DESIGN OF THE INDUCTIVE WIRELESS CHARGER

D5.3 – INDUCAR system design

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*Status: Draft, Final, Approved, Submitted (to European Commission).

Dissemination Level: **PU: Public; **CO**: Confidential, only for members of the consortium (including the Commission Services); **EU-RES** Classified Information - restraint UE; **EU-CON**: Classified Information - confidential UE; **EU-SEC**: Classified Information - secret UE

Abstract

The INDUCAR Product belongs with the INSOC Product, in the USER-CHI project, to the main work package dedicated to the development of new technologies. The INDUCAR – Inductive Charging for e-Cars – consists of an inductive charging system to recharge the e-Cars battery with a solution bringing an important level of automation. The wireless system will implement Machine-to-Machine communication allowing the system to connect to standard user-friendly applications. These applications might take in charge the functionalities typically expected for the whole process, like the identification of the e-Car, the payment and charging feature the user needs to go through for the charging process.

The aim of the deliverable D5.3 – INDUCAR Design is to describe the design for the services, functionalities and specifications of the Product leading to a full operational inductive system to be retrofitted in an existing e-Car. More specifically, in the frame of the USER-CHI project, it has been determined that the INDUCAR will be implemented in the Barcelona Demonstrator in three existing Renault Zoe that belong to the fleet of the AMB – Área Metropolitana de Barcelona. The Renault Zoe will be retrofitted with the inductive charging solution taking into account in its design the mechanical and electrical integration. The INDUCAR design defines the functional integration for the whole charge process and provides the system internal functionalities inherent to it.

Keywords

Wireless charging system, inductive charger, automatic charging, autonomous driving, inductive system for cars, requirements for inductive technology, inductive design.

Copyright statement

Executive summary

The USER-CHI deliverable D5.3 “INDUCAR system design” summarises the results of the task T5.4. “Design of services and specifications of the inductive automated wireless charging system”, aiming to describe the first level prototype (typically the Sample A in the automotive industry) operational design freeze and the complete design requirements made for the final product INDUCAR to be demonstrated in Barcelona.

This document is first constituted of an introduction, situating the task T5.4 and this deliverable inside the USER-CHI project, and then, of two main sections presenting the results of the mentioned task. The first one of these sections presents the INDUCAR Sample A prototype freeze design in its current status, and the second section describes the formal design requirements established to define the guidelines for the optimal final product to be delivered inside USER-CHI project.

The USER-CHI task 5.4 and the present report D5.3 set the base for the development of the INDUCAR product, that have been started with the task T5.5 “Development of the inductive automated wireless charging system”.

Table of Contents

List of figures

List of tables

1. Introduction

1.1 Purpose of the document

The purpose of this deliverable is to document the work carried out in the Task T5.4 "Design of services and specifications of the inductive automated wireless charging system". This document contains the definition of the product INDUCAR design which refers to the Inductive Charging for e-Cars development inside USER-CHI project. Its design shall fit better the "users' charging preferences and maximise their convenience" as described in the USER-CHI project targets.

A wireless system can be decomposed in specific components dedicated to specific tasks required for the energy transfer from the grid connection to the battery in the electric vehicle. For the description of the INDUCAR main design freeze, the present deliverable describes each one of the components to be developed with their main functions and specifications.

Also, a wireless system as a whole, shall fulfill functional, operational and safety requirements bringing features and specifications to the main concept design that can only be implemented iteratively through subsequent prototyping. In order to bring a complete description of the final product, the purpose of this document is also to present the complete requirements determining the final product expected features essential for its deployment.

1.2 Scope of the document

The D5.3 provides the fundamental design information needed to develop the prototypes and final wireless charging system defined as the product INDUCAR inside the USER-CHI project. The document focus is centered on the technical definition of the wireless system, its subsystems and its components.

The D5.3 provides also the description of the complete set of formal requirements needed to describe technically the system with all the operational, functional and safety features. The D5.3 deliverable document focus, for this reason, on the requirement description for the two main subsystems. The description of these subsystems and the aspects concerning their performance, their functionalities, their operational behavior and the safety features are also part of the scope of this document.

1.3 Structure of the document

This document is constituted of two main sections (cf. paragraphs 2. INDUCAR Design Description and 3. Formal Design Requirements) covering the design description from the two different current axes of work. The current state of the developments is foreseen, in one hand, as an intelligible system with clear components fulfilling the tasks needed to provide the power transfer into the batteries as expected by the system as a whole. In the other hand, these components and its more complexes features can only be described with the level of detail coherent with the current prototype status definition. This means that the components presented in the design description at this stage, do not integrate all the features that will be included on the final system. This complete definition of the system, can be properly established today, only through a formal requirement description of the whole system.

For these reasons the next section of the document will first provide the current prototype design, presenting the proper concept of the charging system with its components and main features. Subsequently, the following, and last section presents in detail the complete set of requirements to be fulfilled by the final wireless system design corresponding to the final INDUCAR product.

1.4 Important definitions

Term	Definition
Foreign Object	in the context of this document, is defined as any object that is not an attached part of the vehicle or the WPT system
Ground Assembly	wireless wayside infrastructure components
Ground Clearance	distance from the ground surface to the face of the Pickup
High Voltage	in the context of this document, is defined as a voltage greater than 60V and less than 600V
Quiescent Current	amount of current consumed by a component in a circuit when the circuit is in its powered but non-operating state
Pitch	angle, in the X-axis, of the Pickup to the Charge Coils
Protection Area 1	as defined in IEC 61980-1, is the space formed by the outline of the primary and the secondary device
Protection Area 2	as defined in IEC 61980-1, is the transition area between Area 1 and Area 3
Protection Area 3	as defined in IEC 61980-1, is the area surrounding the vehicle
Protection Area 4	as defined in IEC 61980-1, is the vehicle interior

Roll	angle, in the Y-axis, of the Pickup to the Charge Coils
Vehicle Assembly	wireless vehicle side components
X-axis	direction of travel. Positive (+) X axis is defined as forwards
Y-axis	transverse to the direction of travel. Positive (+) Y axis is defined as leftwards
Yaw	angle, around the Z axis, of the Pickup to the Charge Coil
Z-axis	vertical height. Positive (+) Z axis is defined as upwards

2. INDUCAR Design Description

2.1 System Description

IPT® Charge developed for the USER-CHI project, is an inductive power transfer system which allows automated charging of car batteries without mechanical intervention and without galvanic contact. The system serves for opportunity charging to increase the range of electrically operated cars. IPT® Charge is based on the principle of electromagnetic induction. Similar to a transformer, an electromagnetic alternating field is generated by a primary part, which is fed by alternating current. This field is received by an adjacent secondary part and generates an alternating voltage according to the law of induction.

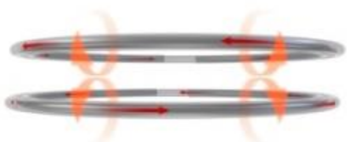

Figure 1: Operating principle inductive power transfer

Essential for the function and efficiency is the frequency of the alternating field. While the normal power supply system is operated with 50 or 60 Hz, IPT® Charge works with an operating frequency of 85 kHz. This frequency enables the transfer of power via larger air gaps with a high degree of efficiency. The induced high-frequency alternating current must be rectified in order to make it usable for electrical consumers.

Each IPT® Charge System is composed of two subsystems, a primary side and a secondary side, which are electromagnetically coupled, comparable to a normal transformer. Within the USER-CHI project the wayside installation is typically named Ground Assembly (primary), the vehicle side components are referred to as Vehicle Assembly (secondary). The stationary primary side consists of a power electronic for the primary, defined in this document as the Track Supply, and the primary coupler, defined as the Charge Coil. The mobile secondary, or car side components, consists of a secondary coupler, defined as the Pickup, and a power convertor for the secondary, defined as the Regulator.

In contrast to normal transformers, where primary and secondary are mechanically connected, IPT® Charge is a loosely coupled system that operates over an air gap, which means the energy transmission is affected across a defined distance between the coils.

2.2 System overview

The Wireless Power Transfer System setup and wiring with its two main sub-systems defined as the Ground Assembly and the Vehicle Assembly are shown in Figure 2. The main components under development designed for USER-CHI project for the Ground Assembly are the Track Supply and the Charge Coils. The main components under development designed for USER-CHI for the Vehicle assembly are the Pickup and the Regulator. The two subsystems shall be physically separated. By definition the Ground Assembly operates from a fixed location and the Vehicle Assembly is fitted to an electrified vehicle.

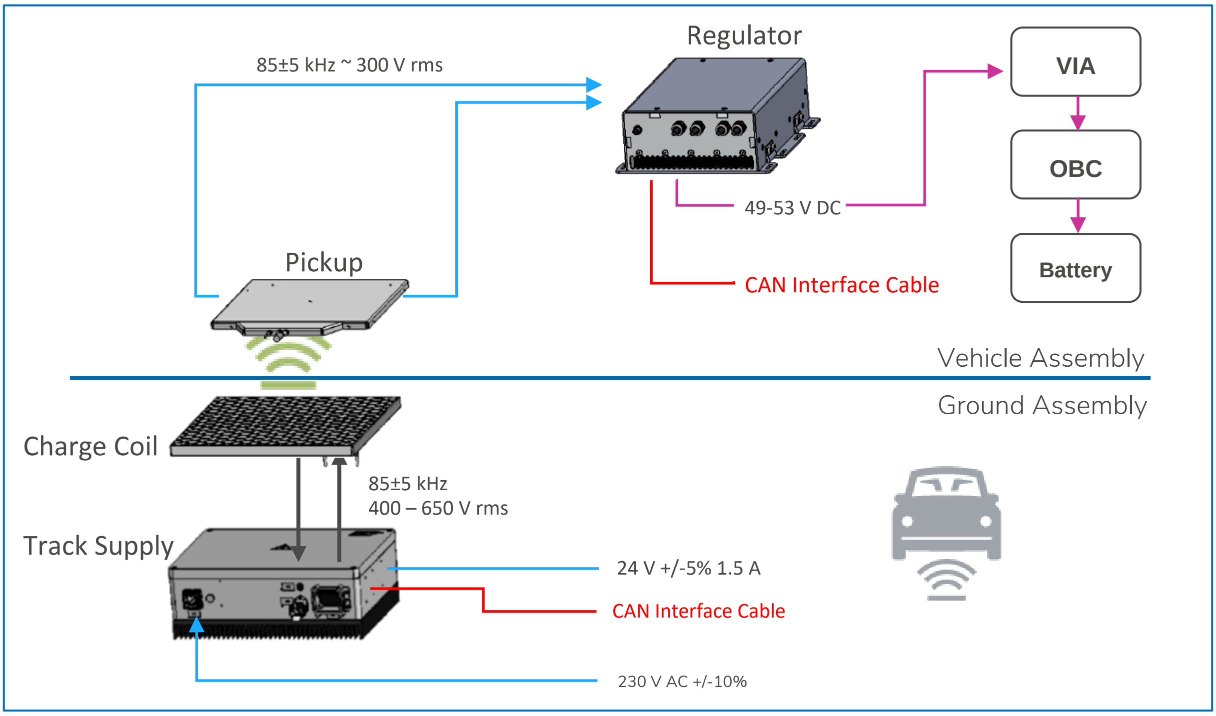

Figure 2: Wireless Charging System Overview

2.3 Components Ground Assembly

2.3.1 Track Supply

The Track Supply provides and regulates the power supply to the Charge Coils. It converts the mains voltage to 85 kHz.

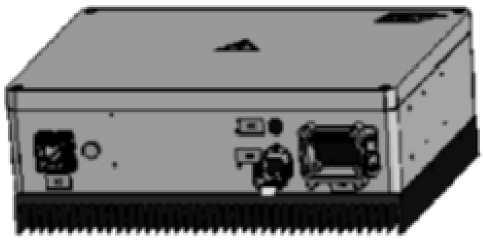

Figure 3: Track Supply

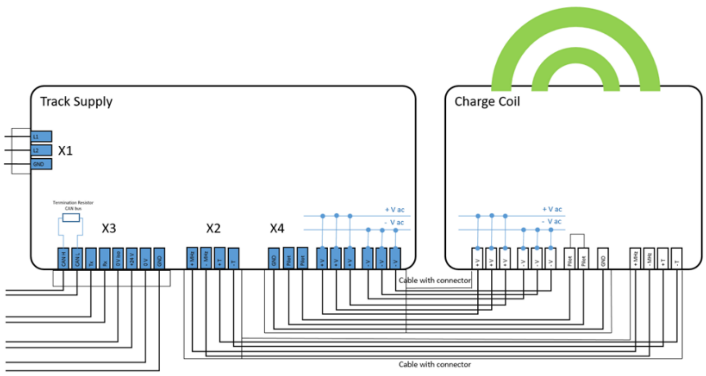

Figure 4: Wiring scheme Ground Assembly Components

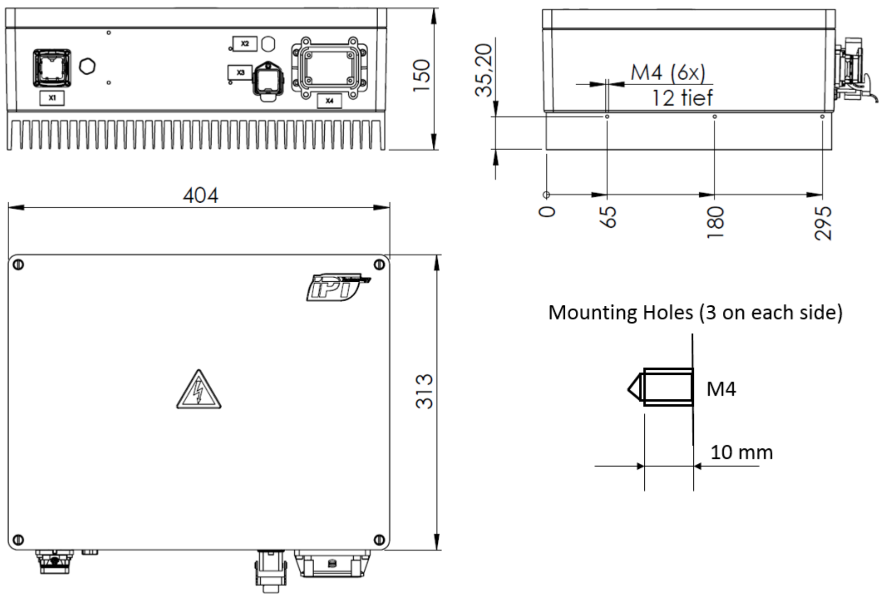

Figure 5: Track Supply foreseen dimensions

The connectors provided with the Track Supply seen in the Figure 6 are as follows:

- X1 – 230 V AC power supply
- X2 – Antenna (inductive communication)
- X3 – various Inputs
- X4 – Power Charge Coil

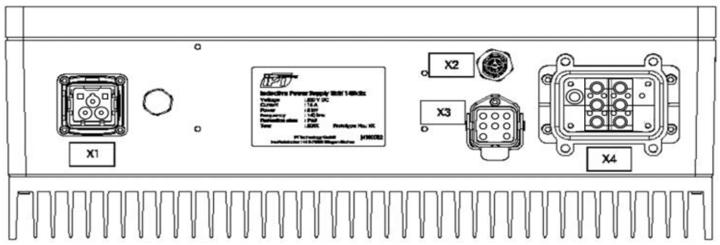

Figure 6: Track Supply connectors

The external power supply of 230 V AC to the system will be brought through the X1 connector of the track supply. The connector on the side of the power supply and the foreseen connector cable are shown in Figure 8.

