



**International
Standard**

ISO 5474-2

**First edition
2024-06**

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

**Part 2:
AC 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 2: Transfert de puissance AC

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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.

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

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

Part 2: AC power transfer

1 Scope

This document in combination with ISO 5474-1 specifies requirements for conductive power transfer using alternating current (AC) with a voltage up to 1 000 V a.c. between electrically-propelled road vehicles and external electric circuits.

NOTE External electric circuits are not part of the vehicle.

This document provides requirements for conductive charging in modes 2, 3 according to IEC 61851-1 and reverse power transfer.

This document applies to vehicle power supply circuits. Examples of circuit diagrams for different configurations of chargers on-board electric vehicles are shown in [Annex A](#).

This document also provides requirements for reverse power transfer through on-board standard socket-outlets and/or a EV plug or vehicle inlet according to IEC 62196-1 or IEC 62196-2 conductively connected to the vehicle power supply circuit. Requirements for AC power transfer using a charger without at least simple separation are under consideration.

This document does not provide:

- requirements for simultaneous operation of multiple EV plugs or vehicle inlets 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;
- requirements for vehicle to load adapters.

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*

IEC 60038, *IEC standard voltages*

IEC 60364-4-43, *Low-voltage electrical installations — Part 4-43: Protection for safety — Protection against overcurrent*

IEC 60364-8-82:2022, *Low-voltage electrical installations — Part 8-82: Functional aspects - Prosumer's low-voltage electrical installations*

IEC 60664-1:2020, *Insulation coordination for equipment within low-voltage supply systems — Part 1: Principles, requirements and tests*

IEC 60898-1:2015, *Electrical accessories — Circuit-breakers for overcurrent protection for household and similar installations — Part 1: Circuit-breakers for a.c. operation*

IEC 61851-1:2017, *Electric vehicle conductive charging system — Part 1: General requirements*

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*

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

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

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

active factor

$\cos \varphi$

for a two-terminal element or a two-terminal circuit under sinusoidal conditions, ratio of the active power to the apparent power

[SOURCE: IEC 60050-131:2002, 131-11-49, modified — The symbol “ $\cos \varphi$ ” was added and the note deleted.]

3.2

protective separation

electrically protective separation

separation of one electric circuit from another by means of:

- double insulation; or
- basic insulation and electrically protective screening (shielding); or
- reinforced insulation

[SOURCE: IEC 60050-826:2004, 826-12-29]

3.3
vehicle-to-load
V2L

power transfer from the vehicle power supply circuit to at least one external electric load, where the load is assumed to be without permanent connection to protective earth

Note 1 to entry: The external electric load can be connected to the vehicle power supply circuit via an on-board standard socket-outlet, or the vehicle inlet, directly or using a *V2L adapter* (3.4).

3.4
V2L adapter

equipment which connects to the vehicle power supply circuit using the vehicle inlet and provides at least one standard socket-outlet for external electric loads

3.5
grid forming mode

mode of reverse power transfer not in parallel with the supply network

3.6
grid following mode

mode of reverse power transfer in parallel and following the operational parameters of the supply network

3.7
isolation

disconnection providing adequate insulation between electrical equipment, a system, an installation or part of an installation and their energy sources

[SOURCE: IEC 60050-195:2021, 195-06-23]

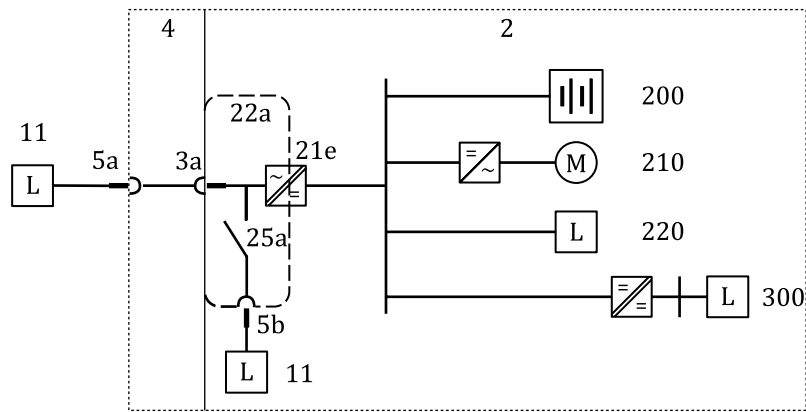
4 System architecture

ISO 5474-1:2024, Clause 4 applies except as follows:

An example of vehicle-to-load AC reverse power transfer (AC reverse power transfer in grid forming mode to unearthed external circuit) is provided in [Figure 1](#).

An example of vehicle-to-grid AC reverse power transfer (AC reverse power transfer in grid following mode to earthed external circuit) is provided in [Figure 2](#).

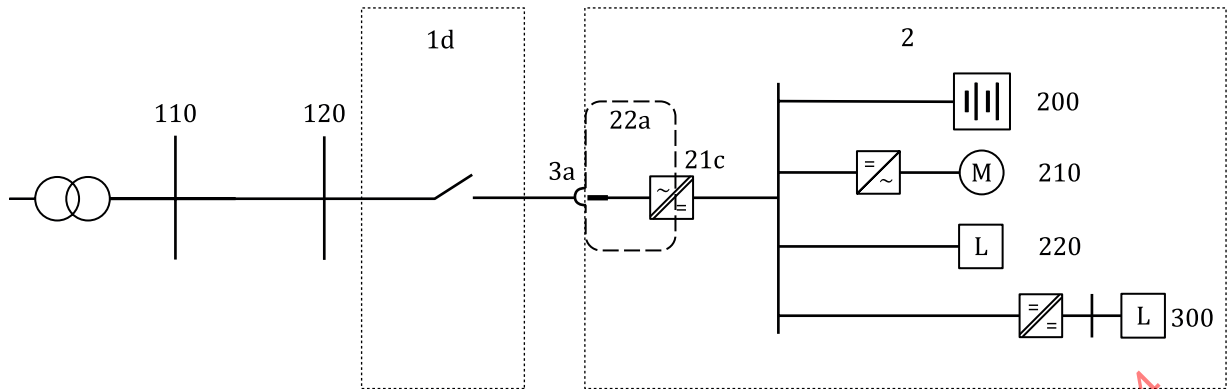
An example of vehicle-to-home AC reverse power transfer (AC reverse power transfer in grid forming mode or grid following mode to earthed external circuit) is provided in [Figure 3](#).



