Position Paper of Charging Interface Initiative e.V.

Automatic Connection Device Interface for automatic conductive charging

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Contents

1 Introduction

As today's charging systems become more powerful in each generation we need to find ways to utilize this infrastructure as efficiently as possible. At the same time as autonomous driving is about to hit the consumer market, which provides new possibilities for a fully automatic customer experience. Despite efforts in wireless power transfer and automatic charging solutions for electric commercial vehicles[1] there are currently no practical harmonization efforts for an automatic conductive charging solution for passenger cars.

To address the lack in harmonization the CharIN subgroup "Automatic Connection Device interface" was established with a focus on passenger cars. CharIN is dedicated to develop and establish the Combined Charging System (CCS) as the standard for charging Battery Electric Vehicles (BEVs) of all kinds.

1.1 Situation today

Today's manual charging systems are commonly used with different standards for every market. The consumer is using an additional cable to connect the EV with the EVSE, so the user is missing an easy way to charge the EV.

Customers have to handle problems with the charging cable like:

- The charging cable is heavy caused by high power transfers and user protection
- The charging cable is dirty caused by the usage around the car on the street
- The charging cable is not flexible and difficult to handle related to the weight and thickness

Simplifying this process will help users adapt to electric vehical mobility. .

1.2 Possible future situation and significance of an Automatic Connection Device

As robotic technologies become more commercialy accessible, it is reasonable to expect customers will expect similar developments in the e-mobility sector. Therefore, a common interface is needed in order to enable manufacturers to develop a variety of solutions for infrastructure providers and end users. As autonomous parking features gain more importance we will soon come to a point where automatic conductive charging is a necessary step in an automatic parking process. Only when the customer is given a seamless experience where they don't need to care about charging, is their barrier to entry lowered. The best charging experience is the one that is not experienced at all.

[1] in this document the term commercial vehicles refers to electric busses and trucks

Besides the pure comfort functionality of an ACD, we face increasing charging powers in the near future which make charging cables become bulky, unsafe and difficult to handle for customers. Also it may be possible that in the future there will be limits on the power levels an individual, consumer operator is allowed to handle.

As charging infrastructure with high power presents a large investment, any equipment purchaser is intrinsically invested in maximum operational utilization. It will be highly attractive to apply automatic charging in combination with autonomous driving in order to utilize the infrastructure efficiently. This may also reduce the number of necessary charging ports.

Naturally a provider will only implement interoperable systems which offer a maximum of flexibility and the highest expected customer usage. These factors are the keys to guarantee investment long term returns for the providers.

For providers of electric car fleets an interoperable system is required to maintain independence from a single supplier of vehicles or infrastructure.

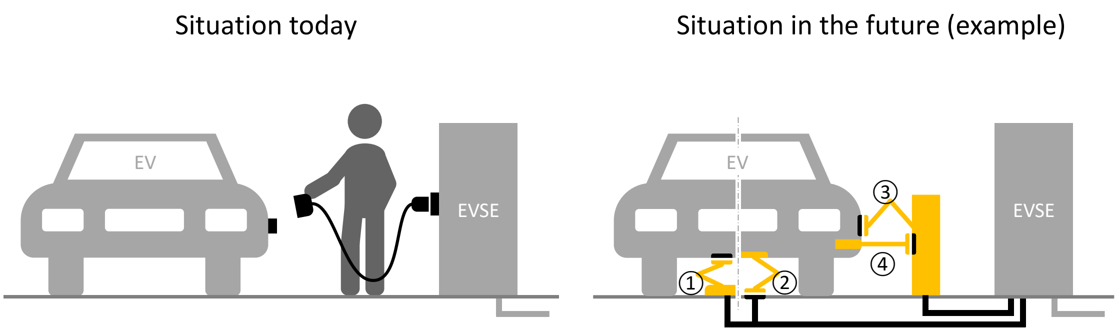


Figure 1, Vehicle charging situation today and in the future

Based on the before listed facts a possible future situation will be: Any autonomous or manually piloted EV will be able to drive to a chosen destination. After arrival at the destination, the EV can select an available parking spot and automatically interact with the available infrastructure to park and recharge its batteries. The EV will autonomously connect to the EVSE without the interaction of the user. Every vehicle that features an implementation of automatic parking also features the common automatic charging solution.

Whether the electric vehicle is manually or autonomously piloted there is a significant benefit to automated charging. Energy management and billing will be automated and the charging experience will remove the customer from the charging process.

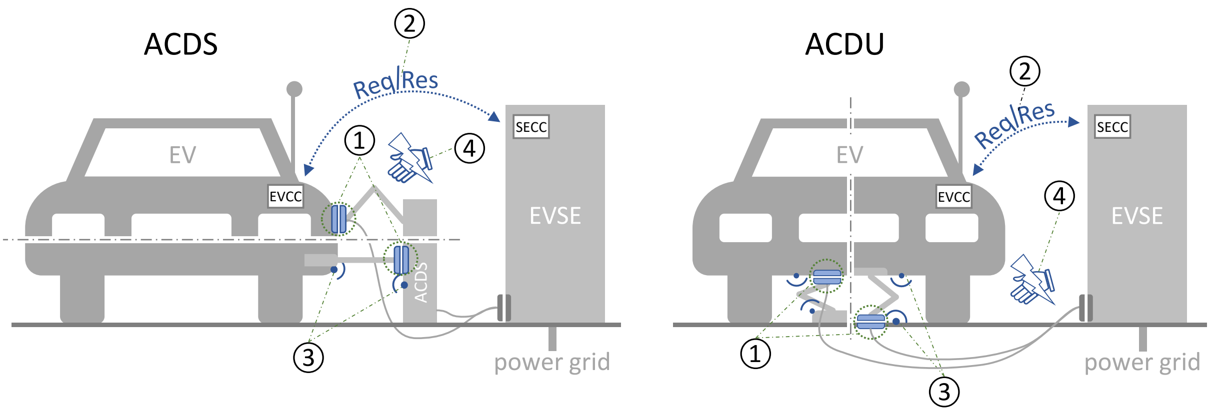
2 Scope

This position paper will focus on two different forms of automatic connection devices for passenger cars.

ACDS (Automatic Connection Device for the conventional Side connection interface) is a solution which uses the common vehicle inlet (CCS) on the vehicle side/front/rear that is used for manual charging for automatic connection. The connection interface on the vehicle may include a moving part as well.

ACDU (Automatic Connection Device for vehicle Underbody connection) applies an ACDU-specific connector located in the vehicle underbody so that the periphery of the vehicle is free while charging. In this application there may be moving parts in the vehicle and the ground unit.

Figure 2 shows in blue color which parts of an ACD-system will be in focus of the position paper.



① = Connection interface; ② = ACD relevant communication; ③ = Pairing and Positioning Device; ④ = Safety Consideration

Figure 2, ACDS and ACDU differentiation, topics covered by this position paper

An additional form will be mentioned here for reasons of completeness although it is not in the scope of this position paper.

ACDR (Automatic Connection Device for vehicle Roof-mounted connections) applies to solutions connected through a roof mounted piece of equipment. Passenger cars are excluded for reasons of safety, because of the accessibility of the roof area. The area around the vehicle is free in a connected state.

The goal of this CharIN position paper is a strategic enhancement of the Combined Charging System (CCS) from "manual charging system" (CCS Basic and CCS Extended) to include "automatic charging system” (Step 3, CCS Advanced) featuring an interoperable Automatic Connection Device (ACD) based on CCS (see Figure 3, charging technologies 3 and 4). It will be focusing on passenger cars although the communication interface, the ACDS interface and certain features of the ACDU interface shall be applicable to commercial vehicles as well.

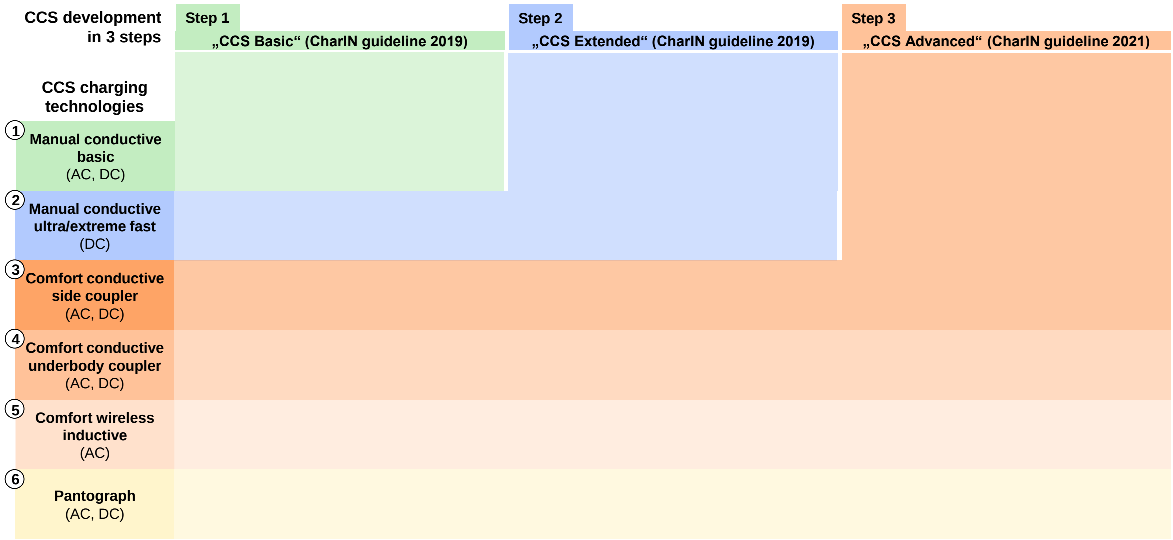


Figure 3, The functional-temporal CCS step model

The development of a charging technology is based on the parallel interconnected work of different parties, which act in the electric vehicle charging eco-system, in different types of organizations (see Figure 4). As shown in Figure 4, the interconnected work is done in five levels:

- Level A: Legislation
- Level B: Standardization
- Level C: Representation of interests
- Level D: Research
- Level E: Product development

