
Electrically propelled road vehicles — Conductive power transfer — Safety requirements

*Véhicules routiers à propulsion électrique — Transfert d'énergie
conductive — Exigences de sécurité*

STANDARDSISO.COM : Click to view the full PDF of ISO 17409:2020



STANDARDSISO.COM : Click to view the full PDF of ISO 17409:2020



COPYRIGHT PROTECTED DOCUMENT

© ISO 2020

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	2
4 Environmental and operational conditions	10
5 Specific requirements for the vehicle inlet, plug, and cable	11
5.1 Requirements for the plug and cable (case A)	11
5.2 Requirements for the vehicle inlet	11
6 Requirements for protection of persons against electric shock	11
6.1 General	11
6.2 Basic protection when connected to an external electric circuit	11
6.3 Protective conductor	12
6.4 Isolation resistance	13
6.4.1 AC connection	13
6.4.2 DC connection	13
6.5 Requirements for unmated vehicle contacts	13
6.5.1 General	13
6.5.2 Normal operation	14
6.5.3 Operation under single fault conditions	14
6.6 Insulation coordination	15
6.6.1 AC connection	15
6.6.2 DC connection	15
6.7 Touch current	16
6.8 Compatibility with residual current devices (RCD)	16
7 Protection against thermal incident	16
7.1 Requirements for normal operation	16
7.2 Overcurrent protection	16
7.2.1 General	16
7.2.2 Overload protection	17
7.2.3 Short-circuit protection for AC connection	17
7.2.4 Short-circuit protection for DC connection	17
7.3 Arc protection for DC connections	18
7.4 Residual energy after disconnection	19
7.5 Transient overvoltage	19
8 Additional requirements for AC power transfer	19
8.1 Voltage and frequency ranges for normal operation	19
8.2 Current characteristics	19
8.2.1 Load current	19
8.2.2 Inrush current	20
8.3 Active factor	20
8.4 Interlock function for the vehicle coupler	21
8.5 Phase order in three-phase operation	21
9 Additional requirements for DC power transfer	21
9.1 General	21
9.2 Disconnection device	21
9.3 Control pilot functions	22
9.4 Vehicle isolation resistance monitoring system	22
9.5 Locking of the vehicle connector	22
9.6 AC or DC electric power at the same contacts	22
9.7 Contact temperature	23
9.8 Overvoltage in case of a load dump	24

9.9	Compatibility with insulation monitoring	24
10	Reverse power transfer	24
10.1	General	24
10.2	AC reverse power transfer	25
10.2.1	General	25
10.2.2	Output power quality	25
10.2.3	Prevention of disconnection of vehicle coupler under load	26
10.2.4	Protection against electrical shock	26
10.2.5	Protection against thermal incident	26
10.3	DC reverse power transfer	26
10.3.1	General	26
10.3.2	Connection to the external electric circuit	27
10.3.3	Protection against overdischarge of the RESS	27
10.3.4	Auxiliary power supply from EV (optional)	27
10.3.5	Protection against thermal incident	27
11	Operational requirements	27
12	Owner's manual and marking	27
12.1	Owner's manual	27
12.2	Marking	27
13	Test procedure	27
13.1	General	27
13.2	Resistance of protective conductor	28
13.3	Isolation resistance test	28
13.4	Withstand voltage test	28
13.4.1	General	28
13.4.2	Test voltage	29
13.5	Inrush current tests	29
13.5.1	General	29
13.5.2	Measurement	30
13.6	Touch current	30
13.6.1	General	30
13.6.2	AC Charging	31
13.6.3	DC charging	33
13.7	DC power transfer with maximum current	34
13.8	DC power contact over temperature	34
Annex A (informative) Y capacitance measurement		37
Bibliography		40

Foreword

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

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

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

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared jointly by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 37, *Electrically propelled road vehicles*, and Technical Committee IEC/TC 69, *Electric road vehicles and electric industrial trucks*.

This second edition replaces the first edition (ISO 17409:2015), which has been technically revised. The main changes compared to the previous edition are as follows:

- terms and definitions have been updated,
- requirements for mode 1 have been removed because it is no longer relevant for new designs,
- requirements for reverse power transfer have been added,
- requirements for a DC connection with a thermal management system have been added,
- short circuit during DC charging has been reworked, and
- requirements for charging with pantograph have been added.

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.

STANDARDSISO.COM : Click to view the full PDF of ISO 17409:2020

Electrically propelled road vehicles — Conductive power transfer — Safety requirements

1 Scope

This document specifies electric safety requirements for conductive connection of electrically propelled road vehicles to external electric circuits. External electric circuits include external electric power supplies and external electric loads. This document provides requirements for the charging modes 2, 3, 4, as defined in IEC 61851-1, and reverse power transfer. For mode 4, this document provides requirements regarding the connection to an isolated DC EV charging station according to IEC 61851-23.

NOTE 1 This edition does not provide requirements for mode 1.

NOTE 2 External electric circuits are not part of the vehicle.

This document applies to the on-board sections of vehicle power supply circuits. It applies also to dedicated power supply control functions used for the connection of the vehicle to an external electric circuit.

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

NOTE 3 ISO 6469-3 provides general electrical safety requirements for electrically propelled road vehicles.

NOTE 4 With this edition of this document the limitation of y -capacitance for protection against electric shock under single failure conditions is no longer applicable as a fault protection provision when the vehicle has a conductive DC connection to an external electric circuit.

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

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

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

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

IEC 60038, *IEC standard voltages*

IEC 60364-4-41:2005, *Low-voltage electrical installations — Part 4-41: Protection for safety — Protection against electric shock*

IEC 60364-4-43:2008, *Electrical installations of buildings — Part 4-43: Protection for safety — Protection against overcurrent*

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

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

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

IEC 61000-3-3, *Electromagnetic compatibility (EMC) — Part 3-3: Limits — Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection*

IEC 61000-3-11, *Electromagnetic compatibility (EMC) — Part 3-11: Limits — Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems — Equipment with rated current ≤ 75 A and subject to conditional connection*

IEC 61032, *Protection of persons and equipment by enclosures — Probes for verification*

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

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

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

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

IEC 62196-3:2015, *Plugs, socket-outlets, vehicle connectors and vehicle inlets — conductive charging of electric vehicles — Part 3: Dimensional compatibility and interchangeability requirements for dedicated d.c. and combined a.c./d.c. pin and contact-tube vehicle couplers*

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 intended to be used with a thermal management system for DC charging*

3 Terms and definitions

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

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://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 60050-131:2001, 131-11-49, modified — The symbol “ $\cos \varphi$ ” was added and the note deleted.]

3.2 automated connection device ACD

active device where the physical connection between *EV supply equipment* (3.25) and vehicle is made and broken without user interaction providing an electromechanical interface

[SOURCE: IEC 61851-23-1:—¹), 3.1.203, modified — The phrase “and broken” was added.]

1) Under preparation. Stage at the time of publication: IEC/ACDV 61851-23-1:2020.

3.3

ACD counterpart

passive device which is used in combination with an *ACD* (3.2) to make and break the physical connection between *EV supply equipment* (3.25) and vehicle providing an electromechanical interface without user interaction

[SOURCE: IEC 61851-23-1:—¹, 3.1.204, modified — The phrase “and break” was added.]

3.4

automatic coupler

system comprising an *ACD* (3.2) and *ACD counterpart* (3.3)

[SOURCE: IEC 61851-23-1:—¹, 3.1.205, modified — The word “of” was deleted.]

3.5

basic insulation

insulation of *hazardous live parts* (3.30) which provides basic protection

Note 1 to entry: This concept does not apply to insulation used exclusively for functional purposes.