Key

2	vehicle
3a	AC vehicle coupler
4	V2L adapter
5a	socket-outlet provided by V2L adapter and standard plug
5b	standard socket-outlet provided on-board the vehicle and standard plug
11	external electric load
21e	bidirectional power converter with at least simple separation in grid forming mode
22a	vehicle power supply circuit
25a	disconnection device
200	RESS
210	electric drive
220	other voltage class B electric loads
300	voltage class A electric loads

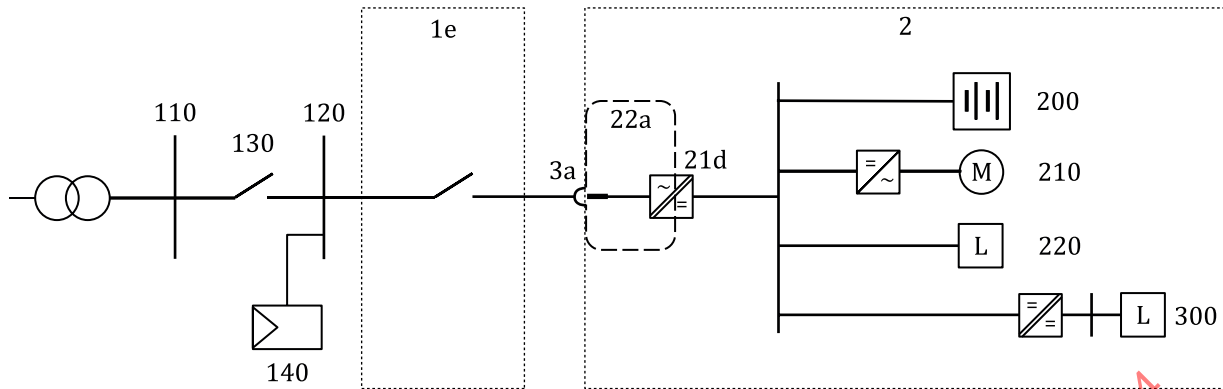
Figure 1 — Single-line diagram of example of vehicle-to-load AC reverse power transfer (AC reverse power transfer in grid forming mode to unearthed external circuit)



Key

1d	AC EV supply equipment capable of reverse power transfer function grid connected
2	vehicle
3a	AC vehicle coupler
21c	bidirectional power converter with at least simple separation in grid following mode
22a	vehicle power supply circuit
110	public network
120	local distribution
200	RESS
210	electric drive
220	other voltage class B electric loads
300	voltage class A electric loads

Figure 2 — Single-line diagram of example of vehicle-to-grid AC reverse power transfer (AC reverse power transfer in grid following mode to earthed external circuit)



Key

1e	AC EV supply equipment capable of reverse power transfer function islanded without grid connection
2	vehicle
3a	AC vehicle coupler
21d	bidirectional power converter with at least simple separation in grid forming mode or grid following mode
22a	vehicle power supply circuit
110	public network
120	local distribution
130	switching device for islanding
140	PV system
200	RESS
210	electric drive
220	other voltage class B electric loads
300	voltage class A electric loads

Figure 3 — Single-line diagram of example of vehicle-to-home AC reverse power transfer (AC reverse power transfer in grid forming mode or grid following mode to earthed external circuit)

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.

6.2 Protection of persons against electric shock

6.2.1 General

ISO 5474-1:2024, 6.2.1 applies except as follows:

The vehicle shall provide at least protective separation between the live parts of the vehicle power supply circuit and voltage class A circuits as provision for basic and fault protection.

The vehicle shall provide at least simple separation between the live parts of the vehicle power supply circuit and other voltage class B2 circuits as provision for fault protection.

6.2.2 Compatibility with external safety devices

NOTE 1 The protective provisions of the vehicle are coordinated with an EV supply equipment which complies with IEC 62752 for mode 2 and IEC 62955 for mode 3.

Compatibility with continuity checking of the protective conductor shall be achieved by limiting the Y-capacitance according to [6.2.4](#).

NOTE 2 High Y-capacitance of the vehicle power supply circuit can interfere with continuity checking of the protective conductor.

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.

Replacement of the last paragraph:

Conformance shall be tested in accordance with [13.5](#).

EV supply equipment may contribute to the touch current for mode 2 charging with a value up to 1 mA in case of loss of continuity of protective conductor, refer to IEC 62752.

NOTE In normal condition, the resistance of the earth electrode in a TT earthing system can have a value up to 166 Ω , see IEC 60364-4-41:2005+AMD1:2017, 411.5.1, NOTE.

6.2.5 Insulation coordination

ISO 5474-1:2024, 6.2.5 applies except as follows:

The insulation shall be designed according to requirements given in [6.2.1](#).

The insulation shall be designed for rated impulse withstand voltage in accordance with IEC 60664-1:2020, Table F.1 with overvoltage category II. If the vehicle power supply circuit includes measures that limit transient overvoltage to a level according to overvoltage category I, parts of the vehicle power supply circuit that are protected by these measures may be designed according to overvoltage category I according to IEC 60664-1.

Conformance of withstand to temporary overvoltages shall be tested in accordance with [13.4](#).