Figure 7: X1 – 230 V power supply connector and proposed cable connector

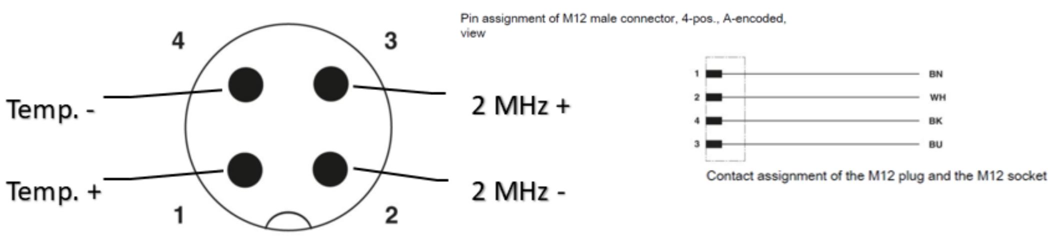

Figure 8: X2 connector – Antenna Communication

The Charge Coil comes with a mounted connector Phoenix Contact M12 female (SAC-4P-5,0-PUR/M12FS SG) and the "Plug Connector" comes with a screw lock. The design ensures the correct orientation when bringing the connectors together (nose between pin 1 and 2). The design imposes a specific torque (6 Nm) to ensure that the screw lock is always fix when the system is in operation.

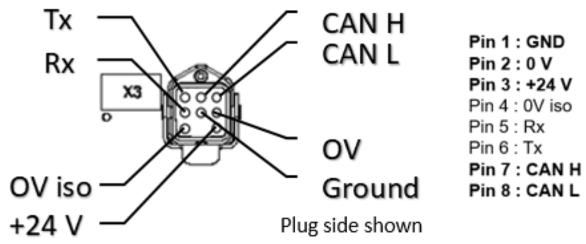

Figure 9: X3 connector – various Inputs

The required plug is a HAN 8D Harting (No. 09360083101). The design imposes that, from the moment of the installation, the locking of the bracket has been respected and remains always applied when the system is in operation.

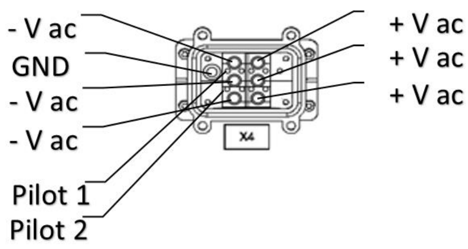

Figure 10: X4 connector – Power Charge Coil

The Charge Coil cable shall be mounted to the connector defined as X4 presented in the Figure 10 (– V ac cable cores 1, 3, 5 +V ac cable cores 2, 4, 6).

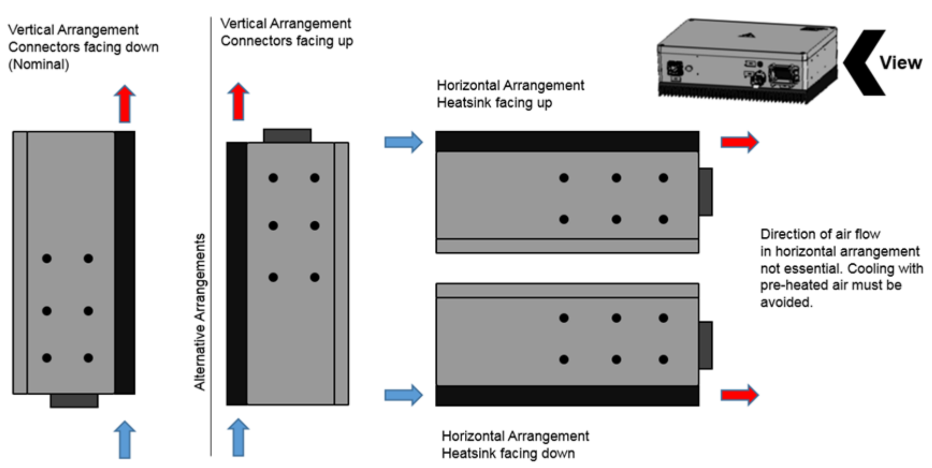

Figure 11: Track Supply possible orientations for its installation

Table 1: Tract Supply – Technical Specifications (electrical)

Designation	Value
Nominal Output Power	3 kW
Power Output limit	3,2 kW shall not be exceeded
Supply voltage	230 V +/-10 % 2 phase + Ground
Supply line	16 A fused
Auxiliary voltage	24 V +/-5% 1,5 A
Output voltage	400 – 650 V rms
Current Charge Coil	15-25 A rms
Output frequency	85 kHz +/-5 kHz
Network configuration	Exclusively Y with grounded star point (TN-system)
Power Factor	0,99
Connection of inputs	via connectors X1: Harting HAN Q2-bu 2,5-6 mm HAN Yellock H. X2: Phoenix Contact 4-pole SACC-DSI-M12M5-4 CON-M16/05 (Material No. 1419629) X3: Harting HAN 8D (Material No. 09360083101) X4: Harting GEMV-gg-M25
Radiated emissions	according to EN 55011 class B
Conducted emissions	according to EN 55011 class A1
Immunity	according to EN 61000-6-2

Table 2: Tract Supply – Technical Specifications (mechanical)

Designation	Value
Housing	Aluminium Cast
Dimensions (L x W x H) (without connectors and supply cables)	~ 400 x 300 x 150 mm
Weight (without connectors and supply cables)	~ 16 kg
Protection class	IP54

Table 3: Tract Supply – Technical Specifications (environment)

Designation		Value
Ambient temperature	during operation	-10 °C – +45 °C
	during storage	-20 °C – +60 °C
	during transport	-20 °C – +60 °C
Humidity (rel.)	Overall	< 90%, non-condensing
Environmental require.	Overall	clean, try, no exposure to chemicals
Loss	Max.	300 W
	Typical	180-200 W
Cooling	Overall	If necessary, to foresee forced air cooling
Vibration	maximum	3 mm at 2 – 9 Hz
	maximum acceleration	0.5 g at 9 – 200 Hz
Maximum shock	in operation	8 g, 11 ms
	during transport (in the packaging)	15 g, 11 ms

2.3.2 Charge Coils

The Charge Coils are connected to the Track Supply and transmit energy inductively to the Pickup Coils installed on the car. The mechanical design of the Charge Coils has been designed to have a pavement-like appearance. The surface layer is composed of a granular material on top of a polymer composite where the assembly with the windings and the ferrite layer will be embedded. An external aluminum housing will be the support of the described components and layers. The different layers and materials foreseen in the design are shown in the Figure 13.

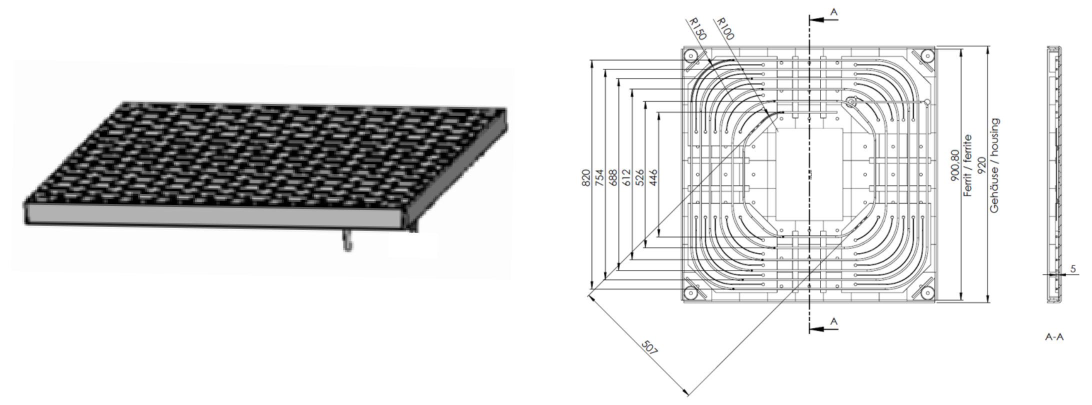

Figure 12: Charge Coils 3D drawing and coils arrangement for A sample prototype

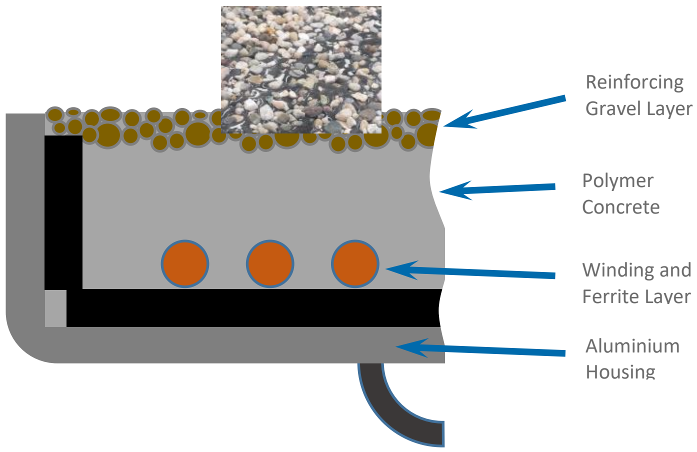

Figure 13: Surface and composition material for the Charge Coils

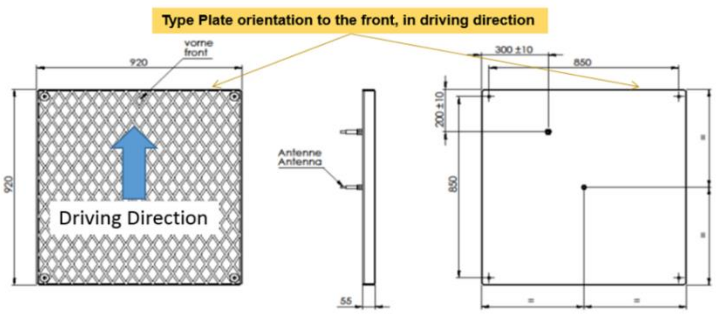

Figure 14: Charge Coil foreseen dimensions and foreseen installation orientation

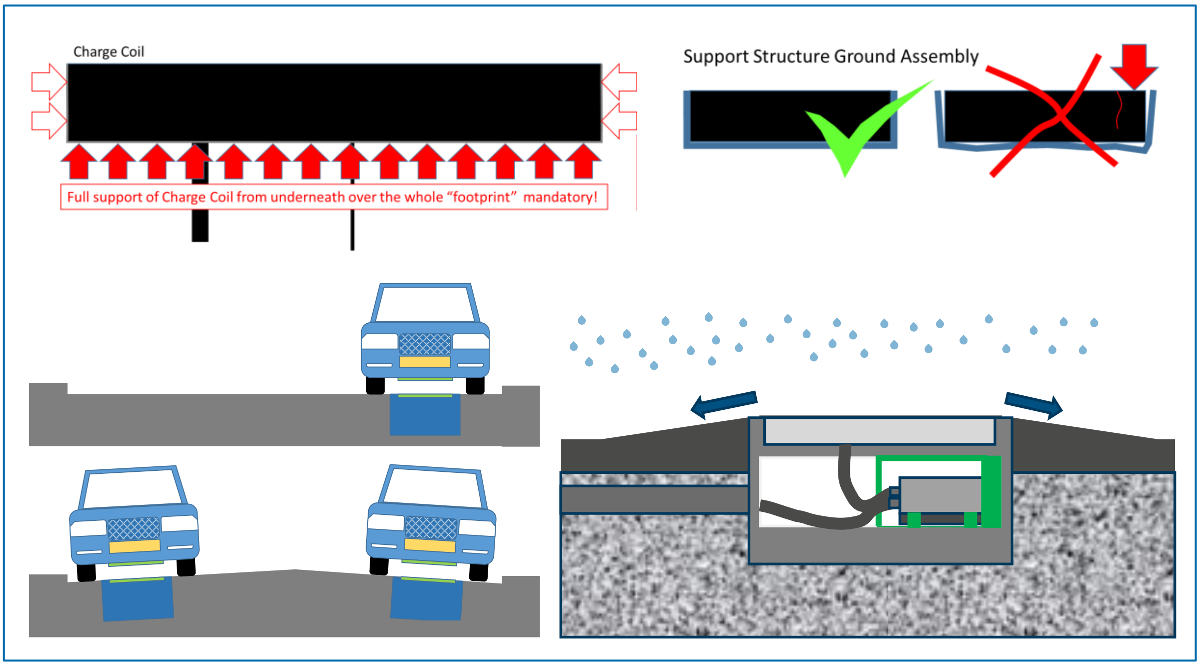

Figure 15 – Schematic drawing and recommendations for the Ground Assembly installation

The construction of the Charge Coils provides an active area slightly smaller than 1 m². Although the Charge Coils shape is symmetric, they have a specific orientation given by the connector positioning. This specific connector position defines a specific orientation for its installation.

