuit shall be:

- the RESS is connected;
- the IMD (insulation monitoring device) of the vehicle is de-activated;
- the high voltage components of the vehicle power circuit shall be in stable functional mode. They can be in OFF mode if the internal capacitance downstream their transistors is negligible;
- the voltages $U(t) = U_0$ and $V(t) = V_0$ shall be stabilized;
- the initial voltages are preferably unbalanced in order to maximize the amplitude of $U(t)$ and $V(t)$ during discharge: $U_0 > Ub/2$ or $V_0 < Ub/2$.

If it is not the case, a solution can be to reverse the sides of R_{dis} and the voltage probe V .

A.4 Test procedure

Start recording $V(t)$ and close S_{dis} .

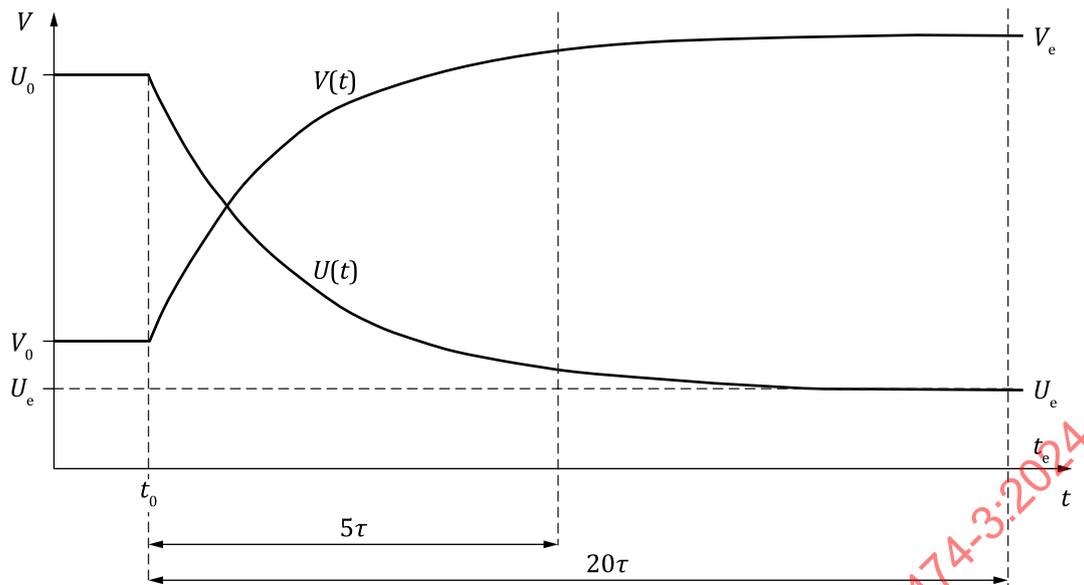
[Figure A.2](#) illustrates an example voltage over time curve.

The duration of recording after connection of R_{dis} shall be at least 5τ , with $\tau = R_{\text{dis}} \times C_{y_total}$.

U_e and V_e shall be determined at a time $t_e = t_0 + 20\tau$ or more.

In order to minimize the measurement noise and incertitude, it is recommended to calculate U_0 , V_0 , U_e , V_e as an average value over a short period.

As C_{y_total} is not known at the beginning of the test, the duration of recording shall have a sufficient margin.



Key

U_0, V_0	initial voltage before closing the switch
U_e, V_e	resulting voltage after charge equalization
t_0	time when closing the switch S_{dis}
t_e	time after charge equalization
τ	$\tau = R_{dis} \times C_{y_total}$
$V(t)$	voltage opposite to R_{dis}
$U(t)$	voltage at R_{dis} side $U(t) = U_b - V(t)$

Figure A.2 — Discharge curve after closing switch S_{dis}

Calculate the total y-capacitance (C_{y_total}) using [Formulae \(A.1\)](#) and [\(A.2\)](#) when measuring the total capacitance of the vehicle.

$$C_{y_total} = \frac{2E}{(U_0 - U_e)^2} \text{ or } C_{y_total} = \frac{2E}{(V_0 - V_e)^2} \quad (A.1)$$

$$E = \int_{t_0}^{\infty} \frac{(U(t) - U_e)^2}{R_{dis}} dt \cong \sum_{t_0}^{\geq t_0 + 5\tau} \frac{(U(t) - U_e)^2}{R_{dis}} \delta t \text{ or} \quad (A.2)$$

$$E = \int_{t_0}^{\infty} \frac{(V(t) - V_e)^2}{R_{dis}} dt \cong \sum_{t_0}^{\geq t_0 + 5\tau} \frac{(V(t) - V_e)^2}{R_{dis}} \delta t$$

As an alternative to [Formulae \(A.1\)](#) and [\(A.2\)](#), [Formula \(A.3\)](#) can be used to determine the y-capacitance:

$$U(t) = (U_0 - U_e)e^{-\frac{t-t_0}{\tau}} + U_e \quad (A.3)$$

where τ represents the product of C_{y_total} and combined resistance of R_{iso_total+} and R_{dis} .

Annex B (informative)

Outlook on megawatt charging applications

B.1 General

By the time of publication of this document, development activities for vehicle charging systems capable of transferring power in the range of megawatts had been ongoing in the industry for several years. The corresponding vehicle connector(s) and vehicle inlet(s) are under development in IEC TS 63379, the requirements for the EV supply equipment are under development in IEC 61851-23-3²⁾.