Conformance of withstand to overvoltage category II impulse voltage shall be tested in accordance with ISO 6469-3:2021, 10.6.

6.2.6 Protective conductor

ISO 5474-1:2024, 6.2.6 applies.

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.

6.3 Protection against thermal incident

6.3.1 Requirements for normal operation

ISO 5474-1:2024, 6.3.1 applies.

6.3.2 Overcurrent protection

6.3.2.1 General

ISO 5474-1:2024, 6.3.2.1 applies.

6.3.2.2 Overload protection

ISO 5474-1:2024, 6.3.2.2 applies.

6.3.2.3 Short-circuit protection

For short-circuit current supplied by an external electric circuit (e.g. external electric power supply), at least one of the following requirements 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 of the external electric circuit. 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 A²s. I^2t value shall be calculated according to IEC 60364-4-43.

Conformance is checked by measuring the cross-sections or by design review.

NOTE The breaking time for short-circuit protection can be up to 5 s (see IEC 60364-4-41).

- b) Overcurrent protection (e.g. fuse, circuit breaker) shall be provided in each live conductor of the vehicle power supply circuit. The live conductors protected by this overcurrent protection shall have sufficient cross-sectional area to carry the overcurrent according to the characteristics of this overcurrent protection. The cross-sectional area of the live conductor between the vehicle inlet and the overcurrent protection shall fulfil [6.3.2.3 a\)](#).

Conformance is checked by checking the parameters of overcurrent protection and by measuring the cross-sections, or by design review.

- c) The charger shall provide an overcurrent protection (e.g. fuse, circuit breaker) in each live conductor of the vehicle power supply circuit. The live conductors between the vehicle inlet and the overcurrent protection shall have sufficient cross-sectional area to carry the overcurrent according to the characteristics of this overcurrent protection. The vehicle power supply circuit between the vehicle inlet and the overcurrent protection shall be protected against mechanical damage so that single failure does not cause an insulation fault between live conductors or between live conductors and electrical chassis.

Conformance is checked by checking the parameters of overcurrent protection and by measuring the cross-sections and by checking the protection against mechanical damage, or by design review.

The vehicle shall provide short-circuit protection for short-circuit current that is supplied by power sources of the vehicle.

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:

If an interlock function is required in accordance with ISO 5474-1:2024, 6.3.4, one of the following types shall be used:

- Electrical interlock: when the proximity detection circuit is used for such an interlock function, the vehicle shall stop power transfer operation and reduce the current through the vehicle coupler to less than or equal 1 A within 100 ms after actuation of the switch in the proximity detection circuit.
- Mechanical interlock: when mechanical interlock is used, the vehicle shall inhibit release of the vehicle connector while the vehicle current exceeds 1 A.

Conformance is checked by design review.

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

6.4 Vehicle movement

ISO 5474-1:2024, 6.4 applies.

6.5 AC or DC electric power at the same contacts

ISO 5474-1:2024, 6.5 applies.

7 Electromagnetic compatibility

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 Voltage and frequency ranges for normal operation

The vehicle power supply circuit shall operate as intended within the voltage range of the nominal voltage with a tolerance of +10 % and –15 %. The vehicle power supply circuit shall operate as intended within the frequency range of 50 Hz $\pm$ 1 % or 60 Hz $\pm$ 1 %.

NOTE 1 This voltage range is derived from an application of values indicated in IEC 60038 (max. –10 %) and IEC 60364-5-52 (low voltage installations supplied directly from a public low voltage distribution system: max. –5 %).

NOTE 2 In a low voltage installation supplied from private low voltage supply, the voltage can be down to –19 %. The voltage range is derived from an application of values indicated in IEC 60038 (max. –10 %), IEC 60364-5-52 (low voltage installation supplied from private low voltage supply: max. –8 %) and voltage drop by IC-CPD cable (about –1 %).

9.2 Inrush current

The vehicle shall limit the inrush current into the vehicle power supply circuit in each live conductor individually as follows.

- Event 1: after closing the EV supply equipment's contactor of a specific live conductor at the peak value of the supply voltage on this live conductor, the current in this specific live conductor shall not exceed 230 A peak within the duration of 100 μ s. The current in this live conductor shall decline and not exceed the limit of the event 2 at and after 100 μ s until event 2 takes place. Currents in this specific live conductor

caused by the closing of an EV supply equipment's contactor of a different live conductor shall not be considered.

NOTE 1 The maximum value of the event 1 inrush current is coordinated with the switching devices in the EV supply equipment to avoid welding.

NOTE 2 230 A for 100 μ s is the limit adopted by IEC 61851-1:2017, 12.2.6 and IEC 62752:2016, 9.8.2.1.

- Event 2: during the precharging of the capacitors in the charger, the RMS value of the current in each live conductor, measured over each period of the supply voltage, shall not exceed 30 A. Current peaks exceeding 42,4 A may occur as long as requirements of IEC 61000-3-3 or IEC 61000-3-11 are not violated. The event 2 shall not exceed 1 s.

NOTE 3 The event 2 inrush current is limited in order to avoid tripping of the miniature circuit breakers (MCB). The value of 30 A (rms) corresponds to a 10 A MCB with tripping characteristic B as defined in IEC 60898-1.

NOTE 4 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 DC circuit (DC voltage link) of the charger power electronics. Event 2 does not necessarily follow event 1 immediately.

Conformance shall be tested in accordance with [13.6](#).

9.3 Load current

The vehicle load current shall not exceed the lowest of the following limits:

- the maximum allowed current value indicated by the typical control pilot function in accordance with IEC 61851-1:2017, A.2.2;
- 10 A from a single phase, if the vehicle is using the simplified control pilot function in accordance with IEC 61851-1:2017, A.2.3;
- the maximum allowed current value provided by digital communication in accordance with the ISO 15118 series or other digital communication standards as applicable;

NOTE 1 SAE J3068 provides requirements for digital communication in the following countries: US.