Some of the main installation recommendations are shown in the Figure 16. The system design requires the Pickup to be oriented parallel to the surface of the Charge Coil in order to provide the specific power transfer with the correct foreseen efficiency. Slight angles as lower than 5° between the Charge Coils and Pickup are permitted and would not have an impact for a e-Car parked within the allowed park positioning tolerances.

The installation foreseen with this design needs the application of specific measures to ensure the mechanical robustness of the Ground Assembly subsystem. The Charge Coils component shall be embedded on the pavement material avoiding empty spaces between the component and the surrounding material. There is a good experience to compensate uneven surfaces support using polyurethane potting to fill any existing void that could weaken the support.

Table 4: Charge Coils – Technical data (electrical)

Designation	Value
Current applied	15 - 25 A
Frequency applied	85 kHz +/- 5kHz
Isolation between coil and housing tested up to	2,5 kV DC

Table 5: Charge Coils – Technical data (mechanical)

Designation	Value
Housing	Aluminium tray, potted with Epoxy resin
Surface Design	“Stones”
Permissible ambient temperature	-20°C – +45°C
Cooling	Natural convection, over surface and surround.
Protection class	IP65
Dimensions (L x W x H) without cables	920 x 920 x 55 mm
Weight	approx. 102 kg (plus Cables)
Max. Load, supported from undern. and sides	Up to 6 tons wheel load central on Charge Coil

Table 6: Charge Coils – Technical data (connection)

Designation	Value
Power Cable	Cable Length 2,5 m, 7G2,5, Diameter ~ 11 mm Minimum Bending Radius 100 mm Connector: HAN GEMV-gg-M25
Communication Cable (Antenna)	Phoenix Contact Sensor/Actor Cable SAC-4P-5.0-PUR/M12FS SH (Material No. 1682867), Cable Length 2,5 m, minimum bending radius 40 mm
Combination	Solely to operate in combination with Track Supply 4200074, Pickup 4200076 and regulator 4200077

2.4 Components Vehicle Assembly

2.4.1 Pickup

The Pickup is under the car and absorbs the magnetic field provided with AC voltage generated by the Charge Coils with a frequency of 85 kHz. The surface material foreseen for the Pickup on its top and at the sides is a standard untreated aluminium and the surface for the bottom of the Pickup is foreseen as being cover with a polyurethane black potting.

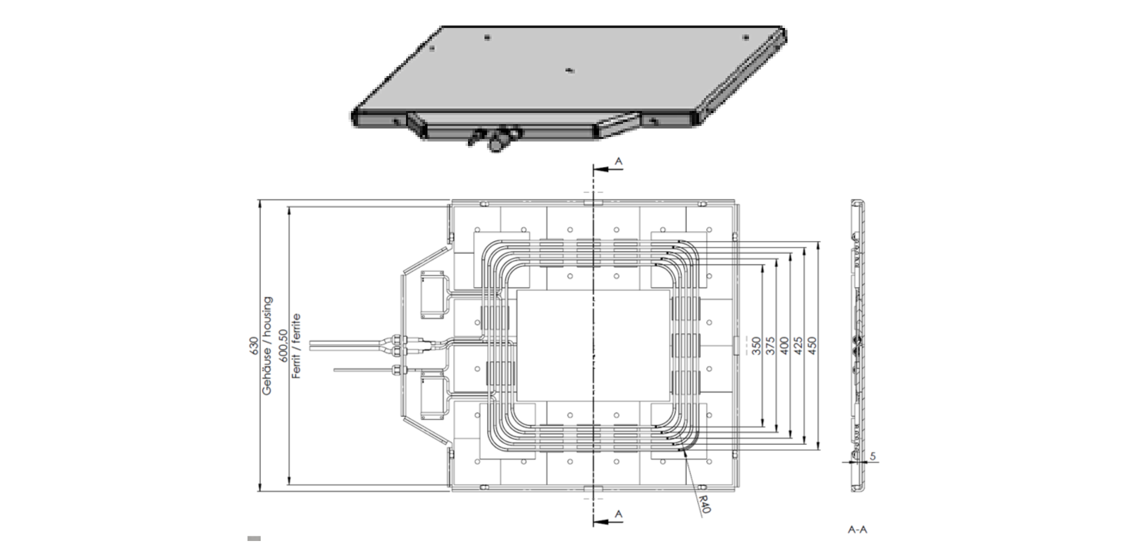

Figure 16: Pickup 3D drawing and coils arrangement pre-design for A sample

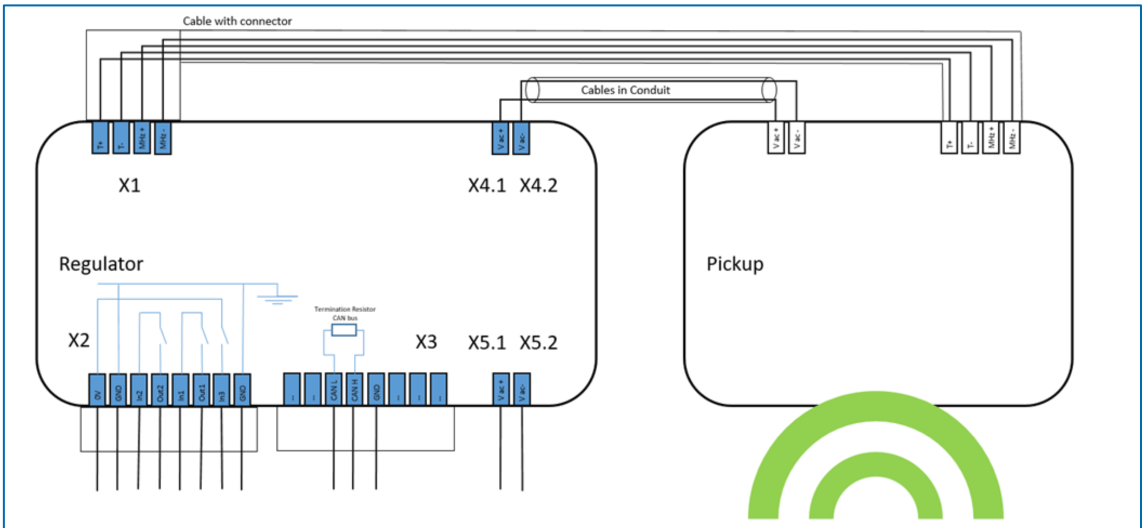

Figure 17: Wiring Scheme Vehicle Side

The Pickup design defines a fix mounting orientation. The cable outlets shall always face to the back. The current design implicates that the Pickup and Charge Coils have been correctly installed as they have a matching orientation. The inductive communication antenna inside the Pickups and the Charge Coils do have an X-orientation (driving direction). So, they either need the same orientation or a 180° opposite orientation. Any other combinations do not allow communication and will also not allow the operation of the system. This imposes some care for the installation which should be planned to ensure that the Charge Coils and the Pickup are installed clearly oriented in the driving direction.

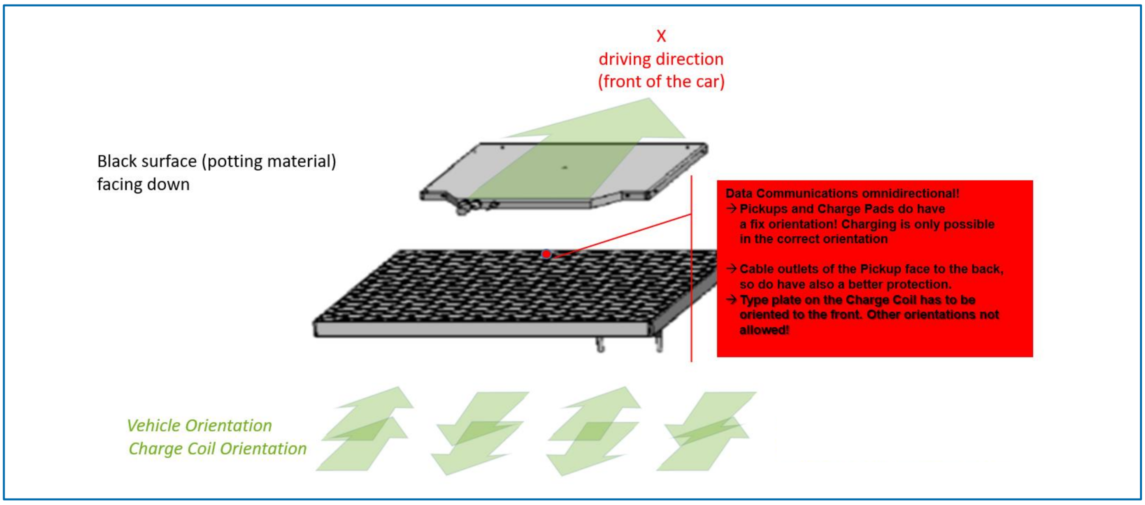

Figure 18: Orientation

The Pickup must be parallel to the Charge Coils when the car is in the charging position for the charging procedure to take place. They will be installed on a straight surface of the car and at the right height to be aligned with the Charge Coil.

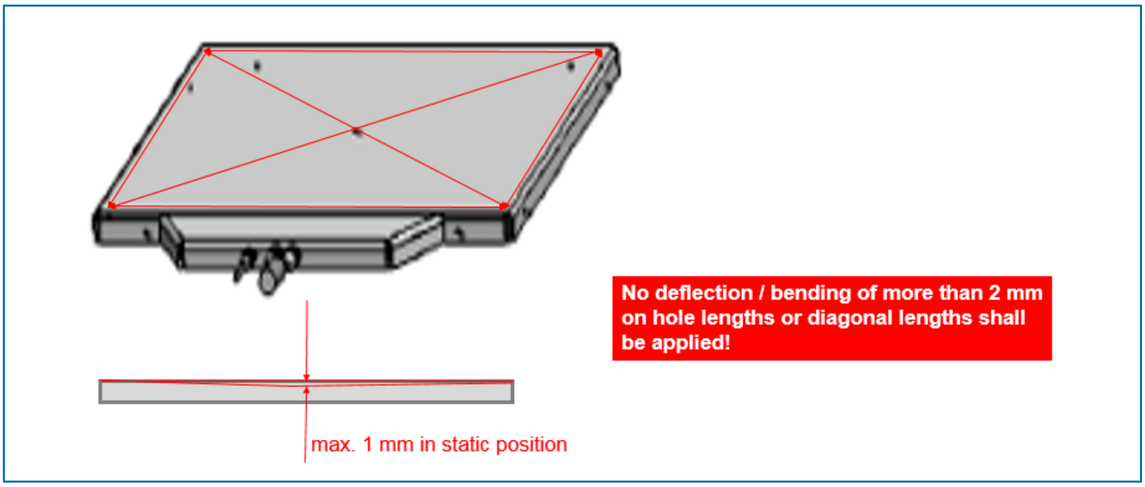

Figure 19: Requirements Mounting Surfaces / Mounting Points

Each Pickup shall come with two mounting holes at the four corners, plus a central mounting hole. The Pickup shall not be provided with the ability of drilling holes into it as this action may damage/destroy the Pickup and can potentially create hazardous situations.

A central mounting hole shall be provided for optional use. This hole is intended to be used whenever the swinging of the Pickup is not controlled with the other mounting holes.

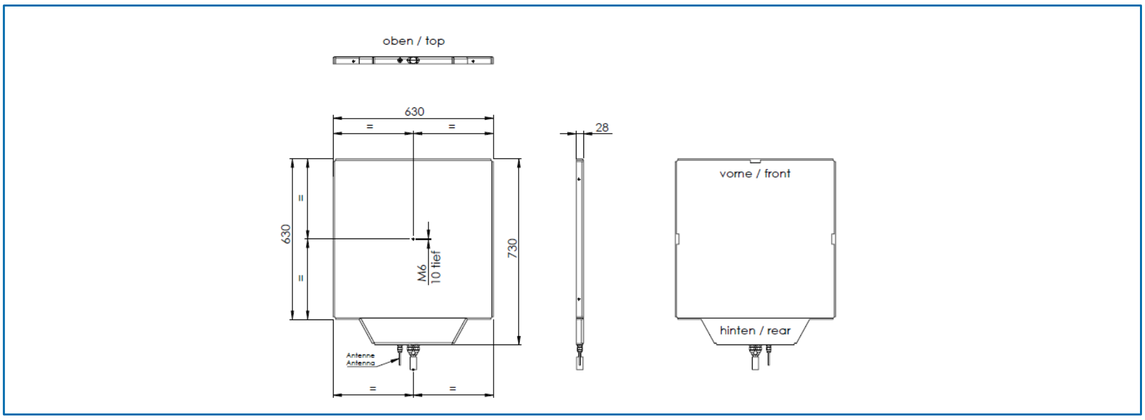

Figure 20: Foreseen dimensions

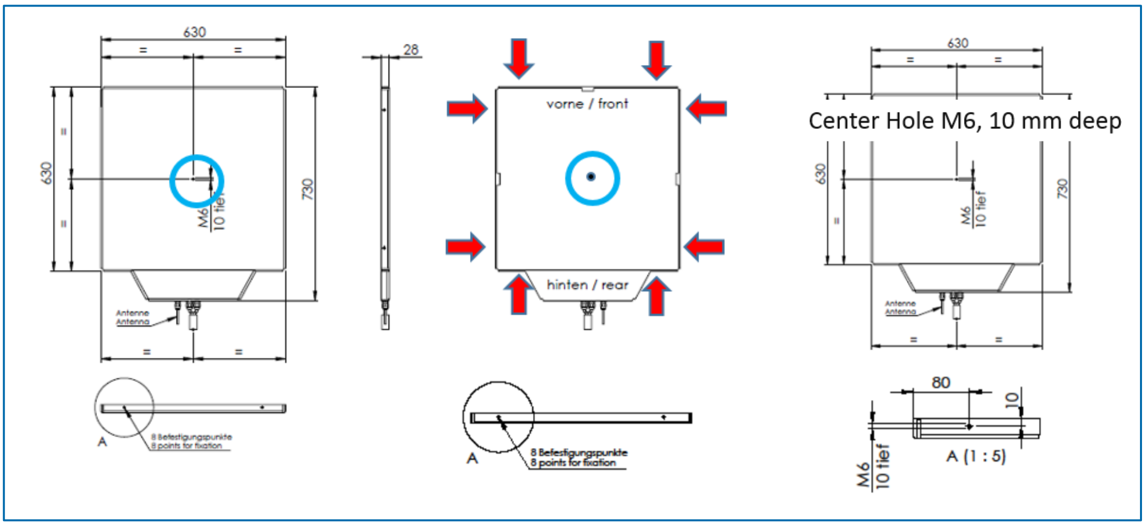

Figure 21: Mounting holes to be provided

If the Pickup can't be attached direct to support structures / mounting points on the car, the Pickup shall be designed with an option to apply extra supports, i.e. holding brackets. If extra support is applied, those supports shall be manufactured out of aluminum.