[SOURCE: ISO 6469-3:2018, 3.3, modified — Note 2 to entry removed.]

3.6

case A

connection of an *EV* (3.19) to the *supply network* (3.53) with a *plug* (3.43) and cable permanently attached to the EV

Note 1 to entry: The cable assembly is part of the vehicle.

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

3.7

case B

connection of an *EV* (3.19) to the *supply network* (3.53) with a cable assembly detachable at both ends

Note 1 to entry: The cable assembly is not part of the vehicle or the *EV charging station* (3.23).

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

3.8

case C

connection of an *EV* (3.19) to the *supply network* (3.53) utilizing a cable and *vehicle connector* (3.58) permanently attached to the *EV charging station* (3.23).

Note 1 to entry: The cable assembly is part of the EV charging station.

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

3.9

case D

connection of an *EV* (3.19) to a *supply network* (3.53) utilizing an *automatic coupler* (3.4) which has an *ACD* (3.2) on the *EV supply equipment* (3.25)

[SOURCE: IEC 61851-23-1:—¹, 3.1.201]

3.10

case E

connection of an *EV* (3.19) to a *supply network* (3.53) utilizing an *automatic coupler* (3.4) which has an *ACD* (3.2) on the EV

[SOURCE: IEC 61851-23-1:—¹, 3.1.202]

3.11
charger

power converter at the on-board section of the *vehicle power supply circuit* (3.61) which supplies electric power

EXAMPLE For charging a *RESS* (3.47).

3.12
conductive part

part which can carry electric current

[SOURCE: ISO 6469-3:2018, 3.6]

3.13
control pilot function

function used to monitor and control the interaction between the *EV* (3.19) and the *EV supply equipment* (3.25)

[SOURCE: IEC 61851-1:2017, 3.3.3]

3.14
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 — “the” deleted from definition, “is” added to the Note to entry.]

3.15
DC EV charging station

EV charging station (3.23) that supplies direct current to an *EV* (3.19)

[SOURCE: IEC 61851-1:2017, 3.1.6]

3.16
degree of protection

protection provided by an enclosure against access, foreign objects and/or water and verified by standardized test methods

[SOURCE: ISO 20653:2013, 3.2]

3.17
direct contact

electric contact of persons or animals with *live parts* (3.35)

[SOURCE: ISO 6469-3:2018, 3.10]

3.18
double insulation

insulation comprising both *basic insulation* (3.5) and *supplementary insulation* (3.52)

[SOURCE: ISO 6469-3:2018, 3.11]

3.19
electrically propelled vehicle

EV
vehicle with one or more *electric drive(s)* (3.21) for vehicle propulsion

[SOURCE: ISO 6469-3:2018, 3.15, modified — “EV” added as an equivalent term.]

3.20**electric chassis**

conductive parts (3.12) of a vehicle that are electrically connected and whose potential is taken as reference

[SOURCE: ISO 6469-3:2018, 3.12]

3.21**electric drive**

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

[SOURCE: ISO 6469-3:2018, 3.13]

3.22**electric shock**

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

[SOURCE: ISO 6469-3:2018, 3.14]

3.23**EV charging station**

stationary part of *EV supply equipment* (3.25) connected to the *supply network* (3.53)

[SOURCE: IEC 61851-1:2017, 3.1.5]

3.24**EV plug**

specific *plug* (3.43) intended to be used as part of *EV supply equipment* (3.25) or for the connection of *EV* (3.19) to EV supply equipment, and defined in the IEC 62196 series

[SOURCE: IEC 61851-1:2017, 3.5.8]

3.25**EV supply equipment**

equipment or a combination of equipment, providing dedicated functions to supply electric energy from a fixed electrical installation or *supply network* (3.53) to an *EV* (3.19) for the purpose of charging

EXAMPLE 1 For *mode 3* (3.39) *case B* (3.7), the EV supply equipment consists of the *EV charging station* (3.23) and the cable assembly.

EXAMPLE 2 For *mode 3 case C* (3.8), the EV supply equipment consists of the EV charging station with its cable assembly.

[SOURCE: IEC 61851-1:2017, 3.1.1]

3.26**exposed conductive part**

conductive part (3.12) of equipment which can be touched and which is not normally live, but which can become live when *basic insulation* (3.5) fails

[SOURCE: ISO 6469-3:2018, 3.18, modified — Note 1 to entry deleted.]

3.27**external electric circuit**

electric circuit which connects to the *vehicle power supply circuit* (3.61) using the *plug* (3.43) [*case A* (3.6)], the *vehicle inlet* (3.60) [*case B* (3.7) and *case C* (3.8)], the *ACD counterpart* (3.3) [*case D* (3.9)] or the *ACD* (3.2) [*case E* (3.10)]

EXAMPLE *EV charging station* (3.23), external electric load.

3.28

external electric power supply

electric power source that is not part of the vehicle for supplying electric energy to an *EV* (3.19) using an *EV supply equipment* (3.25)

3.29

hazard

potential source of harm

[SOURCE: IEC 60050-903:2013, 903-01-02, modified — Notes to entry 1, 2, and 3 deleted.]

3.30

hazardous live part

live part (3.35) which, under certain conditions, can give a harmful *electric shock* (3.22)

[SOURCE: ISO 6469-3:2018, 3.22, modified — Note 1 to entry removed.]

3.31

interlock function

function that prevents the power contacts of a *socket-outlet* (3.51)/*vehicle connector* (3.58) from becoming live before it is in proper engagement with a *plug* (3.43)/*vehicle inlet* (3.60), and which either prevents the plug/vehicle connector from being withdrawn while its power contacts are live or makes the power contacts dead before separation

[SOURCE: IEC 61851-1:2017, 3.5.16, modified — term changed from “interlock” to “interlock function”, definition changed from “device or combination of devices” to “function”.]

3.32

isolation resistance

insulation resistance

resistance between *live parts* (3.35) of an electric circuit and the *electric chassis* (3.20) as well as other electric circuits which are insulated from this electric circuit

[SOURCE: ISO 6469-3:2018, 3.23]

3.33

isolation resistance monitoring system

system that periodically or continuously monitors the *isolation resistance* (3.32) between *live parts* (3.35) and the *electric chassis* (3.20)

[SOURCE: ISO 6469-3:2018, 3.24]

3.34

live conductor

conductor which is energized in normal operation and capable of contributing to the transmission or distribution of electric energy

Note 1 to entry: Live conductors include line conductors (including DC+ conductors and DC– conductors) and neutral conductors.

3.35

live part

conductor or *conductive part* (3.12) intended to be energized in normal use, but by convention not the *electric chassis* (3.20)

[SOURCE: ISO 6469-3:2018, 3.25]

3.36**maximum working voltage**

highest value of AC voltage (rms) or of DC voltage that can occur under normal operating conditions according to the manufacturer's specifications, disregarding transients and ripple

[SOURCE: ISO 6469-3:2018, 3.26, modified — The word “any” was deleted from “normal operating conditions”.]

3.37**mode 1**

method for the connection of an *EV* (3.19) to a standard *socket-outlet* (3.51) of an AC supply network, utilizing a cable and *plug* (3.43), both of which are not fitted with any supplementary pilot or auxiliary contacts

[SOURCE: IEC 61851-1:2017, 6.2.1]

3.38**mode 2**

method for the connection of an *EV* (3.19) to a standard *socket-outlet* (3.51) of an AC supply network utilizing an AC EV supply equipment with a cable and *plug* (3.43), with a *control pilot function* (3.13) and system for personal protection against *electric shock* (3.22) placed between the standard plug and the EV

[SOURCE: IEC 61851-1:2017, 6.2.2]

3.39**mode 3**

method for the connection of an *EV* (3.19) to an AC EV supply equipment permanently connected to an AC supply network, with a *control pilot function* (3.13) that extends from the AC EV supply equipment to the EV

Note 1 to entry: Mode 3 includes the use of cable assembly not permanently connected to the AC supply network [*case A* (3.6) and *case B* (3.7)].