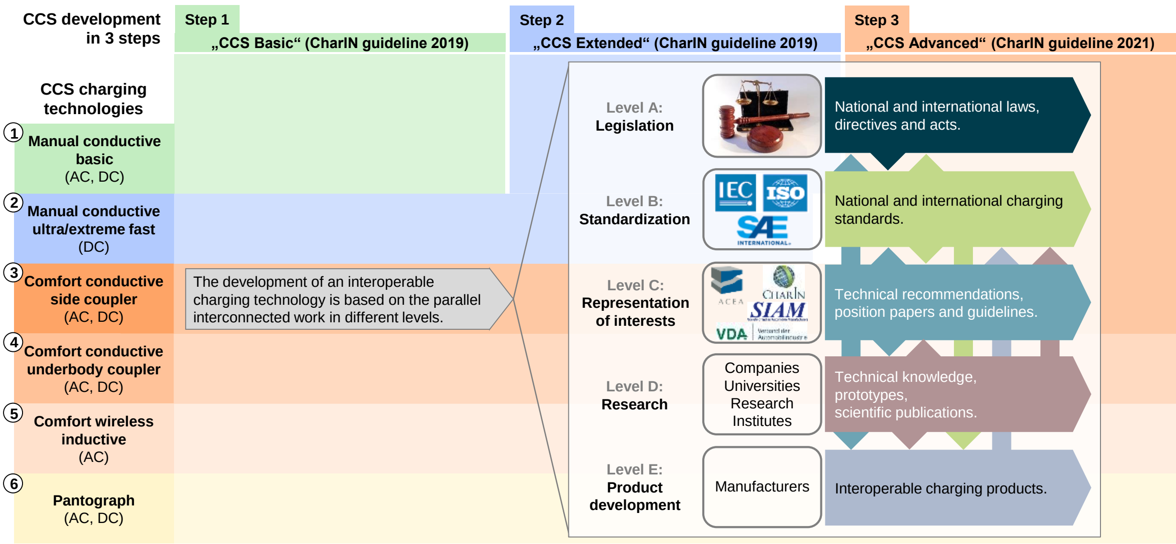


Figure 4, The functional-temporal CCS step model

The timeline to establish an ACD is determined by the timelines of the work in the different types of organizations in different levels (see Figure 4). A timeline to have a CCS product (ACD) in the market at a certain time in future is shown below exemplary (see Figure 5)."

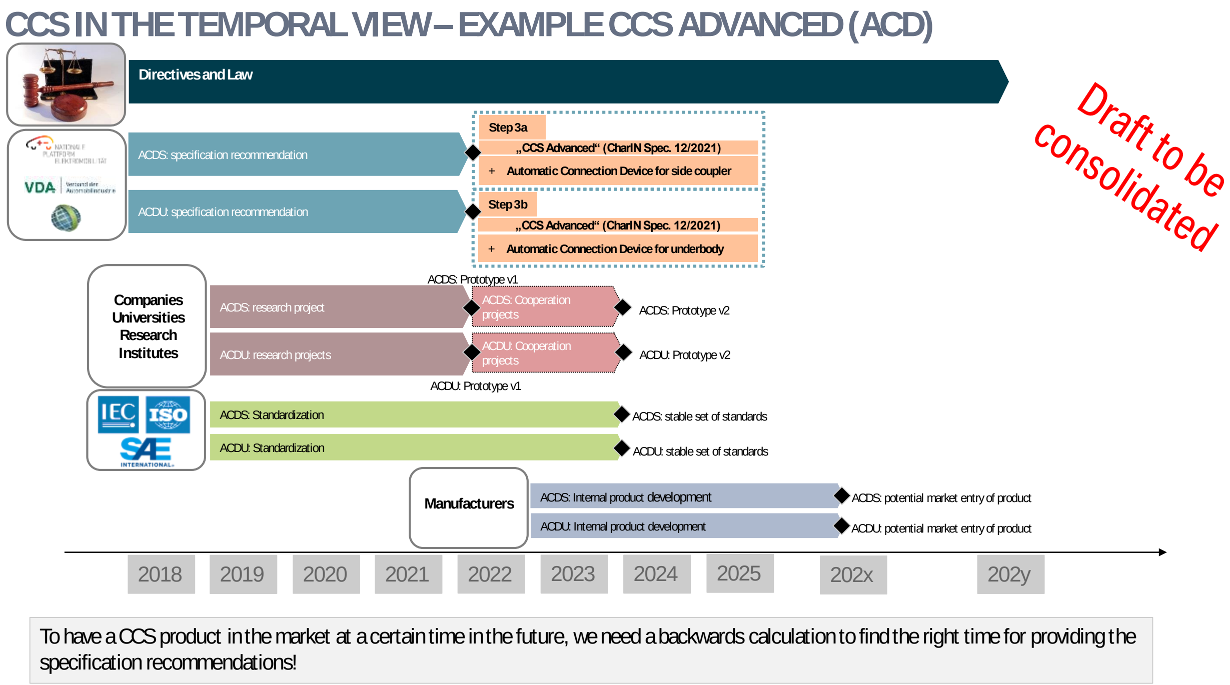


Figure 5, CCS in the temporal view – example CCS advanced (ACD)

This document is not intended as a specification but rather as a recommendation by the CharIN members on how to implement an ACD-system, its communication and its physical connection in order to achieve an interoperable system. Specification on technical details in this position paper are not expected to be as specific as would be expected in the ultimate standard, rather members of this focus group intend to give guidance on develop of such systems to inform future standards.

The position paper considers topics relevant for interoperability of ACS. While edition 1 focuses mostly on interoperability issues of ACD systems, edition 2 is expected include significantly more technical details. These details include:

- Connection interface between vehicle and infrastructure including a range of possible positions and environmental requirements
- Definition of vehicle positioning, active positioning, pairing, description of vehicle guidance systems, and interaction of infrastructure and vehicle
- Communication (includes for example authentication)
- An overall safety consideration to check for already covered topics and open points need to be addressed with proposals
- Error handling of ACD-system

Topics, which are not directly related to interoperability, are not covered, as these have to be developed according to individual design guidelines or existing standards:

- Power control
- Mechatronic design of an ACD (besides connection interface)
- Environmental requirements of an ACD appliance (besides connection interface)

Beside the technical details a consolidation to the following listed questions shall be done in edition 2 to create a timeline for an ACD in the market based on a backwards calculation (see Figure 5).

- What are the key factors / drivers for using an interoperable automatic connection device in the CCS product family?
- When will the key factors / drivers occur?
- Which interoperable automatic connection device will prevail in long term or will there be a multiple interoperable ACD systems?
- Will one ACD be used for both home and public applications, or will there be a separate home and commercial system?
- When will the dominant home and public ACD be commercially available?

3 General requirements and premises

The ACD-interfaces referenced in this position paper shall generally be applicable to all use cases mentioned in chapter 4. While the connection interface shall be interoperably usable for the mentioned use cases, it is up to the manufacturer to develop a specific system for a subset of use cases. This means that a manufacturer may develop an ACD that only supports AC charging, but this system MUST be able to connect to a vehicle inlet that supports automatic connection of both AC and DC chargers. Also even sole home applications shall be interoperable and exchangeable for a higher customer usability. The acquisition of such a system shall guarantee a future-proof investment for a customer.

The development of the present ACD-interface is influenced by the following premises:

- A customer does not need to care about charging anymore. An automatic charging solution shall be comfortable and linked with automatic parking solutions. It shall also be usable for manual parking.
- The CharIN group aims to define the ACD-interface in a way that retrofitting[2] or upgrading[3] an automatic connection system to an existing charging infrastructure is possible.
- The vehicle interface shall universally cover low cost AC charging for home solutions as well as DC high power charging for public application.
- The communication for the connection process will be based on ISO 15118. The same communication protocol shall be used for all ACD charging options.
- The connection interface shall fulfill the same safety requirements as the present CCS interfaces.
- The focus is set on simple and cost effective solutions to increase the prevalence in market.
- An ACD-system shall offer position detection.
- Any parts of an ACD-system placed on ground need drive over protection.
- The ACD-interface shall support the same charging functionalities covered by conventional conductive charging, such as PnC, bi-directional charging, smart charging, etc.
- For the development of a new connection interface the same interface shall be supported for all markets worldwide.
- For an ACDS applying a backwards compatible connector, the vehicle connection interface may be placed at any position of the vehicle side reachable for a human user, specific parking positions may be used to reach the work space of an ACD-system.
- For an ACDU system a limited workspace and a specific position on the parking place will be defined for cost optimization and interoperability when the mechanical interface is specified. A specific parking position such as forward or reverse shall be avoided.

[2] "Retrofit" in this case means to add an ACD to an EVSE that was not originally designed work with an ACD.
[3] "Upgrade" in this case means to subsequently add an ACD to an EVSE that was designed to work with an ACD.

4 ACD use cases

The referred use cases of the ACD are a mix of use cases from NPE, CCS charging community use cases and on top additions of this subgroup ACD.

4.1 NPE use case baseline

The baseline of the description of the ACD-interface are the customer use cases of the NPE (National platform electro mobility) shown below. Letters from A to F were added to ensure an easy reference to the shown NPE use cases in the original picture. Furthermore relations to home, work and public charging are included.

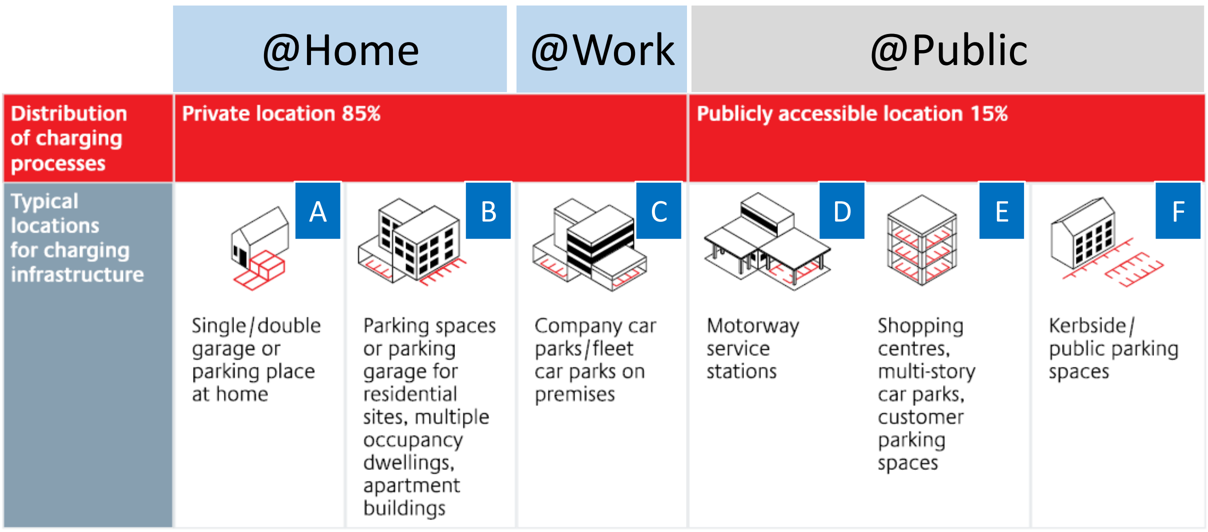


Figure 6, NPE use cases (Source NPE[4])

4.2 CCS charging community use cases

In order to focus the development of an interoperable ACD-interface on the most relevant use cases we try to estimate the current and future demand for automatic charging. Figure 7 includes the results from a study presented by McKinsey showing the energy demand for different charging use cases and regions.