Due to the aluminum housing, the Pickup provides already good shielding protecting the e-Card components which could be positioned at the back and the sides of it. However, this design might be completed with extra shielding plates over a wider area underneath the vehicle. With the present design, an extra aluminum shielding shall respect a minimal distance to the structure of the Pickup. The back of the Pickup and the extra aluminum shielding shall be installed with a minimal distance between them of 10 mm.

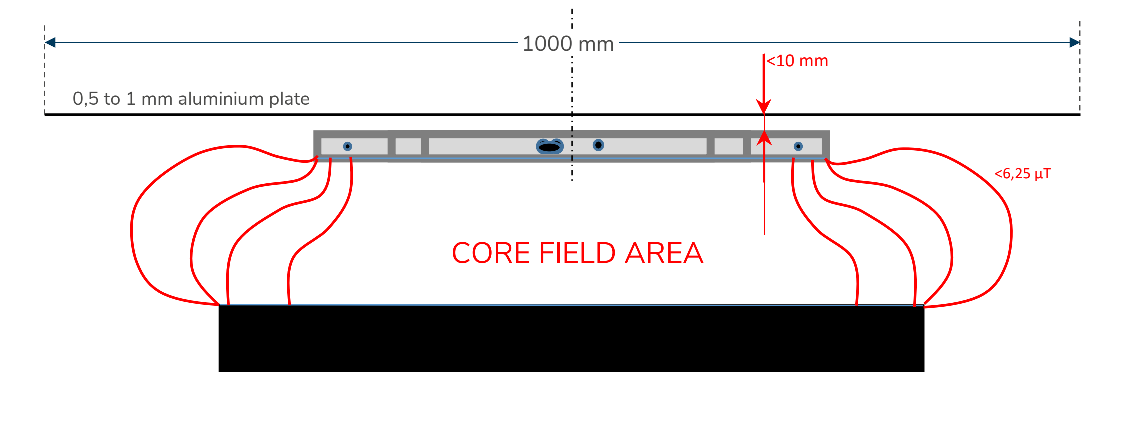

Figure 22: Shielding

The designed magnetic field will decrease with the distance in order to ensure that the field outside area of the vehicle (200 mm from the outline of the vehicle) is lower as 6,25 µT in order to fulfill the most restrictive standards in force.

The shielding plates may improve efficiency by up to 0,5% and provide also a better-defined surrounding for the wireless power transfer, improving the power transfer process in different ways, protecting also from external influences to the field.

The air gap refers to the distance between the top surface of the Charge Coils and the underside of the Pickup.

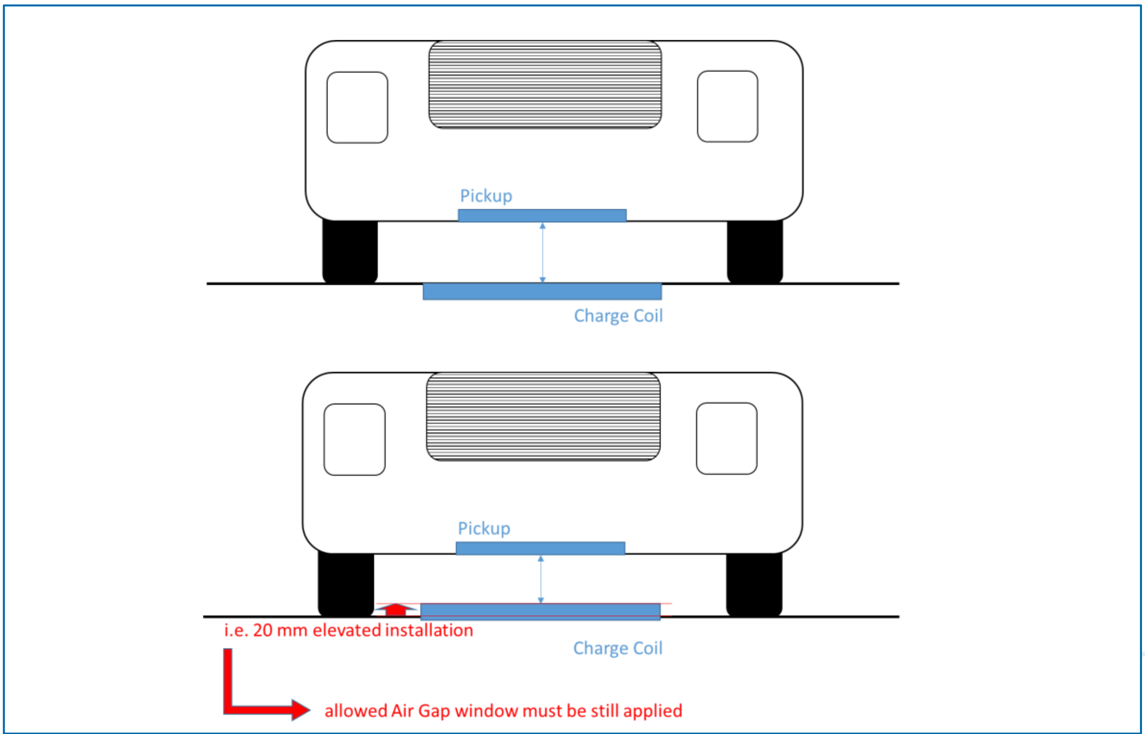

Figure 23: Air gap

Within this definition the system shall allow air gaps between 130 and 180 mm, within positioning tolerances of +/- 100 mm in x- and y-direction. Bigger tolerances and air gaps may be possible, but reductions in the power output must be expected. The safety feature ensuring the proper first level of communication will terminate the power transfer when exceeding the allowed tolerance window.

Table 7 – Pickup Technical data (electrical / thermal)

Designation	Value
Nominal power	3 kW
Duty cycle	100 % duty cycle for max. 10 hours
Operating frequency	85 kHz +/-5 kHz
Output Voltage max.	300 v rms
Output current max.	50 V A rms

Table 8 – Pickup Technical data (mechanical)

Designation	Value
Nominal air gap	130 – 180 mm
Tolerance in X-direction	+/- 100 mm
Tolerance in Y-direction	+/- 100 mm
Permissible ambient temperature	-20 °C – +45 °C
Protection class	IP65
Weight	28 kg (plus Cables)
Dimensions (L x W x H) without cables	730 x 630 x 28 mm
Material	Aluminium tray with PUR 403-FL potting

Table 9 – Pickup Technical data (connection)

Designation	Value
Power Cable	Cable Length 3,5 m 2 x Litz Cable 10 mm² PUR Insulation, Diameter ~10 mm, min. bending radius 100 mm, run in flexible conduit, diam. 25 mm, orange. Connector: Cable Shoes M5, pre-soldered
Communication Cable (Antenna)	Phoenix Contact Sensor/Actor Cable SAC-4P-5.0-PUR/M12FS SH (Material No. 1682867 (M12 male), min. bend. radius 40 mm Cable Length 3,5 m
Combination	Solely to operate in combination with Track Supply 4200074 and Pickup 4200076
Combination	Solely to operate in combination with Track Supply 4200074, Charge Coil 4200075 and Regulator 4200077

2.4.2 Regulator

The Rectifiers convert the AC into DC which is required for battery charging. For each Pickup a Regulator is to be installed.

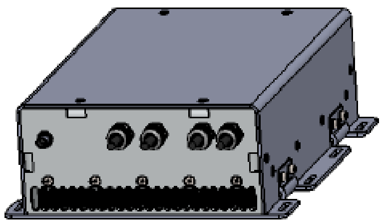

Figure 24: Regulator

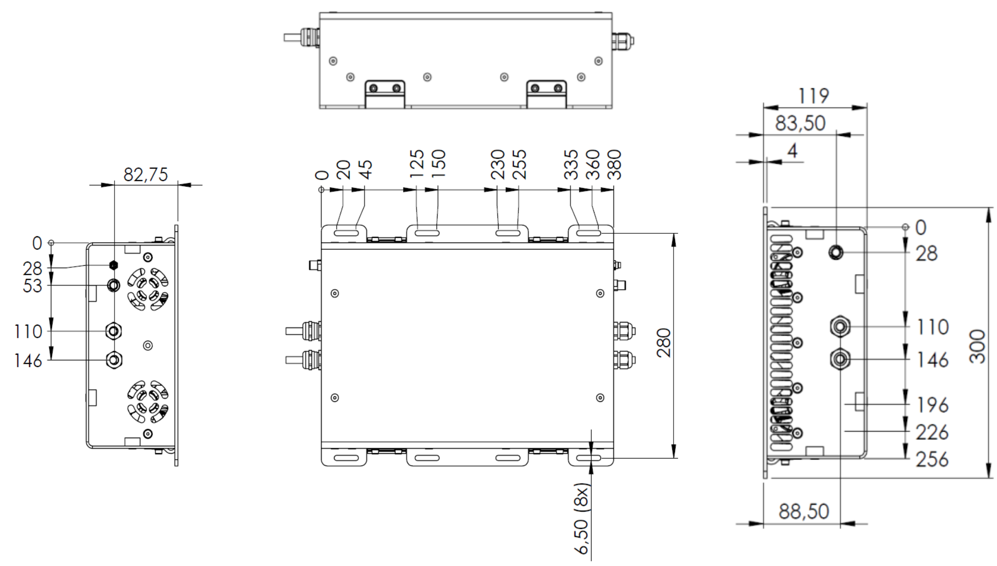

Figure 25: Foreseen Regulator Dimensions

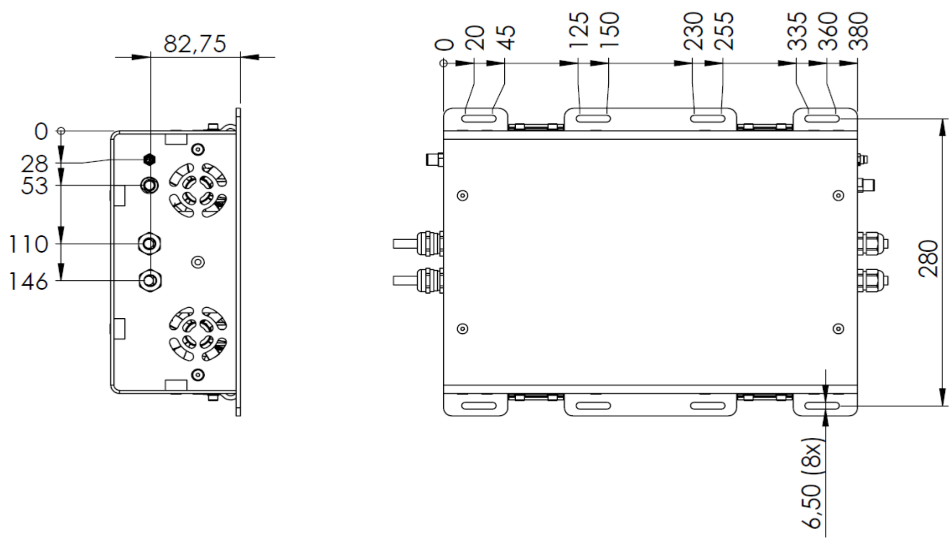

Figure 26: Track Supply mounting design

Connectors and Inlets/Outlets are located on both sides of the Regulator. The power cables in and out shall be hardwired inside the Regulator for technical reasons.

