Fast and Smart Charging Solutions for
Full Size Urban Heavy Duty Applications

D4.4 - ASSURED 1.1 Interoperability Reference

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SUMMARY SHEET

Programme	Horizon 2020
Contract N.	769850
Project Title	Fast and Smart Charging Solutions for Full Size Urban Heavy Duty Applications
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Project Director	Prof. Joeri van Mierlo
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Keywords	Specification, standard, conformance, interoperability, reference
Abstract	*This specification is the baseline for the conformance and interoperability testing being performed in the ASSURED project. It contains the references to the used standards and their version, and definitions, where additional specification is needed in addition to the existing standardisation.*

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DOCUMENT CHANGE LOG

Version number	Date	Organisation name	Description
0.1	22/02/19	VTT	Initial draft.
0.2	28/02/19	VTT	Draft for review by the internal work group.
0.3	04/03/19	VTT	Draft for first review in a monthly meeting.
0.4	07/03/19	VTT	Initial draft for review by all partners, uploaded to CT.
0.5	26/03/19	VTT	Updated draft after the first review session, uploaded to CT.
0.6	04/04/19	VTT	Updated draft after the second review session, uploaded to CT.
0.7	15/04/19	VTT	Updated draft to be approved in the WP4 monthly meeting
0.8	21/05/2019	VTT	Updated draft to be approved in the WP4 May 2019 monthly meeting
1.0	27/05/2019	VTT	First release.
1.0	11/06/2019	VTT	Changed the title of the document.
1.1	06/09/2021	VTT	Updated the document according to ASSURED interoperability tests results and reviewed them with involved partners. Changed the title of the document from “ASSURED 1.0 Interoperability Reference” to “ASSURED 1.1 Interoperability Reference”
1.2	29/09/2021	POLIS, RC, TNO	Quality Assurance Commission review
1.3	30/09/2021	VTT	Implementation according to Quality Assurance Commission suggestion
2.0	01/10/2021	VUB	Final check and submission

ACRONYMS

ACD: Automated Connection Device
CP: Control Pilot
DC: Direct Current
EV: Electric Vehicle
EVCC: Electric Vehicle Charging Controller
EVSE: Electric Vehicle Supply Equipment
HV: High Voltage
OEM: Original Equipment Manufacturer
PE: Protective Earth
PPD: Pairing and Proximity Device
SECC: Supply Equipment Charging Controller
SSID: Service Set Identifier
TLS: Transport Layer Security
V2G: Vehicle-to-Grid

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Executive Summary

This document (ASSURED 1.1 Interoperability Reference) outlines the standards and definitions that are used in the ASSURED project for performing conformance and interoperability testing. As the standards related to the testing were not yet finalized or were lacking definitions of some of the parts required for successful interoperability, we identified the need for developing a reference document that would cover the existing gaps in the standardisations. The first version of this document, called "ASSURED 1.0 Interoperability Reference"[1], was published to public document in June 2019. The current document is updated version of "ASSURED 1.0 Interoperability Reference" according to ASSURED conformance and interoperability testing, which were completed early 2021.

ASSURED 1.1 Interoperability Reference can be used as a reference document by relevant standardisation committees or organisations that are aiming at achieving interoperability for automated connection device (ACD)-based charging solutions (namely infrastructure-mounted, roof-mounted, and floor-mounted ACDs) of electric buses.

The document starts with a general introduction to the work (Chapter 1). The standards referenced in ASSURED project are summarised in Chapter 2. Chapter 3, 4, and 5 include definitions and specifications of the three ACD-based charging solutions used in ASSURED where the solution differs from the referenced standards with additional clarifications if deemed necessary.

Attainment of the objectives and explanation of deviations

This deliverable is part of Task 4.2 "Overview of ongoing and interaction with other standardization activities & initiatives". When the project started, the standards related to the testing were not finalized or lacked definitions of some of the parts required for successful interoperability. Therefore, it was decided to develop a reference document that includes the definition of all the necessary requirements for the conformance and interoperability testing that were missing from the standards. This reference document was added to the project as a new deliverable of WP4 (D4.4) in the second amendment of the project, with due date of M48. D4.4 has fulfilled all the defined objectives and was submitted on due date; thus, it has no deviation from the workplan.

[1] https://assured-project.eu/news-and-events/news/assured-1-0-interoperability-reference

Partners' Contribution

Company	Sections	Description of the partner contribution
VTT	All	Synthesis of the document based on three workgroup's definitions. Organising Workshops and review sessions.
ABB	3	Workgroup definition for Type A solution, participating in reviews.
Volvo	3	Workgroup definition for Type A solution, participating in reviews.
Siemens	3	Workgroup definition for Type A solution, participating in reviews.
VDL	4	Workgroup definition for Type B solution, participating in reviews.
Jema	4	Workgroup definition for Type B solution, participating in reviews.
Heliox	4	Workgroup definition for Type B solution, participating in reviews.
Alstom	5	Workgroup definition for Type C solution, participating in reviews.
TMB	6	Reviewing proposals for bus positioning method.
SWO	6	Reviewing proposals for bus positioning method.
UITP	6	Plan on extending work on chapter 7.
Schunk	2-4	Participating in reviews.
IDIADA	2-4	Reviewing the document and suggesting updates according to ASSURED interoperability testing, participating in reviews.

*All partners participated in updating the document according to the ASSURED interoperability testing.

1. Introduction

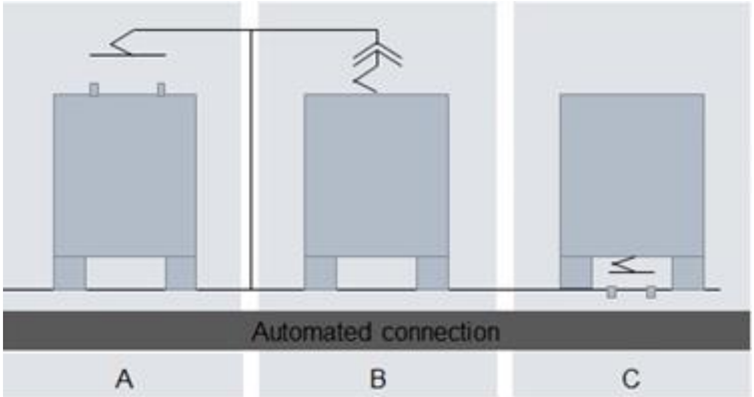
This document describes the standards and definitions that are used in the ASSURED project for conformance and interoperability testing of vehicles and chargers. As the standards related to the testing were not yet finalized or were lacking definitions of some of the parts required for successful interoperability, this document defines the missing requirements.