[SOURCE: IEC 61851-1:2017, 6.2.3, modified — Note 1 to entry added.]

3.40**mode 4**

method for the connection of an *EV* (3.19) to an AC or DC *supply network* (3.53) utilizing a DC EV supply equipment, with a *control pilot function* (3.13) that extends from the DC EV supply equipment to the EV

[SOURCE: IEC 61851-1:2017, 6.2.4]

3.41**overcurrent protection**

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

Note 1 to entry: a charge control function is not considered an overcurrent protection

[SOURCE: ISO 6469-3:2018, 3.28]

3.42**overload protection**

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

[SOURCE: ISO 6469-3:2018, 3.27]

3.43**plug**

accessory having contacts designed to engage with the contacts of a *socket-outlet* (3.51), also incorporating means for the electrical connection and mechanical retention of flexible cables or cords

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

3.44

protective conductor

conductor provided for purposes of safety, for example protection against *electric shock* (3.22)

EXAMPLE Examples of a protective conductor include a protective bonding conductor, protective earthing conductor and an earthing conductor when used for protection against electric shock.

[SOURCE: IEC 61851-1:2017, 3.7.2]

3.45

(electrically) protective separation

separation of one electric circuit from another by means of:

- *double insulation* (3.18); or
- *basic insulation* (3.5) and electrically protective screening (shielding); or
- *reinforced insulation* (3.48)

[SOURCE: IEC 61140:2016, 3.24]

3.46

rated current

current assigned by the manufacturer for a specified operating condition

[SOURCE: IEC 60050:1998, 442-01-02, modified — The phrase “of an accessory” was removed from end of definition.]

3.47

rechargeable energy storage system

RESS

rechargeable system that stores energy for delivery of electric energy for the *electric drive* (3.21)

EXAMPLE Battery, capacitor, flywheel.

[SOURCE: ISO 6469-1:2019, 3.22]

3.48

reinforced insulation

insulation of *hazardous live parts* (3.30) which provides a *degree of protection* (3.16) against *electric shock* (3.22) equivalent to *double insulation* (3.18)

Note 1 to entry: Reinforced insulation may comprise several layers that cannot be tested singly as *basic insulation* (3.5) or *supplementary insulation* (3.52).

[SOURCE: ISO 6469-3: 2018, 3.32, modified — The word “protection” was removed and replaced by “degree of protection”.]

3.49

residual current device

RCD

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

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

[SOURCE: IEC 60050-442:1998, 442-05-02, modified — The phrase “or association of devices” was removed, note 1 to entry was added.]

3.50**reverse power transfer**

supply of electric power from an *EV* (3.19) using the *EV plug* (3.24) [*case A* (3.6)], the *vehicle inlet* (3.60) [*case B* (3.7) and *case C* (3.8)], the *ACD counterpart* (3.3) [*case D* (3.9)] or the *ACD* (3.2) [*case E* (3.10)] to an *external electric circuit* (3.27)

Note 1 to entry: Unintended current flow from an EV to an external electric circuit is not considered a reverse power transfer.

Note 2 to entry: Supply of power by using an on-board equipment that is equipped with a *socket-outlet* (3.51) is not reverse power transfer.

3.51**socket-outlet**

accessory having socket-contacts designed to engage with the contacts of a *plug* (3.43) and having terminals for the connection of cables or cords

[SOURCE: IEC 61851-1:2017, 3.5.10]

3.52**supplementary insulation**

independent insulation applied in addition to *basic insulation* (3.5), for fault protection

[SOURCE: ISO 6469-3:2018, 3.33]

3.53**supply network**

any source of electric energy

EXAMPLE Mains or electric grid, distributed energy resources (DER), battery bank, PV installation generator, etc.

[SOURCE: IEC 61851-1:2017, 3.7.1, modified — The information in the example was previously part of the definition.]

3.54**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, modified — The article "a" was removed at the beginning of the definition.]

3.55**thermal sensing**

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

[SOURCE: IEC 61851-23:—²⁾, 3.3.109]

3.56**thermal transport**

method for managing the heat dissipation of accessories, cable assemblies or parts thereof, independent of changing the current

[SOURCE: IEC/TS 62196-3-1:—³⁾, 3.103]

2) Under preparation. Stage at the time of publication: IEC/TCDV 61851-23:2020.

3) Under preparation. Stage at the time of publication: IEC/RPUB/TS 62196-3-1:2020.

3.57

touch current

electric current passing through a human body or through livestock when it touches one or more accessible parts of an installation or of equipment

[SOURCE: IEC 61140:2016, 3.9]

3.58

vehicle connector

part of a *vehicle coupler* (3.59) integral with or intended to be attached to the cable assembly

[SOURCE: IEC 62196-1:2014, 3.3.1]

3.59

vehicle coupler

means of connecting or disconnecting a flexible cable to an electric vehicle

Note 1 to entry: It consists of a *vehicle connector* (3.58) and a *vehicle inlet* (3.60).

[SOURCE: IEC 62196-1:2014, 3.3]

3.60

vehicle inlet

part of a *vehicle coupler* (3.59) incorporated in, or fixed to, an electric vehicle

[SOURCE: IEC 62196-1:2014, 3.3.2]

3.61

vehicle power supply circuit

voltage class B electric circuit which includes all parts that are conductively connected to the vehicle inlet [case B (3.7), case C (3.8)] or the *plug* (3.43) [case A (3.6)] or part of an autoconnect charging device that is mounted on the *electrically propelled vehicle* (3.19) [case D (3.9), case E (3.10)] and that is operational when connected to an *external electric circuit* (3.27)

Note 1 to entry: The vehicle power supply circuit includes the on-board section of the vehicle power supply circuit and the off-board section being part of the external electric circuit.

3.62

voltage class

classification of an electric component or circuit according to its *maximum working voltage* (3.36)

Note 1 to entry: The classification to the voltage classes A and B is according to ISO 6469-3:2018.

[SOURCE: ISO 6469-3:2018, 3.36, modified — Note 1 to entry was added.]

4 Environmental and operational conditions

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

NOTE See the ISO 16750 series, ISO PAS 19295 and the ISO 19453 series for guidance.

The requirements specified in this document shall be fulfilled under all relevant energy levels (e.g. SOC of RESS) of the electric power sources of the EV.

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

5.1 Requirements for the plug and cable (case A)

The plug shall comply with:

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

NOTE For requirements when a vehicle is equipped with a standard plug, a function box and a cable that are permanently attached to the vehicle, see IEC 62752.

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.

5.2 Requirements for the vehicle inlet

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

- IEC 62196-1, or
- for an AC connection, a vehicle inlet according to IEC 62196-2, or
- for a DC connection, a vehicle inlet according to IEC 62196-3, or
- for a DC connection with a thermal management system, a vehicle inlet according to IEC/TS 62196-3-1:—³⁾.

6 Requirements for protection of persons against electric shock

6.1 General

The requirements given in ISO 6469-3 apply to the on-board section of the vehicle power supply circuit when not connected to an external electric circuit.