[4] source: http://nationale-plattform-elektromobilitaet.de/fileadmin/user_upload/Redaktion/AG3_Statusbericht_LIS_2015_engl_klein_bf.pdf

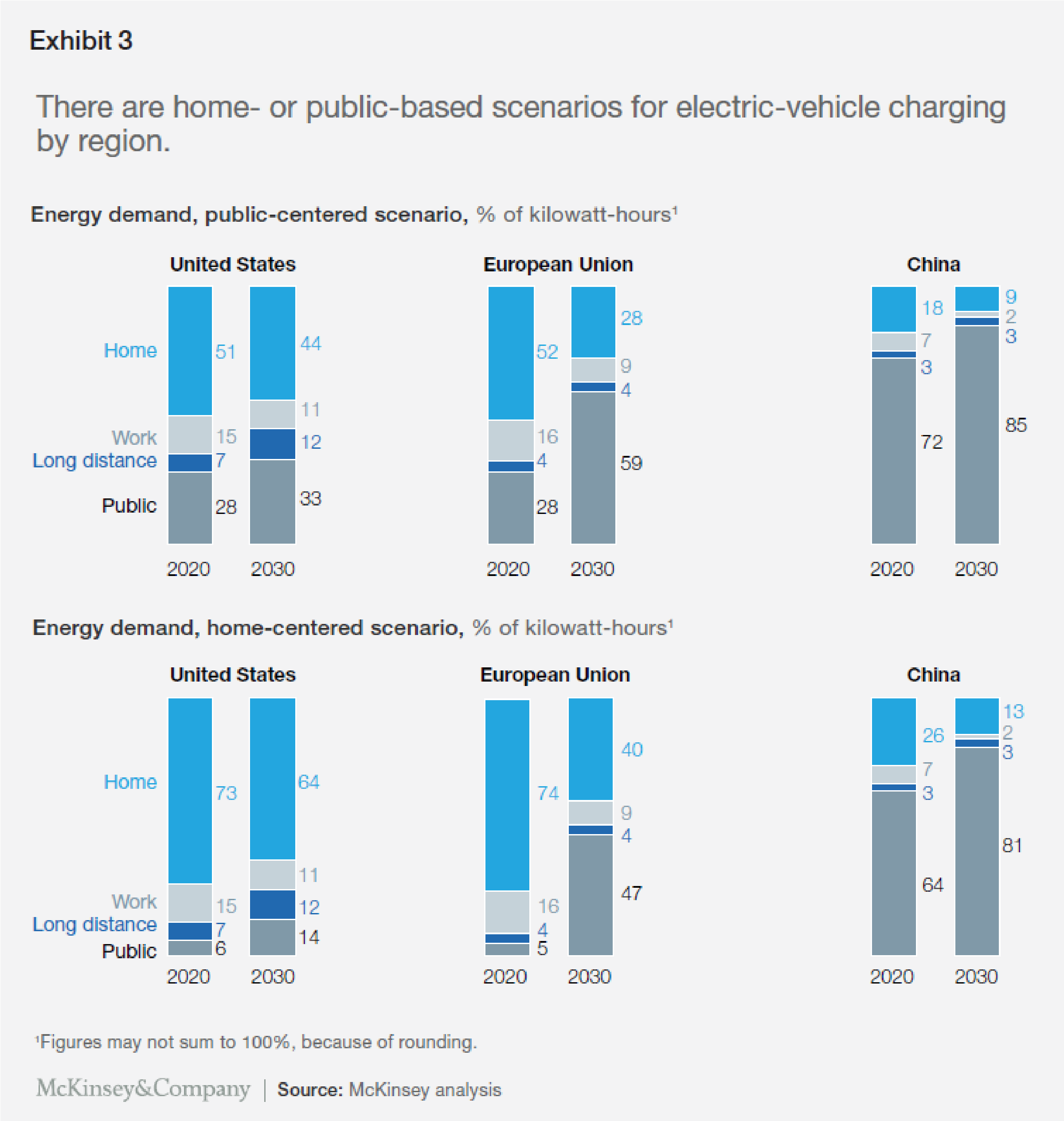


Figure 7, McKinsey analysis of future scenarios for electric vehicle charging[5]

From these analyses results and the above mentioned NPE use cases we can derive the customer relevance of charging use cases for the European and North American market. The following Figure 8 shows these use cases sorted by relevance followed by more detailed descriptions.

[5] Exhibit from "Charging ahead: Electric-vehicle infrastructure demand", August 2018, McKinsey & Company, www.mckinsey.com.

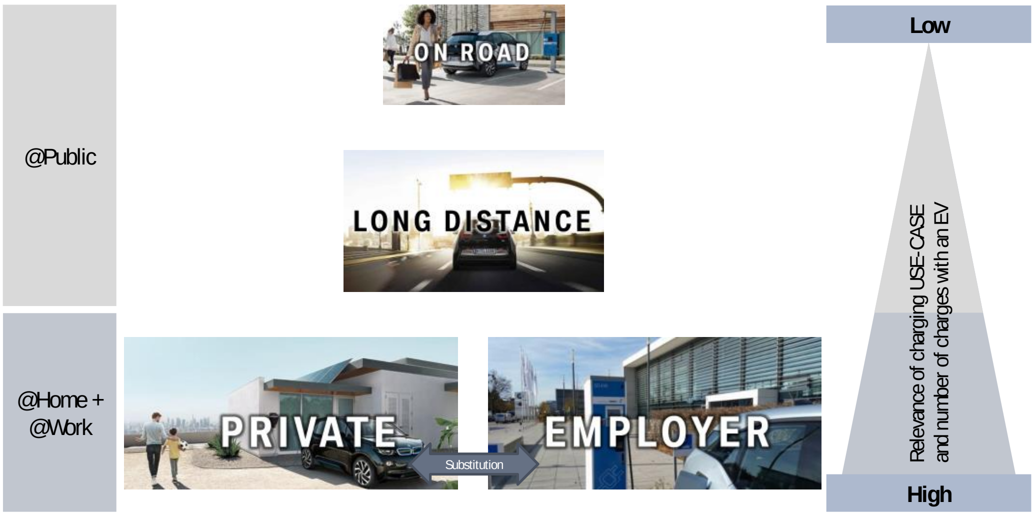


Figure 8, Private charging at home, at work and at public

The most common use case for automatic charging is at the owners home, or at their place of work (Employer). Medium relevance for charging is at long distances and the lowest charging relevance is to be found at public charging on the road. For automatic charging, long distance charging is regarded more relevant than public charging, because it is more critical regarding charging time and utilization of equipment.

According to the CCS charging community private charging includes two solutions. One solution contains manual charging (see Figure 9). The second solution will be automatic charging by a comfort charging system (ACD and inductive charging system; see Figure 10)

Premises

Proportional charging frequency	high
Infrastructure	AC
Infrastructural charging power	EU: 11 kW, max. 22 kW US: 7.4 kW, partly 11-15 kW CN: 7.4 kW, partly 11-22 kW
Charging Accessories	Wallbox / Charging cable
NPE Use Case	A; B

Manual - „Full charging overnight"

Description

- Home charging takes place mostly at night. Customers place vehicles on private parking space with charging possibility and charge.
- Private overnight charging substitutes semi-public charging at work during the day

Requirement

- Charging the vehicle must be possible within max. 9 hours
- Options for customers: immediate charging, departure time charging, DCS controlled charging
- Pre conditioning can be expected depending on the individual customer profile.
- Full charging depends heavily on the individual driving profile and is not required daily
- Full charging is required after long distance trips for subsequent, complete ride and reduced DC charge rates. e.g. return from a weekend trip and start a business trip on the following day.
- Full charging is required before long distance trips for subsequent, complete ride and reduced DC charge rates. e.g. return from daily commute and start of holiday trip on the following day in the morning.
- There must be a simple and intelligent billing and authentication solution available
- For company car user, legal compliance solutions are required
- To achieve high TCO (Total Cost of Ownership) benefits, charging must be cheap

Figure 9, Private manual charging overnight

Premises	
	
Proportional charging frequency	high
Infrastructure	AC
Infrastructural charging power	EU: 11 kW, max. 22 kW US: 7.4 kW, partly 11-15 kW CN: 7.4 kW, partly 11-22 kW
Charging Accessories	Comfort charging system (e.g.: inductive)
NPE Use Case	A; B

Comfort - „Full charging overnight“

Description

- Comfort charging will take place until further notice due to lack of standardization mainly in the private sector (charging overnight)
- Use case of comfort charging is analog to manual- private charging overnight

Requirement

- The investment in private comfort charging infrastructure substitutes the purchase of other charging equipment (Wallbox, etc.)
- In order to ensure the longest possible investment security, the standardization of the charging system should be strived for (OEM and cross-model interoperability).
- Positioning the vehicle / initiating the charging process must be more comfortable than conductive charging to wallbox / cable handling (speed, usability, etc.)
- Requirements analogous to "Private Charging Overnight"
- Pre conditioning can be expected depending on the individual customer profile

Figure 10, Private comfort-charging overnight (relevant for ACDS, ACDU and WPT)

Workplace charging (see Figure 11) with an EV is regarded as one of the most common of charging USE-Cases and number of charges with an EV (see Figure 8).

Premises	
	
Proportional charging frequency	high
Infrastructure	AC
Infrastructural charging power	EU: 11 kW, max. 22 kW US: 7.4 kW, partly 11-15 kW CN: 7.4 kW, partly 11-22 kW
Charging Accessories	Wallbox / Charging cable
NPE Use Case	C

„Full charging during working hours“

Description

- Workplace charging takes place mainly during working hours. Customers place vehicles on company-owned parking space with charging possibility.
- Assumption: (Semi-) public charging at work during the day substitutes private overnight charging

Requirement

- Charging the vehicle must be possible within max. 9 hours
- Options for customers: immediate charging, departure time charging, DCS controlled charging
- Pre conditioning can be expected depending on the individual customer profile.
- Full charging depends heavily on the individual driving profile and is not required daily
- Full charging is required after long distance trips for subsequent, complete ride and reduced DC charge rates. e.g. High amount of driving on the weekend without private charging and starting charging at the start of a work week and long distance driving in the evening.
- Full charging is required before long distance trips for subsequent, complete ride and reduced DC charge rates. e.g. full charging during the day before the departure of holiday trip after work in the evening.
- There must be a simple and intelligent billing and authentication solution available
- To achieve high TCO (Total Cost of Ownership) benefits, charging must be cheap

Figure 11, Workplace charging during the day

Public charging for long distance trips is rated as medium high relevance and includes the following specifications (see Figure 12).