To support an earliest possible market introduction of these vehicle charging systems, this annex gives an outlook on the expected implications to the vehicle power supply circuit.

[B.2](#) describes modifications to requirements in the main part of the document related to megawatt charging applications. Unless otherwise specified in [B.2](#), the requirements in the main part also apply for megawatt charging applications, whereas:

- in case of different requirements for different configurations of IEC 62196-3 or IEC TS 62196-3-1, the requirements for configuration EE or configuration FF apply, but the reference for megawatt charging applications is IEC TS 63379, configuration HH;
- for megawatt charging applications, IEC 61851-23-3 applies instead of IEC 61851-23.

B.2 Outlook on modifications related to megawatt charging applications

B.2.1 Maximum working voltage between DC+ and DC-

The maximum working voltage between DC+ and DC- under normal operation is limited to 1 250 V d.c.

B.2.2 Requirements for unmated vehicle contacts in normal operation

ISO 5474-1:2024, 6.2.8.2 specifies requirements for stored energy and stored charge for unmated vehicle contacts up to 1 000 V d.c. by referencing Curve B in IEC 60479-2:2019, Figure 22. For voltages above 1 000 V d.c., as applied in megawatt charging systems (see [B.2.1](#)), the same values apply for stored energy and stored charge as for 1 000 V. Curve B of IEC 60479-2:2019, Figure 22 is horizontally extrapolated.

B.2.3 Vehicle circuits with a maximum working voltage above 1 250 V d.c.

Instead of [6.2.2.2](#) the following applies for megawatt charging applications.

If the vehicle contains circuits with a maximum working voltage above 1 250 V d.c. and it is intended to be connected to DC EV supply equipment with a maximum working voltage of $\leq 1\ 250$ V d.c., there is a risk that the voltage between the live conductors and protective conductor in the EV supply equipment exceeds 1 250 V d.c.

It can be caused by, but is not limited to, an insulation fault, see [Figure 1](#), or an asymmetric leakage in the section of the vehicle with a working voltage above 1 250 V d.c.

The temporary overvoltage can trip SPDs in the EV supply equipment or damage components in the EV supply equipment.

2) Under preparation. Stage at the time of publication: IEC/CD 61851-23-3:2023.

The current caused by those effects can subsequently:

- cause a touch voltage between earth and vehicle chassis; and/or
- damage the protective conductor connection between the vehicle and the DC supply equipment as a secondary effect.

The vehicle manufacturer performs a safety analysis to minimize the risk of a hazardous electric shock caused by the effects above. The protection measures are, but not limited to:

The vehicle disconnects the vehicle power supply circuit from the EV supply equipment in less than 5 s if the voltage between the live conductors and protective conductor exceeds 1 250 V d.c. in the section of the vehicle power supply circuit with a working voltage of less than or equal to 1 250 V d.c. and the vehicle:

- has simple separation between the vehicle power supply circuit and any circuit which has a working voltage above 1 250 V d.c., if a single fault result in a voltage of maximum 1 250 V d.c. between live conductor and protective conductor, or
- has protective separation between the vehicle power supply circuit and any circuit which has a working voltage above 1 250 V d.c., if a single fault result in a voltage exceeding 1 250 V d.c. between live conductor and protective conductor.

B.2.4 Short circuit energy

B.2.4.1 Short circuit energy supplied by the vehicle

[Subclause 6.3.2.3.2](#) applies with the following values:

- maximum cut-off current of 70 kA (instead of 30 kA);
- switch off of supply within 4 ms (instead of 1 s);
- maximum I^2t value of 12 000 000 A²s (instead of 2 500 000 A²s);

Conformance is checked:

- by inspection, assuming a fault resistance of $R_{\text{fault}} = 5 \text{ m}\Omega$ and a fault inductance of $L_{\text{fault}} = 2 \text{ }\mu\text{H}$ or
- by test, applying a fault resistance of $R_{\text{fault}} \leq 5 \text{ m}\Omega$ and a fault inductance of $L_{\text{fault}} \leq 2 \text{ }\mu\text{H}$ for the short circuit condition external to the vehicle.

B.2.4.2 Short circuit energy through the protective conductor

The protective conductor contact in the coupler is designed for maximum short circuit peak currents of 55 kA. This value is based on the assumption of a simultaneous short circuit in external electric circuit (max. 30 kA) and the vehicle power supply circuit (max. 70 kA) including a minimum impedance of the cables (minimum cable length of 2 m).

The protective conductor of the vehicle power supply circuit has the following characteristics:

- a maximum short circuit peak current of 55 kA through the protective conductor contact of a vehicle inlet, and
- a maximum I^2t value through the protective conductor contact of a vehicle inlet of 11 000 000 A²s.

Conformance is checked:

- by inspection, assuming a fault resistance of $R_{\text{fault}} = 10 \text{ m}\Omega$ and a fault inductance of $L_{\text{fault}} = 4 \text{ }\mu\text{H}$, or
- by test, applying a fault resistance of $R_{\text{fault}} \leq 10 \text{ m}\Omega$ and a fault inductance of $L_{\text{fault}} \leq 4 \text{ }\mu\text{H}$ for the short circuit condition external to the vehicle.