6.2 Basic protection when connected to an external electric circuit

In case A, the degree of protection against contact with voltage class B live parts shall be at least IPXXD according to ISO 20653 when the plug is mated to the corresponding socket-outlet. This requirement is deemed to be met if the vehicle is equipped with an EV plug according to the IEC 62196 series.

In cases B and C, the degree of protection against contact with voltage class B live parts shall be at least IPXXD according to ISO 20653 when the vehicle connector is mated to the vehicle inlet. This requirement is deemed to be met if the vehicle is equipped with a vehicle inlet according to the IEC 62196 series.

For case D and E the vehicle manufacturer shall perform a safety analysis under consideration of IEC 61140. Additional requirements for case D and E are under consideration.

EXAMPLE In case D and case E, the degree of protection against contact with voltage class B live parts is at least IPXXD according to ISO 20653 when the ACD and the ACD counterpart are mated.

Conformance is checked by inspection.

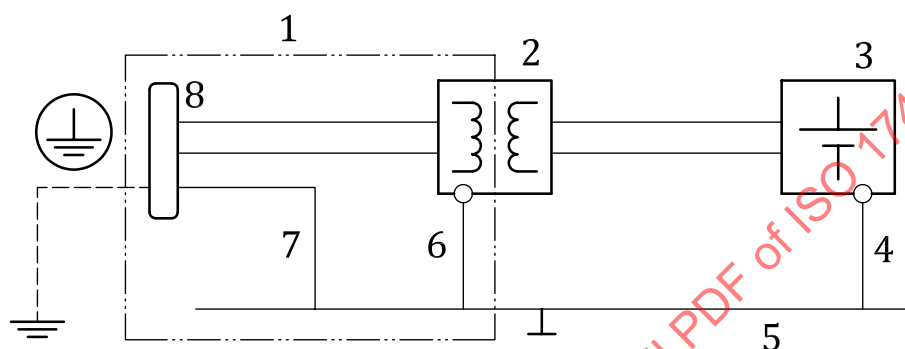
NOTE The requirements for unmated contacts are specified in [6.5](#).

6.3 Protective conductor

The plug (case A), the vehicle inlet (case B and case C), the ACD counterpart (case D) or the ACD (case E) shall have a contact for connecting the vehicle's electric chassis to the protective conductor of an external electric circuit.

The protective conductor terminal of the plug (case A), the vehicle inlet (case B and case C), the ACD counterpart (case D) or the ACD (case E) shall be connected:

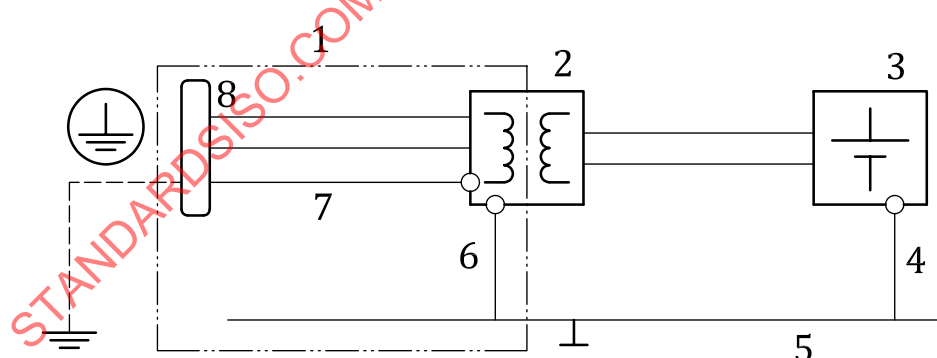
- 1) to the vehicle electric chassis with a protective conductor, see [Figure 1](#), or
- 2) to the exposed conductive parts of the components of the vehicle power supply circuit with a protective conductor, see [Figure 2](#).



Key

- | | |
|--|------------------------|
| 1 on-board section of vehicle power supply circuit | 5 electric chassis |
| 2 charger with galvanic separation | 6 protective conductor |
| 3 RESS | 7 protective conductor |
| 4 equipotential bonding according to ISO 6469-3 | 8 vehicle inlet |

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



Key

- | | |
|--|------------------------|
| 1 on-board section of vehicle power supply circuit | 5 electric chassis |
| 2 charger with galvanic separation | 6 protective conductor |
| 3 RESS | 7 protective conductor |
| 4 equipotential bonding according to ISO 6469-3 | 8 vehicle inlet |

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

All exposed conductive parts of the components of the vehicle power supply circuit shall be connected to the vehicle's electric chassis with a protective conductor.

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

The protective conductor of the vehicle power supply circuit shall be dimensioned according to the relevant quantities (e.g. fault current and disconnecting time) taking into account both energy sources, vehicle and external electric circuit.

The resistance of the protective conductor connection between the protective conductor contact of the plug (case A), the vehicle inlet (case B, case C), the ACD counterpart (case D) or the ACD (case E) and the vehicle electrical chassis, as well as all exposed conductive parts of the vehicle power supply circuit shall be less than 0,1 Ω . This applies to all conductive paths which are intended for protective conductor connection.

The resistance of the protective conductor shall be tested in accordance with [13.2](#).

6.4 Isolation resistance

6.4.1 AC connection

The isolation resistance divided by the maximum working voltage of the vehicle power supply circuit shall be at least 500 Ω /V when the vehicle is not connected to an external electric circuit (e.g. external electric power supply).

Conformance shall be tested in accordance with [13.3](#).

6.4.2 DC connection

The isolation resistance of the on-board section of the vehicle power supply circuit shall conform to the requirements in ISO 6469-3 when the vehicle coupler and the automatic coupler is not mated.

The total insulation resistance of the complete vehicle power supply circuit may be below 100 Ω /V when the vehicle is connected to a DC charging station. Electrical safety when mated is provided with the requirements of [9.1](#) also with the added parallel resistance from the external electric circuit.

For functional reasons, a vehicle that is equipped with a vehicle inlet according to IEC 62196-3 configuration EE or configuration FF should have the on-board section of the vehicle power supply circuit with an isolation resistance of at least 1 M Ω .

NOTE If the insulation resistance is below 1 M Ω the DC charging station might stop the charging process.

Conformance shall be tested in accordance with [13.3](#).

6.5 Requirements for unmated vehicle contacts

6.5.1 General

This subclause specifies the safety requirements for the contacts of the EV plug (case A), the vehicle inlet (case B and case C), the ACD counterpart (case D) or the ACD (case E) when they are not mated.

The requirements given in this clause shall be achieved by implementing basic and fault protection according to ISO 6469-3.

The requirements in [6.5.3](#) shall be fulfilled:

- within 10 s after un-mating if the contacts cannot be touched by a test probe 18 according to IEC 61032, or
- within 5 s after un-mating if the contacts are protected according to IPXXB according to ISO 20653, or

- within 1 s after un-mating if the contacts are not protected according to IPXXB according to ISO 20653.

If there is a latching or locking device the vehicle shall allow only un-latching or un-locking after the relevant thresholds as specified in 6.5.2 and in 6.5.3 are maintained.

If there is no latching and no locking device then 6.5.2 shall be fulfilled:

- within 10 s after un-mating if the contacts cannot be touched by a test probe 18 according to IEC 61032, or
- within 5 s after un-mating if the contacts are protected according to IPXXB according to ISO 20653, or
- within 1 s after un-mating if the contacts are not protected according to IPXXB according to ISO 20653.

NOTE 1 If contacts are protected according to IPXXD, IPXXB is also fulfilled.

NOTE 2 The latching or locking device might be part of the electric vehicle or part of the external electric equipment.

