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

Part 6: Safety and interoperability requirements for heavy-duty vehicles in magnetic field wireless 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 6: Exigences de sécurité et d'interopérabilité pour les véhicules utilitaires lourds dans le cadre du transfert d'énergie sans fil par champ magnétique

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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 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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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 by Technical Committee ISO/TC 22, *Road vehicles*, 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.

Introduction

This document specifies requirements for on-board components of a wireless power transfer systems in heavy-duty vehicles. It gives guidance in terms of safety and performance and additionally addresses interoperability to off-board components from different manufacturers to, for example, support the development of public wireless charging infrastructure. Even if the technology itself is well known, the implementation in a vehicle is new and demands to meet the very specific requirements of the automotive industry. This document is based on limited experience with series development and production. Current and future product developments will continuously prove (and disprove) the applicability of this document to further improve the contents, especially regarding the interoperability between systems from different manufacturers.

The systems specified in this document are intended to work with off-board systems that are compliant with the requirements of the relevant portions of the IEC 61980 series. Some of those relevant documents are currently in development.

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

Part 6: Safety and interoperability requirements for heavy-duty vehicles in magnetic field wireless power transfer

1 Scope

This document defines the requirements and operation of the on-board vehicle equipment that enables magnetic field wireless power transfer (MF-WPT) for traction battery charging of electric vehicles. It specifies requirements for static (vehicle not in motion) and dynamic (vehicle in motion) applications. It is intended to be used for heavy duty vehicles. This does not exclude the application of systems in passenger cars or light commercial vehicles

This document addresses the following aspects for an EV device:

— safety requirements;

— transferred power and power transfer efficiency;

— ground clearance of the EV device;

— functionality with associated off-board systems under various conditions and independent of manufacturer (interoperability);

— test procedures.

EV devices that fulfil the requirements in this document are intended to operate with supply devices that fulfil the MF-WPT related requirements in the IEC 61980 series.

In this edition, multiple secondary devices (modular approach for higher power classes) are not covered.

NOTE The dynamic application is shown in Annex C.

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, *Electrically propelled road vehicles — Functional and safety requirements for power transfer between vehicle and external electric circuit — Part 1: General requirements for conductive power transfer*

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

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

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

IEC 61980-1:2020, *Electric vehicle wireless power transfer (WPT) Systems — Part 1: General requirements*

IEC 61980-2, *Electric vehicle wireless power transfer (WPT) Systems — Part 2: Specific requirements for MF-WPT system communication and activities*

ICNIRP 2010, *Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz – 100 kHz)*

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
alignment
relative position in x- and y-direction of the *secondary device* (3.16) to the *primary device* (3.10) for a given *secondary device ground clearance* (3.17)

3.2
alignment tolerance area
intended *wireless power transfer (WPT)* (3.23) operating area in x- and y-direction for a given *secondary device ground clearance* (3.17)

3.3
embedded mounting
mounting of a *primary device* (3.10) in such a manner that the top covering of the primary device is buried (embedded) under the pavement

3.4
centre alignment point
geometrical centre of the *alignment tolerance area* (3.2)

3.5
electrically propelled vehicle
EV
vehicle with one or more electric drive(s) for vehicle propulsion

3.6
EV device
on-board component assembly of *wireless power transfer (WPT) system* (3.24)

3.7
EV power circuit
EVPC
on-board component assembly, comprising the *secondary device* (3.16) and *EV power electronics* (3.8), as well as the electrical and mechanical connections

3.8
EV power electronics
on-board component that converts the power and frequency from the *secondary device* (3.16) to the DC power output of the *EV power circuit (EVPC)* (3.7)

3.9
magnetic field WPT system
MF-WPT system
system using wireless transfer of energy from a power source to an electrical load via a magnetic field

3.10
primary device
off-board component that generates and shapes the magnetic field for *wireless power transfer (WPT)* (3.23)

3.11
protection area
volume in and around the vehicle that has uniform requirements with regard to effects of exposure to electromagnetic fields

3.12
rated output power
maximum power the *EV power circuit (EVPC)* (3.7) is designed to deliver consistently during a charging cycle

3.13
rechargeable energy storage system
RESS
rechargeable system that stores energy for delivery of electric energy for the electric drive

3.14
reference EVPC
EV power circuit (EVPC) (3.7) that serves for testing purposes

3.15
reference supply power circuit
reference SPC
supply power circuit that serves for testing purposes

3.16
secondary device
on-board component that captures the magnetic field

3.17
secondary device ground clearance
vertical distance between the ground surface and the lowest point of the *secondary device* (3.16) including the housing

3.18
steady state
state of a system at which all state and output variables remain constant in time while all input variables are constant

3.19
supply device
off-board component assembly of *wireless power transfer (WPT) system* (3.24)

3.20
supply power circuit
SPC
off-board component assembly, comprising the *primary device* (3.10) and supply power electronics (3.21), as well as the electrical and mechanical connections

3.21
supply power electronics
off-board component that converts the power and frequency from the supply network to the power and frequency needed by the *primary device* (3.10)

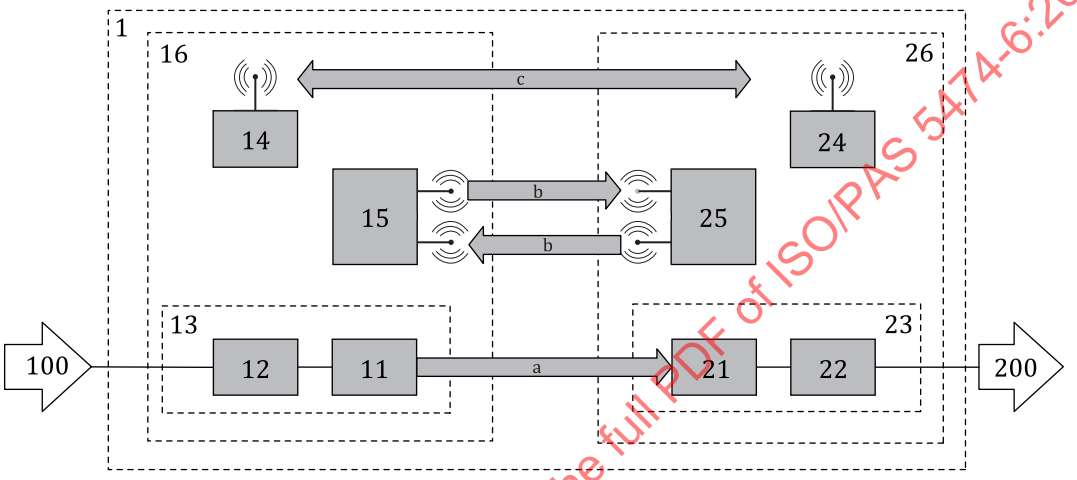
3.22
voltage class B
classification of an electric component or circuit with a maximum working voltage of (>30 and ≤1 000) V a.c. (rms) or (>60 and ≤1 500) V d.c., respectively

3.23
wireless power transfer
WPT
transfer of electrical energy from a power source to an electrical load without galvanic connection

3.24
WPT system
system comprising all necessary components for *wireless power transfer (WPT)* (3.23) and control

4 System structure

The MF-WPT system is structured into functional entities. Figure 1 shows this structure of functional entities in an exemplary static wireless power transfer system.