Premises

Proportional charging frequency	Medium
Infrastructure	DC (HPC)
Infrastructural charging power	EU/US: 150-350kW in 350-500A CN: up to 175kW in 250A
Charging Accessories	-
NPE Use Case	D

„Recharging on long distance trips“

Description

- Charging takes place during long distance trips/route. It is expected to recharge a maximum range in a minimum time. From the customer's point of view, the charging rate "recharged kilometers/minute" is decisive here.
- Quickshot charging (high SOC stroke in a short time) is to ensure sufficient range at the destination, if charging is not possible there. For example, Short recharge on long distance before departure from the motorway in a rural area (ski resort, etc.) to ensure mobility on site.

Requirement

- To minimize charging stops / charging times, intelligent route guidance as well as real-time reservation of charging stations and simple usability or billing of the infrastructure ("plug and charge") are required
- Charging on long distance must be cheap (possibly higher willingness to pay than home charging)

Figure 12, Public charging on long distance trips

The importance of "public charging on the road" (see Figure 13) will increase in the future and will therefore be regarded for ACD-system development. Nevertheless the home use case will be developed as a first step according to its relevance in Figure 7 and Figure 8.

Premises

Proportional charging frequency	Low
Infrastructure	EU/US: AC; CN: AC/DC
Infrastructural charging power	EU: 11 kW, max. 22 kW US: 7.4 kW, partly 11-15 kW CN: 7.4 kW-80 kW
Charging Accessories	- / Charging cable
NPE Use Case	E; F

„Maximum recharging on the way“ or maximum SOC-stroke in 1-2 hours

Description

- Charging takes place (semi-) public during parking on the way (for example, during cinema, shopping, etc.).
- (Semi-) public charging takes place in addition to private charging overnight or charging at work during the day

Requirement

- Adjustable options for customers: immediate charging, departure time charging, DCS controlled charging
- Pre-air conditioning can be expected depending on the individual customer profile.
- Expectation: maximum charging-stroke during the parking time (among other things to the full utilization of free offers, etc.)
- There must be a simple and intelligent billing and authentication solution available
- Public charging must be cheap and represent an alternative to accruing parking costs

Figure 13, (Semi-) public charging on the destination or curb side

Additionally the CharIN subgroup considers the use case fleet charging. This could be a first enabler to automatic conductive charging as it is limited to a known number of privately owned vehicles charged on private ground with an interest in reduction of labor cost.

Premises

Charging frequency	high
Infrastructure	AC/DC
Infrastructural charging power	DC up to 350kW, AC max. power (market specific)
Charging accessories	-
NPE Use Case (s. Backup)	C&D

„Full charging in private depot during regular pause“

Description

- Primarily professional users such as logistics, company car pools but also for on demand mobility offer
- Charging takes place while the intensive utilized vehicle returns to a private depot and may be done in parallel to other activities such as cleaning, loading/unloading, driver replacement, etc.

Requirement

- Low or high variety of vehicles (depending on fleet use case); fleet with different vehicle brands is possible
- Proprietary charging solutions might be possible
- Standardized charging product and interoperability is preferred (especially due to variety of vehicles)
- Time optimized charging
- On demand mobility: maximum charging power needed („time is money“)
- Pre air conditioning

Figure 14, Fleet charging

4.3 Exemplary sequence chart in detail

. Because there is an uncountable number of ways to execute and automatic connection process, this paper cannot propose to detail all possible customer scenarios. The sequence chart matrix in Figure 15 gives an idea of the variety of options possible for automatic conductive charging process. A continuous top to bottom path corresponds to a single customer journey. For better understanding an exemplary path for a specific customer / place / time / vehicle is marked yellow in the overview matrix.

This matrix lists the individual steps involved in an automatic connection process with possible options on how a certain process step might be implemented. These process steps are then used to derive the process description and information exchange described in the next chapters. The IDs used in the sequence chart matrix (Figure 15) correspond to the IDs used in the derived sequence chart in chapter 5.

yellow cells: path of examplary customer journey

ID	item	option 1	option 2	option 3	option 4	option 5	option 6	option 7
	initial situation							
1	**NPE-typical location for charging infrastructure (related to NPE use cases)**	A - domestic garage or parking space	B - apartment building	C - employee parking	D - highway restaurants	E - customer parking (e.g. shopping centres)	F - public car parks	
	CharIN use case	private charging overnight	private comfort charging overnight	workplace charging during the day	public charging on long distance trips	(semi-) public charging on the road		
	ownership	private, person	private, company	semipublic, accessible to the public	public			
	vehicle occurence	single type of known vehicle	multiple types of known vehicles	multiple types of unknown vehicles				
	ACD availability	single known AP in reach	plurality of known APs in reach	single unknown AP in reach	plurality of unknown APs in reach			
	charging mode	mode 2 charging (AC)	mode 3 charging (AC)	mode 4 charging (DC)				
	smart charging	not available	available					
	bidirectional charging	not available	available					
	available charging power	EU: 11 kW, max. 22 kW	US: 7,4 kW, partly 11-15 kW	CN: 7,4 kW, partly 11-22 kW	CN: 7,4 kW-80 kW	EU/US: 150-350kW @350-500A	CN: up to 175kW @250A	
	available time for charging	short time (<30 min)	medium time (2 h)	half day (12 h)	long term parking (>1 day)			
	access point availability	one-to-one ralationship of AP and EVSE	one-to-many ralationship of AP and EVSE					
	surface of the ground	solid ground	grit					
	environmental conditions	Indoor (Garage or equal....)	Outdoor with shelter (underneath carport, roof,...)	outdoor without shelter				
	Position of ACD	fixed on ground	not fixed on ground	fixed on wall				
	preparation							
	driver/user	stays in EV during approach	driverless EV (locked)	driver disembarks before approach				
	automatic charging option enabled	by user via HMI	by user with app	automatically by circumstancas (slow driving)				
2.1	**wireless communication established**	EVSE SSID and password is known to vehicle	EVSE access point is open, EV connects to all available EVSE and broadcasts EVID					
2.2	**pairing**	first-time manual pairing necessary only, automatic connection subsequently	EVSE recognizes EVID via camera (registration plate) and confirms successful connection to EV	infra recognizes EVID via NFC or other technologie and confirms successful connection to EV				
	approach							
3	**EV compatibility check connector**	not necessary because proprietary system	EV sends service request, EVSE returns connector types, EV checks compatibility					
	EVSE compatibility check workspace	not necessary because proprietary system	EV sends position of connector, EVSE sends workspace polygon, EVSE calculates compatibility					
5.1	**positioning information**	no positioning information available	EVSE confirms when EV connector is within workspace	EV confirms when EVSE connector is in reach	relative distance of EV inlet and workspace of EVSE measured by EV	relative distance of EV inlet and workspace of EVSE measured by EVSE	EV calculates relative distance according to its absolute position (geo-coordinates), the EVSE workspace (geo-coordinates) and the EV inlet position	EVSE calculates relative distance of EV according to its absolute position (geo-coordinates), the EVSE workspace (geo-coordinates) and the EV inlet position
	EV approach	manual driving without guidance	manual driving with guidance for driver	autonomous driving without map	autonomous driving with detailed map and known absolute position			
	EV stop on final position	driver stops manually	autonomous driving function stops vehicle					
5.2	**EV immobilization of vehicle**	driver confirms connecting procedure, EV is immobilized	EV is immobilized automatically					

Figure 15, Exemplary sequence chart matrix (1/2)

	connection							
6	**EV connection preparation**	charging flap opens (side or underbody)	charging flap and additional DC-Pin flap opens	optional air suspension disabled	vehicle locked			
7.1	**EV connection request**	EV requests connection (readiness is confirmed implicitly)						
	connector misalignment	EV measures connector misalignment	EVSE measures connector misalignment					
	connection	EVSE connects	EV connects					
7.2	**connector locking**	connector is not locked	EV locks connector	EVSE locks connector				
	connection confirmation	EV confirms connection	EVSE confirms connection					
	charging							
8	**charging start**	starts automatically	waits for user input	waits for function input				
	charging pause possible	not available	available					
	suspend wireless communication	wireless communication stays on permanently	wireless communication suspends (sleep mode)					
	disconnection							
	reestablish wireless connection	wireless connection stays on permanently	EV establishes WiFi connection to EVSE automatically (timer)	EV establishes WiFi connection to EVSE by user request	EVSE wakes up EV via WoWLAN, EV establishes WiFi connection	EVSE wakes up EV via cable bound connection, EV establishes WiFi connection	EVSE or infrastructure wakes up EV via back-end, EV establishes WiFi connection	
9.1	**stop charging**	EV stops charging automatically	EV stops charging due to user request (HMI, App, etc.)	EVSE stops charging				
	EVSE disconnection preparation	no preparation necessary	EV requests readiness for disconnection, EVSE prepares					
	EVSE disconnection preparation confirmation	no preparation necessary	EVSE confirms readiness for disconnection					
	EV disconnection preparation	no preparation necessary	EV unlocks connector	EVSE requests readiness for disconnection, EV prepares				
	EV disconnection preparation confirmation	no preparation necessary	readiness is given implicitly by requesting disconnection	EV confirms readiness for disconnection				
9.2	**EV disconnection request**	EV requests disconnection	no request necessary					
	disconnection	EVSE disconnects	EV disconnects					
	disconnection confirmation	EVSE confirms disconnection	EV confirms disconnection					
10	**EV suspend communication session**	wireless communication terminated	wireless communication remains active for further actions					
	departure							
11	**EV preparation for departure**	no preparation necessary	EV closes charging flap automatically					
	EV readiness confirmation	EV confirms readiness to driver in HMI	EV confirms readiness to driver via app	EV confirms readiness to EVSE via WiFi	EV confirms readiness to EVSE or infrastructure via back-end			
12	**EV departure**	EV remains in position and goes to sleep mode	driver starts EV, EV is mobilized automatically, drives away manually	autonomous EV starts, EV is mobilized automatically, drives away autonomous				

Figure 16, Exemplary sequence chart matrix (2/2)

5 Process description

This chapter specifies the sequence chart of the automatic connection between EV and EVSE. The entirety of all steps involved from approach, connection, charging and disconnection is described as ACD-sequence.

The sequence chart describes an automated charging process using an Automatic Connection Device (ACD). Hereby the main steps are listed by using a structure organized by different windows. The windows are numbered from 1 up to 12 and labeled with the names of the main steps of the sequence chart. Each window position is representing a process. The processes can be executed in a row or parallel. The example sequence chart in Figure 17 shows the methodology of parallel and serial processes in the sequence chart (process 3 in a row to processes 4 and 5, and processes 4 and 5 in parallel).

