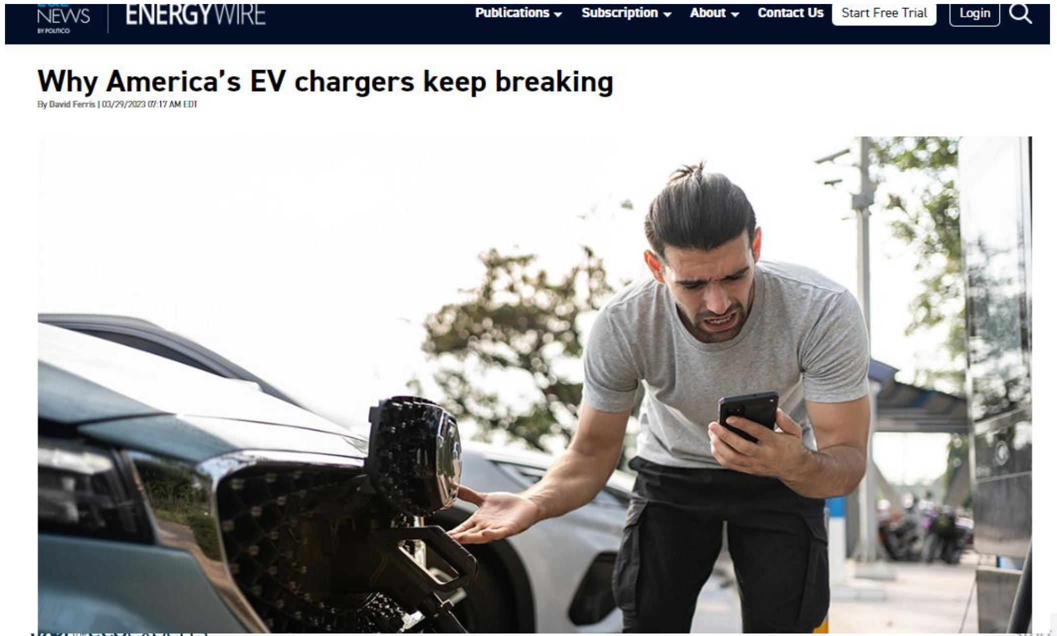
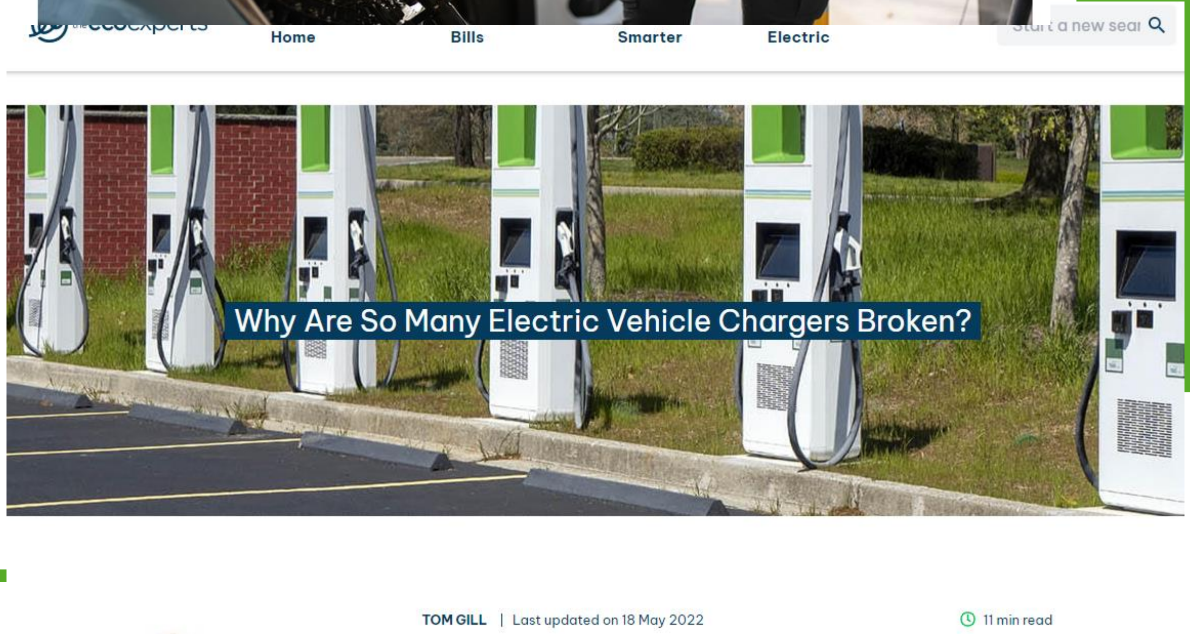
DC EVSE DESIGN BASED ON IEC 61851-23 ED 2. AND SAE J1772:2024