Key

1	MF-WPT system		
11	primary device	21	secondary device
12	supply power electronics	22	EV power electronics
13	supply power circuit	23	EV power circuit
14	supply equipment communication controller (SECC)	24	EV communication controller (EVCC)
15	supply device P2PS controller	25	EV device P2PS controller
16	supply device	26	EV device
100	supply network	200	RESS

a Wireless power flow.
b Wireless P2PS interface.
c Wireless communication interface.

Figure 1 — Example of system structure for static wireless power transfer

5 Requirements regarding environmental conditions

The requirements given in this document shall be met across the range of environmental conditions as specified by the vehicle manufacturer.

The environmental requirements applicable to a component depend on its mounting position. The component shall withstand and retain its degree of protection under the typical loads and stresses it is subjected to in its intended mounting position.

Components of the EV device installed at the underbody of the EV shall have IP degree IP6K7 and IP6K9K according to ISO 20653.

NOTE See ISO 16750 series, ISO 21498 series and ISO 19453 series for guidance.

6 Classification

This document specifies requirements that address the following aspects of MF-WPT systems:

— system safety,

— system performance, and

— interoperability.

Requirements regarding system safety and system performance are relevant and applicable to any MF-WPT system (including dedicated single-supplier solutions).

The interoperability requirements supplement the safety and performance requirements in order to allow for interoperability of a supply device and an EV device provided by independent suppliers. Cross-supplier interoperability is tested with the reference SPCs (under consideration) as specified in this document.

Two compatibility classes have been specified to accommodate these design considerations:

— Compatibility class A: EV devices of this class are intended for interoperable application and are required to meet a set of safety and performance requirements.

— Compatibility class B: EV devices of this class are not intended for interoperable application but still are required to meet the set of safety requirements. Performance requirements may be different than those of compatibility class A. EV devices of this class are tested with supplier-specified supply power circuits.

7 MF-WPT power transfer requirements

7.1 General

The supplier shall specify the rated conditions of an EVPC according to Table 1.

Table 1 — EVPC rated conditions

Specifications of EVPC		Compatibility class A	Compatibility class B
Frequency range		Operation within (79 – 90) kHz	Operation within (79 – 90) kHz, (19-21) kHz (TBD)
Secondary device ground clearance		EVPC specific within 100 mm – 250 mm	EVPC specific
Centre alignment point(s)		EVPC specific	
Alignment tolerance area	x-direction	±100 mm	EVPC specific
	y-direction	±100 mm	EVPC specific
Output voltage range		EVPC specific within voltage classes A and B according to ISO 6469-3.	
Rated output power		EVPC specific up to 22 kW (MF-WPT4) EVPC specific up to 50 kW (MF-WPT5)	EVPC specific

7.2 Frequency

MF-WPT for EVs with compatibility class A is allowed to operate in the frequency range of (79 - 90) kHz. The operating frequency during power transfer is set by the supply device based on negotiations with the EV device.

7.3 Requirements for output power

An EVPC shall be able to deliver power up to its rated output power when operated with a supply power circuit.

An EVPC shall support the maximum ramp up rate of the supply power circuit. The maximum ramp up rate of supply circuits for EVPCs is specified in IEC 61980-4[1)].

7.4 Requirements for power transfer efficiency

Power transfer efficiency is the ratio of the output power of the EVPC (output of block #23 in Figure 1) divided by the input power of the supply power circuit (input to block #13 in Figure 1).

An EVPC shall support the minimum power transfer efficiency according to Table 2 when operated at rated output power with a supply power circuit.

An EVPC should support the minimum power transfer efficiency according to Table 2 when operated at power levels below the rated output power. Typical local supply network connections should be considered.

Table 2 — Minimum power transfer efficiency for static WPT

Alignment	Minimum power transfer efficiency
Centre alignment point	85 %
Within alignment tolerance area	80 %

7.5 Requirements for output voltage

7.5.1 Performance requirements at different output voltage levels

An EVPC shall meet the requirements of 7.3 and 7.4 throughout its specific voltage range when operated with a supply power circuit.

7.5.2 Voltage ripple and voltage overshoot

The DC output voltage overshoot, the peak voltage and the voltage ripple amplitude of an EVPC shall be agreed between the vehicle manufacturer and supplier, taking into account the implication on the RESS and other on-board components.

NOTE Reference SPCs (supply power circuits) are shown in Annex A and Annex B.

7.6 MF-WPT power transfer test procedure

7.6.1 General

This subclause describes the test setup and procedure to be applied for conformance testing of the requirements.

7.6.2 Test setup

7.6.2.1 Apparatus

7.6.2.1.1 General

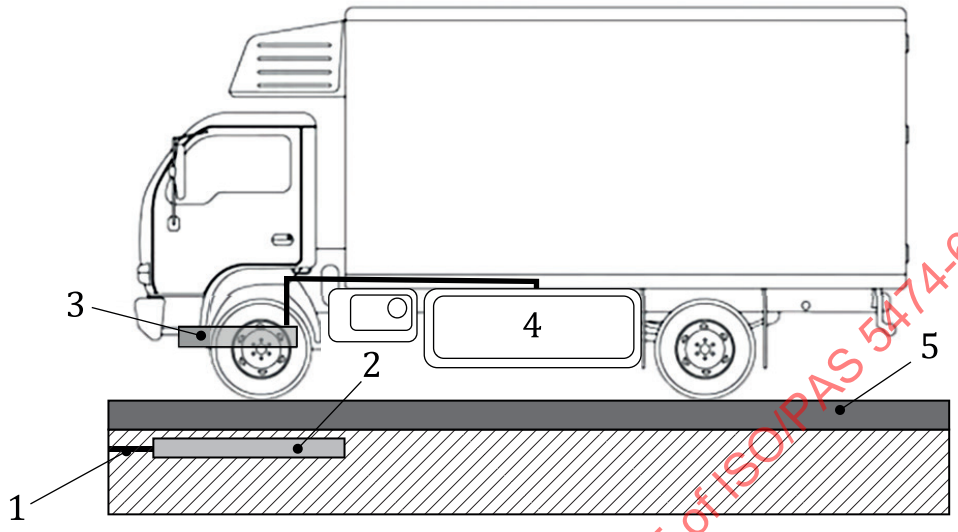
MF-WPT is influenced by the materials in the close surroundings, especially by the material structure of the EV. Reliable testing results can only be achieved when influencing materials of the EV are adequately

1) Under preparation. Stage at the time of publication: IEC/CD 61980-4:2025.

represented in the test setup. This can either be accomplished by testing at a vehicle level or by including relevant parts of the vehicle when testing is done at component level.