- the maximum current of the cable assembly, as indicated by the coding resistor of the vehicle connector, if the vehicle inlet provides a proximity contact for simultaneous proximity detection and current coding as specified in IEC 61851-1:2017, B.2.

For PWM related pilot control function interactions and thresholds, see IEC 61851-1:2017 Table A.6.

NOTE 2 The EV supply equipment can cut off the power in case the EV load current exceeds the maximum allowed current indicated by PWM signal according to IEC 61851-1:2017, Annex A.

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

New vehicle designs should not use the simplified control pilot function according to IEC 61851-1:2017, A.2.3.

9.4 Active factor

This subclause applies for power transfer from the external electric circuit to the electrically propelled vehicle.

The active factor of the vehicle at its rated power shall be at least 0,95 unless the vehicle allows to adjust the active factor of its charger according to additional information provided by the EV supply equipment. See IEC 61851-21-1 for requirements for emissions of harmonics on AC power lines.

For each individual line conductor, the active factor shall be at least 0,9 unless the active power of this phase is less than 5 % of the rated power of the charger or 300 W whichever is higher.

The operation of an individual line conductor at an active factor of below 0,9 should be limited to 30 min per charging session.

If the active factor is below 0,9, the reactive power should be limited to 300 var per line conductor.

NOTE 1 Extended operation durations at low $\cos(\phi)$ / active factor unnecessarily loads the AC grid with reactive power.

NOTE 2 The vehicle can open S2 (see IEC 61851-1) which triggers a transition to state B (i.e. disconnection of the vehicle from the AC grid by the EV supply equipment) which avoids further loading of the AC grid with reactive power.

NOTE 3 The active factor can be below 0,9 during certain operating conditions (e.g. preconditioning, cell balancing).

NOTE 4 In the following countries the time to operate at active factors below 0,9 is limited to 1 hour per charging session by the connection requirements of distribution system operators: DE.

NOTE 5 In the following countries the reactive power is limited to 1 kvar if the active factor is below 0,9 per line conductor by the connection requirements of distribution system operators: DE.

If the vehicle allows to adjust the active factor of its charger according to additional information provided by the EV supply equipment, the vehicle should:

- implement applicable communication from the ISO 15118 series, and
- adjust either:
 - a) its active factor as a fixed value within the range between 0,90 inductive and 0,90 capacitive, or
 - b) its reactive power as a function of supply voltage, $Q(U)$, or
 - c) its active factor as a function of power, $\cos \varphi (P)$.

The conformance may be checked at the vehicle level or the relevant component level with the resistive load connected at the operating power range of the device under test.

NOTE 6 In case of component level test, only the operating power points that are defined at vehicle level can be considered.

9.5 Phase order and number of phases in three-phase operation

This subclause applies if the vehicle supports three-phase power transfer.

The vehicle shall be fully operational:

- when connected to an external electric circuit with clockwise phase sequence (L1-L2-L3) and
- when connected to an external electric circuit with anti-clockwise phase sequence (L1-L3-L2).

If the vehicle supports reverse power transfer in three-phase operation, the vehicle shall be fully operational when connected to an external electric circuit with clockwise phase sequence (L1-L2-L3).

Dynamic change of phases is under consideration in IEC 61851-1 and should be considered by the vehicle manufacturer.

Conformance is checked by inspection.

9.6 Requirements for the plug and cable

The plug (case A) shall comply with:

- IEC 62196-1 or
- IEC 62196-2.

See IEC 62440 for general guidance on the safe usage of cables.

A cable that is specifically intended for charging of electric vehicles is specified in IEC 62893-3 or similar national standards.

9.7 Requirements for the vehicle inlet

The vehicle inlet (case B and case C) shall conform to:

- IEC 62196-1 or
- IEC 62196-2.

9.8 Compatibility with self test functions of EV supply equipment

Self test functions of the EV supply equipment are under consideration in IEC 61851-1 and should be considered by the vehicle manufacturer.

10 Additional requirements for reverse power transfer

ISO 5474 1:—, Clause 10 is applicable except as follows.

10.1 General

Reverse power transfer through a plug is under consideration.

NOTE SAE J2847-5 provides requirements for vehicle to load applications in the following countries: US and Canada.

Requirements for multiphase reverse power transfer in grid forming mode to unearthed external circuit are under consideration.

10.2 Safety requirements

10.2.1 General

Unless otherwise specified fault protection shall be applied based on the fault mode analysis by vehicle manufacturer.

10.2.2 Reverse power transfer in grid forming mode to unearthed external circuit (vehicle to load)

The vehicle manufacturer shall give adequate methods for the initial and periodic verification of the power electronic converter.

10.2.2.1 Protection against electric shock

10.2.2.1.1 Insulation resistance

The value of insulation resistance of the vehicle power supply circuit shall be higher than the thresholds given in ISO 5474-1:2024, 6.2.3.

10.2.2.1.2 Protection under single fault condition

Requirements are given for a vehicle power supply circuit isolated from electric chassis (i.e. similar to IT-system). Requirements for a vehicle power supply circuit not isolated from electric chassis (i.e. similar to TN-System) are under consideration.

The vehicle shall provide one of the following protective provisions between the vehicle power supply circuit and other voltage class B circuits of the vehicle:

- protective separation;
- simple separation, and the vehicle shall detect a fault of the simple separation. In case of a fault of the simple separation the vehicle shall perform both of the following:
 - reduce the touch voltage between any contact and any other contact of the vehicle inlet or any on-board socket-outlet as well as the touch voltage between any contact of the vehicle inlet or any on-board socket-outlet which is conductively connected to the vehicle power supply circuit and the electric chassis to below 60 V d.c. and 30 V a.c. within less than or equal to 1 s and
 - remove a temporary overvoltage, if applicable, within a time according to IEC 60664-1:2020, 5.4.3.2 (e.g. de-energization of the vehicle power supply circuit or disconnection from the source of overvoltage).