6.5.2 Normal operation

At least one of the following requirements applies for each contact of the EV plug (case A), the vehicle inlet (case B and case C), the ACD counterpart (case D) or the ACD (case E) when it is not mated:

- the contact shall be protected by the degree of protection IPXXD according to ISO 20653;
- the voltage between the contact and any other contact not protected by IPXXD according to ISO 20653 as well as the voltage between the contact and the electric chassis shall be below 60 V DC and 30 V AC;
- the steady state touch current between the contact and any other contact not protected by IPXXD according to ISO 20653 as well as the steady state touch current between the contact and the electric chassis shall be below 0,5 mA AC and 2 mA DC and the stored energy between the contact and any other contact not protected by IPXXD according to ISO 20653 as well as the stored energy between the contact and the electric chassis shall not cause a startle reaction. The limit shall be specified by the OEM under the consideration of the IEC 60479 series.

NOTE 1 The thresholds for steady state touch current are derived from IEC 61140 and IEC 60479-1.

NOTE 2 The energy stored in electrical power sources (e.g. RESS) that is only available through a sufficiently high protective impedance which limits the touch current is not relevant.

NOTE 3 A threshold of perception and a threshold of pain are defined in IEC 60479-2.

NOTE 4 According to IEC 60479-2 the threshold of pain is the specific charge or specific energy. The specific energy given in IEC 60479-2 might not correlate with the fault case for the inlet.

The steady state touch current requirement is deemed to be fulfilled if it can be proven by design review, that there is no conductive path from electrical power sources (e.g. RESS) to accessible conductive parts.

6.5.3 Operation under single fault conditions

In case of a single fault condition at least one of the following requirements applies for each contact of the EV plug (case A), the vehicle inlet (case B and case C), the ACD counterpart (case D) or the ACD (case E) when it is not mated:

- the contact shall be protected by the degree of protection IPXXD according to ISO 20653;

- the voltage between the contact and any other contact not protected by IPXXD according to ISO 20653 as well as the voltage between the contact and the electric chassis shall be below 60 V DC and 30 V AC;

NOTE 1 De-energization will result in the same voltage level as for normal operation. A different threshold is not relevant for single fault conditions.

- the steady state touch current between the contact and any other contact not protected by IPXXD according to ISO 20653 as well as the steady state touch current between the contact and the electric chassis shall be below 3,5 mA AC and 10 mA DC and the stored energy between the contact and any other contact not protected by IPXXD according to ISO 20653 as well as the stored energy between the contact and the electric chassis shall not cause strong involuntary muscular reactions. The limit shall be specified by the OEM under the consideration of the IEC 60479 series.

NOTE 2 The thresholds for steady state touch current are derived from IEC 61140 and IEC 60479-1.

NOTE 3 The energy stored in electrical power sources (e.g. RESS) that is only available through a sufficiently high protective impedance which limits the touch current is not relevant.

The steady state touch current requirement is deemed to be fulfilled if it can be proven by design review, that there is no conductive path from electrical power sources (e.g. RESS) to accessible conductive parts.

The vehicle should detect and issue a warning, if an applied threshold for normal operation, i.e. voltage or touch current and energy, is exceeded.

6.6 Insulation coordination

6.6.1 AC connection

The vehicle shall provide at least basic insulation between the live parts of the AC vehicle power supply circuit and electric chassis.

The vehicle shall provide at least protective separation between the live parts of the AC vehicle power supply circuit and voltage class A circuits.

The insulation of the vehicle power supply circuit shall be designed according to the circuit's maximum working voltage and overvoltage category II according to IEC 60664-1. If the vehicle power supply circuit includes measures that limit transient overvoltage to an appropriately low level, parts of the vehicle power supply circuit may be designed according to its maximum working voltage and overvoltage category I according to IEC 60664-1.

Conformance shall be tested in accordance with [13.4](#). Neither dielectric breakdown nor flashover shall occur during the test.

6.6.2 DC connection

The on-board section of the vehicle power supply circuit shall be designed according to a rated impulse voltage of at least 2 500 V between DC+ and protective conductor as well as between DC- and protective conductor.

NOTE 1 According to IEC 61851-23 the DC charging station limits the overvoltage at its output to this value.

Conformance shall be tested in accordance with [13.4](#). Neither dielectric breakdown nor flashover shall occur during the test.

For normal operation the on-board section of 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 IMD of the external electric circuit (e.g. see IEC 61851-23) shall be considered.

NOTE 2 For system C according to IEC 61851-23 an additional voltage of 50 V applies.

6.7 Touch current

When the vehicle is connected to an external electric circuit (i.e. in mated position), in case of a fault the RMS value of the AC touch current of the vehicle shall not exceed 3,5 mA and the DC touch current shall not exceed 10 mA.

NOTE For touch current requirement in unmated position, see [6.5](#).

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

In normal condition the touch current should not exceed 0,5 mA AC or 2 mA DC.

6.8 Compatibility with residual current devices (RCD)

NOTE Protective coordination for mode 2 is specified in IEC 61851-1 and IEC 62752. The coordination for mode 3 is specified in IEC 61851-1 and IEC 62955.

7 Protection against thermal incident

7.1 Requirements for normal operation

The cross-sectional area of the live conductors of the vehicle power supply circuit, as well as the rated current of the plug (case A), the vehicle inlet (case B and case C), the ACD counterpart (case D) or the ACD (case E), shall be according to the highest value of current that can flow in the vehicle power supply circuit under normal operating conditions.

For DC power transfer, the cross-sectional area of the live conductors may be reduced as long as temperature limits according to [9.7](#) are not exceeded. In this case, protection against thermal overheating shall be provided to protect the vehicle power supply circuit from exceeding its temperature limit. 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 based on an agreement between the vehicle manufacturer and the manufacturer of the vehicle inlet as long as the temperature requirement for the DC contacts according to [9.7](#) is not violated.

7.2 Overcurrent protection

7.2.1 General

The vehicle power supply circuit shall have means to prevent a thermal incident caused by:

- an overload;
- a short circuit.

Different measures to provide overcurrent protection may be used for different sections of a circuit.

NOTE 1 Overcurrent protection is not a measure for detection and cutting off of serial or parallel arcing. Arcing can cause harm. Appropriate measures to address arcing are, for example service plan, pollution degree, insulation, clearance, creepage distance and other measures.

NOTE 2 The rated current of an external electric circuit might be higher than the rated current of the on-board section of the vehicle power supply circuit.

7.2.2 Overload protection

The vehicle shall provide an overload protection to prevent the current exceeding the rated current of the vehicle power supply circuit or exceeding the temperature limits of the vehicle power supply circuit.

NOTE Overload protection measures include but are not limited to overload detection and contactor opening function.

7.2.3 Short-circuit protection for AC connection

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

- a) The cross-sectional area of the live conductors of the vehicle power supply circuit shall have a short-circuit current withstand rating (I^2t) according to the characteristics of the overcurrent protection 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.

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 [7.2.3 a\)](#).
- 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 on-board section of 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;

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

7.2.4 Short-circuit protection for DC connection

7.2.4.1 Short-circuit energy supplied by external electric circuit

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

- a) The vehicle power supply circuit shall have a short-circuit current withstand rating (I^2t) of at least the following values:
 - 1 000 000 A²s, if a vehicle is equipped with a vehicle inlet of configuration AA, configuration EE or configuration FF according to IEC 62196-3, or
 - 500 000 A²s, if a vehicle is equipped with a vehicle inlet of configuration BB according to IEC 62196-3, or
 - a value in A²s to be coordinated for any other vehicle coupler, ACD, or ACD counterpart.