7.6.2.1.2 Vehicle level testing

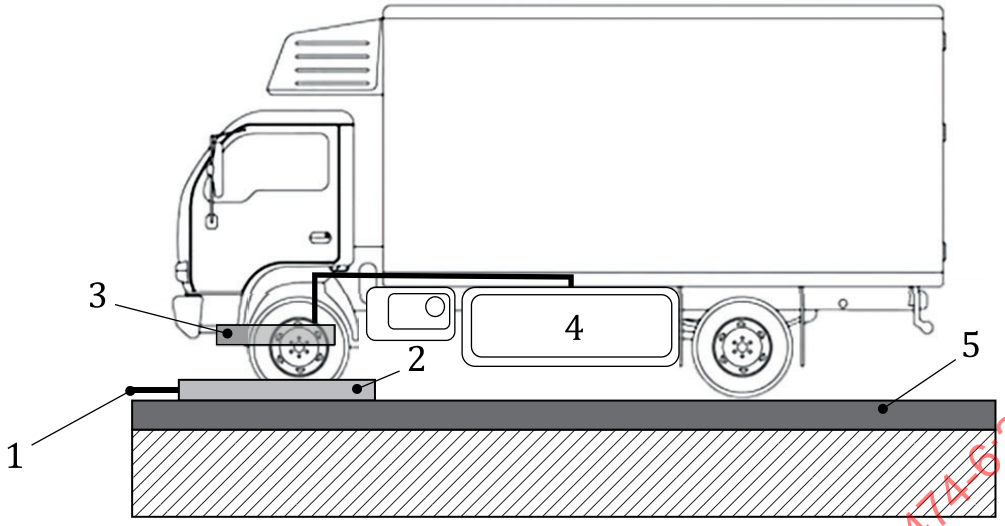
Figures 2 and 3 exhibit an exemplary test setup for vehicle level testing.



Key

1 connection to supply network
2 embedded supply power circuit at installed at the proper depth
3 EVPC under test
4 RESS or representative simulated load
5 ground

Figure 2 — Exemplary test setup for vehicle level testing (embedded mounting)



Key

1 connection to supply network
2 supply power circuit
3 EVPC under test
4 RESS or representative simulated load
5 ground

Figure 3 — Exemplary test setup for vehicle level testing (surface mounting)

The EVPC shall be fixed to the EV at its intended mounting position.

NOTE This includes the positions of all components of the EVPC, in case they are not within one housing.

The load shall either be a RESS or a representative simulated DC load.

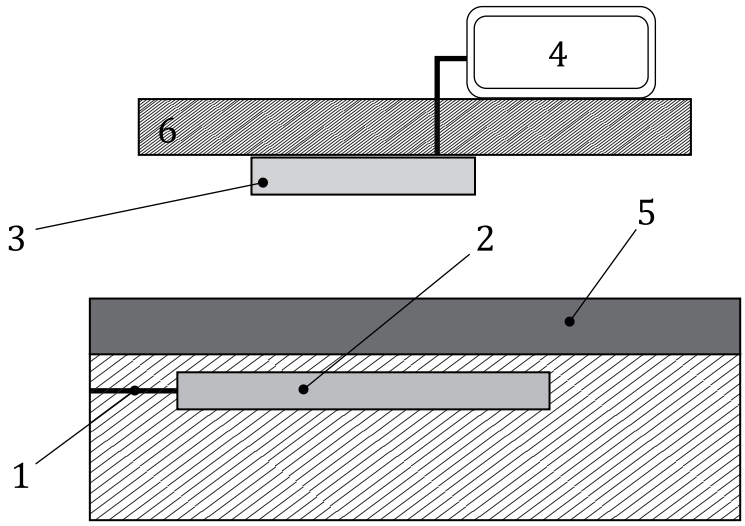
The supply power circuits to be used for testing the EVPC are described in 7.6.2.2.

The alignment shall be changeable in x-, y-, and z-direction to enable measurements at the alignment points according to Table 3. Alignment adjustment may be realised by either moving the EV, moving the supply power circuit or moving both.

The components of the test bench and the ground shall not significantly influence the MF-WPT. The entire test setup may also be lifted to a height that avoids potential influences of the ground.

7.6.2.1.3 Component level testing

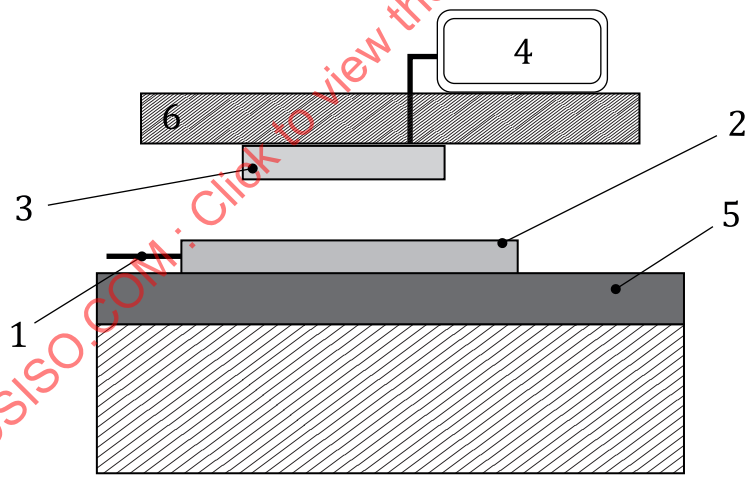
As an alternative for vehicle level, the testing may also be done on component level. Figure 4 and Figure 5 exhibit the components required for MF-WPT testing in an exemplary test setup for component level testing.



Key

1 connection to supply network
2 supply power circuit
3 EVPC under test
4 load
5 ground
6 vehicle mimic

Figure 4 — Exemplary test setup for component level testing (embedded mounting)



Key

1 connection to supply network
2 supply power circuit
3 EVPC under test
4 load
5 ground
6 vehicle mimic

Figure 5 — Exemplary test setup for component level testing (surface mounting)

Compared to vehicle level testing, a vehicle mimic shall be used instead of an EV.

The vehicle mimic shall include all components of the EV the EVPC is intended to be mounted to, that significantly influence MF-WPT. This includes, for example, shielding components or metallic beams exposed to the magnetic field.

7.6.2.2 Supply power circuits to test against

An EVPC of compatibility class A shall be tested with the reference SPCs.

An EVPC of compatibility class B shall be tested with a supply power circuit specified and provided by the supplier.

7.6.2.3 Test conditions

Testing is carried out in the following conditions:

— the ambient temperature of (20 ± 5) °C; and

— the MF-WPT system is in steady state.