NOTE 1 A long-term temporary overvoltage can have a duration longer than 5 s according to IEC 60664-1:2020, 5.4.3.2.

Conformance of separation and de-energization is checked by design review.

Conformance of detecting fault of the simple separation is checked by simulation of a fault or by design review.

If the vehicle power supply circuit provides more than one socket-outlet, the protective provisions shall provide the same level of safety for each socket-outlet.

If a socket-outlet provides a protective conductor terminal, it shall be connected to the vehicle electric chassis with a protective conductor.

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

Conformance is checked by design review.

For vehicle to load operation, at least one of the following protective provisions shall be applied.

a) An individual residual current protective function shall be provided for

- each of the on-board standard socket-outlets and
- each of the vehicle inlets

that are simultaneously conductively connected to the vehicle power supply circuit. For a definition of the term “conductively connected” refer to ISO 6469-3:2021, 3.7.

The residual current protective function shall after operation effectively isolate the circuit concerned from all live conductors of the supply.

The residual current protective function shall operate at $I_{\Delta nom}$ not exceeding 30 mA a.c., the disconnection timing requirements shall be fulfilled according to IEC 60479-1.

The position of the contacts of the residual current protective function or other means of isolation should, in the isolated position, be either externally visible or clearly and reliably indicated.

NOTE 2 In some countries specific requirements for the residual current protective functions exist: US.

NOTE 3 The requirement to have an individual residual current protective function for each standard socket-outlet in an IT system is derived from IEC 60364-4-41:2005, 411.6.1 and 411.6.3, NOTE 2.

NOTE 4 According to IEC Guide 116:2018, 7.2.3.1, a double fault situation with two independent and unrelated faults must be considered when the first fault situation is not automatically detected.

NOTE 5 The indication can be achieved by suitable marking to indicate the isolated and closed positions respectively.

The devices used for the residual current protective function shall be designed to prevent unintentional operation.

NOTE 6 Such operation can be caused, for example, by mechanical shocks and vibrations.

In case DC protective conductor currents are possible, the residual current protective function shall have suitable properties.

- b) An insulation resistance monitoring system which monitors periodically or continuously the insulation resistance of the vehicle power supply circuit during vehicle to load operation, shall be provided.

The insulation resistance divided by the maximum working voltage of the vehicle power supply circuit shall be more than 500 Ω/V .

- In case of an asymmetric insulation fault, the vehicle shall reduce the output voltage at the vehicle inlet and conductively connected on-board standard socket-outlets to below 30 V a.c. and 60 V d.c. within less than or equal to 1 s.
- In case of a symmetric insulation fault, the vehicle shall reduce the output voltage at the vehicle inlet and conductively connected on-board standard socket-outlets to below 30 V a.c. and 60 V d.c. within less than or equal to 10 s.

NOTE 7 The time value for an asymmetric fault is taken from HD 60364-5-551, Annex ZC, ZC.3.2.2.2.

NOTE 8 The time value for a symmetric fault is taken from IEC 61851-23.

If the protective conductor between exposed conductive parts of connected external electric loads and chassis is not provided by the class of equipment or by accessories that are connected to the vehicle power supply circuit, option b) alone is not sufficient.

NOTE 9 In some countries where rated voltages of less than or equal to 150 V a.c. are used, certain equipment like class 0 equipment according to IEC 61140 or certain accessories like adapters between plugs and socket-outlets of Type A or B according to IEC 60884-1 might be used which do not provide or possibly interrupt the protective conductor path.

NOTE 10 Safety of class II equipment does not rely on a protective conductor.

The vehicle shall reduce the output voltage at vehicle inlet or on-board standard socket-outlet to 30 V a.c. or less in the event of a short circuit current between a live conductor and the protective conductor in a time as given in IEC 60364-4-41:2005, 411.3.2.2.

10.2.2.2 Overcurrent protection

The vehicle shall provide overcurrent protection means to interrupt the power transfer and reduce the output voltage at the vehicle inlet, if any of the following values are exceeded:

- the rated current of the vehicle power supply circuit;
- the rated current of the vehicle inlet;
- the maximum current indicated by the V2L adapter, e.g. resistor coding or digital communication;
- the maximum current indicated by an external electric load, e.g. resistor coding or digital communication.

The vehicle shall cut off the output current if the thresholds of the chosen tripping characteristics are reached.

The overcurrent protection tripping characteristics shall not be slower than type B or C according to IEC 60898-1:2015, Table 7.

NOTE 1 Typically, the power electronics providing the energy for the V2L application will be the limiting factor. Very fast tripping characteristics will limit the availability of the V2L function in case the connected load has high inrush currents.

NOTE 2 In some countries, the maximum reverse power from the vehicle is limited to less than 10 kW: Japan.

NOTE 3 It is possible that the overload or short circuit current provided by the power electronic converter does not trigger an external overcurrent protection, e.g. a fuse or circuit breaker.

Conformance of overcurrent protection means is checked by design review.

The vehicle manufacturer shall give adequate methods for the initial and periodic verification of the power electronic converter.

10.2.3 Reverse power transfer in grid following mode to earthed external circuit (vehicle to grid)

Requirements for reverse power transfer in grid following mode to earthed external circuit are under consideration.

10.2.4 Reverse power transfer in grid forming mode to earthed external circuit (vehicle to home)

Requirements for reverse power transfer in grid forming mode to earthed external circuit are under consideration.

10.3 Functional requirements

10.3.1 General

The vehicle shall follow the grid code specific thresholds for power supply as provided by the external electric circuit. During reverse power transfer, the vehicle power supply circuit shall be able to supply in accordance with IEC 60038 and IEC 60364-8-82:2022, 7.1 and within the voltage range of the nominal voltage with a tolerance of $\pm 15\%$.