X1 – Antenna (inductive communication)

X2 – Vehicle I/O

X3 – CAN-Bus

X4 – X4.1 + X4.2 – Pickup in

X5 – X5.1 + X5.2 – DC out (X5.1 + / X5.2 -)

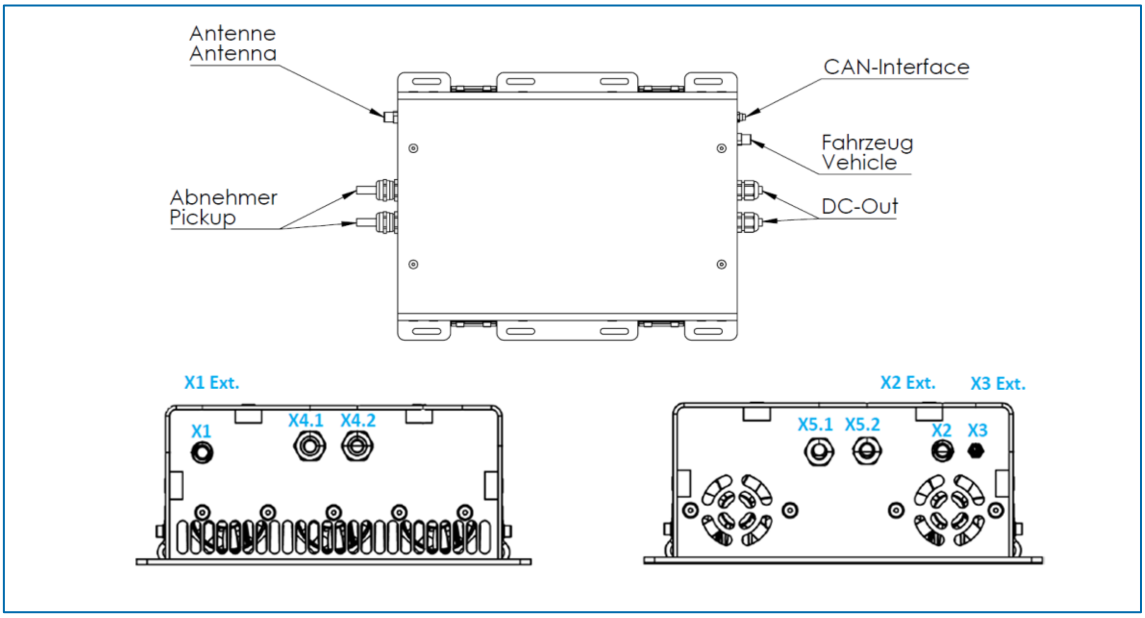

Figure 27: Regulator foreseen connectors

Table 10 – Regulator Technical data (electrical / thermal)

Designation	Value
Power output	2,6 kW
Duty cycle	100 % duty cycle for max. 10 hours
Output Voltage	49 – 53 V DC
Output current	56 A (limited)
Max. heat dissipation	Up to 300 W
Input Frequency	85 kHz +/- 5 kHz

Table 11 – Regulator Technical data (mechanical)

Designation	Value
Weight	~ 9,5 kg
Dimensions (without connectors)	380 x 300 x 119 mm
Protection Grade	IP23
Environment requirements	Clean, dry, no exposure to chemicals
Humidity (rel.)	< 90%, non-condensing
Permissible ambient temperature	0 °C – +40°C
Cooling	Forced Air Cooling

Table 12 – Regulator Technical data (connection)

Designation	Value
Power in	Cable entry through 2 Cable Glands Fixing of Cable shoes on Copper bus bar inside Regulator
Power out	Cable exit through 2 Cable Glands Fixing of Cables in terminal clamps, Cable > 10 mm² cross section recommended, check local regulations for higher requirements
Communication Cable (Antenna)	Phoenix Contact 4-pole SACC-DSI-M12M5-4CON-M16/05 (Material No. 149629)
CAN-Interface	Phoenix Contact sensor/actor flush type 8-pos. (Material No. 1424230)
Vehicle Interface	Phoenix Contact M12 Flush Type Connector (Material No. 1419687)
Combination	Solely to operate in combination with Track Supply 4200074, Charge Coil 4200075 and Pickup 4200076

2.5 State Machine

The following state machine shows the basic principles involving the connections and behaviour principles of the inductive power transfer system. Start and Stop shall be controlled automatically, connecting or disconnecting the 230 V AC power supply to the system in the appropriate chronology. The 24 V DC supply to the Track Supply has no explicit control functionality, it is only foreseen to supply controls within the Track Supply with power to keep them active, even if the 230 V power supply is removed. If the Track Supply shall be completely switched off or shall receive a reset also the 24 V supply needs to be removed.

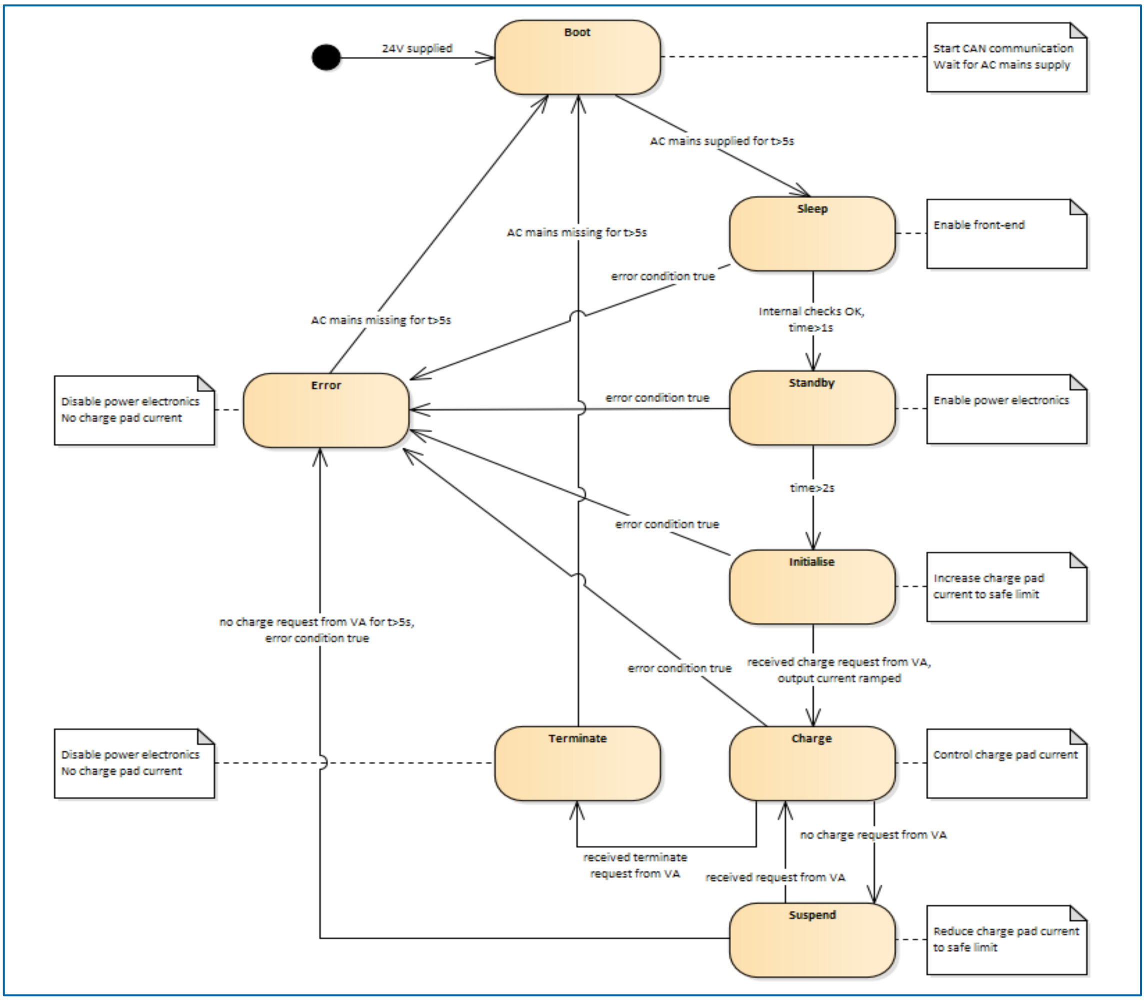

Figure 28: Machine State

2.6 Communication Channels

The main standard IPT design setup provides an inductive communication (Regulator to Track Supply). An additional Wi-Fi communication shall integrate in the overall charging system at a later stage.

Primary choice for communication is the inductive communication. If inductive communication is not available, alternatively the Wi-Fi communication may be used.

If only the Wi-Fi communication is available and therefore additional functionalities of the inductive communication, i.e. pairing, position verification, are not available, it shall be assured by the means of the Wi-Fi application that those functionalities are compensated to maintain a safe operation.

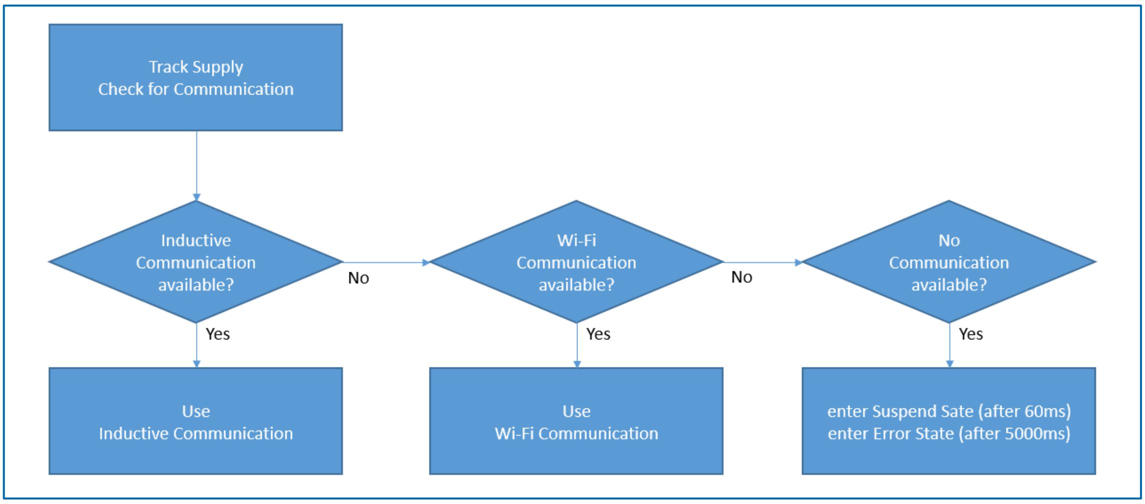

Figure 29: Process diagram for the communication priorities

The Track Supply checks the data received through the two communication channels. If the inductive communication is available, it will listen solely to this. If no data is received through the inductive communication link, it will check alternatively for received Wi-Fi communication.

If either is not available the Track Supply will transition to the Suspend State (reduced power transfer) and eventually to the Error State (no power transfer). The availability of one of the communication channels will be checked continuously in the background during regular operation (i.e. when in Charge and Suspend States). If no communication is available, the system will go into error state after 5 seconds.

2.7 CAN-Messages

On the CAN-Interfaces of the Track Supplies and the Regulators are different sets of CAN-Messages available. Mainly those messages are foreseen for diagnosis purposes. The information transferred between Vehicle Assembly and Ground Assembly are different, which means that the information received by the Track Supplies in the Ground Assemblies doesn't contain, for example, differentiated error codes from the Regulators. The Track Supplies does receive only a general error message. Only error codes generated by the Track Supplies themselves and general Regulator error message are available at the Track Supply level.

The wireless charging system as reflected herein, contributes 3 devices communicating over the CAN bus, the Track Supply and the 2 Power Modules inside the Regulator. The 2 Power Modules are linked through an internal CAN-Bus in the Regulator. Control over the communication between Regulator and Track Supply is at Power Module 1.

All devices do have fix ID node addresses:

Track Supply: transmit IDs 183h, 283h, 383h CAN-Firmware Update: 703h+583h

Regulator Module a: transmit IDs 181h, 281h, 201h, 203h

Regulator Module b: transmit IDs 182h, 282h, 202h

The Track Supply and the Regulator do have termination resistors terminating the CAN-Bus at either end.

2.8 System Integration in the Renault ZOE

The possible integration of a pickup and the Regulator into a Renault ZOE was examined.

The same installation areas and volumes were identified in the old and new Renault ZOE models. The battery box offers a large flat surface with the dimensions 140cm x 86cm, as well as possible attachment points for a pickup adapter. A volume was identified for the installation of the Regulator on the right rear of both models. The connection to the pickup can be made to the right or left of the battery box.

Figure 30: Pickup location

2.9 Integration at the AMB in Barcelona

The INDUCAR integration in USER-CHI project shall be provided in Barcelona at the AMB offices installations. The potential parking places where the wireless charging Ground Assembly could be installed have been identified (Figure 31). Three parking spots have been identified. The existing electric fleet and its arrangement has been inspected to foreseen the source of power for the e-Cars implemented in the offices underground parking garage.

The potential Renault ZOE to be adapted with the wireless Vehicle Assembly have been also identified. One extra Nissan Leaf could be also available to be adapted with the INDUCAR technology.

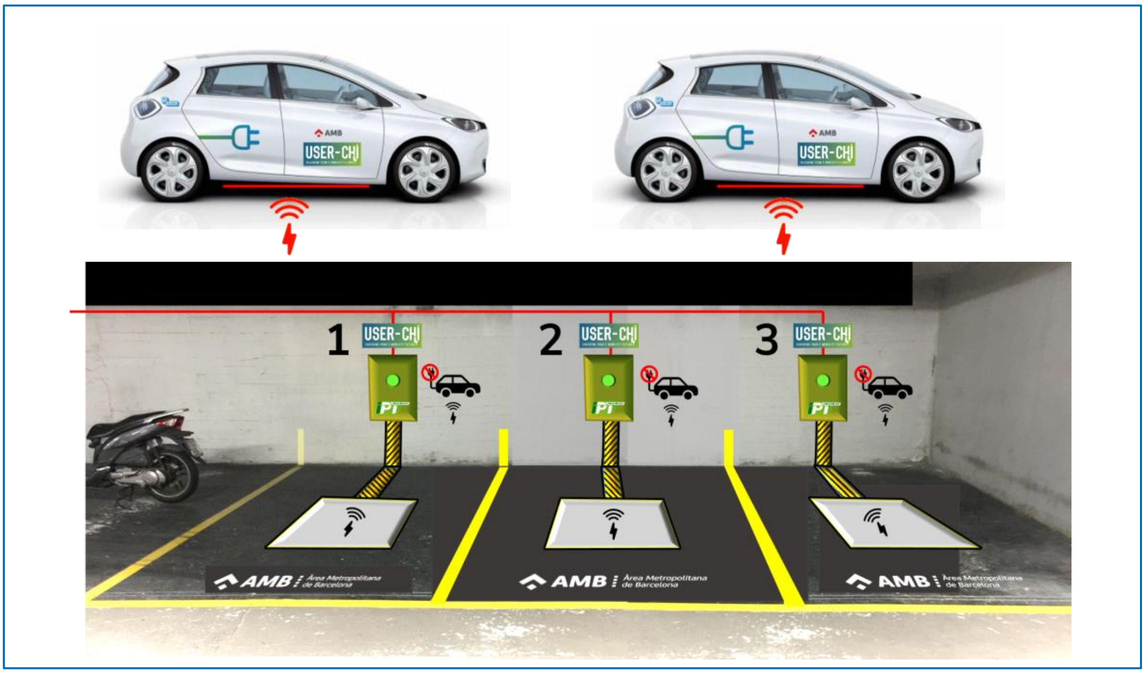

Figure 31: Parking spaces identified and schematic view of the installed wireless system

3. Formal Design Requirements

3.1 Introduction

The formal design requirements description brings together all the fundamental requirement that must be met to provide a complete and fully operational wireless power charger system for EVs.