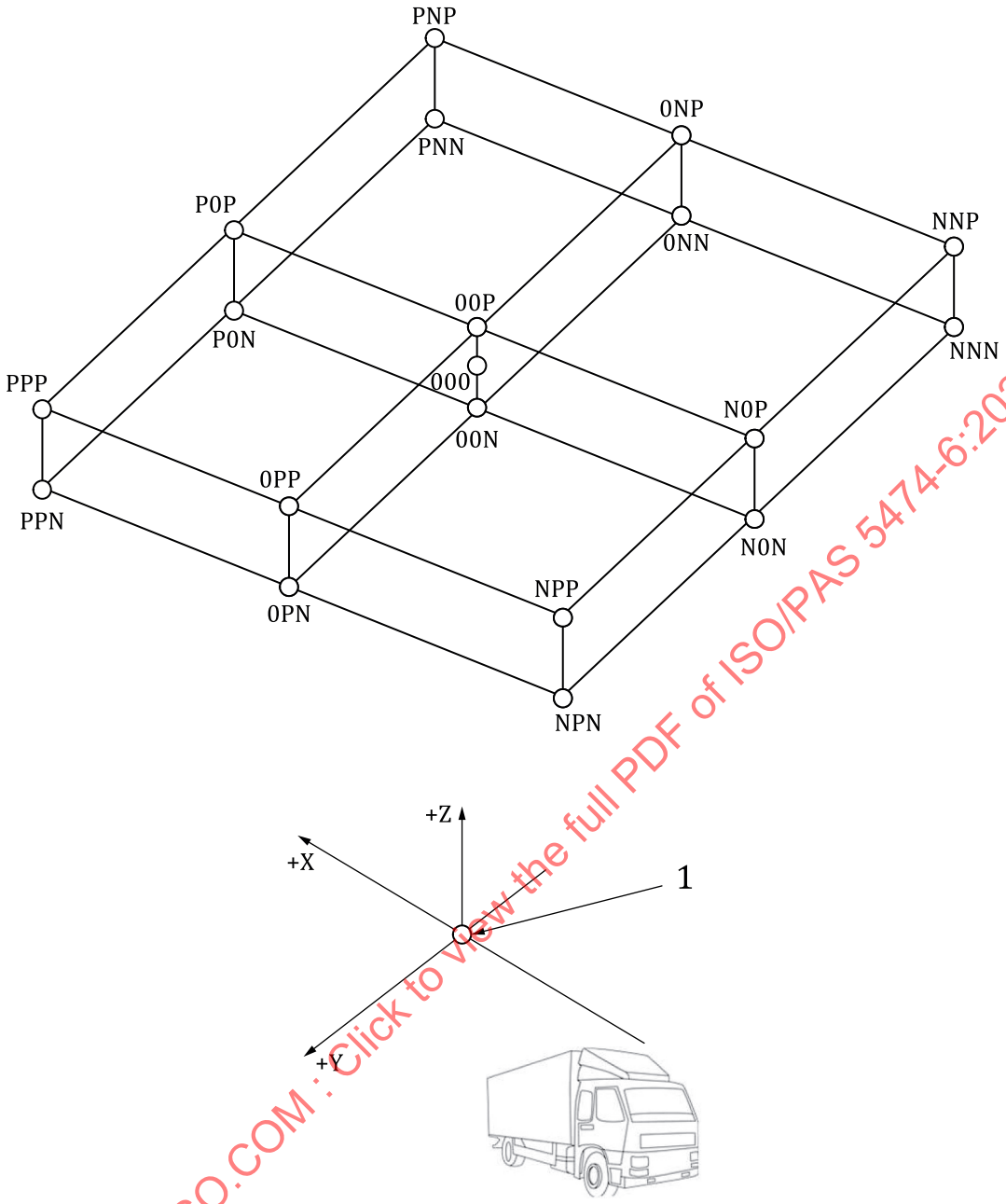
7.6.3 Test procedure

7.6.3.1 General

The measurements described in 7.6.3.2 to 7.6.3.4 are conducted within the rated conditions specified by the supplier according to Table 1.

7.6.3.2 Alignment points

The alignments points for conformance testing are depicted in Figure 6 and Table 3. In one of the points at maximum misalignment in x- and y-direction, additional testing or appropriate simulations shall be performed with +3° yaw and –3° yaw. The positive direction of the yaw angle is counter clockwise and the negative direction is clockwise around the centre alignment point, looking from above (towards the negative z-direction).



Key

1 centre alignment point of the EVPC

Figure 6 — Alignment points

NOTE The coordinate system conforms with ISO 4130, where the EV driving direction is in the negative x-direction.

The coordinates of the alignment points in Figure 4 are given in Table 3, where:

— “max.” is the maximum secondary device ground clearance;

— “min.” is the minimum secondary device ground clearance; and

— “mid.” is the mean value of the maximum and minimum secondary device ground clearance range.

Table 3 — Alignment points

Alignment point as per Figure 5	X [mm]	Y [mm]	Secondary device ground clearance range
P P P	+100	+100	max.
P P N			min.
P 0 P		0	max.
P 0 N			min.
P N P		−100	max.
P N N			min.
0 P P	0	+100	max.
0 P N			min.
0 0 P		0	max.
0 0 0			mid.
0 0 N			min.
0 N P		−100	max.
0 N N			min.
N P P	-75	+100	max.
N P N			min.
N 0 P		0	max.
N 0 N			min.
N N P		−100	max.
N N N			min.

7.6.3.3 Output power and power transfer efficiency

At each alignment point described in 7.6.3.2 the supply power circuits according to 7.6.2.2 shall be operated with the MF-WPT input power that is needed by the EVPC to provide its rated output power. These measurements shall be performed at the following voltage levels:

— minimum voltage of output voltage range +50 % of output voltage range, and

— maximum voltage of output voltage range -10 % of output voltage range.

EXAMPLE For an output voltage range of 200 V to 400 V the corresponding voltage levels are 300 V and 380 V.

For EVPCs of compatibility class A, the normative reference SPCs shall be operated at 85 kHz. In case the performance requirements are not met, the frequency may be adjusted within the range according to 7.2.

For EVPCs of compatibility class B, the supply power circuit shall be operated at the frequency 85 kHz or (19-21) kHz (TBD) within the range according to 7.2.

7.6.3.4 Output voltage

In order to verify the requirements for the DC output voltage, the following test shall be applied.

It is recommended to connect the EVPC to a RESS, as used in the EV the EVPC is designed for.

The EVPC shall be placed in one of the alignment points with maximum misalignment. The power shall be ramped up from zero to the rated output power of the EVPC with the maximum rate of supply power circuits according to 7.3. The test is passed when the DC output voltage is within the requirements of 7.6.2 during the entire test procedure.

8 Requirements for communication and MF-WPT activities

The requirements for communication in static WPT are covered in IEC 61980-2. According to IEC 61980-2 the operation process for MF-WPT is modelled as a WPT session, which is organized by a sequence of activities.

These activities are executed respectively supported by communication between the EV device and the supply device, but also imply additional hardware requirements for components of an EV device beyond the specifications in this document. The requirements for an EV device related to the execution of the activities are described in IEC 61980-2 . An EV device shall fulfil the applicable requirements given in IEC 61980-2.

The requirements of communication in dynamic WPT are covered in IEC PAS 61980-6[2)].

9 EMC requirements

An EVPC shall conform to the limits described in IEC 61980-1, when operated with a supply device.

The measurement shall be done at worst-case operating conditions of the EVPC.

10 Safety requirements

10.1 Protection in case of unintended power transfer

The MF-WPT system shall be treated as an electric power source, that can be de-energized.

Unintended power transfer is either:

— power supply from an uncoordinated or unknown supply device; or

— power supply from a supply device in excess of the request of the EV device.

Whenever the EVPC is required to be de-energized, the EV or EV device shall activate means to prevent the supply device from transferring power.

Examples for such means are:

— protection measures against overcharge of the RESS (e.g. disconnection relay);

— protection measures against overcurrent of the EVPC and RESS (e.g. disconnection relay); or

— protection measures against overvoltage of the EVPC (e.g. emergency short circuit device).

Conformance is checked by inspection.

NOTE The specification for detection and reaction timing of the EV device is at the discretion of the supplier. Requirements for reaction times of the supply device are specified in IEC 61980-3.

10.2 Protection against electric shock

10.2.1 General

This clause applies only to voltage class B electric circuits of an EV device.