NOTE In case of a grid connected reverse power transfer (under consideration) it is possible that the vehicle needs to provide the active power and reactive power based on request by the EV supply equipment (e.g. by digital communication).

The vehicle shall supply the voltage and frequency according to IEC 60038 and coordinated with the V2L adapter.

The vehicle shall not exceed the maximum current threshold as coordinated with the V2L adapter.

The means of coordination (e.g. communication, signalling) is under consideration.

10.3.2 Reverse power transfer in grid forming mode

10.3.2.1 Output voltage

The voltage shall be standard voltage in accordance with IEC 60038.

10.3.2.2 Output frequency

The frequency shall be 50 Hz or 60 Hz. The tolerance of the frequency should be $\pm 1\%$.

10.3.2.3 Output waveform

The output waveform shall be a sine wave or a modified sine wave (e.g. stepped sine wave).

The total harmonic distortion rate shall be less than 10 % in accordance with IEC 62109-2:2011, 4.7.5.

NOTE For more information, see EN 50160.

10.3.2.4 Phase order

The vehicle shall supply a clockwise phase sequence (L1-L2-L3) when connected to an external electric circuit.

10.3.3 Reverse power transfer in grid following mode

Requirements for grid following mode are under consideration.

11 Requirements for power transfer to on-board standard socket-outlets

11.1 General

If the vehicle power supply circuit provides more than one socket-outlet, the protective provisions shall provide the same level of safety for each socket-outlet.

Socket-outlets on-board the vehicle, which are conductively connected to the vehicle power supply circuit, shall be disconnected by devices suitable for isolation (e.g. disconnectors) during charging.

Additional requirements to socket-outlets, which are conductively connected to the vehicle power supply circuit, during charging modes 2 or 3, are under consideration.

Check either by design review or by connecting the vehicle to an EV supply equipment and then checking that all socket-outlets that are conductively connected to the vehicle power supply circuit are disconnected (i.e. all live conductors are isolated).

The vehicle manufacturer shall define the conditions to energize on-board socket outlets conductively connected to the vehicle power supply circuit based on a safety analysis.

Requirements for multiphase reverse power transfer in grid forming mode to an unearthed external circuit are under consideration.

11.2 Protective conductor

If a socket-outlet provides a protective conductor terminal, it shall be connected to the vehicle electric chassis with a protective conductor.

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

Conformance is checked by design review.

11.3 Insulation resistance

The value of insulation resistance of the vehicle power supply circuit shall be higher than the thresholds given in ISO 5474-1:2024, 6.2.3.

12 Owner's manual and marking

ISO 5474-1:2024, Clause 11 applies.

13 Test procedure

13.1 General

ISO 5474-1:2024, 12.1 applies.

13.2 Resistance of protective conductor

ISO 5474-1:2024, 12.2 applies.

13.3 Insulation resistance

ISO 5474-1:2024, 12.3 applies.

13.4 Withstand voltage test

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 the plug (case A), vehicle inlet (case B and case C).
- if the vehicle power supply circuit includes contactors or disconnection devices, they are closed.

The AC withstand voltage test of the vehicle power supply circuit shall be performed with an AC voltage with frequency of 50 Hz or 60 Hz raised uniformly from 0 V to the following RMS value within not more than 5 s and held at that value for at least for 60 s:

- $(U_n + 1\,200\text{ V})$ if basic insulation applies;
- $2 \times (U_n + 1\,200\text{ V})$ if double insulation or reinforced insulation applies,

where U_n is the nominal line to neutral voltage of the neutral-earthed supply system.

NOTE The values for AC test voltage originate from IEC 60664-1:2020, 5.4.3.2 and IEC 60364-4-44:2007, 442.2.2.

Equivalent values of the DC voltage can be used instead of the AC peak values. The equivalent DC test voltage is 1,41 times the RMS value of the AC voltage.

Further test conditions conform to IEC 60664-1, considering the specific operating conditions as specified by the vehicle manufacturer.

Neither dielectric breakdown nor flashover shall occur during the test.

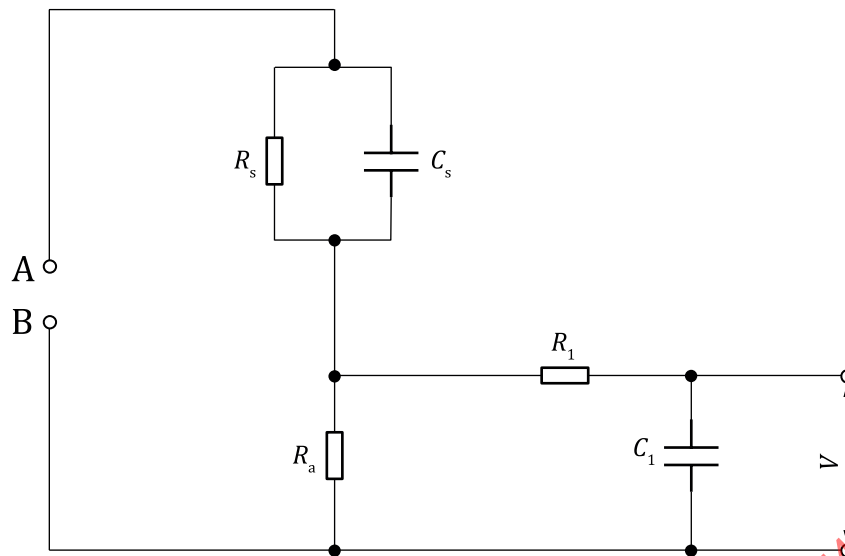
13.5 Measurement of touch current

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 an AC external electric power supply.

The test is conducted with a cable assembly conforming with IEC 61851-1, IEC 62752 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 4](#) (see also IEC 60990).