To be able to meet the testing deadlines, the baseline was defined according to the standardisation situation in January 2019, utilizing the existing draft standards at that point in time. This baseline was published as a public document called “ASSURED 1.0 Interoperability Reference” in June 2019.

ASSURED conformance and interoperability testing were completed early 2021, after which, the reference document was updated according to the results and observations of these tests and was published as “ASSURED 1.1 Interoperability Reference” in September 2021.

2. Standards referenced in ASSURED project

Table 1. Standards used for the Types A, B and C Automated Connection Device based solutions



		Type A	Type B	Type C
Mechanical implementation and parking tolerance		EN 50696:2021 -Annex A (normative) - Annex B (normative)		EN 50696:2021 -Annex C (normative)
Electrical implementation		IEC 61851-23-1 CD3 Annex CC case D	IEC 61851-23-1 CD3 Annex CC case E	IEC 61851-23-1 CD3 Annex KK
Communication	Control Pilot	IEC61851-23-1 CD 3 Annex CC case D	IEC 61851-1 Ed. 3 & SAE J1772™	IEC 61851-23-1 CD3 Annex KK
	Physical layer	ISO 15118-8:2018	ISO 15118-3	ISO 15118-8:2018
	implementation (application layer)	ACD extension of ISO/IEC DIS 15118-2 (2012)	ISO 15118-2:2014	ISO15118-20 (former ISO 15118-2 Ed 2.0 DIS)

Process of Energy Transfer	Type A	Type B	Type C
General	ACD extension ISO/IEC DIS 15118-2 (2012), ISO 15118-8:2018, IEC 61851-23-1 Ed1 chapter C.3	IEC 61851-23 Ed 2.0 CD chapter C.3	ISO15118-20 (former ISO 15118-2 Ed 2.0 DIS), ISO 15118-8:2018
IT requirement	411 of IEC 60364-4-41:2005 or ISO 17409		411 of IEC 60364-4-41:2005 or ISO 17409
Insulation monitoring device	IEC 61557-8		IEC 61557-8
Pre-charging	101.2.1.6		101.2.1.6
Specific requirements: turn on inrush current (DC side) Load dump Short circuit current	*This clause of Part 23 is applicable*		
Contact sequence	IEC 62196-3 clause 6.7 not required		IEC 62196-3 clause 6.7 not required
Initialization	ISO 15118-2:2014		ISO 15118-2:2014
Connecting			
Insulation Check & Pre-charge			
Energy transfer			
Battery charging			
Auxiliary, HVAC energization			
Disconnection			
Vehicle free to move			

* References to available standardisations are provided in Chapter 7 (References).

3. Infrastructure-mounted ACD (Type A)

3.1 Introduction

The ASSURED project has performed perform interoperability testing between different vehicles and charging stations. At the time of ASSURED testing, the standardisation related to the infrastructure-mounted automated connection device (ACD) was still under construction, and therefore the ASSURED project decided to base the communications specification of the Type A system on the existing ACD extension of ISO/IEC DIS 15118-2 (2012) protocol. Interoperability testing in ASSURED was performed against the specification as described in this chapter.

For conformance testing, all ASSURED solutions were tested against the ASSURED specification. Optionally, original equipment manufacturer (OEM’s) have an opportunity to also perform conformance testing of their equipment against the upcoming ISO 15118-20 standard.

The first message of the protocol (supportedAppProtocol) determines which protocol version shall be used during the charging process (ASSURED or ISO 15118-20).

This chapter describes the solution based on references to published draft standards available for the ASSURED community. It includes definitions where the solution differs from the referenced standards and additional clarifications if deemed necessary.

3.2 Mechanical interface

The mechanical interface is described in EN 50696:2021 - Annex A (normative), ACD mounted on the infrastructure.

3.2.1 Deviations and additional specifications

3.2.1.1 Mounting and orientation of the Wi-Fi antenna

Location of the Wi-Fi antenna is required for the positioning by directional Wi-Fi. This is not defined in EN 50696:2021. The centre of the Wi-Fi antenna shall be located 680 mm from the centre of the contact interface of the bus on the right hand side in driving direction (see Figure 1), and at least 100 mm below the surface of the rails.

The horizontal polarization orientation of the antenna shall be in the driving direction (see Figure 1 “H.P.”)

Recommendation: The Wi-Fi antenna on the EV should be mounted with 4 degrees skew to the centre of the antenna of the EVSE (see Figure 2).

Recommendation: Pantograph knee should be on the opposite side of the Wi-Fi antenna to avoid the knee from blocking the Wi-Fi signal path.

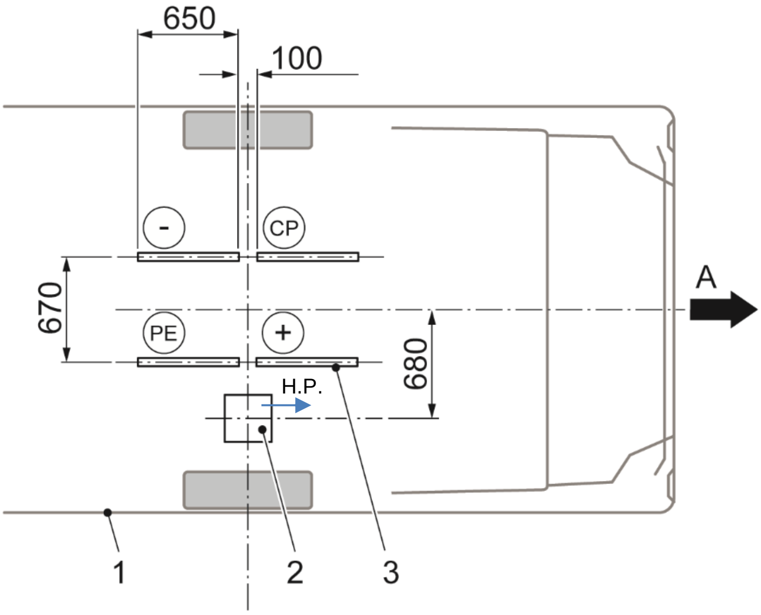


Figure 1. Dimensioning and positioning of the contacts and Wi-Fi antenna on the vehicle roof.
(1) Vehicle (2) Wi-Fi antenna (3) Connector pole