Design and testing for protection against electric shock shall be in accordance with ISO 6469-3, unless otherwise specified in 10.2.

The EV device shall fulfil the requirements for non-maintained isolation resistance according to ISO 6469-3:2021, 6.3.2.2.

2) Under preparation. Stage at the time of publication: IEC/DPAS 61980-6:2025.

Protection against electric shock shall be implemented as specified by the vehicle manufacturer.

NOTE Requirements on post-crash electrical safety are specified in ISO 6469-4.

10.2.2 Insulation coordination

Insulation coordination shall consider the maximum internal operational and over voltages inside the EV device. Either of the following shall be implemented:

— robust design with the capability to physically withstand possible operational and over voltages; or

— means to limit the voltages to values the insulation coordination of the components is based on.

The frequency of the alternating current in the EVPC, which is considerably higher than 50 Hz or 60 Hz, shall be considered for the insulation coordination, temperature-resistance of the materials used and dimensioning of active parts and insulation.

Clearance, creepage distance and solid insulation of voltage class B components and wiring shall be designed according to the applicable sections of the IEC 60664 series.

10.3 Protection against thermal incidents

10.3.1 General

Thermal loads to the insulation and active parts of the EV device shall be considered under

— all operational situations;

— shut off situations of the vehicle; and

— unintended power transfer situations.

10.3.2 Overload protection and short-circuit protection

The overload protection and short circuit protection shall be according to ISO 6469-3.

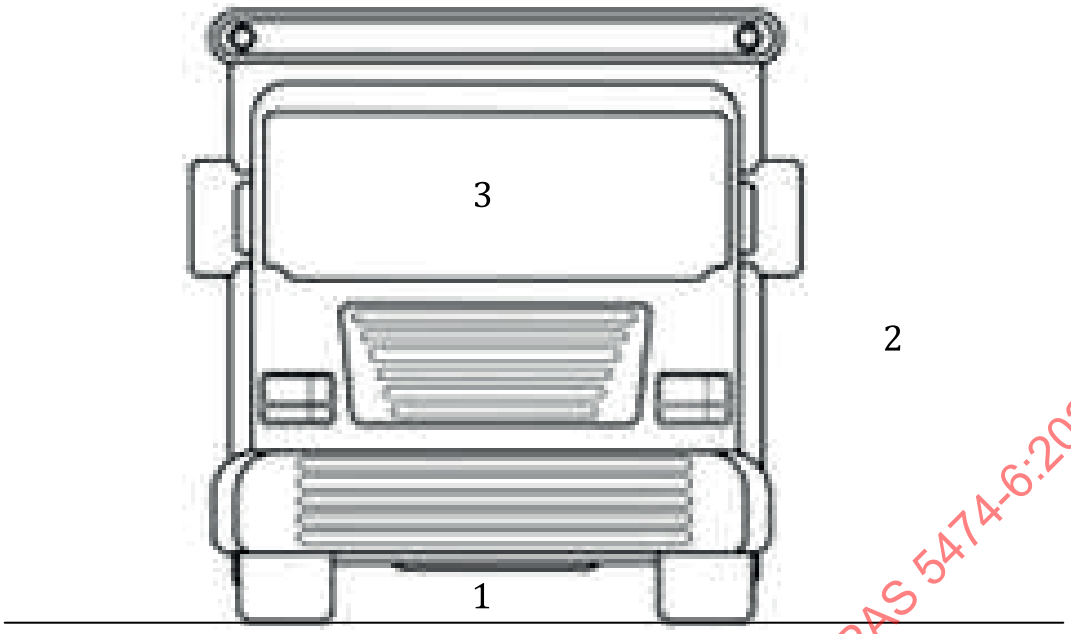
10.4 Protection of persons against electromagnetic effects

10.4.1 General

This subclause specifies requirements to protect persons against the effects resulting from exposure to electromagnetic fields. This covers the protection against harmful effects of exposure to electromagnetic fields and the protection of the functionality of cardiac implantable electronic devices (CIEDs).

10.4.2 Protection areas

The space inside, under and around the vehicle is divided into three protection areas according to Figure 7.



Key

1 protection area 1: area underneath the vehicle

2 protection area 2: area surrounding the vehicle; public area to the side, front, rear and top of the vehicle

3 protection area 3: vehicle interior

Figure 7 — Protection areas

10.4.3 Requirements for protection of persons against exposure to hazardous electromagnetic fields

In protection area 2 and 3, persons shall not be exposed to electromagnetic fields above the applicable limits from the ICNIRP 2010 Guidelines.

NOTE In protection area 1, protection against exposure to hazardous electromagnetic fields is the responsibility of the supply device.

The basic restrictions of ICNIRP Guidelines 2010, Table 2 or the reference levels of ICNIRP Guidelines 2010, Table 4 shall be met.

10.4.4 Requirements to protect the functionality of CIEDs

Pacemakers and implanted cardiac defibrillators are required to remain fully functional and operational when magnetically induced voltages in pacemaker leads, in the range of 3 kHz to 150 kHz are less than $V_{MAX\_INDUCED\_RMS} = \frac{3\sqrt{2}}{2}$ mV × F (e.g. 180,31 mV RMS at 85 kHz). Where F is the frequency expressed in kHz. This formula is based on the assumption that the voltage is induced into a 225 cm^2 lead loop and determines the limits that need to be met by MF-WPT systems.

NOTE ISO 14117 contains requirements for pacemakers and implants.

To enable simplified and repeatable measurements, these induced voltage levels have been transferred to a conservative averaged magnetic flux of 15,0 µT or a magnetic field strength of 11,9 A/m (for 79 kHz to 90 kHz) within a 225 cm^2 plane.

In protection areas 2 and 3, an EVPC shall comply with these limits when operated with a supply power circuit at worst-case operating conditions.

10.5 Protection against overheating

Means to prevent the overheating of components of the EV due to the magnetic field generated by the supply device shall be provided, if necessary. Examples of protection means are shielding, thermal sensing or cooling.

Conformance shall be declared by the vehicle manufacturer.

11 Owner's manual and marking

11.1 Owner's manual

The following information shall be included in the owner's manual:

a) description of the MF-WPT system operation and location of the secondary device on the vehicle;

b) functional operations to be performed by the user; and

c) any special precautions required by operators wearing CIEDs;

d) the rated conditions as specified in Table 1.

11.2 Marking

Marking of voltage class B components and wiring shall be in accordance with ISO 6469-3.

Annex A
(informative)

Multi-phase coil reference SPC for MF-WPT 4/5

A.1 Multi-phase coil reference SPC for MF-WPT4 / MF-WPT5

A.1.1 General

Clause A.1 describes reference SPC for MF-WPT4, MF-WPT5, Z classes Z1, Z2 and Z3.

A.1.2 Mechanical specification

Figure A.1 shows the general layout of the primary device and Figure A.2 shows the mechanical dimensions of the primary device. Figure A.1 shows the view of the mechanical construction of the primary device with the aluminum plate positioned at the bottom.

The primary device can be installed above ground surface, as flush ground surface or as buried 50 mm below ground surface.