Key

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

Figure 4 — Measurement circuit

V_{rms} , which is the root mean square value of the voltage V , is measured, see [Figure 4](#). For voltage measurement, an instrument according to IEC 60990:2016, Annex G is used.

The touch current, I_{rms} , is calculated by [Formula \(1\)](#):

$$I_{\text{rms}} = \frac{V_{\text{rms}}}{500 \text{ }\Omega} \quad (1)$$

The test is passed if all touch currents measured during the test do not exceed the specified limits. It is also regarded to fulfil the requirement, if touch current cannot be measured due to stop charging with disconnecting protective conductor.

EV supply equipment may contribute to the touch current with a value up to 1 mA, refer to IEC 62752.

After each single test, the original operation conditions are re-established without any fault or damage.

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.

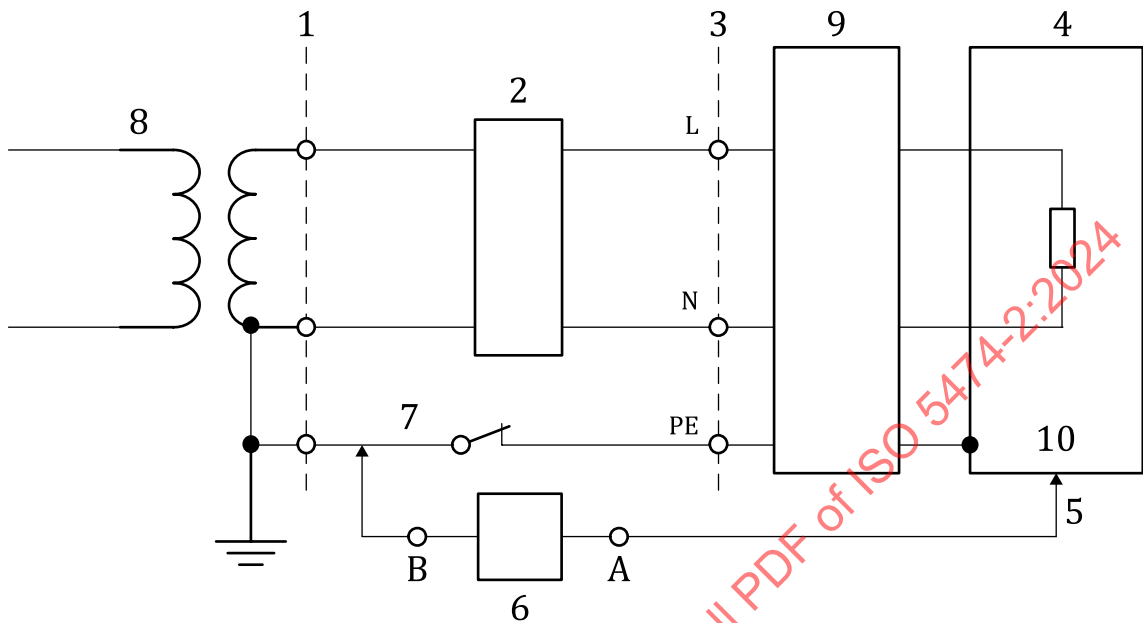
If the device under test is intended for connection to single-phase supply, it is connected between phase and neutral of an earthed neutral power distribution system (see [Figure 5](#)).

If the device under test is intended for connection to three-phase supply, it is connected to a three-phase star power distribution system, with earthed neutral (see [Figure 6](#)).

The use of a test transformer for isolation is optional. For increased safety, a test transformer for isolation is used and the main protective earthing terminal of the device under test earthed. Any capacitive leakage in the transformer is then taken into account. As an alternative to earthing the device under test, the secondary

side of the test transformer and the device under test can be left floating (not earthed), in which case the capacitive leakage in the test transformer shall not be taken into account.

If a test transformer is not used, the device under test is mounted on an insulating stand and appropriate safety precautions taken, in view of the possibility of the electric chassis and exposed conductive parts of the device under test being at hazardous voltage.