The components and equipment description shown in the precedent section constitute the current design freeze fulfilling the basic operational requirements with the basic safety features inside. The subsequent levels of the design development shall enter in more detail and fully integrate the complete requirement defined in the formal design requirements statements.

3.2 Design requirement document conventions

In order to introduce the proper understanding of the different level of requirements and their priorities, the following conventions are defined:

The word SHALL in the text denotes a mandatory requirement. Departure from such a requirement will probably endanger the fundamental functions of the system and leads to major change requests in the development.

The word SHOULD in the text denotes a recommendation or advice that is expected to be followed unless good reasons are stated for not doing so.

The word MUST in the text is used for legislative or regulatory requirements (e.g. Health and Safety) and shall be complied with. It is not used to express a user requirement.

The word WILL in the text denotes a provision or service or an intention in connection with a user requirement.

The word MAY in the text denotes a permissible practice or action. It does not express a user requirement.

The prefix "NOTE:" shall be used to provide information or an action relating to a user requirement.

3.3 WPT System Requirements

3.3.1 General Requirements

The WPT System must comply with the requirements of Electric Vehicle Wireless Power Transfer Systems IEC 61980 - all parts and the requirements of Road vehicles – Functional safety ISO 26262.

The WPT System must comply with the requirements of Electrically propelled road vehicles – Inductive wireless connection to an external electric power supply – Interoperability and safety requirements ISO 19363.

NOTE: In the absence of a mature ISO/IEC 19363 standard, the conductive charging standard Electrically propelled road vehicles - Connection to an external electric power supply - Safety specifications ISO/IEC 17409 should be used.

The WPT System must comply with the guidelines for general public exposure as given by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) 2010.

3.3.2 Functional Requirements

3.3.2.1 Primary Functions

The WPT System shall wirelessly transfer energy from an electrical source to the high voltage battery of an electrified vehicle.

The WPT System shall protect against excessive temperature rise in metallic foreign objects.

The WPT System shall protect living objects from exposure to harmful magnetic fields by implementing an active feature or by complying to ICNIRP 2010 in terms of accessible areas restrictions.

3.3.2.2 Secondary Functions

The WPT System shall communicate with the vehicle.

The WPT System shall provide real time alignment information.

The WPT System shall only release charge to an authorised vehicle.

3.3.3 Performance Requirements

3.3.3.1 Power Transfer

The WPT System shall draw a maximum power of 3,6 kW from the electrical supply.

The WPT System shall achieve a maximum output power of 3,6 kW to the HV battery.

The WPT System shall transfer energy at a peak efficiency of at least 92%.

NOTE: Efficiency shall be measured from the AC input to the Ground Assembly and the DC HV output of the Vehicle Assembly.

The WPT System shall transfer energy at a minimum efficiency of 88%, when transferring > 80% of maximum power, within the System Alignment Tolerance.

NOTE: Efficiency shall be measured from the AC input to the Ground Assembly and the DC HV output of the Vehicle Assembly.

3.3.3.2 System Alignment Tolerance

The WPT System shall operate within a System Alignment Tolerance, as defined by X, Y, Z, Pitch, Roll and Yaw requirements. The WPT System shall operate at one of these two ground clearance classes: Z Class 1 or Z Class 2.

NOTE: Ground clearance is defined as from the road surface to the surface of the Pickup housing.

Z Class 1 shall be defined as ground clearance in the Z axis of 100 mm to 140 mm.

Z Class 2 shall be defined as ground clearance in the Z axis of 160 mm to 200 mm.

The WPT System shall have a Y-axis tolerance of +/- 100 mm.

The WPT System shall have a X-axis tolerance of +/- 100 mm.

The WPT System shall have a combined X/Y axis tolerance defined as the area enclosed by the following points:

Point A shall equal + 75 mm (+ X axis), Point B shall equal - 75 mm (- Y axis), Point C shall equal - 75 mm (- X axis), Point D shall equal + 75 mm (+ Y axis).

The WPT System shall have a Yaw tolerance of 5 degrees, irrespective of any other alignment tolerance.

3.3.3.3 Metallic Foreign Object Protection

The WPT System must limit the temperature rise in metallic foreign objects, within Protection Area 1 (IEC 61980-1: Areas of Protection), to 20°C above ambient, during maximum energy transfer. It is permissible to de-rate from maximum energy transfer to meet this requirement.

The WPT System must limit the maximum temperature of a foreign object, within any Protection Area (IEC 61980-1: Areas of Protection), to 80°C (IEC 61980-1: Protection against burns from Heating of foreign objects).

The WPT System must ensure that under no circumstances a foreign object, within any Protection Area (IEC 61980-1: Areas of Protection), emits sparks, flame, smoke or noxious fumes as a result of the WPT System operation, within the operating temperature range specified within this document.

Note: Any form of protection system shall be packaged within the Ground Assembly in order to minimise weight and complexity of on vehicle components.

3.3.3.4 Living Object Protection

The WPT System shall limit the magnetic field strength to a maximum of 27 microTesla, within Protection Areas 3, during maximum power transfer.

The WPT System shall limit the magnetic field strength to a maximum of 15 microTesla, within Protection Areas 4, during maximum power transfer.

Note: Any form of protection system shall be packaged within the Ground Assembly in order to minimise weight and complexity of on vehicle components.

3.3.3.5 Communication & Authentication

The WPT System shall detect when the Pickup is within 8 m of the Charge Coils.

The WPT System shall provide a real time index of all Ground Assembly within communications range to the vehicle.

Information such as Status, Availability, etc, shall be provided to the vehicle.

The WPT System shall be capable of operating in a Secured mode, defined as only allowing an authorised vehicle to operate the system.

3.3.3.6 Alignment Feedback

The WPT System shall provide information to the user of the absolute position of the Pickup, with respect to the Charge Coils, when within < 1 m.

The accuracy of the position information shall be of +/- 5 when the distance of the vehicle is 1 meter (or lower) to the Charge Coils.

NOTE: The accuracy of the position information shall be sufficient to achieve peak power transfer.

The WPT System may need to provide information to the vehicle of the absolute position of the Pickup, with respect to the Charge Coils.

3.3.3.7 Dynamic Response

The WPT System shall operate in a Constant Power Mode.

When operating in Constant Power Mode, the WPT System shall respond to demanded power at a rate of 3,6 kW.

The Vehicle Assembly shall be tolerant to step changes in power demand.

The WPT System shall operate in Constant Voltage Mode when the Vehicle Assembly output voltage exceeds the output voltage limit.

The WPT System shall operate in a Constant Current Mode.

The WPT System shall operate in Constant Current Mode when the Vehicle Assembly output current exceeds the output current limit.

When operating in Constant Current Mode, the WPT System shall limit the Vehicle Assembly output current to within +1 A and – 1 A of the target current.

The WPT System shall support an instant disconnection or reconnection of a HV load or source from the HV DC bus during operation.

The WPT System shall resume normal operation, following an event which caused the WPT System to be inhibited, without further user input.

Any circuit breaker, RCD or other device providing personnel protection against electric shock shall not automatically reset (IEC 61980-1: 9.6.2 Manual/automatic reset).

3.3.3.8 De-rating Strategy

The WPT System shall de-rate based on the limitations of the Ground Assembly and the Vehicle Assembly.

The WPT System may de-rate based on some 'Metallic Foreign Object Protection' or 'Living Object Protection' use cases. See system requirements within this document.

3.3.3.9 Noise and Vibration

The WPT System shall not radiate noise that exceeds the TARGET within the vehicle cabin (L405 HEV Small Machine Radiated Noise Guidelines,1m, 1/2 Space, Vehicle Standby, Fan Speed 1) when the WPT System is supplying power to the HV DC bus.

The WPT System shall not conduct vibrations that exceeds the TARGET within the vehicle cabin (L405 HEV Small Machine Force Targets,1m, 1/2 Space, Vehicle Standby, Fan Speed 1) when the WPT System is supplying power to the HV DC bus.

The WPT System shall not create audible Noise Error States (e.g. tones) outside of the vehicle cabin.

3.3.3.10 Electromagnetic Emissions

The WPT System, on-vehicle components, shall be designed in accordance with Electric vehicle conductive charging system – Part 21-1: Electric vehicle onboard charger EMC requirements for conductive connection to an AC/DC supply IEC 61851-21-1.

The WPT System, off-vehicle components, shall be designed in accordance with Electric vehicle conductive charging system - Part 21-2: EMC requirements for OFF board electric vehicle charging systems IEC 61851-21-2.

The WPT System shall meet the requirements of Electromagnetic compatibility (EMC) — Part 3 – 2: Limits — Limits for harmonic current emissions (equipment input current ≤16 A per phase), IEC 61000-3-2.

The WPT System shall meet the requirements of Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and ≤ 75 A per phase, IEC 61000-3-12.

The WPT System shall meet the requirements of 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 61000-3-3.

The WPT System shall meet the requirements of 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 61000-3-11.

The WPT System shall meet the requirements of Automotive EMC Directive 2004/104/EC.

3.4 Ground Assembly Requirements

3.4.1 General Requirements

The Ground Assembly shall bear the relevant product certification markings, and be tested in accordance with, local regulation in European (CE).

The Ground Assembly should be designed in accordance with Electric vehicle conductive charging system - Part 1: General requirements IEC 61851-1.

The Ground Assembly should be designed in accordance with Electric vehicle conductive charging system - Part 21: Electric vehicle requirements for conductive connection to an A.C./D.C. supply IEC 61851-21.

The Ground Assembly should be designed in accordance with Electric vehicle conductive charging system - Part 22: A.C. electric vehicle charging station IEC 61851-1.

The Ground Assembly should be designed in accordance with Electric vehicle conductive charging system - Part 23: D.C electric vehicle charging station IEC 61851-23.

The Ground Assembly shall comply with the requirements of Low voltage electrical installations: Part 7-722: Requirements for special installations or locations - Supply of Electric vehicle IEC 60364-7-722.

The Ground Assembly may comply with the requirements of Low-voltage switchgear and control gear assemblies - Part 7: Assemblies for specific applications such as marinas, camping sites, market squares, electric vehicles charging stations IEC 61439-7.

The Ground Assembly may be designed in accordance with Power Quality Requirements for Plug-In Electric Vehicle Chargers SAE J2894

3.4.2 Functional Requirements

3.4.2.1 Primary Functional Requirements

The Ground Assembly shall convert an AC electrical supply into an AC magnetic field.

3.4.2.2 Secondary Functional Requirements

The Ground Assembly shall communicate wirelessly with the Vehicle Assembly.

The Ground Assembly shall receive vehicle instructions via the Vehicle Assembly.

The Ground Assembly shall only release charge to an authorised Vehicle Assembly.

3.4.3 Performance Requirements

3.4.3.1 Power, Voltage & Current

The Ground Assembly shall draw a maximum current of 16 A from the electrical supply.

The Ground Assembly shall draw a maximum power of 3.7 kW from the electrical supply.

The Ground Assembly shall operate, at maximum power, with an input voltage range of 85 V AC to 265 V AC with a linear power limitation below 230 V AC.

The Ground Assembly shall have a minimum input voltage of 75 V AC with a linear power limitation below 230 V AC.

The Ground Assembly shall have a maximum input voltage of 275 V AC with a linear power limitation below 230 V AC.

The Ground Assembly shall operate within an input frequency range of 45Hz to 65 Hz.

The Ground Assembly quiescent current draw from the AC input shall be less than 1 W (continuous average), when not transferring power.

3.4.3.2 De-rating & Shutdown

The Ground Assembly may de-rate when the ambient temperature is outside of the operational ambient temperature range.

The Ground Assembly may de-rate output power linearly to zero from +50°C to 65°C

The Ground Assembly may de-rate output power linearly to zero from -30°C to -40°C

The Ground Assembly shall shutdown on over-temperature above 65°C.

The Ground Assembly may de-rate when the input voltage is outside of the operational voltage range.

The Ground Assembly may de-rate output power linearly to zero from 265 V AC to 275 V AC.

The Ground Assembly shall not transfer power if the input AC voltage is outside of the maximum to minimum voltage range.

The Ground Assembly should not transfer power if the input frequency is outside of the operation frequency range.

3.4.4 Interface Requirements

3.4.4.1 Physical Interfaces

The Ground Assembly Charge Coils shall be floor mounted.

The fitting method shall comply with the Charge Coils requirements for Noise, Vibration and Harshness, as defined in this document.

The fitting method shall comply with Charge Coils requirements for Mechanical Shock, as defined in this document.

The Ground Assembly fitting method shall be capable of withstanding an attack by an individual with a simple standard tool of 2 minutes without the Ground Assembly being removed or sustaining 10 % of damage.

The Ground Assembly may dissipate thermal energy to the surrounding air and physical structure.

The Ground Assembly shall not dissipate greater than 220 W during normal operation.

The Primary Power Electronics shall have a maximum surface temperature of 80°C.

The Charge Coils shall have a maximum surface temperature of 80°C.

The Ground Assembly shall have no exposed burrs or sharp edges.

3.4.4.2 Electrical Interfaces

The Ground Assembly shall be connected to a two-wire AC supply (2P+E, P+N+E).

The Ground Assembly shall be connected to a protective conductor, to establish a connection between the earthing terminal of the electrical supply and the Ground Assembly.

The Ground Assembly HV connections should be by 'hard wired' installation.

NOTE: The Ground Assembly shall not require any Low Voltage connections.

3.4.4.3 Communication Interfaces

The Ground Assembly shall have a diagnostic / software programming connection.

The Ground Assembly shall communicate wirelessly with the Vehicle Assembly.

The Ground Assembly may implement the Supply Equipment Communications Controller (SECC), as defined in ISO 15118, for communications to the EVCC.

The Ground Assembly may implement the low-level communications controller, as defined in IEC 61980.