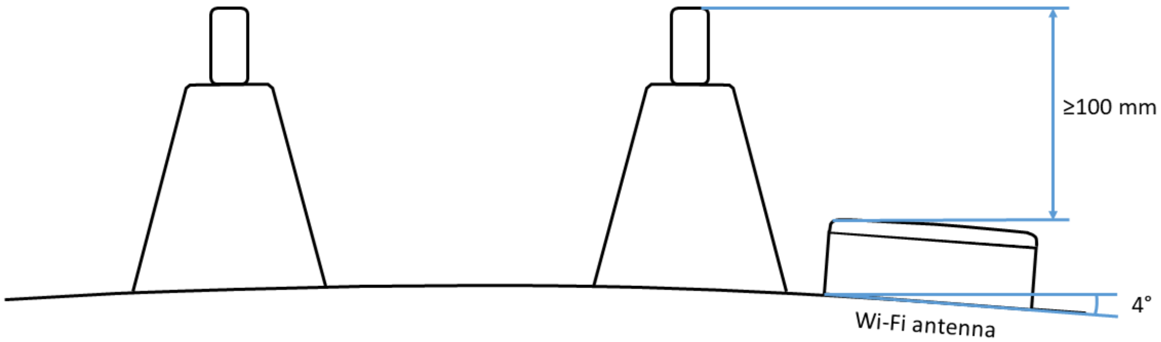


Figure 2. Recommended Wi-Fi antenna mounting

3.3 ELECTRICAL INTERFACE

The electrical implementation is described in IEC 61851-23-1 CD3 Annex CC case D.

3.3.1 Deviations and additional specifications

3.3.1.1 CHARGING SEQUENCES

Charging sequences are described in IEC 61851-23-1 CD3, with some references to ISO 15118-2 Ed.2.0 DIS variables are made. In the sequences described in this document, the references are exchanged with the names that reference to the specification “Road vehicles — Vehicle to grid communication interface — Network and application protocol specification for Siemens — Volvo OppCharge implementation”.

Figure 3. Replacement of "Figure CC.1 – Sequence diagram for normal start up"

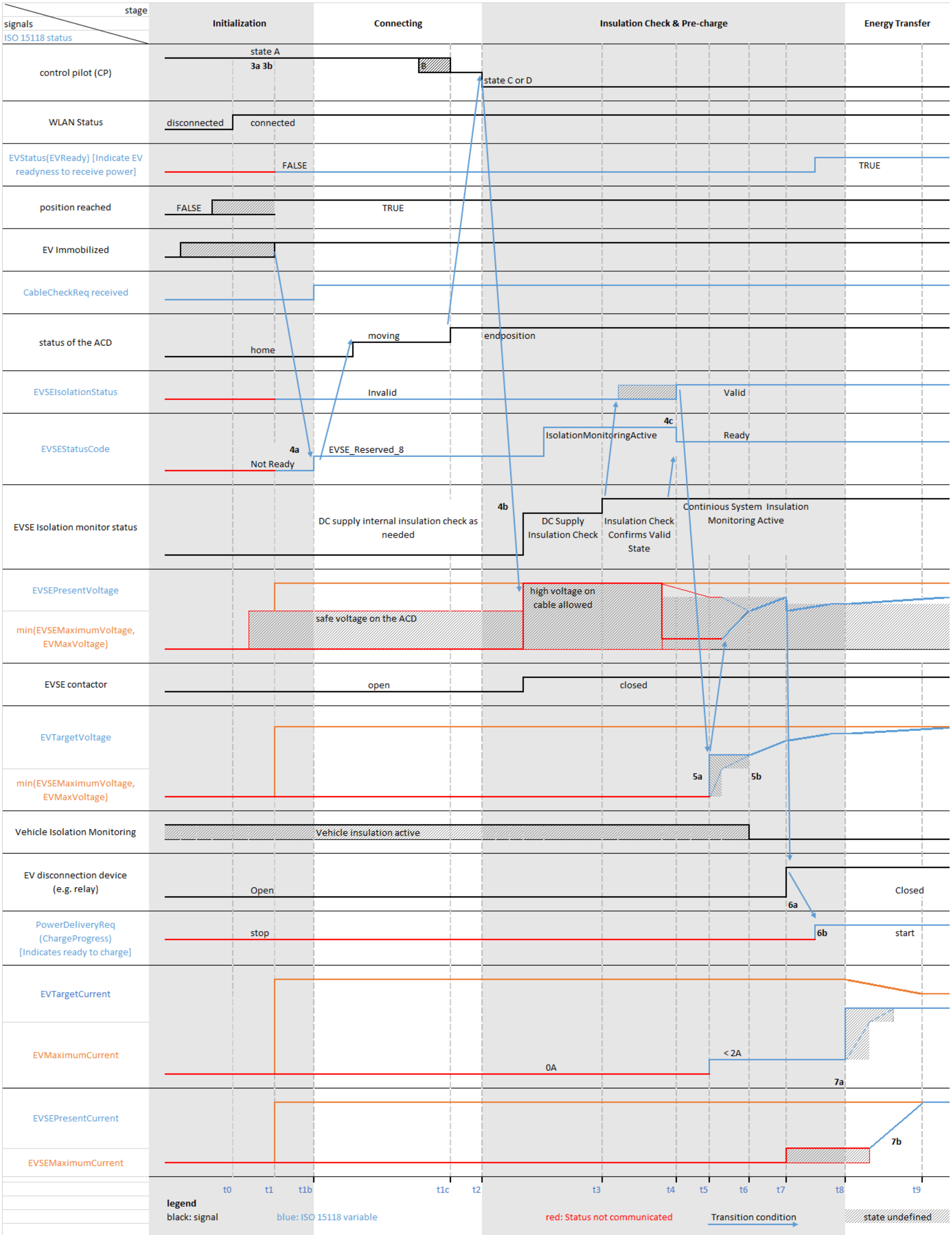


Table 2. Replacement of "Table CC.3 − Sequence description for normal start up"