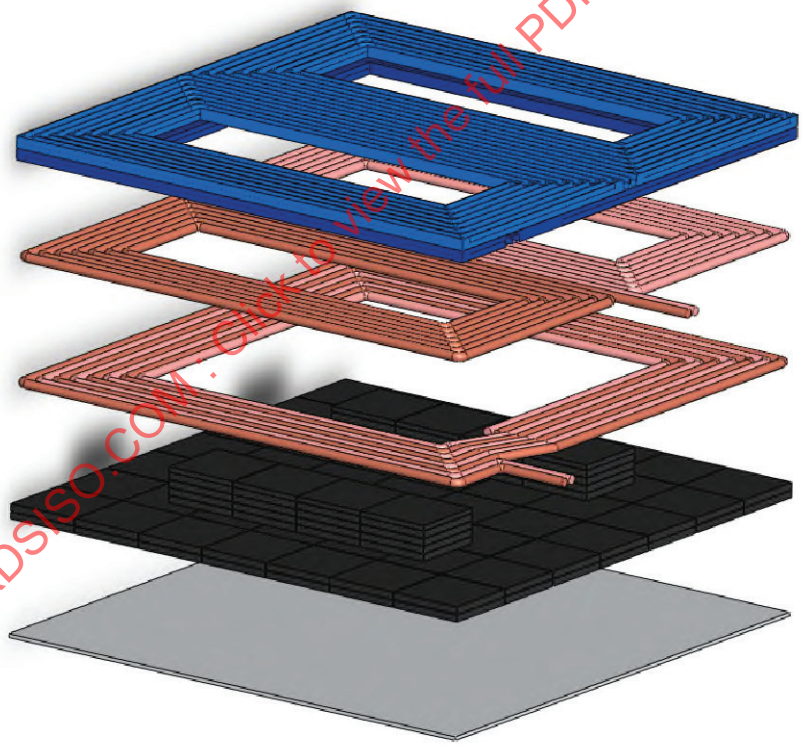


Figure A.1 — General layout of the MF-WPT4 / MF-WPT5 reference primary device

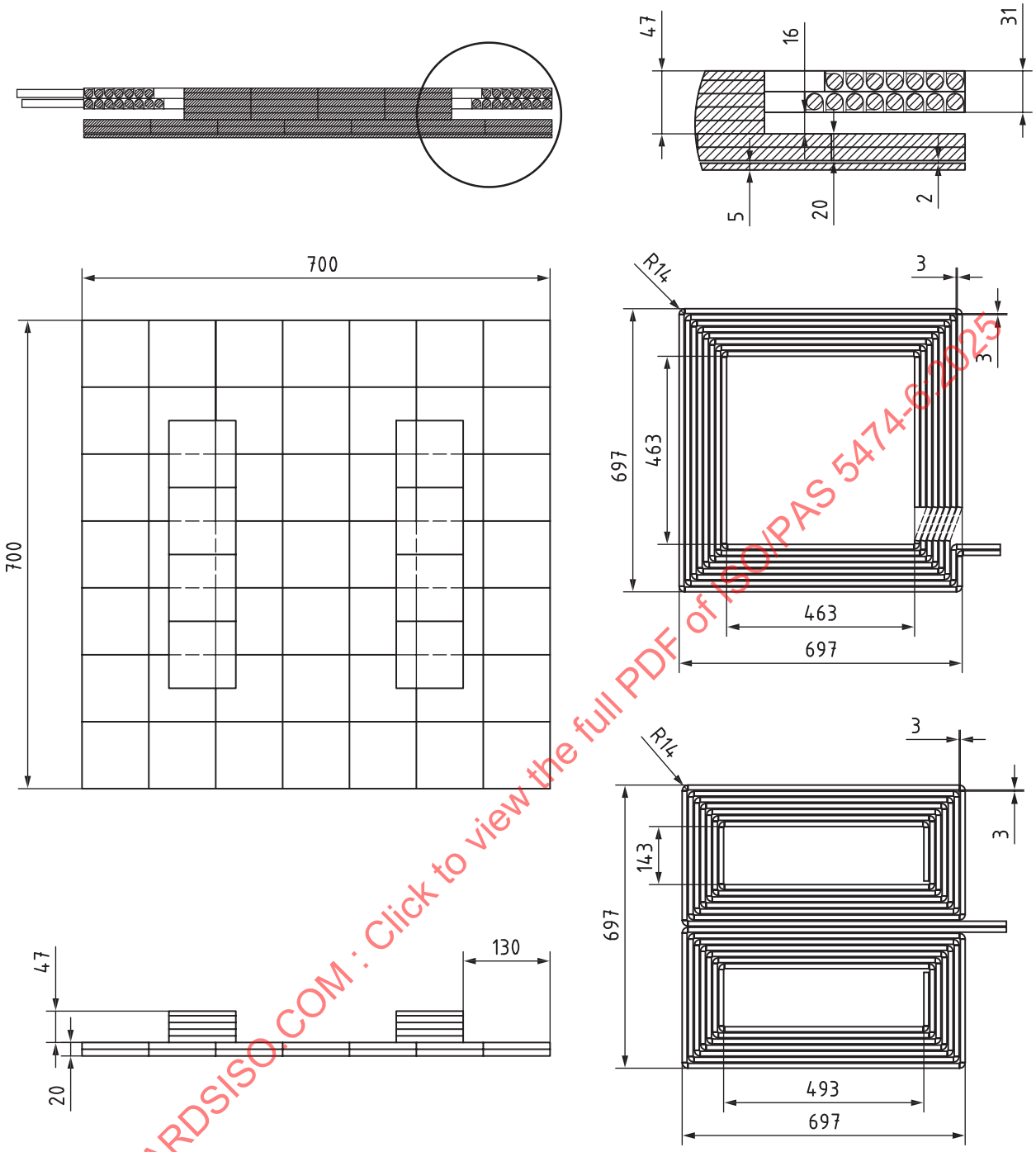


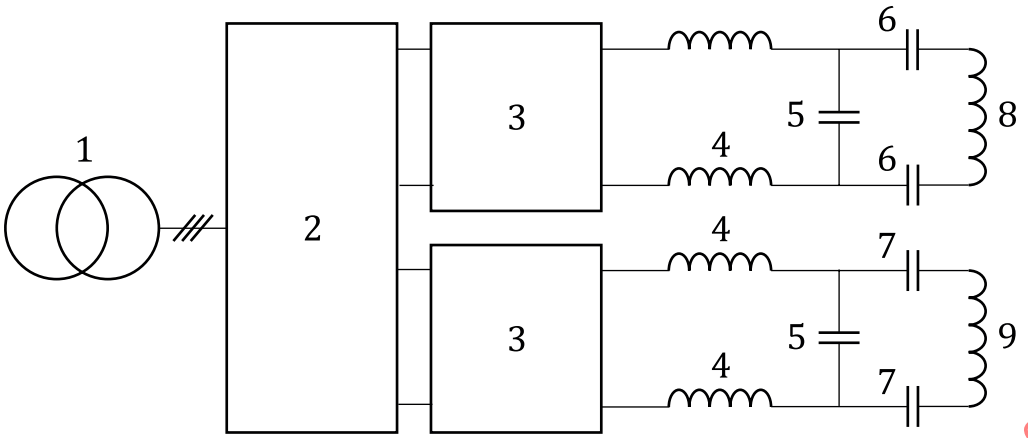
Figure A.2 — Mechanical dimension of the MF-WPT4 / MF-WPT5 reference primary device

A.1.3 Electrical specification

Figure A.3 shows the schematic of the power electronics for the MF-WPT4/ MF-WPT5 reference SPC. This circuit consists of independent circuits of circular coils or DD coils, and is controlled by independent phase and duty.