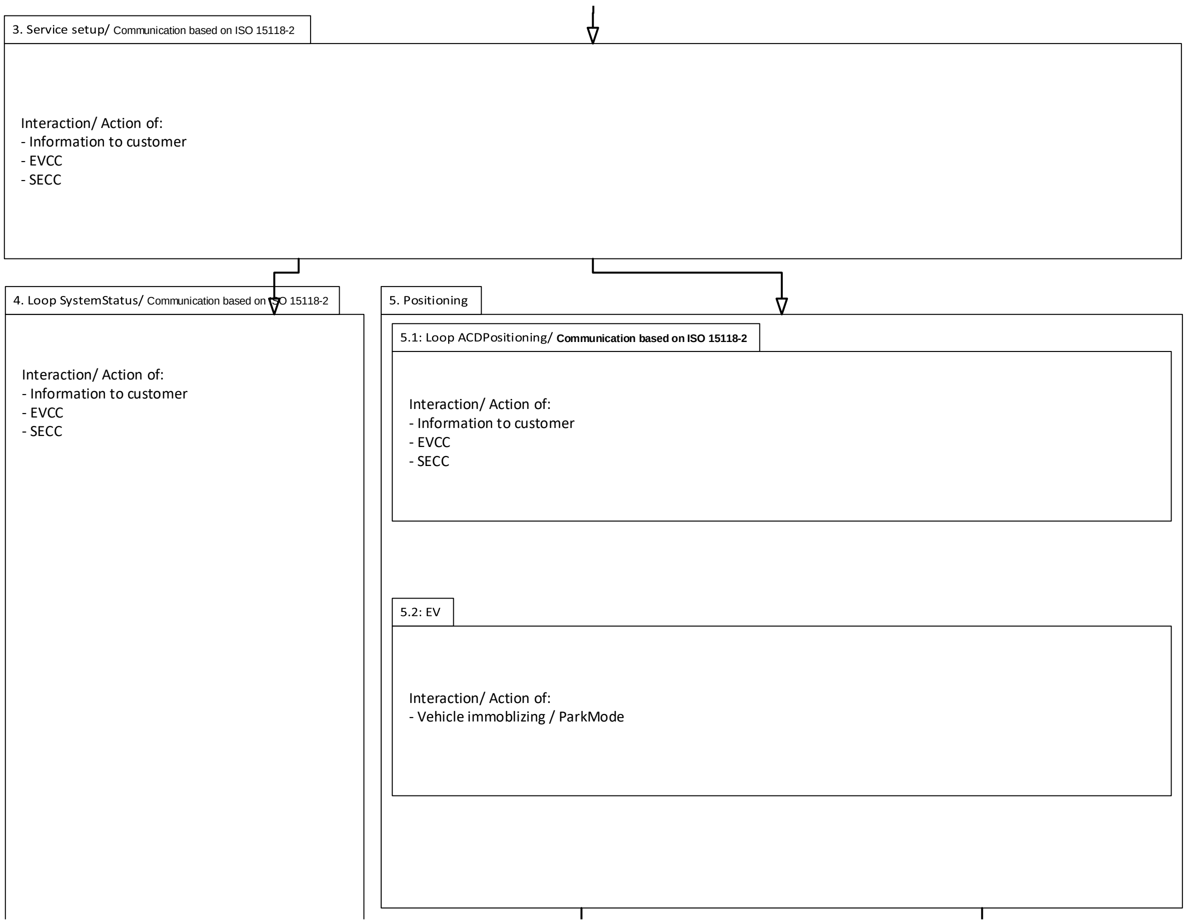


Figure 17, example snippet from sequence chart

Inside the windows are the actions or interactions defined with the involved partners. The starting situation is based on the shown "scenario" on the top of the customer sequence chart. Additionally to the sequence shown in Figure 18, the Edition 2 of the position paper will contain a detailed description of the message request and the message response by the different partner interactions. It should be noted that the sequence described here does not contain error handling.

Scenario:
Good case: customer wants to charge and leave after charging process

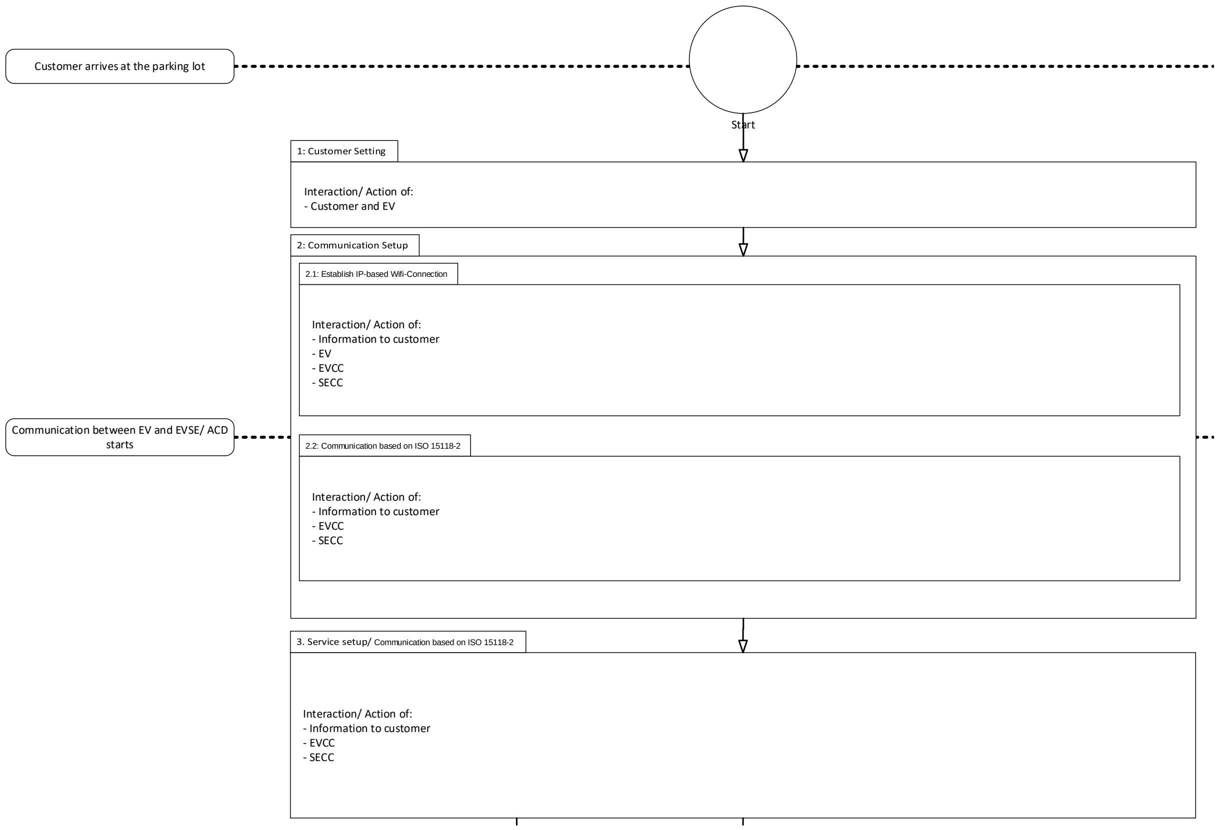


Figure 18, Sequence chart (1/5)

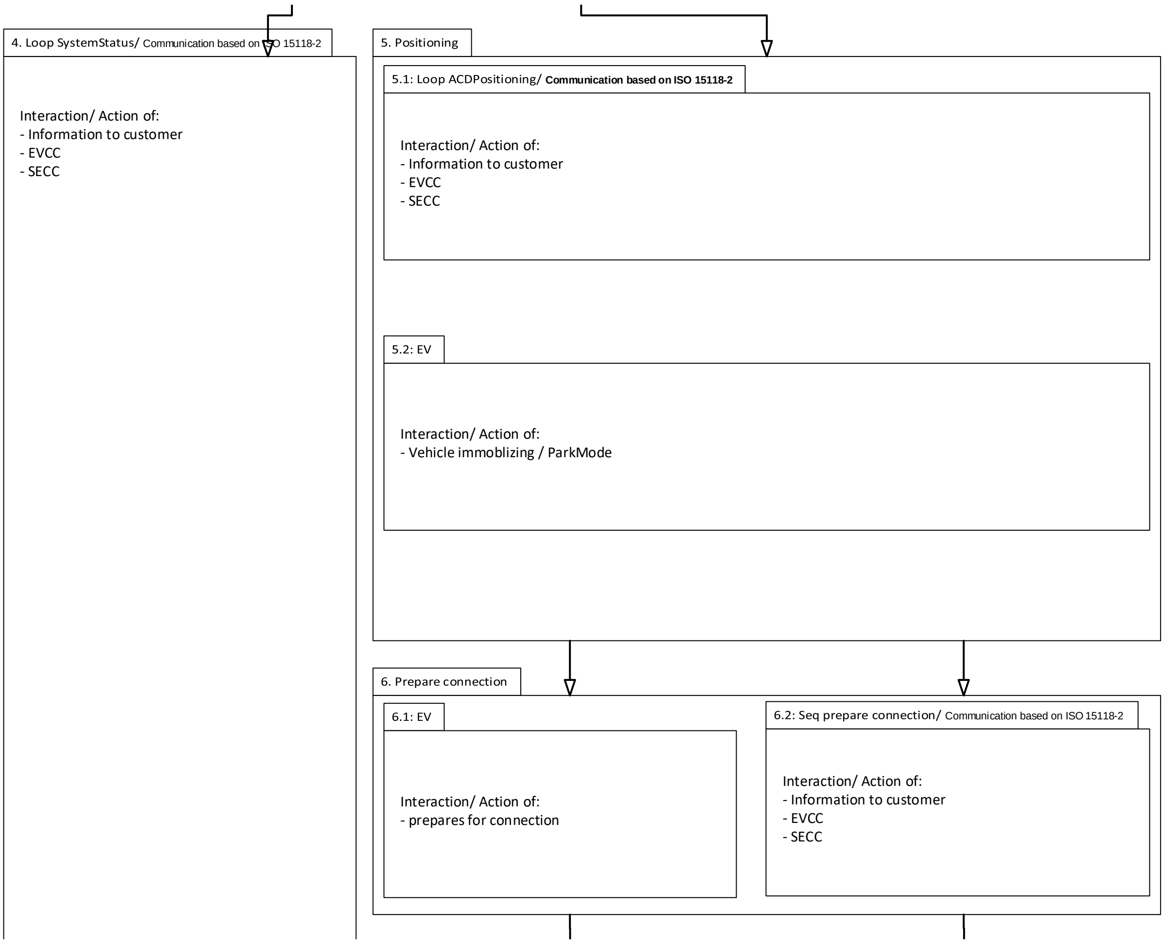


Figure 19, Sequence chart (2/5)