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

NOTE This short-circuit current withstand rating (I^2t) 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, or
- the ACD counterpart, or
- the ACD

and this overcurrent protection shall conform to the requirement of [7.2.4.1 a](#)). The breaking time for interruption of a short-circuit current shall be gathered from the technical data of the selected overcurrent protection.

7.2.4.2 Short-circuit energy supplied by the EV

WARNING — Attention is drawn to the fact that the changes made to the content of 7.2.4.2 compared to ISO 17409:2015 can cause safety issues in combination with legacy vehicles that still exist in the field. In addition to that, for vehicles already in development and based on ISO 17409:2015, 6.1.3 a transitional period for the requirement is given which ends 2022-12-31.

The vehicle shall provide overcurrent protection for the vehicle power supply circuit and the external electric circuit. The overcurrent protection shall have the following characteristics:

- the cut-off current supplied by vehicle sources does not exceed 30 kA at the contacts of the vehicle inlet, and
- the vehicle shall switch off the supply to the external electric circuit within 1 s after start of the short-circuit condition, and
- a maximum I^2t value at the contacts of a vehicle inlet
 - of 2 500 000 A²s, if the vehicle is equipped with an inlet of configuration AA according to IEC 62196-3, or
 - of 5 000 000 A²s, if the vehicle is equipped with an inlet of configuration EE or configuration FF according to IEC 62196-3, or

NOTE 1 The I^2t requirement for System C according to IEC 61851-23 was 12 000 000 A²s in ISO 17409:2015.

- to be coordinated for any other vehicle coupler or automatic coupler.

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

NOTE 2 These characteristics are coordinated with the short-circuit current withstand rating of the line conductors of a DC EV charging station according to IEC 61851-23.

Conformance is checked by inspection.

7.3 Arc protection for DC connections

Arc protection is covered by the requirement of locking in [9.5](#)

7.4 Residual energy after disconnection

For the protection against thermal incident one second after having disconnected the vehicle from the external electric circuit (e.g. external electric power supply), the stored energy at the voltage class B live parts at the plug (case A), vehicle inlet (case B and case C), the ACD counterpart (case D) or the ACD (case E), shall be less than 20 J.

NOTE 1 This requirement does not include a voltage limit.

NOTE 2 Circuits whose voltages are safe to touch can become hazardous with respect to energy related hazards. For protection against electric shock see 6.5.

7.5 Transient overvoltage

The on-board section of the vehicle power supply circuit shall be designed according to a rated impulse voltage between DC+ contact and DC- contact according to IEC 61851-23:—²⁾, 12.7.101.

8 Additional requirements for AC power transfer

8.1 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 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 %).

8.2 Current characteristics

8.2.1 Load current

The vehicle load current shall not exceed:

- the maximum allowed current value indicated by the typical control pilot function according to IEC 61851-1:2017, A.2.2;
- 10 A from a single phase, if the vehicle is using the simplified control pilot function according to IEC 61851-1:2017, A.2.3;
- the maximum allowed current value provided by digital communication according to the ISO 15118 series;
- 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.

NOTE 1 In some countries, the maximum current is limited for mode 2 according to used plug. See IEC 61851-1, IEC 60364-7-722.

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

8.2.2 Inrush current

The vehicle shall limit the inrush current into the vehicle power supply circuit as follows:

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

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 capacitor in the charger, the current in each live conductor shall not exceed 30 A (rms). The absolute value of the current peak shall not exceed 42,4 A peak. Current peak 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 30A (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 [13.5](#).

8.3 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.

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

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

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

NOTE 1 In Germany, according to VDE AR-N 4100, vehicles with rated power of their charger above 12 kVA are required to have an adjustable active factor.

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

8.4 Interlock function for the vehicle coupler

When equipped with a vehicle inlet that is not suitable for making and breaking an electrical circuit under load, the vehicle shall provide an appropriate interlock function.

- 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.
- When locking is used for such an interlock function, the vehicle shall inhibit release of the vehicle connector while the vehicle current exceeds 1 A.

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

8.5 Phase order 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).

Conformance is checked by inspection.

9 Additional requirements for DC power transfer

9.1 General

“Alternative protection measures” according to ISO 6469-3:2018, 6.3.5 shall be applied to the on-board section of vehicle power supply circuit.

ISO 6469-3:2018, 6.5 shall not be applied for the vehicle power supply circuit.

NOTE The vehicle safety concept impacts the interoperability with the DC charging station.

9.2 Disconnection device

The vehicle shall provide a disconnection device for each voltage class B contact (excluding protective conductor) at the vehicle coupler or at the automatic coupler. Only measurement circuits (e.g. welding detection) may remain connected to the voltage class B contacts at the vehicle coupler or the automatic coupler when the disconnection device is operational. The disconnection device shall withstand an inrush current according to system specific requirements of IEC 61851-23.

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

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

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

For system C according to IEC 61851-23, the voltage difference between both sides of the disconnection device shall be lower than 20 V DC 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 Vehicle isolation resistance monitoring system

If the vehicle is equipped with a vehicle isolation resistance monitoring system which monitors the vehicle power supply circuit, the operation of the insulation monitoring device (IMD) of the external electric circuit shall not be affected (e.g. DC EV charging station). The vehicle may deactivate its isolation resistance monitoring system to avoid such interference.

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

9.5 Locking of the vehicle connector

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

- the vehicle shall lock the connector to 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 position of the mechanical locking means shall be checked after closing;
- if the lock opens falsely, the vehicle shall change the system state of the control pilot function to state B, according to the sequence diagrams as specified in IEC 61851-23, in order to request the stop of the power transfer process;
- the vehicle connector shall not be unlocked unless the voltage at the vehicle inlet is below 60 V DC or 30 V AC (rms) and vehicle load current is less than 1 A;
- in case of a malfunction of the external electric circuit, a means for disconnection specified by vehicle manufacturer may be provided;
- if other options for a safe disconnect are available, information for the unlock procedure shall be stated in the owner's manual;
- the vehicle shall provide measures to ensure that actuation of the latch position switch (S3) of the configuration EE vehicle connector is not possible when the vehicle connector is locked to the vehicle inlet.

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

9.6 AC or DC electric power at the same contacts

The disconnection device (see 9.2) shall interrupt all line conductors of the DC vehicle power supply circuit. The relevant parts of the vehicle power supply circuits shall fulfil the requirements for AC and DC electric power transfer or they shall be disconnected by a mechanical disconnection device.

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 DC vehicle power supply circuit 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 DC vehicle supply circuit through the vehicle inlet under single failure conditions in the DC vehicle supply circuit (e.g. disconnection device) and in the AC vehicle power supply circuit (e.g. charger).

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

- installation of supplemental diodes at all live conductors of the vehicle power supply circuit;
- more than one independent disconnection devices with independent control system for each;
- use of safety related components in accordance with appropriate standards or combination of standards such as ISO 13849;
- use of charger which provides basic insulation by galvanic separation.

Analysis and design shall be in accordance with 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.

9.7 Contact temperature

The temperature of the DC power contacts of the vehicle inlet or the automatic coupler shall not exceed the temperature limit as specified by the manufacturer of the vehicle inlet or the automatic coupler. For an ambient temperature up to 40 °C the temperature of the DC power contacts of the vehicle inlet shall not exceed 90 °C during power transfer.

NOTE 1 The temperature limits are derived from the IEC 62196 series.

NOTE 2 At the time of publication of this document no product standard for automatic couplers exists.

NOTE 3 The IEC 62196 series provides cross sections of the live conductors for type testing of the vehicle inlet. IEC/TS 62196-3-1:—³⁾, 24.102.3, provides cross sections of the live conductors, which leads to thermal stabilization at the DC contacts below 90 °C when used with a vehicle connector with the same current rating.