Phase	Description
(t0)	High level communication starts and handshaking with exchange of charging parameters takes place.
(t1)	EV sends its maximum limits (amongst other parameters) for DC supply output current and voltage with <3a>. Maximum values of the DC supply are responded to the EV with <3b>. DC supply can check internal insulation as long as no voltage is applied to the ACD. If EV and EV supply equipment are not compatible, then the vehicle will not go to Ready, and will transition to step t16 in the normal shutdown sequence.
(t1b)	EV has reached the correct position for charging. DC supply checks if DC output voltage is less than 60 V and terminates supply session if 60 V is exceeded. EV initiates connection process <4a> by sending CableCheckReq. DC supply sets its status to "EVSE_Reserved_8" until the ACD is in the working position.
(t1c)	EV supply equipment reports that the mechanical contact is secured DC supply checks if DC output voltage is less than 60 V and terminates supply session if 60 V is exceeded.
(t2)	EV changes CP state from B to C/D by closing S2 which ends connecting phase.
(t2 → 3)	EV requests cable and insulation check by <4b>. DC supply starts checking HV system insulation and continuously reports insulation state.
(t3)	DC supply determines that insulation resistance of system is above 100 Ohm/V (cf. CC.4.1).
(t3 → t4)	After having successfully finished the insulation check, DC supply indicates status "Valid" with subsequent message.
(t4)	EVSEStatusCode changes to "Ready" with Cable Check Response <4c>.
(t5)	Start of pre-charge phase with EV sending Pre-Charge Request <5a>, which contains both requested DC current <=2 A (maximum inrush current acc. to CC.5.2) and requested DC voltage.
(t5 → t6)	DC supply adapts DC output voltage to requested value in <5a> while limiting current to maximum value of 2 A (maximum inrush current according to CC.6.1) even if the requested current 0A.
(t6)	DC output voltages reaches requested voltage within tolerances given in IEC 61861-23-1 CD3 chapter 101.2.1.2.
(t6 → t7)	If necessary, EV adapts requested DC voltage with cyclic messages <5a> in order to limit deviation of DC output voltage from EV battery voltage to less than 20 V (cf. Note in CC.5.1). Before the EV closes any contactor the EV stops vehicle internal insulation monitoring.
(t7)	EV closes its disconnecting device after deviation of DC output voltage from EV battery voltage is less than 20 V.

(t7 → t8)	EV sends Power Delivery Request <6a> with ChargeProgress “Start” to enable DC power supply output. EV sets EVReady status “TRUE”. After disabling pre-charge circuit, if any, and switching on its power supply output, DC Supply gives feedback <6b> that it is ready for energy transfer.
(t8)	EV sets DC current request with <7a> to start energy transfer phase.
(t8→t9)	DC supply adapts its output current and voltage to the requested values. DC supply reports its present output current and output voltage, its present current limit and voltage limit, and its present status back to the EV in message <7b>. NOTE: EV may change its voltage request and current request even if output current has not reached the previous request.
(t9)	DC output current reaches DC current request within delay time Td defined in IEC 61851-23-1 CD3 chapter 101.2.1.3. (time span t9 – t8 = Td, if one request has been made, bold line shown this situation)
(t9→)	EV adapts DC current request and DC voltage request according to its charging/supply strategy with cyclic message <7a>.

Figure 4. Replacement of "Figure CC.2 – Sequence diagram for normal shutdown"

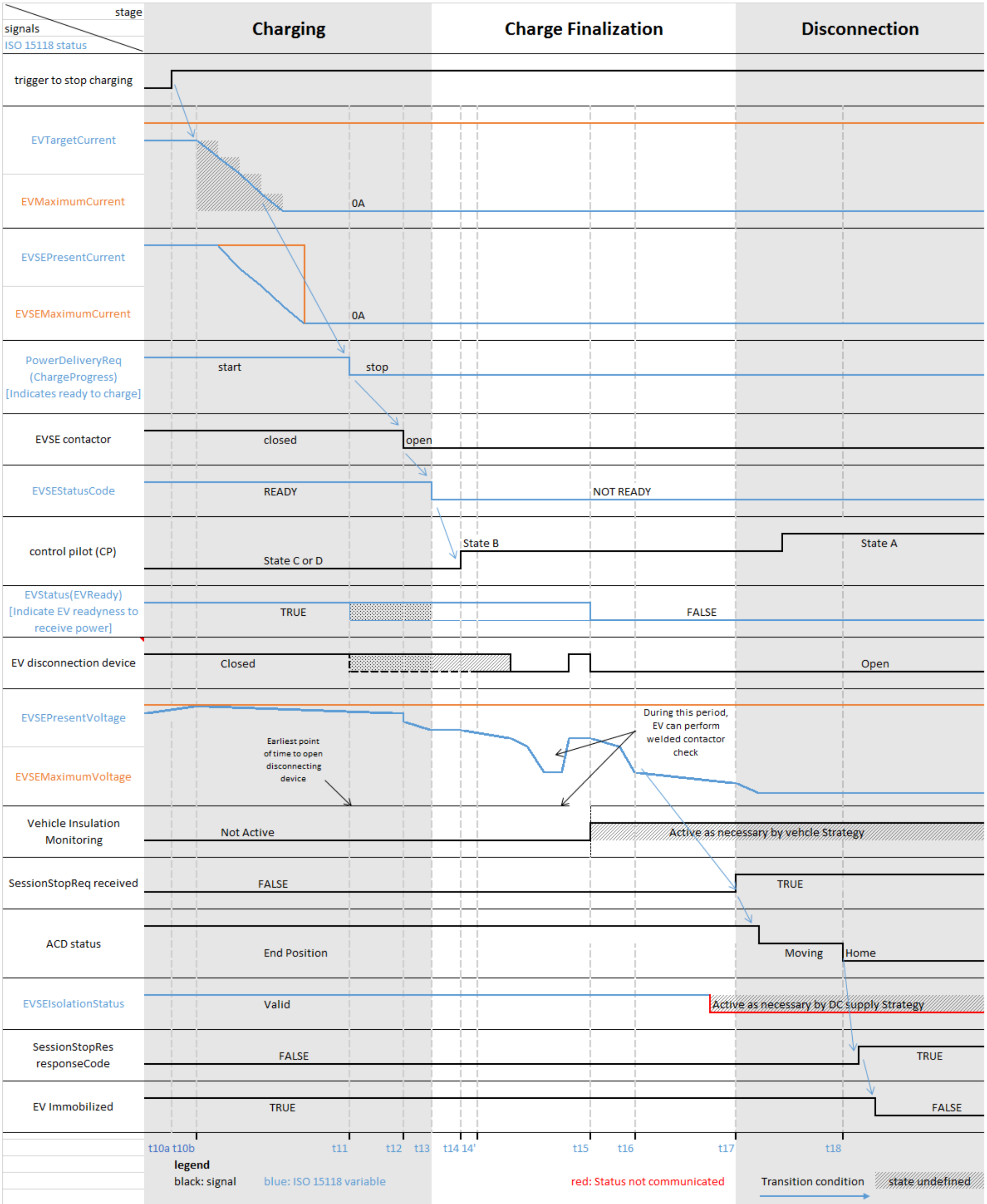


Table 3. Replacement of "Table CC.5 – Sequence description for normal shutdown"

Phase	Description
(t10a)	The user or vehicle system indicates that charging should be stopped.
(t10b)	The EV reduces the current request to complete the energy transfer. Reduction is done based on EV charging/supply strategy.
(t11)	When the current requests are reduced to 0A and verify that EVSE present current is less than 5 A. The EV requests the DC supply to disable its output power. ChargeProgress set to Stop.
(t12)	DC supply disables its output and opens contactors, if any. DC supply shall enable its circuit to actively discharge any internal capacitance on its output after receiving message with "PowerDeliveryReq(chargeProgress)" set to stop. DC supply shall not cause any current flow on EV input during discharge.
(t13)	DC supply reports EVSEStatusCode "Not Ready" within 2s after the DC supply has disabled its output.
(t14)	EV changes CP state to B after receiving message PowerDeliveryRes() with EVSEStatusCode: "Not ready" or after timeout to ensure that DC supply has discharged its output at latest by t14 (in case message was lost).
(t14')	EV can optionally perform its welded contactor check and indicating this to the DC supply.
(t15)	Earliest time for EV isolation monitoring active.
(t16)	The DC output voltage is checked to be below 60 V DC.
(t17)	The SessionStopReq is received.
(t17 → t18)	State A is observed.
(t18)	The EV shall be mobilized only when the ACD is confirmed to be in the home position by a sessionStopRes with responseCode = Ok.