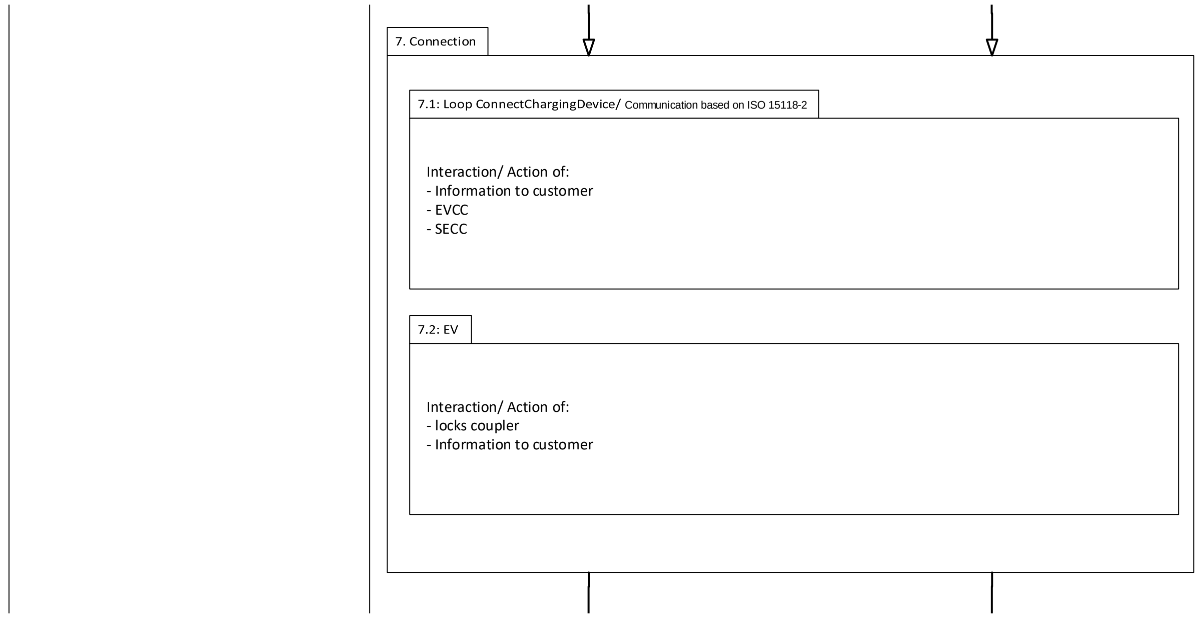


Figure 20: Sequence chart (3/5)

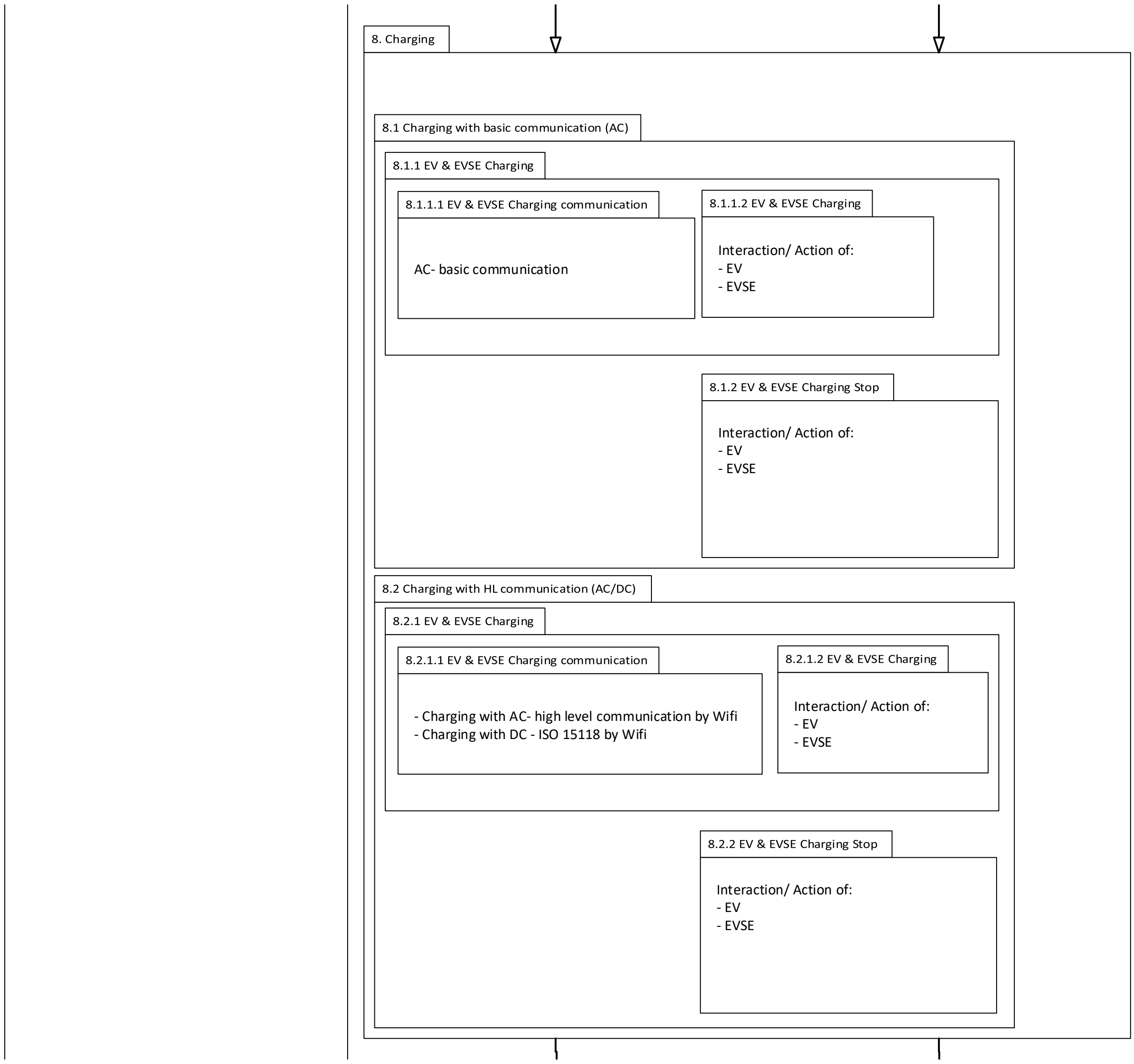


Figure 21: Sequence chart (4/5)

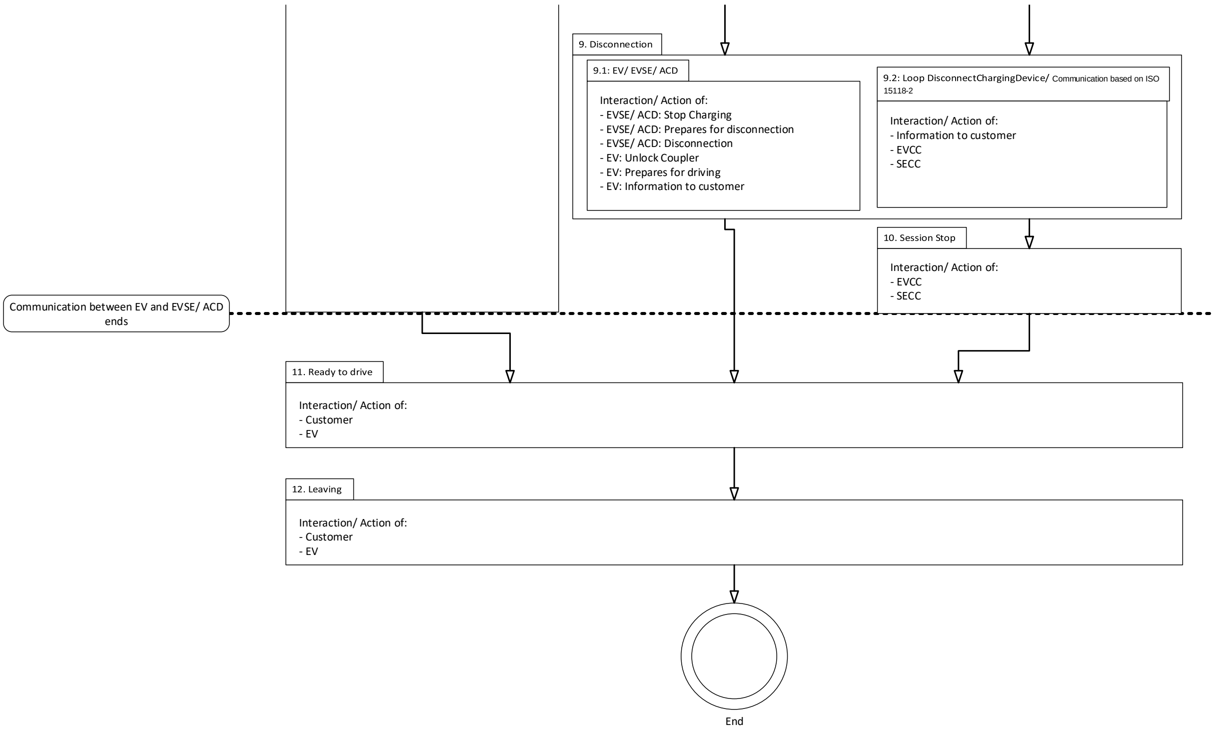


Figure 22: Sequence chart (5/5)

6 Communication interface

In order to achieve a robust communication interface between the EV and EVSE, many factors are involved and different communication methodologies are incorporated depending on the state of the EV. The different states can be broadly classified into the below categories.

- Approach and communication setup (wireless)
- Positioning (wireless)
- Prepare connection (wireless)
- Connection (wired and wireless)
- Charging (wired and wireless)
- Disconnection (wired and wireless)

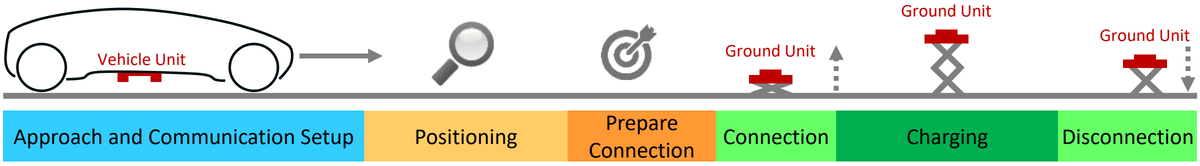


Figure 23, EV states during ACD charging process

Wireless communication primarily covers all communication prior to charging event. During the charging event the communication shall be wired or wireless according to ISO 15118 or the respective standards for conductive charging (e.g. Control Pilot PWM). CharIN recommends to retain the same communication path (wireless) over the entire process.