3.4.4.4 Information Interfaces

The Ground Assembly shall communicate the status of a supply disconnect device to the Vehicle Assembly.

3.4.4.5 Material Interfaces

The Ground Assembly shall not exchange any physical material with any other system.

3.4.5 Hardware & Software Design Requirements

3.4.5.1 Diagnostics

The Ground Assembly shall preform diagnostics functions. The details of this diagnostic functions shall be determined during the establishment of the software architecture.

The Ground Assembly shall perform Initialisation Built In Test (IBIT), as defined by ISO 26262.

The IBIT shall test the status of each Ground Assembly interface (details to be defined).

The IBIT shall test all critical functions whose failure modes may impact the safe operation of the Ground Assembly (details to be defined).

The Ground Assembly shall perform Continuous Built In Test (CBIT), as defined by ISO 26262.

The CBIT should test, where possible, all critical functions whose failure modes may impact the safe operation of the Ground Assembly.

3.4.5.2 Temperature Monitoring

The Ground Assembly shall monitor the temperature of all major semiconductor components (details to be defined).

The Ground Assembly shall monitor the temperature of all major magnetic components (details to be defined).

The Ground Assembly shall measure the temperature of all heat sinks (details to be defined).

The Ground Assembly shall monitor the temperature of the active discharge resistor (details to be defined).

3.4.6 Mechanical Requirements

3.4.6.1 Mass & Geometry

The Ground Assembly Charge Coils should have a surface area no greater than 1000 mm x 1000 mm. The Charge Coils should limit the trip hazard by chamfering the edges from the top surface to the bottom surface.

3.4.7 Environmental Requirements

3.4.7.1 Thermal & Solar

The Ground Assembly shall not suffer deterioration in performance or malfunction (temporary or permanently) when operating within an ambient temperature range of -30°C to +50°C.

The Ground Assembly shall not suffer any permanent deterioration in performance or malfunction when not operational within an ambient temperature range of -40°C to +85°C.

The Ground Assembly shall not suffer deterioration in performance or malfunction (temporary or permanently), while operating, when exposed to an outer case temperature rate of change of greater than or equal to 10°C/min.

The Ground Assembly shall not suffer any permanent deterioration in performance or malfunction, while not operational, when exposed to an outer case temperature rate of change of greater than or equal to 20°C/min.

The Ground Assembly shall not suffer deterioration in performance or malfunction (temporary or permanently) when exposed to peak solar loads of 1000 W/m².

3.4.7.2 Fluid Ingress

The Ground Assembly Primary Power Electronics shall be sealed to IPX7k, as defined in IEC 60529 and ISO 20653.

The Ground Assembly Charge Coils shall be sealed to IPX9k, as defined in IEC 60529 and ISO 20653.

The Ground Assembly shall not suffer deterioration in performance or malfunction (temporary or permanently) within 0 % RH to 100 % RH relative humidity.

3.4.7.3 Humidity

The Ground Assembly shall not suffer deterioration in performance or malfunction (temporary or permanently) within 0 % RH to 100 % RH relative humidity.

3.4.7.4 Salt, Dust & Chemical Resistance

The Ground Assembly Charge Coils shall be sealed to IP6Xk, as defined in IEC 60529 and ISO 20653.

The Ground Assembly shall ensure protection against corrosion by the use of suitable materials or by protective coatings to the exposed surface, taking account of the normal service conditions.

3.4.7.5 Altitude and Pressure

The Ground Assembly shall not suffer deterioration in performance or malfunction (temporary or permanently) between an altitude of -100 m below sea level and an altitude of 3000 m above sea level.

Creepage and clearance distances for altitudes of more than 2000m shall be in accordance with the requirements specified in Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests IEC 60664-1.

The Ground Assembly shall not suffer deterioration in performance or malfunction (temporary or permanently) between a minimum air pressure of 800 mmHg and a maximum air pressure of 394 mmHg.

3.4.7.5.1 Mechanical Shock

The Charge Coils shall meet the requirements of Static Load for ground mounted equipment, as defined by IEC 61439-5, 10.2.101.

The Charge Coils shall meet the requirements of Shock Load for ground mounted equipment, as defined by IEC 61439-5, 10.2.101.

The Charge Coils should meet the requirements of Torsional Stress for ground mounted equipment, as defined by IEC 61439-5, 10.2.101.

The Charge Coils should meet the requirements of Mechanical Shock for ground mounted equipment, as defined by IEC 61439-5, 10.2.101.

3.4.7.6 EMC Immunity Requirements

The Ground Assembly shall meet the requirements of Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test, IEC 61000-4-3.

The Ground Assembly shall meet the requirements of Electromagnetic Compatibility (EMC) - Part 4-2 : Testing and measurement techniques - Electrostatic discharge immunity test, IEC 61000-4-2.

The Ground Assembly shall meet the requirements of Electromagnetic Compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test, IEC 61000-4-4.

The Ground Assembly shall meet the requirements of Electromagnetic Compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test, IEC 61000-4-5.

3.5 Vehicle Assembly Requirements

3.5.1 General Requirements

The Vehicle Assembly must meet the requirements of UNECE Regulation 100.

The Vehicle Assembly shall meet the requirements of Functional Safety of Electric, Electronic and Programmable Electronic safety related systems IEC 61508.

The Vehicle Assembly shall meet the requirements of Electrically propelled road vehicles -- Safety specifications ISO 6469.

The Vehicle Assembly shall be designed in accordance with Electric vehicle conductive charging system - Part 1: General requirements IEC 61851-1.

The Vehicle Assembly shall be designed in accordance with Electric vehicle conductive charging system - Part 21: Electric vehicle requirements for conductive connection to an A.C./D.C. supply IEC 61851-21.

3.5.2 Functional Requirements

3.5.2.1 Primary Functional Requirements

The Vehicle Assembly shall convert an AC magnetic field into a DC electrical output.

3.5.2.2 Secondary Functional Requirements

The Vehicle Assembly shall send information to the vehicle.

The Vehicle Assembly shall receive information from the vehicle.

The Vehicle Assembly shall communicate wirelessly with the Ground Assembly.

The Vehicle Assembly shall communicate vehicle instructions to the Ground Assembly.

The Vehicle Assembly shall provide real time alignment information to the vehicle.

The Vehicle Assembly shall communicate an authorisation code to the Ground Assembly to enable the WPT System.

3.5.3 Performance Requirements

3.5.3.1 Power, Voltage & Current

The Vehicle Assembly Current Output shall have a pk-pk ripple of less than 2 A, when the traction battery is in-circuit, at the switching frequency of the converter.

The Vehicle Assembly shall have a Voltage Output range of 300 V DC to 420 V DC.

The Vehicle Assembly Voltage Output shall have a pk-pk ripple of less than 4V, when the traction battery is in-circuit, at the switching frequency of the converter.

The Vehicle Assembly shall draw power from the Low Voltage (LV) DC vehicle bus.

The Vehicle Assembly shall operate normally when the LV DC bus is between 8 V DC and 16 V DC.

The Vehicle Assembly shall maintain safety critical systems when the LV DC bus is between 5.5 V DC and 18 V DC.

The Vehicle Assembly shall not draw more than 5 W from the LV DC bus.

The Vehicle Assembly quiescent current draw from the LV DC bus shall be less than 100 microA.

3.5.3.2 De-rating Strategy

The Vehicle Assembly may de-rate when the ambient temperature is outside of the operational ambient temperature range.

The Vehicle Assembly may de-rate output power linearly to zero from 50°C to 70°C.

The Vehicle Assembly may de-rate output power linearly to zero from -30°C to -40°C.

The Vehicle Assembly may de-rate when the voltage output is above the voltage output range.

The Vehicle Assembly may de-rate output power linearly to zero from 420 V DC to 450 V DC.

3.5.4 Interface Requirements

3.5.4.1 Physical Interfaces

The Vehicle Assembly shall be fitted to the vehicle.

The fitting method shall comply with Vehicle Assembly Noise, Vibration and Harshness requirements, as defined in this document.

The fitting method shall comply with Vehicle Assembly Mechanical Shock requirements, as defined in this document.

The fitting method shall be capable of withstanding an attack of 2 minutes by an individual with a simple standard tool without the Vehicle Assembly being removed from the vehicle or sustaining 10 % of damage.

The Vehicle Assembly shall have no burrs or sharp edges on the exterior.

The Vehicle Assembly shall not dissipate greater than 110 W during normal operation.

3.5.4.2 Electrical Interfaces

The Vehicle Assembly shall be connected to the HV DC bus of the vehicle.

The Vehicle Assembly HV DC connector shall be rated for continuous operation at the specified WPT class.

The Vehicle Assembly HV DC connector shall include one HV positive terminal and one HV negative terminal.

The Vehicle Assembly shall be connected to the LV DC bus of the vehicle.

The Vehicle Assembly shall be connected to the ground of the LV bus.

The Vehicle Assembly shall be connected to the permanent 12V of the LV bus.

The Vehicle Assembly shall make provision for the fitment of an Earth Strap

3.5.4.3 Communication Interfaces

The Vehicle Assembly shall be connected to the private CAN bus of the vehicle.

The Vehicle Assembly shall make provision for a connection to the vehicle CAN High.

The Vehicle Assembly shall make provision for a connection to the vehicle CAN Low.

The Vehicle Assembly shall have a wireless communications connection with the Ground Assembly.

3.5.4.4 Information Interfaces

NOTE: The following signal descriptions are given to support required functionality and are for INDICATION only.

The Vehicle Assembly shall receive the Output Power demand signal on the CAN bus.

The Vehicle Assembly shall receive the Output Voltage limit signal on the CAN bus.

The Vehicle Assembly shall receive the Output Current limit signal on the CAN bus.

The Vehicle Assembly shall ignore a CAN bus request to operate outside of normal parameters.

The Vehicle Assembly shall transmit the operating mode via CAN.

The Vehicle Assembly shall transmit the Ground Assembly unique identifier via CAN.

The Vehicle Assembly shall transmit the alignment status of the Primary and Pickups via CAN.

The Vehicle Assembly shall transmit the value of Ground Assembly Input Voltage via CAN.

The Vehicle Assembly shall transmit the value of Ground Assembly Input Current via CAN.

The Vehicle Assembly shall transmit all active fault codes via CAN.

The Vehicle Assembly shall transmit the measured voltage of the HV DC bus connection as a node of the HV Interlock system (HVIL), via CAN.

The Vehicle Assembly shall transmit the measured temperature values via CAN.

The Vehicle Assembly shall transmit the de-rated mode status via CAN.

The Vehicle Assembly shall transmit an error message via CAN if a request to operate outside of normal parameters is received.

3.5.4.5 Material Interfaces

The Vehicle Assembly shall not exchange any physical material with any other system.

3.5.5 Hardware & Software Design Requirements

3.5.5.1 Processors, Memory & Software

The Vehicle Assembly shall store key parameters (details to be defined) in non-volatile memory prior to shut down.

The Vehicle Assembly shall recover and operate normally and safely in the event of these parameters being corrupted or not saved.

The Vehicle Assembly shall be able to store its own faults in memory.

The Vehicle Assembly shall store the Vehicle Identification Number (VIN) electronically in memory.

3.5.5.2 Electrical / Electronic Design

The Vehicle Assembly should comply with the requirements of Requirements for Soldered Electrical and Electronic Assemblies IPC J-STD-001.

The Vehicle Assembly should be designed in accordance with Generic Standard on Printed Board Design IPC-2221.

The Vehicle Assembly should comply with the requirements for the manufacture of electrical and electronic assemblies as defined in Acceptability of Electronic Assemblies IPC-A-610.

The Vehicle Assembly shall provide an isolation barrier (e.g. galvanic / optical) between LV and HV circuits.

The measured insulation resistance between LV and HV circuits shall be 2 mega ohms according with the FMVSS 305.

The Vehicle Assembly shall withstand an applied voltage of 2.5 kV between the HV and LV circuits.

The Vehicle Assembly shall withstand an applied voltage of 2.5 kV between the HV and Ground circuits.

3.5.5.3 Low Voltage Energy Management

The Vehicle Assembly shall be capable of receiving beacons in all operational modes.

The Vehicle Assembly shall support "Wake On Beacon".

3.5.5.4 Low Voltage Power Interrupts & Reverse Polarity

The Vehicle Assembly shall be robust to power interruptions and reverse polarity on the LV bus, in respect of the Low Voltage Transients test procedures.

The Vehicle Assembly shall be robust to power interruptions and reverse polarity on the LV bus, in respect of the Low Voltage Vehicle Electrical System Testing.

The Vehicle Assembly shall not be damaged under any operating condition by a short circuit of any Low Voltage supply.

The Vehicle Assembly shall not be damaged under any operating condition by the disconnection of any Low Voltage supply.

The Vehicle Assembly shall protect against HV overshoot and potential damage to the HV output in the event of the HV battery being suddenly disconnected from the HV bus.

3.5.5.5 High Voltage Fault Detection

The Vehicle Assembly shall detect for open circuit conditions on its HV DC connector.

If the Vehicle Assembly detects an open circuit on its HV DC connector, the WPT shall shutdown in a controlled manner.

If the Vehicle Assembly detects an open circuit on its HV DC connector, any demand from the CAN bus shall be ignored.

If the Vehicle Assembly detects an open circuit on its HV DC connector, the event shall be transmitted via CAN.

If the Vehicle Assembly detects an open circuit on its HV DC connector, relevant diagnostic data shall be stored in internal non-volatile memory.

The Vehicle Assembly shall detect for short circuit conditions on its HV DC connector.

If the Vehicle Assembly detects a short circuit on its HV DC connector, the WPT shall shutdown in a controlled manner.

If the Vehicle Assembly detects a short circuit on its HV DC connector, any demand from the CAN bus shall be ignored.

If the Vehicle Assembly detects a short circuit on its HV DC connector, the event shall be transmitted via CAN.

If the Vehicle Assembly detects a short circuit on its HV DC connector, relevant diagnostic data shall be stored in internal non-volatile memory.

The Vehicle Assembly shall detect for over voltage conditions on its HV DC connector.