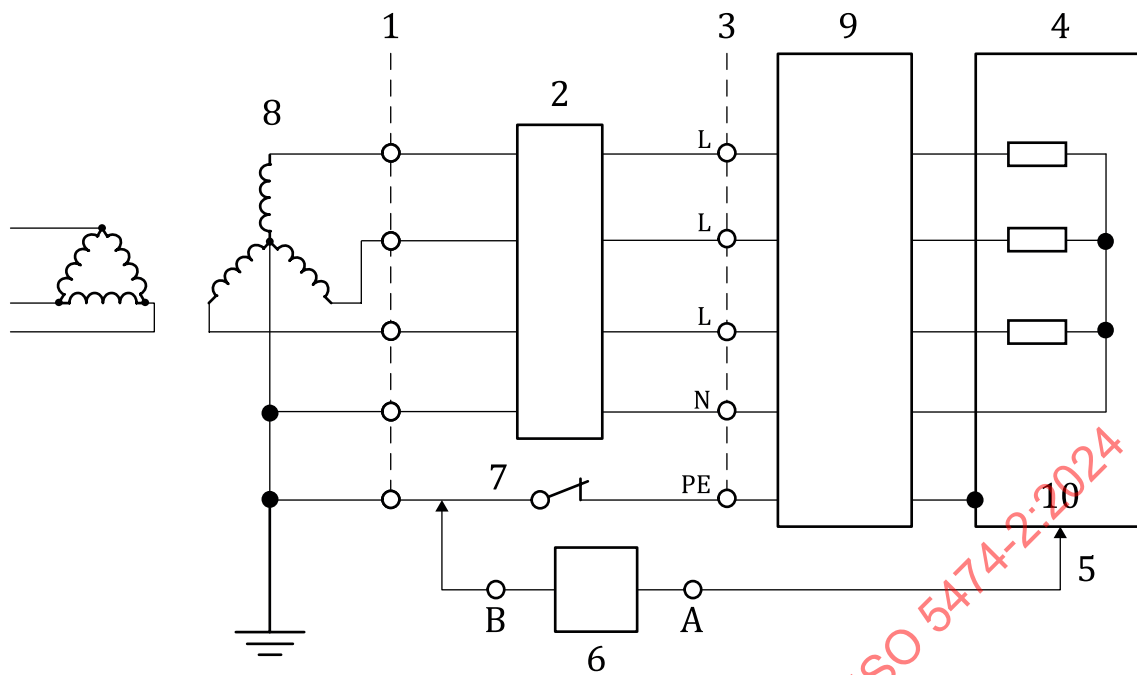
Key

1	connection to external electric power supply	8	external electric power supply
2	polarity switch	9	EV supply equipment
3	connection of device under test	10	device under test
4	enclosure device under test	L	line terminal
5	test probe	N	neutral terminal
6	measurement circuit	PE	terminal for protective conductor
7	protective conductor	A, B	terminals of measurement circuit

Figure 5 — Example test setup for touch current with single phase TN system under AC charging

The vehicle power supply circuit operates at its highest rated power, highest rated frequency, and 110 % of the highest rated voltage with disconnection of the protective conductor (switch protective conductor open, see [Figure 5](#) and [Figure 6](#)). If the worst-case conditions for the external electric power supply cannot be applied for the test, the measurement may be performed with any voltage in the range of the rated voltage and the results is calculated accordingly.

The terminal B of the measurement circuit is connected to the protective conductor of the measurement setup. 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 enclosure of the device under test, see [Figure 5](#) and [Figure 6](#). The measurement is performed for the whole surface of the device under test. Non-conductive parts of the enclosure of the device under test is covered by a metal foil, which is connected to the PE terminal of the device under test and terminal A of the measuring circuit.



Key

1	connection to external electric power supply	8	external electric power supply
2	line or neutral fault switch	9	EV supply equipment (except mode 2, case A)
3	connection of device under test	10	device under test
4	enclosure device under test	L	line terminal
5	test probe	N	neutral terminal
6	measurement circuit	PE	terminal for protective conductor
7	protective conductor	A, B	terminals of measurement circuit

Figure 6 — Example test setup for touch current with multi-phase TN system under AC charging

The test is repeated with reversed polarity of the current carrying conductors, (see polarity switch in [Figure 5](#) and [Figure 6](#)) or with activated fault switches (see [Figure 5](#) and [Figure 6](#)).

13.6 Inrush current test

13.6.1 General

The conformance is checked by measurement. The following test conditions apply:

- supply voltage is the rated voltage of the device under test;
- external power supply has a supply system impedance (loop impedance) of not more than 150 mΩ;
- supply system impedance is the loop impedance between the relevant live conductors. It is measured at the connecting point of the device under test to the external power supply in accordance with IEC 60364-6;
- the external power supply is one of the following:
 - fixed installation, switching device for testing and test cable (e.g. cable assembly for case B or case C);
 - fixed installation and EV supply equipment including test cable (e.g. cable assembly for case B or case C);

- specific test device (e.g. short-circuit test device, transformer), switching device for testing and test cable (e.g. cable assembly for case B or case C). This equipment shall have a sufficient prospective short-circuit current capability to not affect the value of the inrush current over time in accordance with the loop impedance of 150 mΩ (e.g. 1,5 kA capability). Conformance is checked by measuring the voltage drop at the device under test after closing the switching device.
- e) If the measured supply system impedance is less than 150 mΩ, a different test cable (e.g. cable assembly for case B or case C) can be used to adjust the loop impedance to 150 mΩ.

13.6.2 Measurement

The measurements are performed at vehicle level or at component level with the relevant parts of the vehicle power supply circuit. The device under test is operated under normal operating conditions.

The voltage of the external electric power supply is measured. The peak voltage at a phase angle of $90^\circ \pm 5^\circ$ is applied at the device under test. This condition can be achieved, for example, by triggering the switching device of the EV supply equipment.

The current is measured continuously for the duration of the measurement.

The peak value of the voltage of the power supply is measured.

If the power supply does not provide the rated voltage of the device under test, the measurement may be performed with any voltage in the range of the rated voltage and the results is calculated accordingly.

If the measurement is repeated, sufficient time shall pass between consecutive measurements to ensure discharging of capacitors of the device under test.

The required inrush current limits for event 1 and event 2 in accordance with [9.2](#) shall be met at a supply system impedance of not more than 150 mΩ.

Annex A

(informative)

Examples of circuit diagrams for different configurations of chargers on-board an electric vehicle

A.1 General

This annex gives examples of circuit diagrams for the connection of chargers to the vehicle inlet. For vehicles that are intended to be used in case A, the EV plug replaces the vehicle inlet.

It provides an overview of relevant vehicle topologies and should be read in combination with similar information about infrastructure topologies which can be included in EV supply equipment standards.

This annex numbers the contacts of the vehicle connector using the position numbers of the basic interface according to IEC 62196-1, see [Table A.1](#). The type 1 vehicle coupler does not implement the position numbers 2 and 3 of the basic interface. The functions that are given in IEC 62196 series for the different position numbers are intentionally not shown in this table, because the function of each position depends on the infrastructure topology.

Table A.1 — Equivalent position numbers of the basic interface and configuration types

Position number of basic interface	Position number of configuration type 1 according to IEC 62196-2:2022, Table 201	Position number of configurations types 2 and 3 according to IEC 62196-2:2022, Table 202
1	1 (L1)	1 (L1)
2	n.a.	2 (L2)
3	n.a.	3 (L3)
4	2 (L2 / N)	4 (N)
5	3 (PE)	5 (PE)