The wireless communication between infrastructure and vehicle will not be considered safety relevant. Each component has to fulfill its safety requirements without the need of communication.

CharIN recommends that the communication for ACD shall be based on and compatible with conventional communication for manual charging. Therefore the ACD related communication is modularized and can be fitted on the existing charging related communication description.

The communication interface described in this position paper shall be applicable for passenger cars as well as commercial vehicles.

6.1 Wireless communication setup

The first step in this process is to establish a wireless link (WLAN) between the EV and EVSE according ISO 15118-8. In this phase, the link between the EV and EVSE shall be authenticated. It is important that the charging network has information of the EVs using a network to authenticate the connection. In order to protect the link from unauthorized sources, security measures shall be in place. Once the connection is established, the EV and EVSE can communicate the necessary signals to initiate the charging process up to the point when the EVSE ends charging and the EV is ready to complete the charging process.

6.2 Extended message set

In order to establish and perform an automatic connection process an ACD-system shall utilize the message set according to ISO 15118-20. Furthermore, the CharIN group recommends an extended set of messages and parameters related to the ISO 15118-20 to adapt the message set to the needs of passenger cars. These additional parameters shall support the ACD-systems according to chapter 2. The parameter set is described on a high level, as a higher degree of detail will be part of the actual standardization process within the official standardization bodies.

The following list shows the information exchange between EV and EVSE according to ISO 15118. Any proposed additions or changes are listed below the specific signal. Signals that are marked grey represent information that are not ACD specific but are added for reasons of better overview.

- Communication setup with SECC discovery Protocol (SDP)
  - To set up the communication between EVCC and SECC it is recommended to locally communicate the EVID independent from WLAN communication. This will give the SECC the opportunity to make sure it is communicating to the right EVCC by comparing the EVID received via WLAN and received locally. This local communication could for instance be done optically or via locally limited radio wave signals.
- supportedAppProtocol
- SessionSetup
- ServiceDiscovery
- ServiceDetail
  - It is recommended that the message set ServiceDetail is expanded, so that the exchange of a ServiceParameterList is possible in both directions from EV to EVSE and reverse.
  - The parameter ACDType, as part of the ServiceParameterList, shall be available for both directions of communication. It is recommended to implement the types ACDS and ACDU and additional types for other ACD-systems according to IEC 61851-23-1 such as ACDR.
  - The ServiceDetail message from EV to EVSE shall contain information about the connection interface position within the EV as well as the outer dimensions of the vehicle. This allows an ACD-system to calculate the appropriate position of the vehicle connection interface so that the connecting procedure might be more efficient. Specific information about the connection interface position and vehicle dimensions message are given in chapter 6.3.
  - The ServiceDetail message from EVSE shall provide information about the effective workspace of the ACD-system and the dimensions of the parking space where the ACD-system is located.

This will allow a vehicle to calculate whether it is capable of fitting its vehicle connection interface into the available workspace and eventually to optimize its parking position. Specific information about the workspace and parking spot size message are given in chapter 6.3.

- Payment related messages
- SystemStatus
  - The information EV_InChargePosition is also given in the ACDPositioning message block. It shall be considered bidirectional as well, as it is not clear whether the EV or EVSE might provide information regarding positioning determination. In the beginning it shall be determined which partner (EV or EVSE) provides positioning information.
- ACDPositioning
  - Additionally to the messages already defined, it is recommended that these messages also include the relative deviation in z-direction. This is especially helpful for an ACDS but also beneficial for an ACDU in order to calculate the vertical distance before connecting.
  - As already described in the current version of the referenced standard, messages regarding relative deviation and orientation shall be defined bidirectional, as it is yet undetermined where the PPD is located. Furthermore the information EVInChargePosition shall also be available in both directions, as this information might be provided from either side, depending on the positioning determination technology.
  - As for all bidirectional defined information flows it needs to be determined which side provides information. This can be done either implicitly by definition or explicitly by active negotiation during service detail exchange.
- Pairing
  - Pairing ensures that the EVCC is communicating to the correct SECC in the corresponding parking slot.
  - Pairing solution strongly depends on technical implementation of Pairing and Positioning Device (PPD). This is not yet defined and will might be different for ACDS and ACDU.
- Payment related messages
- Authorization
- ChargeParameterDiscovery
  - It is planned to design an ACD in a way that no ACD specific target settings for power transfer are required. Once the connection is established the power transfer and related power transfer communication shall behave as in a manually plugged vehicle.
- AlignmentCheck
  - The alignment check as currently defined in the ISO 15118 is not necessary for an ACD, as this information is already given by the EVInChargePosition message. Unlike in WPT the efficiency in conductive charging is independent of the alignment. Therefore an alignment check is obsolete.
- ConnectChargingDevice

- It is recommended to consider a signal that indicates the state of a potential locking mechanism of the connector by the EV. The use of a locking mechanism will be evaluated in edition 2 of the position paper.

- Power delivery related messages
  - It is recommended that the power delivery procedures are regarded independent from the connection procedure. This could be achieved by modularizing the message sequence
- DisconnectChargingDevice
  - The charging process has to be stopped prior to requesting disconnection.
  - An EV might apply a locking mechanism for the connection. To provide for this case the mechanical charging device status of EV shall differentiate between "end position unlocked" and "end position locked". In this case it is recommended that the connector is unlocked before requesting a disconnection. This makes sure an ACD-system does not try to physically disconnect a still locked connector.
  - It shall be considered that an EVSE might apply a mechanically safe state of force free actuated joints when connected and locked. This case shall be taken into account with the introduction of a new EVSE mechanical charging device status "end position locked or force free". In this case the disconnection procedure would be:
    - EV requests disconnection
    - EVSE disables force free state
    - EV disengages connector locking mechanism
    - EVSE disconnects
  - CharIN recommends that the locking mechanism is located on the EV. Locking mechanisms in existing standards shall be unaffected by this.
- SessionStop

6.3 Positioning and workspace information

In order to ensure mechanical compatibility of the EV and EVSE, information about the vehicle connection interface position and the available workspace of an ACD shall be exchanged before the actual approach on a parking space. This provides both EV and EVSE the possibility to check whether EVSE and EV are physically capable of connecting on the available parking space. The EV provides information about its outer dimensions and the location of its ACD connection interface in spatial position and direction (6 DOF) as shown in Figure 24. This allows for rough positioning of the EVSE connection interface prior to fine positioning with different sensors. The inlet position information applies a cartesian coordinate system derived from the ISO 4130 with the zero X plane located at the vehicle front. The spatial direction of the vehicle connection interface for Φ, Θ, $\Psi = 0$ is defined as upright facing the driving direction. This accounts for ACDS and ACDU units. An ACDU unit would usually read a spatial direction of Φ = 0, Θ = –90°, Ψ = 0. The applied data types shall be usable for the dimensions of commercial vehicles as well.

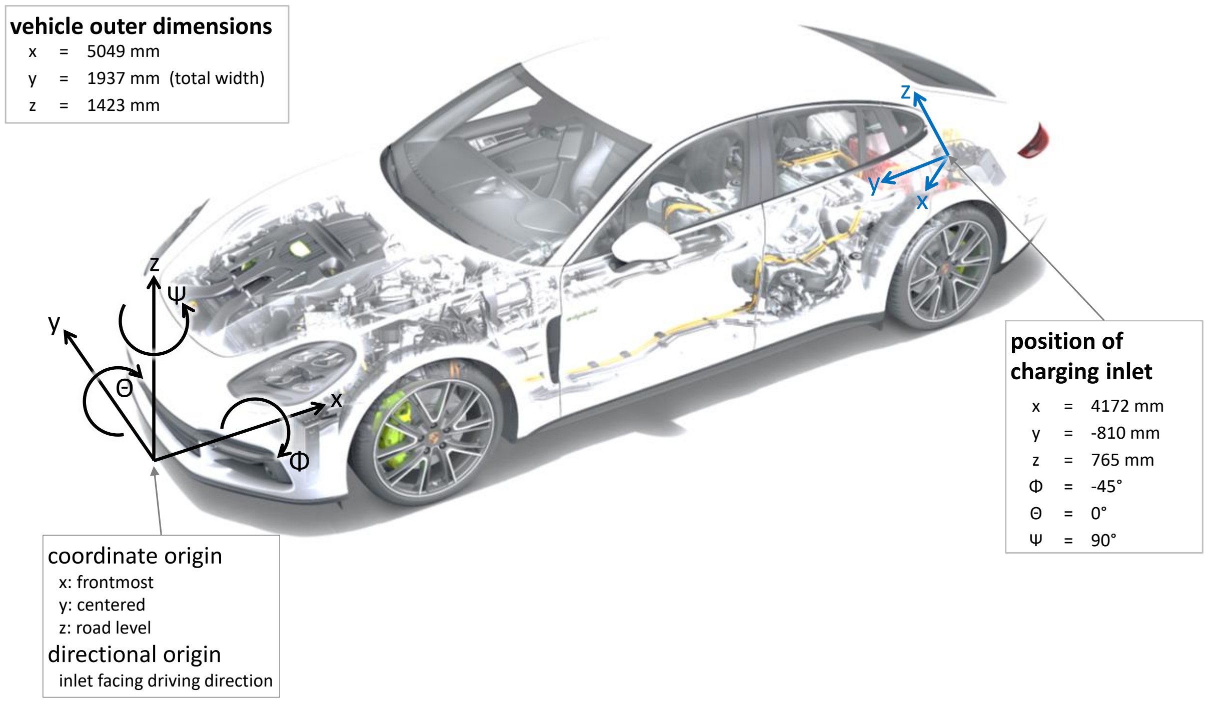


Figure 24, EV information with exemplary values

In return the EVSE provides information about the parking space dimensions as well as the available workspace of the ACD infrastructure, as depicted in Figure 25. The workspace defines each point on which the vehicle connection interface could be placed that is reachable by the ACD infrastructure. If the active part of the ACD is located on the EV, the workspace defines the area or point where the ACD can be contacted. An overview featuring example workspaces is shown in Figure 25.

The applied Cartesian coordinate system is derived from ISO 4130 with the zero X plane at the end and the zero Y plane through the center of the parking space.

Besides the spatial dimensions the workspace also includes the allowed tilting angle of the vehicle connection interface within the entire workspace or for each point of it.

In case a large scale workspace for ACDU systems for public applications is not acceptable, the ACDU workspace on the parking space shall be placed in the same position as a wireless power transfer system (WPT).