Conformance is checked by inspection and test 13.7.

If the vehicle supports currents above 200 A, the vehicle shall be equipped with a vehicle inlet according to IEC/TS 62196-3-1.

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

- 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 4 Plausibility check of thermal sensing might be implemented by comparing the ambient temperature of the vehicle with the temperature of the power contacts while the vehicle inlet or the automatic coupler is not used.

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

Vehicle manufacturers shall perform a hazard analysis to determine if the measures in [9.7 a\)](#) or b) shall be applied to a vehicle that supports currents below or equal to 200 A.

Conformance is checked by inspection and test as in [13.8](#).

9.8 Overvoltage in case of a load dump

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.

NOTE Load dump is a sudden increase of the voltage caused by a failure. A load dump can occur when a component feeds electrical energy into an electric circuit and high load is disconnected abruptly. See ISO PAS 19295.

9.9 Compatibility with insulation monitoring

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

For a vehicle equipped with a vehicle inlet according to IEC 62196-3 configuration AA with a maximum working voltage up to 500 V DC, the total y-capacitance of the on-board section of the vehicle power supply circuit shall not exceed 2,2 µF.

For a vehicle equipped with a vehicle inlet according to IEC 62196-3 configuration EE with a maximum working voltage up to 500 V DC, the total y-capacitance of the on-board section of the vehicle power supply circuit is under consideration.

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

$$C_y = \frac{1,6mV}{U} F \quad (1)$$

NOTE 1 The formula assumes a measurement current of the IMD of 1 mA and limits the time to perform a single measurement for one rail 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.

NOTE 2 The requirement supports proper operation of the insulation monitoring device.

NOTE 3 For requirement for protection against electric shock, see [Clause 6](#).

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

See [Annex A](#) for guidance on the measurement of the total y-capacitance.

10 Reverse power transfer

10.1 General

A vehicle that implements reverse power transfer shall do reverse power transfer through an EV plug (case A), vehicle inlet (case B and case C), an ACD counterpart (case D) or an ACD (case E) according to the IEC 62196 series or other relevant standard.

An EV that is not designed for reverse power transfer shall not transfer power to the external electric circuit in normal operation and under single failure conditions. The vehicle manufacturer shall specify

time and current limits for unintended reverse power transfer. An EV that is designed for reverse power transfer shall transfer power to the external electric circuit only when it is connected to an external electric circuit that is intended for reverse power transfer.

In case of reverse power transfer the vehicle shall provide overcurrent protection.

An EV that is designed for reverse power transfer shall only supply power to the external electric circuit if the following requirements are met:

- the vehicle detects that the EV plug (case A), the vehicle inlet (case B and case C), the ACD counterpart (case D) or the ACD (case E) is correctly mated;
- the vehicle detects that the control pilot circuit is connected;
- the vehicle detects an external electric circuit which supports reverse power transfer e.g. by digital communication.

NOTE IEC 60364-7-722 includes requirements for installation of equipment that supports reverse power transfer.

10.2 AC reverse power transfer

10.2.1 General

The requirements in this subclause apply to the AC reverse power transfer to the external electric circuit that is not connected to the supply network (mains).

NOTE 1 Use cases include vehicle to load and vehicle to home.

The requirements for the AC reverse power transfer to the external electric circuit that can be connected to the supply network (mains) are under consideration.

NOTE 2 In case of grid connected reverse power transfer the vehicle might need to provide the active power and reactive power based on request by the EV supply equipment (e.g. by digital communication).

10.2.2 Output power quality

10.2.2.1 Output voltage

The voltage shall be standard voltage according to IEC 60038.

10.2.2.2 Output frequency

The frequency shall be 50 Hz or 60 Hz. The tolerance of the frequency should be ± 2 %.

10.2.2.3 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 8 %.

NOTE For more information, see EN 50160.

10.2.2.4 Output current

The maximum output current shall meet the following requirements:

- the rated current of the on-board section of the vehicle power supply circuit;

- the rated current of the EV plug (case A), vehicle inlet (case B and case C), the ACD counterpart (case D) or the ACD (case E);
- the maximum current of the external electric circuit indicated by 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;
- the maximum current as indicated by digital communication if any.

The EV shall provide the overcurrent protection means to interrupt the power transfer if the maximum allowed current is exceeded.

NOTE 1 In some countries, the maximum reverse power from the EV is limited to less than 10 kW: JP.

The EV shall reduce the output voltage of its power electronic converter to 50 V AC or less in the event of a short circuit in a time as given for TT circuits in IEC 60364-4-41:2005, 411.3.2.2 or 411.3.2.4, as appropriate.

NOTE 2 As the time limits for TT circuits are lower than for TN circuits, and the vehicle might be connected to either earthing system, the lower time limit is applied.

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

10.2.3 Prevention of disconnection of vehicle coupler under load

[8.4](#) applies for reverse power transfer also.

10.2.4 Protection against electrical shock

10.2.4.1 Protection against unintended voltage

[6.5](#) applies for reverse power transfer.

10.2.4.2 Protection under single failure condition

Fault protection shall be applied based on the fault mode analysis by vehicle manufacturer.

10.2.4.3 Additional protection

Additional protection is under consideration, for example RCD function, IMD function.

10.2.5 Protection against thermal incident

The EV shall provide the overcurrent protection means to interrupt the power transfer if the maximum allowed current is exceeded.

10.3 DC reverse power transfer

10.3.1 General

[Clause 9](#) applies.

The requirements in this subclause apply to the DC reverse power transfer to the DC EV charging station according to IEC 61851-23.

NOTE For reverse power transfer the connected external electric circuit is assumed to fulfil the relevant requirements of IEC 61851-23.

10.3.2 Connection to the external electric circuit

The communication between the EV and external electric circuit shall conform with IEC 61851-24.

NOTE In some countries, the maximum reverse power from the EV is limited to 10 kW: JP.

10.3.3 Protection against overdischarge of the RESS

During reverse power transfer the requirements concerning overdischarge according to ISO 6469-1 apply.

10.3.4 Auxiliary power supply from EV (optional)

The EV may provide auxiliary power supply to the DC EV charging station in accordance with IEC 61851-23.

10.3.5 Protection against thermal incident

The EV shall provide the overcurrent protection means to interrupt the power transfer if the maximum allowed current is exceeded.

11 Operational requirements

Vehicle movement by its own propulsion system shall be impossible as long as the vehicle is physically connected to the external electric circuit.

Conformance is checked by inspection.

NOTE ISO 6469-2 defines operational requirements for EV.

12 Owner's manual and marking

12.1 Owner's manual

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

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

- instruction for connection of the EV to an external electric circuit;
- information about the need of a proper installation of the fixed electrical installation.

12.2 Marking

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

Parts of the plug (case A) and the vehicle inlet (case B and case C) which are visible for the user should have no marking in accordance with ISO 6469-3.

NOTE In some countries, regulations might require additional marking of the vehicle according to EN 17186.

13 Test procedure

13.1 General

All tests are type tests.

Room temperature is a temperature of $(25 \pm 2) ^\circ\text{C}$.

If not otherwise specified, the tests described apply to the vehicle power supply circuit referred to as device under test.

Unless specified otherwise in the individual test method, the device under test is operated under normal operating conditions.

Unless specified otherwise in the individual test method, the tests are carried out under normal laboratory conditions:

- Temperature: 15 °C to 35 °C;
- Air pressure: 86 kPa to 106 kPa at sea level;
- Relative humidity: 25 % to 75 %.