Figure 5. Replacement of Figure CC.3 – Sequence diagram for DC supply initiated emergency stop

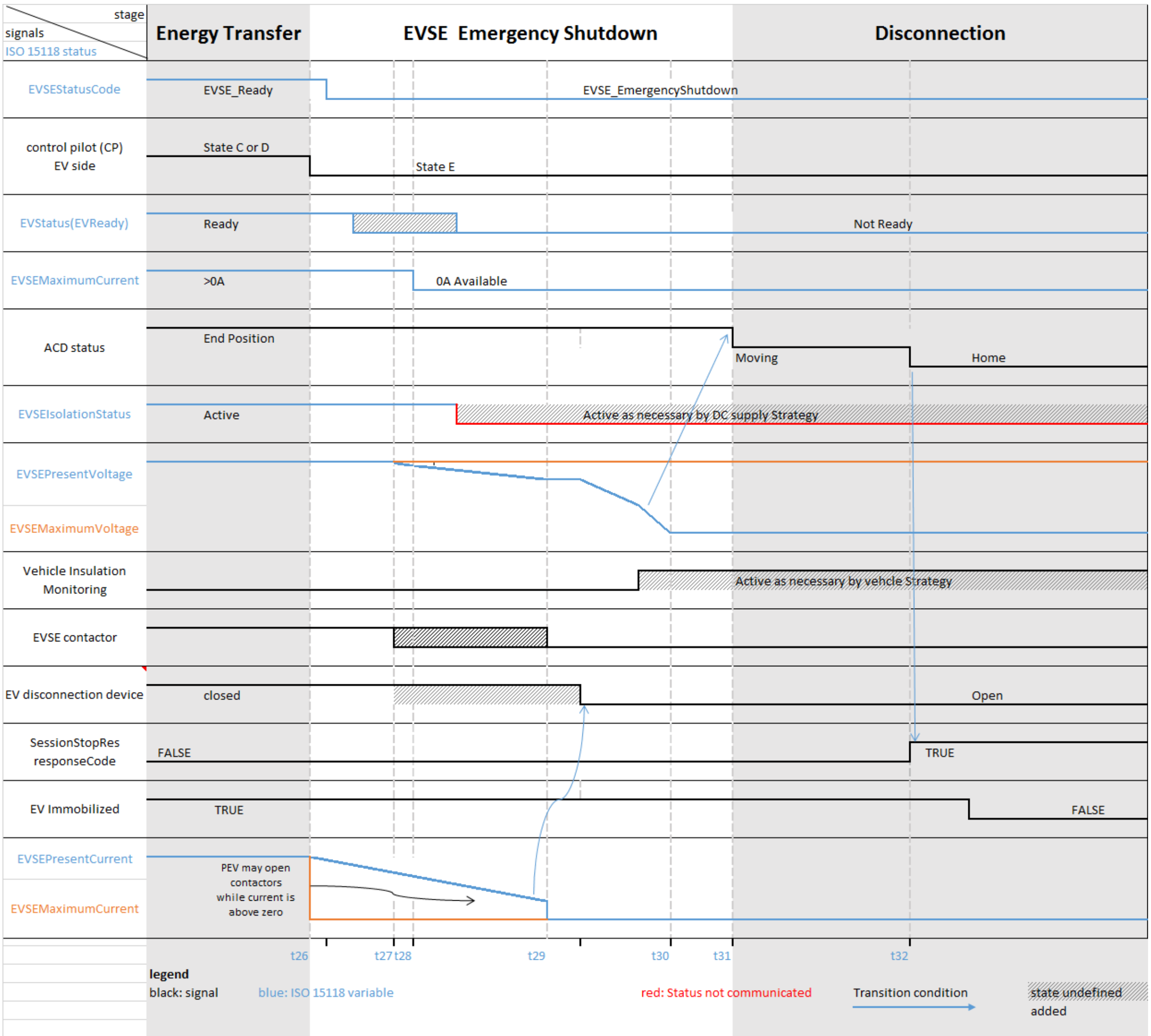


Table 4. Replacement of Table CC.5 – Sequence description for DC supply initiated emergency stop

Phase	Description
(t26)	EV supply equipment experiences an emergency (Isolation fault, emergency button press, etc.) and sets the control pilot signal to state E. The EV supply equipment reduces its maximum current limit and start reducing its current.
(t27)	The EV reacts by disabling S2 and may open its contactor from this time.
(t29)	The EV supply equipment has reduced its current to <5 A and has opened its contactors. The EV has opened its contactors as well.
(t30)	The EV supply equipment reduced its voltage below 60V.
(t31)	The EV supply equipment starts disconnecting the ACD.
(t32)	The EV observes state A and gets a confirmation that the ACD is in its home position indicated by a sessionStopRes with responseCode = Ok.