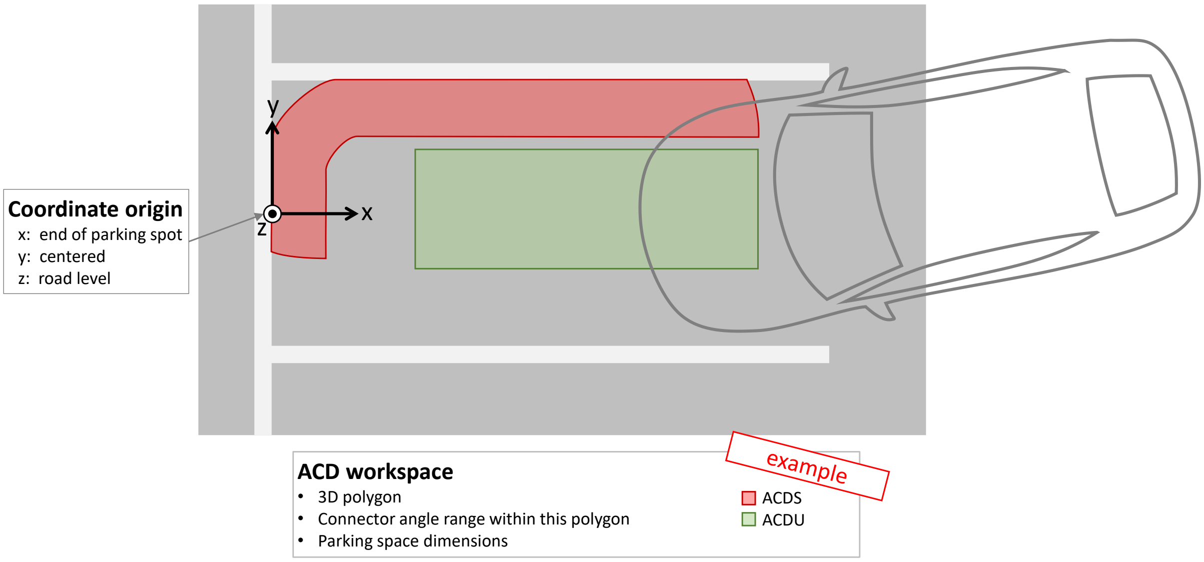


Figure 25, EVSE information with exemplary values for public use case

It is recommended that this EVSE information is also considered for detailed maps as are used for autonomous driving in multi store car parks. Additional information for these high detailed maps might be:

- Available ACD-types and connector types
- Available max. power or voltage
- Plug and Charge / Park and Charge readiness
- Absolute geo coordinates of workspace
- Real time information about availability or reservation

It would be beneficial to include some of this information in ordinary navigational maps.

7 Relevant standards

The ACD-system being a mix of electrical and mechanical components imposes safety relevant topics across several domains. Automatic charging applications shall be differentiated from industrial robotic applications. Unlike industrial environments, an ACD may be utilized by untrained users. As requirements for speed and mechanical force are low compared to common industrial robots, an ACD shall be designed in a way that it is not regarded as an industrial application for skilled persons.

The following paragraph lists the most relevant standards with no claim on completeness.

Standard	Title	Applicable	Type of standard
IEC 61851-1	Electric vehicle conductive charging system - Part 1: General requirements	EV	Safety, Communication
IEC 61851-21-2	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	EVSE	EMC; Offboard Charger
IEC 61851-23	Electric vehicle conductive charging system - Part 23: DC electric vehicle charging station	EVSE	Safety, power transmission
IEC 61851-23-1	Electric vehicle conductive charging system - Part 23-1: DC Charging with an automatic connection system	EV, EVSE	Safety, power transmission, Positioning, Pairing
IEC 61851-24	Electric vehicle conductive charging system - Part 24: Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging	EV, EVSE	Communication
IEC 61439-7	Low-voltage switchgear and control gear assemblies - Part 7: Assemblies for specific applications such as marinas, camping sites, market squares, electric vehicle charging stations	EVSE	power transmission
IEC 60364-7-722	Low-voltage electrical installations - Part 7-722: Requirements for special installations or locations - Supplies for electric vehicles	EVSE	Safety
IEC 62752	In-cable control and protection device for mode 2 charging of electric road vehicles (IC-CPD)	EVSE	Safety
IEC 62196-1	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 1: General requirements	EV, EVSE	Cable& Plug

IEC 62196-2	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 2: Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories	EV, EVSE	Cable& Plug
IEC 62196-5 (EN 50696)	Contact Interface for Automated Connection Devices (ACD)	EV, EVSE	Cable& Plug, Safety, Positioning
IEC 62196-3	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 3: Dimensional compatibility and interchangeability requirements for d.c. and a.c./d.c. pin and contact-tube vehicle couplers	EV, EVSE	Cable& Plug
IEC 62893-1	Charging cables for electric vehicles for rated voltages up to and including 0,6/1 kV - Part 1: General requirements	EV, EVSE	Cable
IEC 62893-2	Charging cables for electric vehicles for rated voltages up to and including 0,6/1 kV - Part 2: Test methods	EV, EVSE	Cable
IEC 62893-3	Charging cables for electric vehicles for rated voltages up to and including 0,6/1 kV - Part 3: Cables for AC charging according to modes 1, 2 and 3 of IEC 61851-1 of rated voltages up to and including 450/750 V	EV, EVSE	Cable
IEC 62893-4-1	Charging cables for electric vehicles for rated voltages up to and including 0,6/1 kV - Part 4-1: Cables for DC charging according to mode 4 of IEC 61851-1	EV, EVSE	Cable
EN 50620	Electric cables - Charging cables for electric vehicles	EV, EVSE	Safety
ISO 17409	Electrically propelled road vehicles -- Connection to an external electric power supply -- Safety requirements	EV, EVSE	Safety
ISO 6469-2	Electrically propelled road vehicles -- Safety specifications -- Part 2: Vehicle operational safety	EV, EVSE	Safety
ISO 6469-3	Electrically propelled road vehicles -- Safety specifications -- Part 3: Electrical safety	EV, EVSE	Safety
ISO 6469-4	Electrically propelled road vehicles -- Safety specifications -- Part 4: Post crash electrical safety	EV, EVSE	Safety
ISO 15118-1	Road vehicles -- Vehicle to grid communication interface -- Part 1: General information and use-case definition	EV, EVSE	Communication
ISO 15118-2	Road vehicles -- Vehicle-to-Grid Communication Interface -- Part 2: Network and application protocol requirements	EV, EVSE	Communication

ISO 15118-3	Road vehicles -- Vehicle to grid communication interface -- Part 3: Physical and data link layer requirements	EV, EVSE	Communication
ISO 15118-4	Road vehicles -- Vehicle to grid communication interface -- Part 4: Network and application protocol conformance test	EV, EVSE	Communication
ISO 15118-5	Road vehicles -- Vehicle to grid communication interface -- Part 5: Physical layer and data link layer conformance test	EV, EVSE	Communication
ISO 15118-8	Road vehicles -- Vehicle to grid communication interface -- Part 8: Physical layer and data link layer requirements for wireless communication	EV, EVSE	Communication
ISO/DIS 15118-20	Road vehicles -- Vehicle to grid communication interface -- Part 20: 2nd generation network and application protocol requirements	EV, EVSE	Communication
IEC 61980-2	Electric vehicle wireless power (WPT) systems - Part 2: Specific requirements for communication between electric road vehicle and infrastructure with respect to wireless power transfer (WPT) systems	EV, EVSE	Communication
ISO 26262-x	Road vehicles -- Functional safety	EV	Safety
ISO 13849-x	Safety of machinery -- Safety-related parts of control systems	EVSE	Safety
IEC 61508-x	Functional safety of electrical/electronic/programmable electronic safety-related systems	EVSE	Safety
IEC 60204	Safety of machinery - Electrical equipment of machines - ALL PARTS	EVSE	Safety
IEC 60335-x	Household and similar electrical appliances - Safety	EVSE	Safety
ISO 10218-x	Robots and robotic devices -- Safety requirements for industrial robots	EVSE	Safety
ISO/TS 15066	Robots and robotic devices -- Collaborative robots	EVSE	Safety
ISO 20653	Road vehicles -- Degrees of protection (IP code) -- Protection of electrical equipment against foreign objects, water and access	EV	Safety
IEC 60529	Degrees of protection provided by enclosures (IP Code)	EVSE	Safety
IEC 62262	Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)	EVSE	Safety
UNECE GTR 20	Global Technical Regulation on the Electric Vehicle Safety (EVS)	EV	Safety

UNECE R 100	Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train	EVSE	Safety
UNECE R 10	Uniform provisions concerning the approval of vehicles with regard to electromagnetic compatibility	EVSE	EMC
2014/35/EU	Directive 2014/35/EU on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits	EV	Safety
2014/30/EU	Directive 2014/30/EU on the harmonisation of the laws of the Member States relating to electromagnetic compatibility (recast) Text with EEA relevance	EVSE	EMC
2014/53/EU	Directive 2014/53/EU on the harmonization of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC Text with EEA relevance	EV	EMC

8 Conclusion & Next Steps

This position paper was created to support the industry to develop a first generation of interoperable automatic conductive charging systems. In the future, further developments and definitions in standardization are expected and will be followed by the industry.

9 Acronyms

acronym	meaning
AC	Alternating Current
ACD	Automatic Connection Device
ACDR	Automatic Connection Device for vehicle Roof-mounted connections
ACDS	Automatic Connection Device for conventional Side connection interface
ACDU	Automatic Connection Device for vehicle Underbody connector
AP	Access Point
BEV	Battery Electric Vehicle
CCS	Combined Charging System
CP	Control Pilot
DC	Direct Current
DOF	Degree Of Freedom
DUT	Device Under Test
EMC	Electro Magnetic Compatibility
EV	Electric Vehicle
EVCC	Electric Vehicle Communication Controller
EVSE	Electric Vehicle Supply Equipment
OEM	Original Equipment Manufacturer
PE	Protective Earth
PHEV	Plug-In Hybrid Electric Vehicle
PLC	Power Line Communication
PnC	Plug and Charge / Park and Charge
PP	Proximity Pilot
PPD	Pairing and Positioning Device
SDP	SECC Discovery Protocol

SECC	Supply Equipment Communication Controller
TCO	Total Cost of Ownership
WLAN	Wireless Local Area Network
WPT	Wireless Power Transfer

10 Glossary

connection interface

Describes just the common connection interface, such as plug and inlet, on vehicle and infrastructure without manufacturer specific robotic mechanics or controller.

ACD-system

The totality of the automatic connection system, including charging cable, robotic equipment, connector, control unit, pairing and positioning device, etc.

Reference

This document was created by the sub group Automatic Conductive Charging of the CharIN association.

The focus group has the following goals:

- Harmonize the development of automatic connection devices with regard to passenger cars
- Develop recommendations for standardization