Table A.1 shows the electrical specification of the MF-WPT4/ MF-WPT5 reference SPC.

Table A.2 and Table A.3 show the coil inductance and coupling k of the MF-WPT4/ MF-WPT5 reference SPC (surface mounting).



Key

1 grid
2 PFC (AC-DC converter)
3 full-bridge inverter
4 matching inductance (tuning inductance, Lx)
5 parallel capacitance (parallel tuning capacitance, Cx)
6 series capacitance for circular coil compensation
7 series capacitance for DD coil compensation
8 primary circular coil
9 primary DD coil

Figure A.3 — Schematic of the reference SPC for the MF-WPT4 / MF-WPT5

Table A.1 — Values of circuit elements and maximum currents

Circular coil capacitance #6 (nF)	DD coil capacitance #7 (nF)	Parallel capacitance #5 (nF)	Matching inductance #4 (µH)	PFC voltage range (V)	Max. PFC Output Current (A)	Max. SPC inverter output current (Arms)	Max. primary coil current (Arms)
64,2 nF (series total 32,1)	64,2 nF (series total 32,1)	343 nF	5,1 µH (series total 10,2)	550~ 720 V	90 A	110 Arms (750 Vbat boost mode)	110 Arms (300 Vbat buck mode)

Table A.2 — Primary coil inductance each L(circular and DD) depending on the Z-class : surface mounting

Z-class	EVPC	Circular coil L min. 8 (µH)	Circular coil L max. 8 (µH)	DD coil L min. 9 (µH)	DD coil L max. 9 (µH)
WPT4/Z1	IEC PAS 61980-5	97,38	104,62	134,42	186,59
WPT4/Z2	IEC PAS 61980-5	98,66	108,46	125,50	202,43
WPT4/Z3	IEC PAS 61980-5	101,97	113,00	122,85	210,70
WPT5/Z1	IEC PAS 61980-5	104,29	113,56	141,66	207,53
WPT5/Z2	IEC PAS 61980-5	104,58	117,60	127,98	218,90
WPT5/Z3	IEC PAS 61980-5	104,57	121,75	124,24	224,20

Table A.3 — Coupling k between primary and secondary coil depending on the Z-class: surface mounting

Z-class	EVPC	Circular coil k Min.	Circular coil k max.	DD coil k min.	DD coil k max.
WPT4/Z1	IEC PAS 61980-5	0,23	0,31	1,29	1,36
WPT4/Z2	IEC PAS 61980-5	0,19	0,39	0,98	1,02
WPT4/Z3	IEC PAS 61980-5	0,17	0,49	0,88	0,92
WPT5/Z1	IEC PAS 61980-5	0,30	0,50	1,51	1,54
WPT5/Z2	IEC PAS 61980-5	0,24	0,58	1,21	1,24
WPT5/Z3	IEC PAS 61980-5	0,20	0,63	1,29	1,34

Table A.4 and Table A.5 show the coil inductance and coupling k of the MF-WPT4/ MF-WPT5 reference SPC (flush mounting).

Table A.4 — Primary coil inductance each L(circular and DD) depending on the Z-class : flush mounting

Z-class	EVPC	Circular coil L min. 8 (µH)	Circular coil L max. 8 (µH)	DD coil L min. 9 (µH)	DD coil L max. 9 (µH)
WPT4/Z1	IEC PAS 61980-5	102,18	103,38	120,62	126,28
WPT4/Z2	IEC PAS 61980-5	102,49	103,82	119,35	128,18
WPT4/Z3	IEC PAS 61980-5	103,08	104,54	118,98	129,52
WPT5/Z1	IEC PAS 61980-5	103,57	104,97	122,09	129,09
WPT5/Z2	IEC PAS 61980-5	103,53	105,61	120,13	130,46
WPT5/Z3	IEC PAS 61980-5	103,50	106,45	119,48	131,26

Table A.5 — Coupling k between primary and secondary coil depending on the Z-class: flush mounting

Z-class	EVPC	Circular coil k min.	Circular coil k max.	DD coil k min.	DD coil k max.
WPT4/Z1	IEC PAS 61980-5	0,13	0,19	1,28	1,29
WPT4/Z2	IEC PAS 61980-5	0,11	0,23	0,97	0,98
WPT4/Z3	IEC PAS 61980-5	0,10	0,26	0,88	0,89
WPT5/Z1	IEC PAS 61980-5	0,17	0,26	1,49	1,51
WPT5/Z2	IEC PAS 61980-5	0,13	0,29	1,20	1,22
WPT5/Z3	IEC PAS 61980-5	0,12	0,31	1,29	1,30

Table A.6 and Table A.7 show the coil inductance and coupling k of the MF-WPT4/ MF-WPT5 reference SPC (in the buried mounting).

Table A.6 — Primary coil inductance each L(circular and DD) depending on the Z-class : buried mounting

Z-class	EVPC	Circular coil L min. 8 (µH)	Circular coil L max. 8 (µH)	DD coil L min. 9 (µH)	DD coil L max. 9 (µH)
WPT4/Z1	IEC PAS 61980-5	102,74	103,34	119,14	121,74
WPT4/Z2	IEC PAS 61980-5	102,92	103,45	118,53	122,64
WPT4/Z3	IEC PAS 61980-5	103,08	103,79	118,41	123,38
WPT5/Z1	IEC PAS 61980-5	103,45	104,25	120,00	123,20
WPT5/Z2	IEC PAS 61980-5	103,40	104,45	119,05	123,91
WPT5/Z3	IEC PAS 61980-5	103,35	104,95	118,76	124,37

Table A.7 — Coupling k between primary and secondary coil depending on the Z-class: buried mounting

Z-class	EVPC	Circular coil k min.	Circular coil k max.	DD coil k min.	DD coil k max.
WPT4/Z1	IEC PAS 61980-5	0,10	0,15	1,27	1,28
WPT4/Z2	IEC PAS 61980-5	0,08	0,17	0,97	0,97
WPT4/Z3	IEC PAS 61980-5	0,08	0,19	0,87	0,88
WPT5/Z1	IEC PAS 61980-5	0,13	0,20	1,49	1,49
WPT5/Z2	IEC PAS 61980-5	0,10	0,22	1,20	1,21
WPT5/Z3	IEC PAS 61980-5	0,09	0,23	1,29	1,29

Annex B
(informative)

DD reference SPCs for MF-WPT4/5 (static/dynamic)

B.1 DD reference SPCs for MF-WPT4/5 (static)

B.1.1 General

Clause B.1 describes a reference SPC proposal for MF-WPT4/5 to supply Z classes Z1, Z2 and Z3 for static wireless power transfer.