Figure 6. Replacement of "Figure CC.4 – Sequence diagram for EV initiated emergency stop"

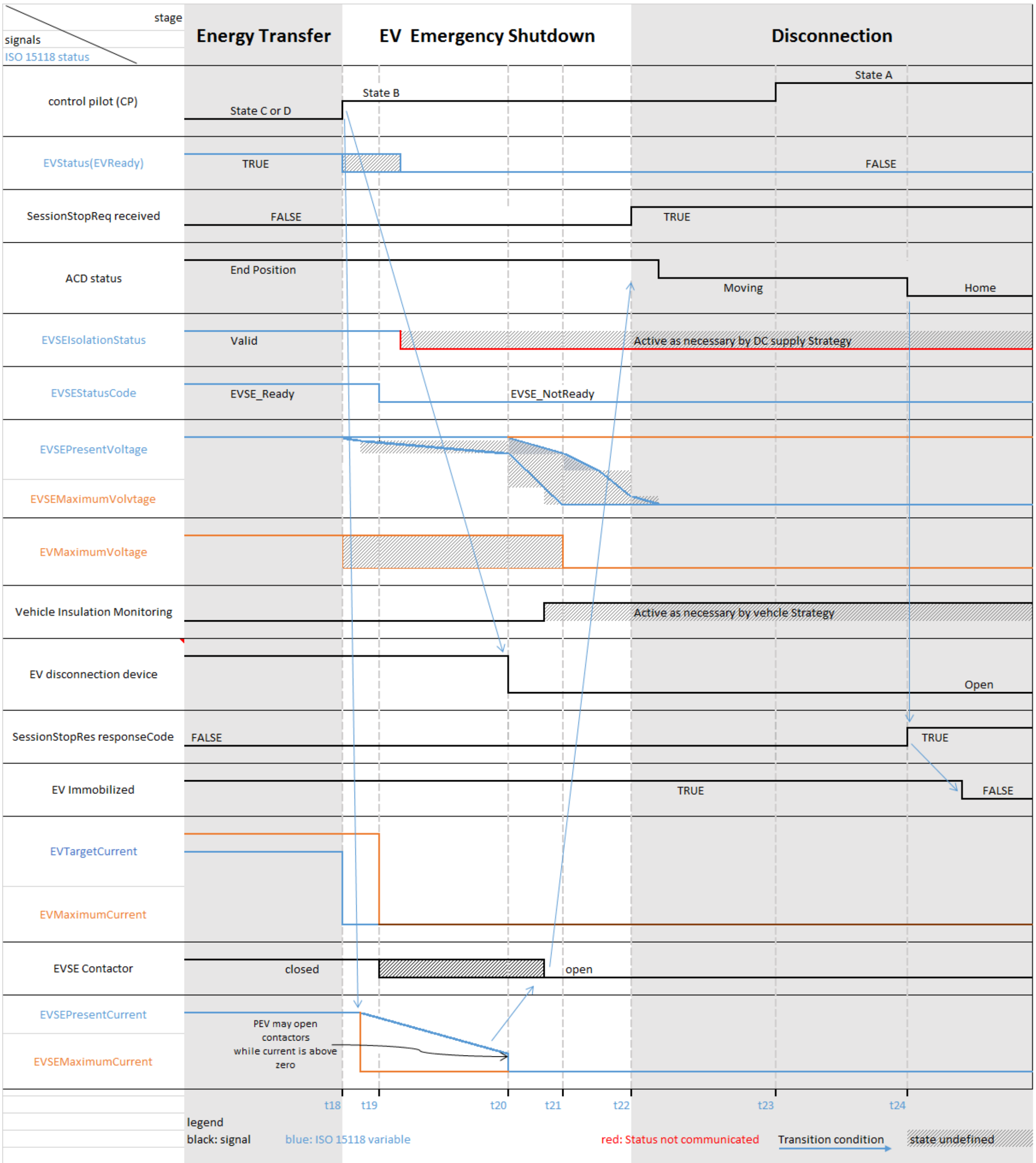


Table 5. Replacement of "Table CC.6 – Sequence description for EV initiated emergency stop"

Phase	Description
(t18)	The EVCC opens S2 Switch on the CP-PE circuit and STATE B is reached.
(t19)	The EVSESstatusCode changes from Ready to not Ready and the EV maximum current limit value changes to 0 A.

(t20)	The current shall be reduced to < 5A by the EVSE (within 70 ms for an emergency shutdown). The maximum time for EV disconnection device to open its relays. The output current drops to <5 A the instant the EV disconnection device opens.
(t21)	The DC output voltage drops to <60V.
(t22)	The SessionStopReq received.
(t23)	The ACD disconnects and STATE A is reached.
(t24)	The ACD has reached Home position indicated by a SessionStopRes with responseCode = Ok. Note: HLC continues until the ACD reaches the home position.

3.4 Communication

The physical communication is to be implemented according to ISO 15118-8.

The communication implementation is described in the following specification:

Road vehicles — Vehicle to grid communication interface — Network and application protocol specification for Siemens — Volvo OppCharge implementation

Version: 1.3.0

ACD extension for OppCharge on ISO/IEC DIS 15118-2 (2012)

Available at oppcharge.org

3.4.1 Deviations and additional specifications

3.4.1.1 Frequency band

Only the 5 Ghz band shall be used.

3.4.1.2 Contract authentication

Contract authentication loop shall be allowed by charging station and vehicle. The parameter "EVSEProcessing=Ongoing" shall be processed in the EV accordingly.

3.4.1.3 Wi-Fi credentials

The Wi-Fi access shall be secured by WPA2 including IEEE 802.11w-2009. The credentials defined in Table 6 shall be used in ASSURED testing in both chargers and vehicles.

Table 6. Wi-Fi credentials for ASSURED testing

SSID (Type A)	ASSURED_TypeA
SSID (Type C)	ASSURED_TypeC
Password	assured_test

3.4.1.4 Pairing and positioning device (PPD)

A dedicated PPD device defined in ISO 15118-20 shall not be used in ASSURED testing. In case interoperability is required for pairing and positioning, refer to recommendation mentioned in ISO 15118-20 on this topic. Pairing and positioning detection shall be implemented in ASSURED by using a directional Wi-Fi-antenna. In this case, because the selectivity is limited, there should be no bus stops within 10 m of the charging spot to prevent crosstalk. The safety distance is measured from the centre of the Wi-Fi antenna. In practise, the distance can be shorter, but in implementation, a precaution should be taken that there might be issues due to crosstalk if the 10 m distance is not obeyed.

The Wi-Fi antenna 3 dB beam width is 9 degrees. The start of communication shall not be allowed if the signal is less than -75dBm. EV shall use SDP to start the communication.

3.4.1.5 TLS/Certificates

TLS shall not be used in ASSURED project.

3.4.1.6 Session setup

A vehicle ID shall be sent for reference during interoperability testing with the following definition:

2 alphanumeric characters representing the OEM – 6 last digits of VIN. E.g. AB123456

Table 7. OEM ID's

OEM	ID
Irizar	IR
IVECO	IV
Solaris	SO
URBASER	UR
VDL	VD
Volvo	VO

3.4.1.7 Misalignment

When a misalignment is observed by the charger, the charger shall respond with CableCheckRes where the responseCode = failed and abort the charging session.

After aborting the charging session, the charger shall prepare itself for a new charging session. The charger shall not enter a locked state by the failed charging session.

Condition to detect misalignment:

- ACD is in the end position, i.e. completely extended
- Control pilot status is state A.

3.4.1.8 Cable check

During cable check the minimum of the maximum voltages of the vehicle and charger shall not be exceeded.