Over voltage shall be defined as a voltage greater than 450 V DC on the HV DC connector.

Over voltage detection shall be made by hardware, not software.

If the Vehicle Assembly detects an over voltage on its HV DC connector, any demand from the CAN bus shall be ignored.

If the Vehicle Assembly detects an over voltage on its HV DC connector, relevant diagnostic data shall be stored in internal non-volatile memory.

Severe overvoltage (>500V) shall not be foreseen in the design and it shall be accepted that it might result destructive to the device.

The Vehicle Assembly shall detect for under voltage conditions on its HV DC connector.

Under voltage shall be defines as a voltage less than 250 V DC on the HV DC connector

Under voltage detection may be made by software evaluation.

If the Vehicle Assembly detects an under voltage on its HV DC connector, the WPT shall stop transferring power.

If the Vehicle Assembly detects an under voltage on its HV DC connector, any demand from the CAN bus shall be ignored.

If the Vehicle Assembly detects an under voltage on its HV DC connector, the event shall be transmitted via CAN.

If the Vehicle Assembly detects an under voltage on its HV DC connector, relevant diagnostic data shall be stored in internal non-volatile memory.

3.5.5.6 CAN Communications

The Vehicle Assembly CAN communications should conform to standard requirements for CAN Network Management Components.

The Vehicle Assembly CAN communications should be aligned with the design rules for Robust Controller Area Network Monitoring.

The Vehicle Assembly CAN communications should be aligned with the requirements of Engineering Standard for Communication Layer.

The Vehicle Assembly CAN physical layer should be aligned with CAN & LIN Approved Components.

3.5.5.7 Diagnostics

The Vehicle Assembly shall generate Diagnostic Trouble Codes (DTCs) when a fault occurs.

The Vehicle Assembly shall perform Initialisation Built In Test (IBIT), as defined by ISO 26262.

The IBIT shall test the status of each Vehicle Assembly interface.

The IBIT shall test all critical functions whose failure modes may impact the safe operation of the Vehicle Assembly.

The Vehicle Assembly shall perform Continuous Built In Test (CBIT), as defined by ISO 26262.

If a fault does not cause a user observable effect or warning, the Vehicle Assembly shall update a service log.

3.5.5.8 Hazardous Voltages

The Vehicle Assembly shall measure the value of the HV DC voltage present on its HV DC connector, as part of the vehicle High Voltage Interlock (HVIL) system, with a resolution of +/- 2 V (between 0 to 60 V DC) and +/- 4 V (between 60 to 500 V DC).

The Vehicle Assembly shall detect the detachment of all of its HV connectors via a hardwired interlock system.

The Vehicle Assembly shall ensure that in the event of a loss of communications, or in the event of its inability to perform active discharge, that internal capacitance is passively discharged to below 60 V in less than 60 seconds of the event occurring.

3.5.5.9 Temperature Monitoring

The Vehicle Assembly shall monitor the temperature of all major semiconductor components.

NOTE: The list of components has to be defined for final design.

The Vehicle Assembly shall monitor the temperature of all major magnetic components.

NOTE: The list of components has to be defined for final design.

The Vehicle Assembly shall measure the temperature of all heat sinks.

NOTE: details on the methods have to be defined for final design.

3.5.5.10 Connectors

The Vehicle Assembly LV connectors shall be of latching type.

The Vehicle Assembly HV connectors shall be of latching type or bolt down type.

The Vehicle Assembly connectors shall be polarised to ensure that it is not possible to misconnect a connector.

The Vehicle Assembly connectors shall have sufficient spare capacity to allow for 20% interface growth, if the connector includes LV electrical signal interfaces.

3.5.6 Mechanical Requirements

3.5.6.1 Mass and Geometry

The Vehicle Assembly should have a package volume less than 20L.

The Regulator should have a package volume less than 10 L.

The Pickup should have a width (X) no greater than 400 mm.

The Pickup should have a length (Y) no greater than 500 mm.

The Pickup should have a thickness (Z) no greater than 30 mm.

3.5.7 Environmental Requirements

3.5.7.1 General

The Vehicle Assembly shall meet the applicable parts of Road vehicles – Environmental conditions and testing for electrical and electronic equipment. ISO 16750.

3.5.7.2 Thermal & Solar

The Vehicle Assembly shall not suffer deterioration in performance or malfunction (temporary or permanently) when operating within an ambient temperature range of -30°C to +50°C.

The Vehicle Assembly shall not suffer any permanent deterioration in performance or malfunction when not operational within an ambient temperature range of -40°C to +85°C.

The Vehicle Assembly shall not suffer deterioration in performance or malfunction (temporary or permanently), while operating, when exposed to an outer case temperature rate of change of greater than or equal to 10°C/min.

The Vehicle Assembly shall not suffer any permanent deterioration in performance or malfunction, while not operational, when exposed to an outer case temperature rate of change of greater than or equal to 20°C/min.

The Vehicle Assembly shall not suffer any permanent deterioration in performance or malfunction, while not operational, when exposed to an outer case temperature step change of greater than or equal to 40°C.

3.5.7.3 Fluid Ingress

The Vehicle Assembly shall be sealed to IPX7, as defined in IEC 60529 and ISO 20653.

The Vehicle Assembly shall be sealed to IPX9k, as defined in IEC 60529 and ISO 20653.

3.5.7.4 Humidity

The Vehicle Assembly shall not suffer deterioration in performance or malfunction (temporary or permanently) within 0% RH to 100% RH relative humidity.

3.5.7.5 Salt, Dust & Chemical Resistance

The Vehicle Assembly shall be sealed to IP6X, as defined in IEC 60529 and ISO 20653.

The Vehicle Assembly shall not suffer deterioration in performance or malfunction (temporary or permanently) within a maximum salt mist concentration of 5 % salt water solution.

3.5.7.6 Noise, Vibration and Harshness

The Vehicle Assembly shall meet the vibration requirements of a component located 'On the Body near Suspension mounting points'.

The Vehicle Assembly shall not produce audible buzzes, squeaks or rattles when exposed to the vibration profile.

3.5.7.7 Mechanical Shock & Handling Drop

The Vehicle Assembly shall not suffer deterioration in performance or malfunction (temporary or permanently) following a Medium Mechanical Shock.

3.5.7.8 EMC Immunity Requirements

The Vehicle Assembly shall meet the requirements of Electromagnetic Compatibility Specification For Electrical/Electronic Components and Subsystems specified in automotive EMC Standards.

The Vehicle Assembly shall be defined as an Active Electronic Module and shall be tested as (A), (AM) and (AY), within the specifications in automotive EMC Standards.

The Vehicle Assembly shall be defined as Class B for Functional Importance Classification, within the specifications in automotive EMC Standards.

The Vehicle Assembly shall be defined as Status 1 for Function Performance Status, within the specifications in automotive EMC Standards.

The Vehicle Assembly shall meet the requirements of Whole Vehicle EMC Standard specified in automotive EMC Standards.

3.5.8 Installation, Reliability, Maintenance

3.5.8.1 Reliability

The Vehicle Assembly shall not suffer deterioration in performance or malfunction (temporary or permanently) for a duration of 15 years or 150,000 miles, whichever occurs first.

The Vehicle Assembly shall not suffer deterioration in performance or malfunction (temporary or permanently) for 25,000 charging events.

The Vehicle Assembly shall not suffer deterioration in performance or malfunction (temporary or permanently) for 30,000 cumulative charging time.

The Vehicle Assembly shall not suffer deterioration in performance or malfunction (temporary or permanently) due to corrosion for a period of 15 years.

The Vehicle Assembly shall not suffer deterioration in performance or malfunction (temporary or permanently) due to corrosion within a period of 15 years.

The Vehicle Assembly should ensure fail-safe operation to 300,000 for the 99%ile charging cycle.

3.5.8.2 Maintenance & Service

The Vehicle Assembly shall not require any scheduled or periodic maintenance, but may require occasional superficial cleaning done by non-expert person.

The Vehicle Assembly should be removed and replaced by a trained service person, using standard service equipment tools, within 30 minutes.

4. Conclusion

The activities implemented during the task T5.4 “Design of services and specifications of the inductive automated wireless charging system”, have successfully led to the definition of a basic first prototype design of an operative wireless charging system for e-Cars, that can be clearly developed out of it, following the directives of the first main section of this deliverable D5.3 “INDUCAR system design”.

The first level prototype, typically the sample A in the automotive industry, is needed as a first step in every automotive development, and, although it can be executed out of the design freeze described in this document, further developments and iterative design improvement shall be done based on the execution and test of prototypes.

To successfully meet the objective of bringing this innovative technology to a user level, the D5.3 deliverable presents in its last section, a structured complete set of requirements necessary to ensure that the INDUCAR developments will lead to the implementation of an optimal operational wireless charging system. The result of this design improvement shall be the implementation of the final INDUCAR product with the performances, functionalities, and safety standards in line with the objectives of the USER-CHI project.

5. References and acronyms

5.1 References

[1] CETP.00.00-E-412 – Corporate Engineering Test Procedure Title: Electrical and Electronic Component Environmental CETP: 00.00-E-412 Compatibility Test.

[2] Directive 2004/104/EC – Commission Directive 2004/104/EC of 14 October 2004 European Automotive EMC directive.

[3] FMVSS 305 – National Highway Traffic Safety Administration (NHTSA) - Federal Motor Vehicle Safety Standard (FMVSS) No. 305 “Electric-powered vehicles".

[4] ICNIRP 2010 – ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1hz – 100 kHz) International Commission on Non-Ionizing Radiation Protection.

[5] IEC 60068-2-52 – International Standard Environmental testing – Part 2-52: Tests – Test Kb: Salt mist, cyclic (sodium chloride solution).

[6] IEC 60364-7-722:2018 – Low-voltage electrical installations - Part 7-722: Requirements for special installations or locations - Supplies for electric vehicles.

[7] IEC 60529:1989+AMD1:1999+AMD2:2013 CSV – Consolidated version - Degrees of protection provided by enclosures (IP Code).

[8] IEC 61000-3-11:2017 RLV – Redline version – 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.

[9] IEC 61000-3-12:2011 - Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and ≤ 75 A per phase.

[10] IEC 61000-3-2:2018+AMD1:2020 CSV – Consolidated version – Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤16 A per phase).

[11] IEC 61000-3-3:2013+AMD1:2017 CSV – Consolidated version – 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.

[12] IEC 61000-4-2:2008 – Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test.

[13] IEC 61000-4-3:2020 – Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test.

[14] IEC 61000-4-4:2012 RLV Redline version – Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test.

[15] IEC 61000-4-5:2014+AMD1:2017 CSV Consolidated version – Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test.

[16] IEC 61000-4-6:2013 – Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio – frequency fields.

[17] IEC 61439-5:2014 – Low-voltage switchgear and control gear assemblies – Part 5: Assemblies for power distribution in public networks.

[18] IEC 61439-7:2018 – Low-voltage switchgear and control gear assemblies – Part 7: Assemblies for specific applications such as marinas, camping sites, market squares, electric vehicle charging stations.

[19] IEC 61508:2010 CMV Commented version – Functional safety of electrical/ electronic/ programmable electronic safety-related systems – Parts 1 to 7 together with a Commented version.

[20] IEC 61851-1:2017 – Electric vehicle conductive charging system – Part 1: General requirements.

[21] IEC 61851-21-1:2017 – Electric vehicle conductive charging system – Part 21-1 Electric vehicle on-board charger EMC requirements for conductive connection to AC/DC supply.

[22] IEC 61851-21-2:2018 – Electric vehicle conductive charging system – Part 21-2: Electric vehicle requirements for conductive connection to an AC/DC supply – EMC requirements for off board electric vehicle charging systems.

[23] IEC 61851-23:2014 – Electric vehicle conductive charging system – Part 23: DC electric vehicle charging station.

[24] IEC 61980-1:2020 – Electric vehicle wireless power transfer (WPT) systems.

[25] IEC 61980-1:2020 – Electric vehicle wireless power transfer (WPT) systems – Part 1: General requirements.

[26] IPC-J-STD-001H – Requirements for Soldered Electrical and Electronic Assemblies.

[27] IPC-2221 – Generic Standard on Printed Board Design.

[28] IPC-A-610 – Acceptability of Electronics Assemblies.

[29] ISO 15118 – Road vehicles - Vehicle to grid communication interface

[30] ISO 16750 – Road vehicles – Environmental conditions and electrical testing for electrical and electronic equipment

[31] ISO 20653:2013 – Road vehicles – Degrees of protection (IP code) – Protection of electrical equipment against foreign objects, water and access.

[32] ISO 26262 – Road vehicles – Functional safety.

[33] ISO 6469 – Electrically propelled road vehicles. Safety specifications.

[34] ISO/IEC 17409:2020 – Electrically propelled road vehicles – Conductive power transfer – Safety requirements.

[35] ISO/IEC 19363:2020 – Electrically propelled road vehicles – Magnetic field wireless power transfer – Safety and interoperability requirements.

[36] SAE J2894 – Power Quality Requirements for Plug-In Electric Vehicle Chargers

[37] UNECE R.100 – Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train Addendum 99: Regulation No. 100.

5.2 Acronyms

Acronym	Meaning
AMB	Área Metropolitana de Barcelona
BIT	Built In Test
CBIT	Continuous Built In Test
D	Deliverable
DE	Deutschland / Germany
DTC	Diagnostic Trouble Code
EC	European Commission
ETRA	ETRA I+D (project partner)
EVCC	Electric Vehicle Communications Controller
EMC	Electro Magnetic Compatibility
FOD	Foreign Object Detection
FMVSS	Federal Motor Vehicle Safety Standard
GA	Grant Agreement
HV	High Voltage
IBIT	Initialisation Built In Test
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
LV	Low Voltage
O	Objective
MOD	Metal Object Detection
P	Product
PBIT	Power down Built In Test
RCD	Residual-current device
SECC	Supply Equipment Communications Controller
SOW	Statement of Work
USER-CHI	Project Title: innovative solution for USER centric CHarging Infrastructure
VIN	Vehicle Identification Number
WP	Work Package
WPT	Wireless Power Transfer