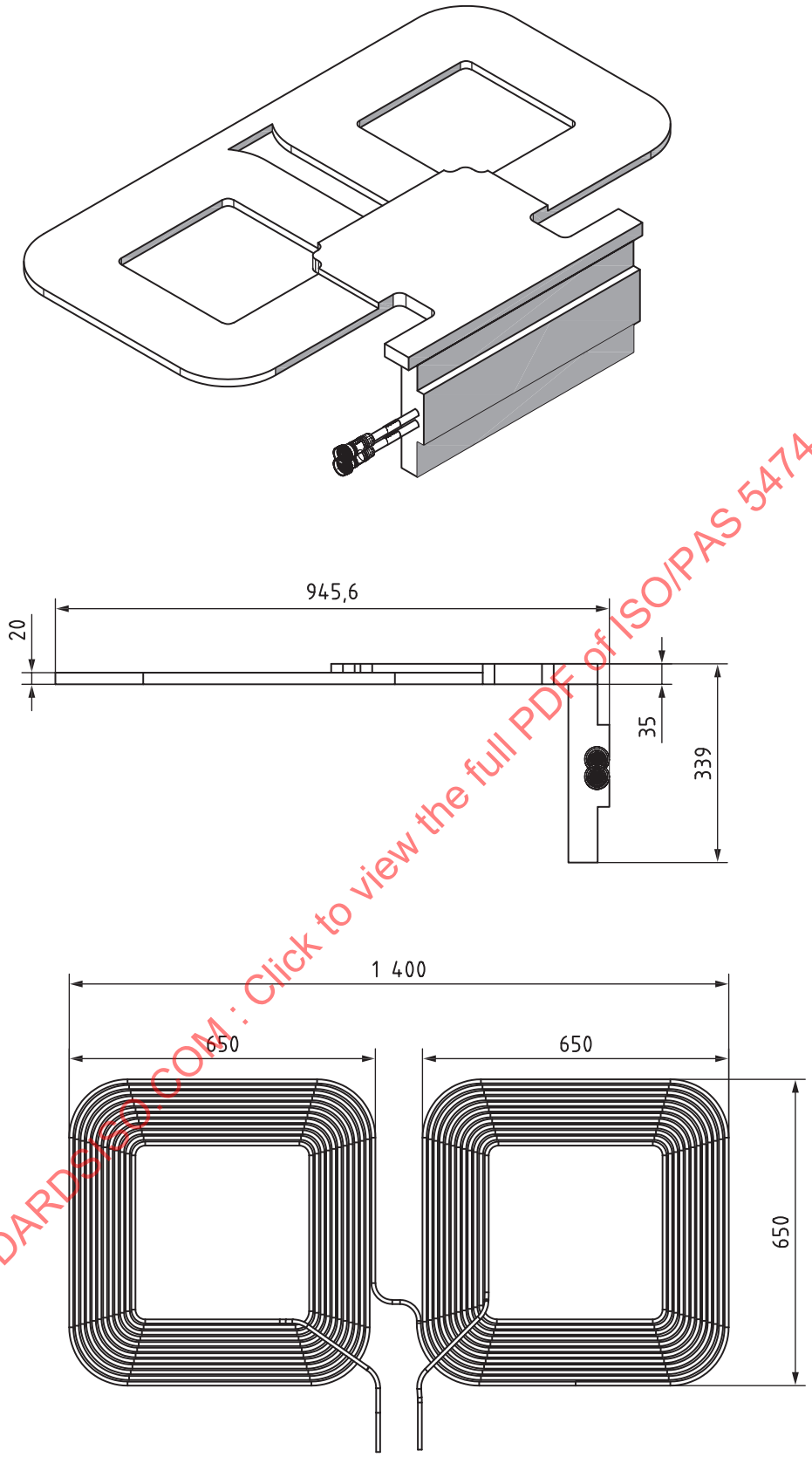
The centre alignment points for the MF-WPT4/5 reference SPC described in B.1 are 0 mm in X- direction (direction of travel) and 0 mm in Y- direction (lateral direction) with respect to the geometric centre of the coils (see Figure B.1) of the primary device when paired with any secondary devices listed above.

The rated input power of MF-WPT4 reference SPCs is 25 kW, the input power of the MF-WPT5 reference SPCs is 60 kW. The reference SPCs will perform over the system frequency range of 79,00 kHz to 90,00 kHz.

The proposed SPC is typically integrated at a distance to the road surface of (70 – 120) mm (Z_{RS}-Class 3). It can supply EVPC at ground clearances between 100 mm and 250 mm (Z1, Z2, Z3), when operated with the EVPC listed in B.1.1.

B.1.2 Mechanical

Figure B.1 shows the general layout and the mechanical dimensions of the MF-WPT4/5 reference primary device.



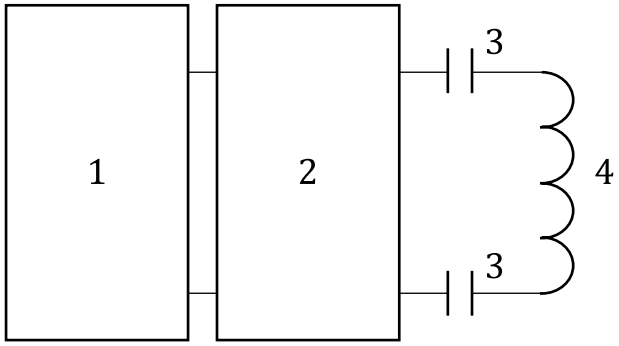
NOTE The arrow indicates driving direction.

Figure B.1 — General layout of the MF-WPT4/5 reference SPC and mechanical dimensions

The mechanical configuration of the MF-WPT4/5 reference primary device features an air-core coil of 12 turns, covering a coil width of 140 mm. For the application as WPT4 SPC a Litz wire diameter of at least 6 mm is recommended, for an application as WPT5 SPC a Litz wire diameter of at least 8 mm is recommended.

B.1.3 Electrical

Figure B.2 shows the schematic of the power electronics for the MF-WPT4/5 reference SPC.



Key

1 PFC (AC/DC converter)
2 high-frequency power inverter
3 serial tuning capacitor
4 transmitter coil

Figure B.2 — Schematic of the MF-WPT4/5 reference SPC

In a multi-charger configuration, several high-frequency power inverters can be connected to a common PFC.

Table B.1 — Values of circuit elements, magnetic properties, and coil current of SPC

Tuning capacitor	Inductance [µH]	Coupling	Coil current WPT 4	Coil current WPT 5
27 nF	235 – 258	0,108 – 0,191	90 Arms	100 Arms

The magnetic properties, and maximum coil current of the MF-WPT4/5 reference SPC (when used in combination with the reference EVPC) are shown in Table B.1. The values are obtained with an aluminum shield equal to 1 200 mm x 700 mm x 1 mm at the receiver.

As the reference EVPC consists of two independent coils, two values for coupling exist. Here the higher value is given.

B.2 DD reference SPCs for MF-WPT5 (dynamic)

B.2.1 General

Clause B.2 describes a reference SPC proposal for MF-WPT5 to supply Z classes Z1, Z2 and Z3 for dynamic wireless power transfer.

The centre alignment points for the MF-WPT5 reference SPC described in B.1 are 0 mm in X- direction (direction of travel) and 0 mm in Y- direction (lateral direction) with respect to the geometric centre of the coils (see Figure B.2) of the primary device when paired with any secondary devices listed above.

The rated input power of the MF-WPT5 reference SPCs is 60 kW. The reference SPCs will perform over the system frequency range of 79,00 kHz to 90,00 kHz.