3.4.1.9 Voltage during cable check until PreCharge

During the period between CableCheck and PreCharge the voltage of the charger shall be between 0 and the minimum of the maximum voltages of the vehicle and charger.

(V > 0 V) & (V < min(EVSEMaxVoltage,EVMaxVoltage))

Note: In IEC 61851-23 Ed2 and IEC 61851-23-1 CDV:

- No Warning level

- One error level of 100kOhm,
- CableCheck voltage reference at Max EVSE Voltage or 110% of RESS Max voltage

3.4.1.10 PreCharge

During PreCharge the charger shall supply the requested voltage, regardless of what the current setpoint is. The charger shall limit the current to maximum 2 A.

Note: EVSE present voltage offset shall be positive with respect to EV voltage.

In ISO 15118-20 FDIS the timeout is 10s, instead of 7s (ISO 15118-2). Here it is recommended is to implement 10s for interoperability purpose.

It is recommended that the vehicle requests either 0A or the minimum current of the charger.

The vehicle shall close the EV contactors when the difference in voltage is less than 20 V.

It is mandatory that the vehicle shall measure the input (EVSE) voltage as the controlled voltage charging (CVC) accuracy is 2 % (40 V for a 1000 V charger). In the case of polarity mismatch a voltage measurement is the only means to prevent a battery short circuit.

3.4.1.11 Failure of Wi-Fi

If the vehicle has a communication timeout, then the EV shall trigger an emergency shutdown by changing the CP signal state from C to B. This shall trigger an emergency shutdown on the EVSE side, and the charger shall raise the ACD.

If the charger has a communication timeout, then the EVSE shall trigger an emergency shutdown by changing the CP signal state from C to E. This shall trigger an emergency shutdown on the EV side.

NOTE: When the communication has stopped, the confirmation that the ACD is in idle position cannot be communicated.

After a failed session, the EV can try to connect again to the Wi-Fi and may start a new session. During the new session, the EV shall proceed as usual starting the V2G communication with the supportedAppProtocolReq message. The SECC shall respond to this message with supportedAppProtocolRes and ResponseCode = “Ok” only when the ACD is in the home position. The EV can abort the session at any time by issuing a SessionStopReq. Then the SECC shall respond with a SessionStopRes with ResponseCode = “Ok” only when the ACD is again in home position and the EV can be mobilized.

If a Wi-Fi re-connection is not possible, the EVCC shall mobilize the vehicle only if the CP is in state A for more than 10 seconds. In this exceptional case the driver has to visually check before he is allowed to move the bus again.

4. Roof-mounted ACD (Type B)

4.1 Introduction

The roof-mounted ACD solution is primarily based on the CCS Mode 4 charging, with minor updates to the related standards taking into account higher charging power and utilization of a roof-mounted pantograph as a charging connector. Therefore, the standards related to the roof-mounted ACD are the most mature. There are still a few gaps, for which definitions are presented in this document.

4.2 Mechanical interface

The mechanical interface is to be implemented according to EN 50696:2021, specifically annex B.

4.2.1 Deviations and additional specifications

4.2.1.1 Definition of contact pin positions

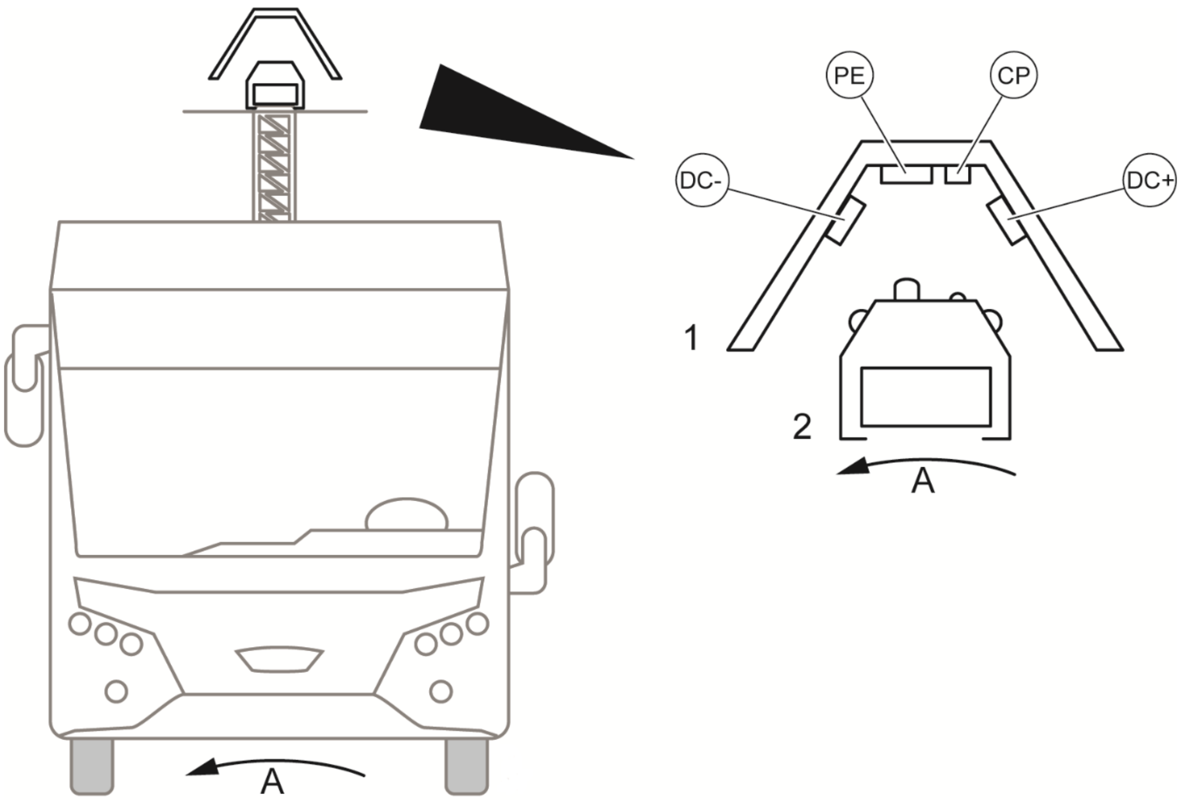


Figure 7. Contact pin positions with Type B ACD

4.2.1.2 Contact force

According to EN 50696:2021 specification.

4.2.1.3 Contacting sequence

For safety reasons, the pantograph shall make contact with the contact hood in a given order. When raising the pantograph, first the protective earth (PE) shall make contact, then DC+ and DC- and last the control pilot (CP). When retracting the pantograph, disconnection shall be performed in the exact opposite order. This way, the CP connection is lost first when disconnecting such that the EVSE and EV can perform an emergency scenario before DC+ and DC- disconnect to prevent high voltage arcing.