13.2 Resistance of protective conductor

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

The resistance of the path used for protective conductor connection is tested with a test current of at minimum 200 mA and a voltage <60 V DC. The test current is passed through the protective conductor paths between the protective conductor terminal of the plug (case A), vehicle inlet (case B and case C), the ACD counterpart (case D) or the ACD (case E) and any connected conductive part of the vehicle power supply circuit and the electric chassis for at least 5 s. This path is isolated from other unintended potential paths for purpose of the test.

13.3 Isolation resistance test

Perform preconditioning and conditioning according to ISO 6469-3:2018, 10.3.1.

The isolation resistance test according to ISO 6469-3:2018, 10.3.4, applies with the following modifications:

- Instead of the “entire conductively connected voltage class B2 electric circuits”, the on-board section of the vehicle power supply circuit is tested.
- The measurement is performed at the contacts of the plug (case A), vehicle inlet (case B and case C), the ACD counterpart (case D) or the ACD (case E).

13.4 Withstand voltage test

13.4.1 General

The withstand voltage test according to ISO 6469-3:2018/Amd 1⁴⁾, applies with the following modifications:

- The test is performed on the on-board section of the vehicle power supply circuit at the contacts of the plug (case A), vehicle inlet (case B and case C), the ACD counterpart (case D) or the ACD (case E).
- If the on-board section of the vehicle power supply circuit includes contactors or disconnection devices, they are closed.

The test voltage is as specified in [13.4.2](#).

4) Under preparation. Stage at the time of publication: ISO 6469-3: 2018/FDAmd 1:2020.

13.4.2 Test voltage

13.4.2.1 AC connection

The RMS value of the AC test voltage of a frequency of 50 Hz or 60 Hz is raised uniformly from 0 V to the following 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 origin from IEC 60664-1:2007, 5.3.3.2.3 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 of 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.

13.4.2.2 DC connection

The test voltage is derived from the relevant overvoltage of the electric circuit to which the component is connected. Transient overvoltage that can be expected, including influences from other connections to grid, if any, is included. The test voltage and its duration are specified, considering the applicable parts and sections of the IEC 60664 series by the vehicle manufacturer.

The AC test voltage of a frequency of 50 Hz or 60 Hz is raised uniformly from 0 V to the following value within not more than 5 s and held at that value for at least for 60 s.

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

NOTE The DC EV charging station limits its overvoltage in accordance with IEC 61851-23.

13.5 Inrush current tests

13.5.1 General

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

- a) supply voltage is the rated voltage of the device under test;
- b) external power supply has a supply system impedance (loop impedance) of not more than 150 mΩ;
- c) 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;
- d) 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.

13.5.2 Measurement

The measurements is 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 last between consecutive measurements to ensure discharging of capacitors of the device under test.

Measurement devices shall have an appropriate resolution.

The required inrush current limits for event 1 and event 2 in accordance with [8.2.2](#) shall be met at a supply system impedance of not more than 150 mΩ.

13.6 Touch current

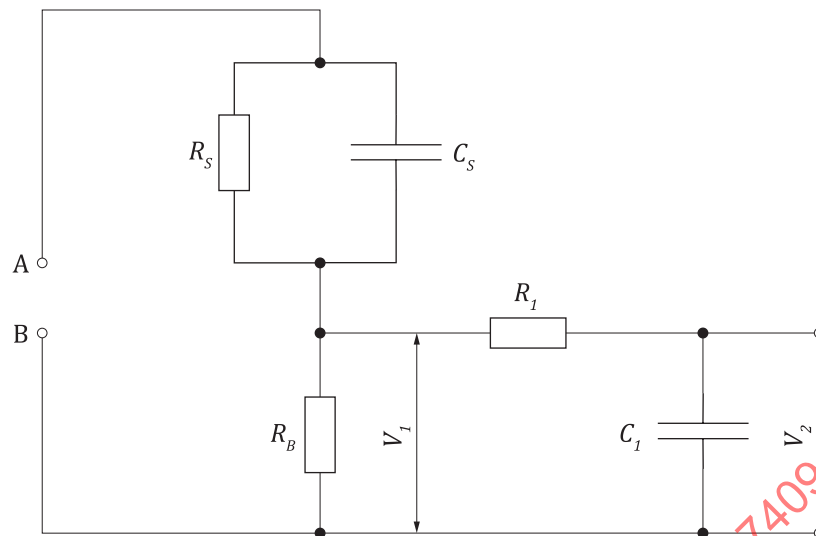
13.6.1 General

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

When testing an AC connection, the touch current is measured when the device under test is connected to an AC external electric power supply. When testing a DC connection, the touch current is also measured when the device under test is connected to a DC external electric power supply.

The test is conducted with a cable assembly conforming with IEC 61851-1, IEC 62752 or an equivalent national standard or a DC EV charging station 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 3](#) (see also IEC 60990).

**Key**

A, B terminals of measurement circuit

R_S = 1,5 k Ω $\pm$ 5 %

R_B = 500 Ω $\pm$ 5 %

R_1 = 10 k Ω $\pm$ 5 %

C_S = 0,22 μ F $\pm$ 10 %

C_1 = 0,022 μ F $\pm$ 10 %

Figure 3 — Measurement circuit

$V_{2\text{rms}}$, which is the root mean square value of the voltage V_2 , is measured, see [Figure 3](#). For voltage measurement, an instrument according to IEC 60990:2016, Annex G is used.

The touch current is calculated by [Formula \(2\)](#):

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

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.

After each single test, the original operation conditions is 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.

13.6.2 AC Charging

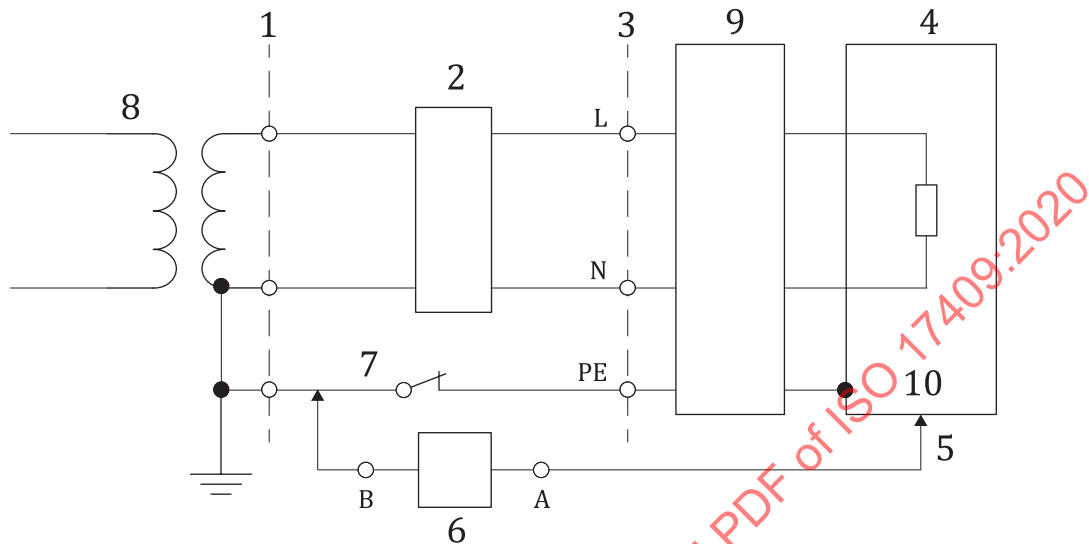
If the device under test is intended for connection to single-phase supply, it is connected between phase and neutral of an earthed neutral power distribution system (see [Figure 4](#)).

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 5](#)).

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 4 — 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 4](#)). 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 4](#). 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.