4.2.1.4 Indication of driving direction

For each installed contact hood it shall be clearly indicated what the driving direction is and/or it must be enforced that a vehicle can only approach the contact hood in such a way that the contact pins of the pantograph match the contacts of the contact hood. This measure helps preventing that a vehicle approaches the contact hood from the wrong direction and then connects to the contact hood which leads to a mismatch of the contacts.

4.2.1.5 ACD mounting tolerances

According to EN 50696:2021, the minimal positioning tolerances that have to be compensated while positioning the vehicle for charging, are in X- and Y- directions and, for positioning angle, between vehicle and curb:

- X at least ± 200 mm (Δx)
- Y at least ± 200 mm (Δy), Y at least 0 to + 200 mm for Annex C

4.2.1.6 Release of the ACD

ACD will be retracted automatically and a charging session is terminated when the vehicle parking brake is released.

4.3 Electrical interface

The electrical interface is to be implemented according to IEC 61851-23-1 CD3 Annex CC case E.

4.3.1 Deviations and additional specifications

4.3.1.1 Minimum cable length

The current standardisation supports cabling length up to 10 m, which can be easily exceeded with e-buses. To ensure the interoperability, the attenuation has to be according to ISO 15118-3:2015 (Figure A.11 is a diagram for the calculation of the attenuation). Additional cable length could be compensated as long as the attenuation is within the limits of ISO 15118-3:2015.

4.3.1.2 Voltage drop compensation

The EVSE shall report the output voltage at the connector pins in the charging pole within the limits specified in IEC 61851-23-1 CD3, to compensate for potential voltage drop in the cabling from the charger to the charging connector.

4.4 Communication

The communication shall be implemented according to ISO15118-3.

4.4.1 Deviations and additional definitions

4.4.1.1 Pre-charge

Maximum time limit of 2 seconds from the moment the pre-charge request is sent, and the pre-charge set value is received at the EVSE.

5. Floor-mounted ACD (Type C)

5.1 Introduction

With the floor-mounted ACD solution, the implementation is following the standards mentioned in Table 1, with minimal deviations.

5.2 Mechanical interface

Mechanical implementation shall be implemented according to the requirements of EN 50696:2021 and particularly annex C.

Due to the proximity of the contact to ground and passengers, IPXXB or protection by obstacle must be used for floor mounted ACD.

Mechanically sufficient parking tolerances should be offered to the bus OEM and tolerances shall comply with annex C of EN 50696:2021.

5.3 Electrical interface

For electrical safety and charging sequences (normal start, normal stop, emergency stops) IEC 61851-23-1 CD3 and especially annex KK are to be followed.

Floor mounted ACD consist of 3 contacts where CP signal is implemented using a high frequency signal (according to Annex KK of IEC 61851-23-1 CD3). If 4 contacts are to be used (using a dedicated CP contact) the sequence shall be performed according to Annex CC of IEC 61851-23-1 CD3.

5.4 Communication

Communication between the charger and the vehicle is to be implemented with Wi-Fi communication, following ISO15118-8 standard requirements.

5.4.1 Deviations and additional definitions

5.4.1.1 Pairing and proximity device (PPD)

Pairing and proximity device is not standardized yet but needs to be used and can be implemented differently as for a pantograph-based solution.

The used pairing solution consists of an exchange of ID between the charger and the vehicle. The ID of the charger is transferred to the vehicle using the conductive communication signal (see Annex KK of IEC 61851-23-1 CD3) and returned by the vehicle to the charger through the wireless connection. If ID is similar the pairing process is confirmed.

The proximity is checked by the communication from the ACD counterpart to on board ACD (see Annex KK). The communication is only received when the vehicle is sufficiently close to the ACD counterpart and consequently well positioned.

5.4.1.1 Session setup

A vehicle ID shall be sent for reference during interoperability testing with the following definition.

Vehicle ID shall consist of 2 alphanumeric characters representing the OEM and 6 last digits of VIN. Example: AB123456

Table 8. OEM ID's using floor-mounted ACD

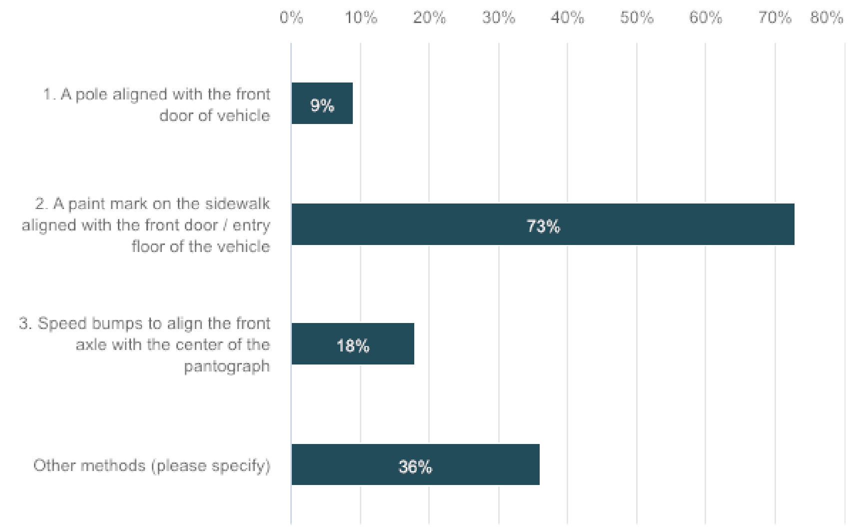
OEM	ID
Alstom	AL

6. Bus positioning method

Currently, there is no standard indicator available for guiding the bus to the charging point. But in ASSURED, a pole mounted on the sidewalk, that is aligned with the front door (Figure 8) is proposed, if the implementation location is not already using some other means for positioning.

Figure 8. Proposed method for bus positioning guidance for drivers in ASSURED, i.e. use of a pole mounted on the sidewalk

In the frame of T4.1 Pre-normative research and roadmaps, VTT, TNO and UITP ran a series of surveys targeting, among others, bus owners and/or users. Respondents were asked to report about the methods used for bus positioning. According to the results, a paint mark on the sidewalk is the most common method (Figure 9) and no difficulties regarding the visual marks were reported in the survey.



Other methods:

- A beacon
- Use of special traps for trolley boom rods for installation on a contact network
- Automatic positioning (the bus talks with the charging station)

Figure 9. Proposed method for bus positioning guidance for drivers in ASSURED, i.e. use of a pole mounted on the sidewalk

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