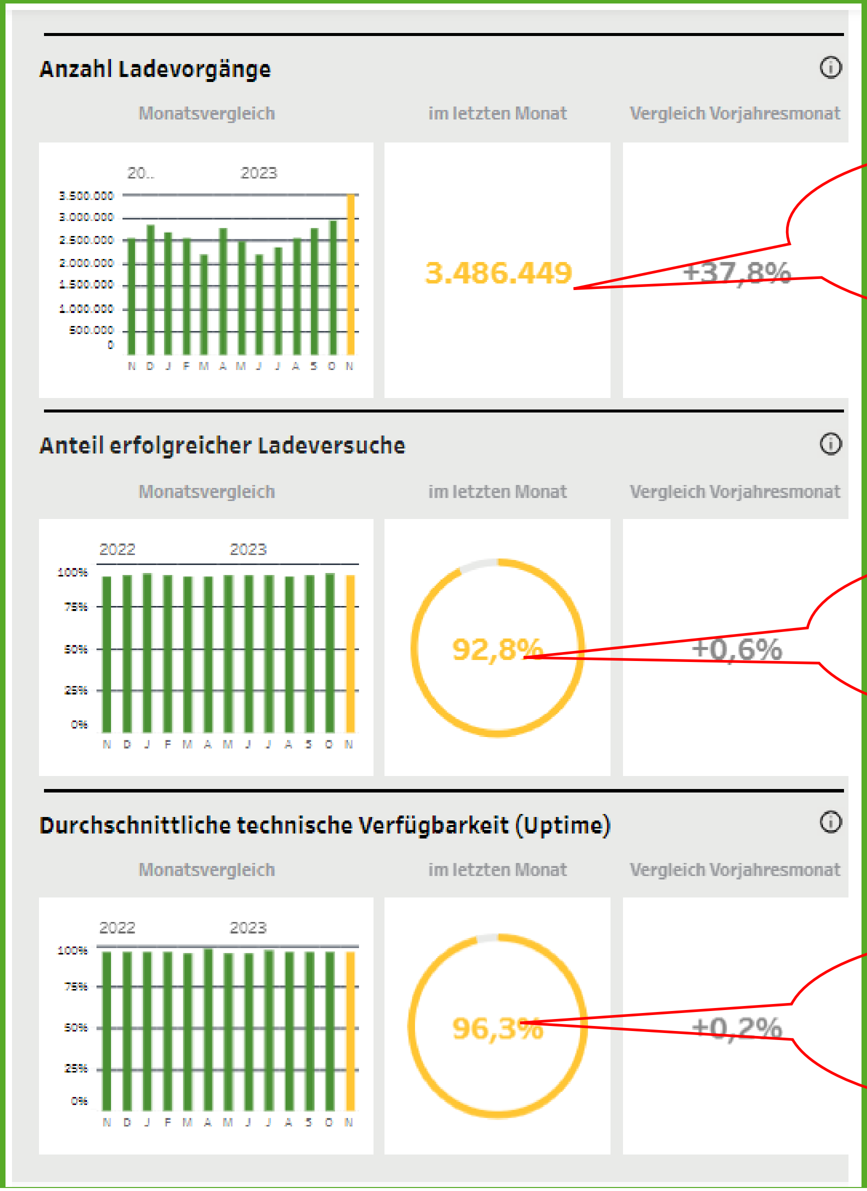
Beat.kreuter@dekra.com

The **Challenge**

Challenges to **adoption** of Electric Vehicle







Number of charging sessions (success)

8% of charging session are terminated within 2 minutes

5% of EVSE's are not avialble

The Solution

SAE INTERNATIONAL

SURFACE VEHICLE STANDARD	J1772™	JAN2024
	Issued 1996-10 Revised 2024-01 Superseding J1772 OCT2017	

(R) SAE Electric Vehicle and Plug-in Hybrid Electric Vehicle Conductive Charge Coupler

RATIONALE

The SAE J1772 document has been updated to refine the language of the standard; better define the AC connector dimensions; correct typogriphical errors found in the previous version; address changes needed in Y-capacitor limitations due to supporting charging at up to 1000V; address harmonization with IEC 61851 and ISO 15118 series documents related to DC charging, safety improvements and interoperability; and to reflect liquid cooling of cable/plug to support high current DC fast charging.

FOREWORD

Energy stored in a battery provides power for an electric vehicle (EV) or plug in hybrid electric vehicles (PHEV). Conductive charging is a method for connecting the electric power supply network to the EV/PHEV for the purpose of transferring energy to charge the battery and operate other vehicle electrical systems, establishing a reliable equipment grounding path, and exchanging control information between the EV/PHEV and the supply equipment. This document describes the electrical and physical interfaces between the EV/PHEV and supply equipment to facilitate conductive charging. Functional and

IEC®

IEC 61851-23

Edition 2.0 2023-12

INTERNATIONAL STANDARD

colour inside

Electric vehicle conductive charging system – Part 23: DC electric vehicle supply equipment

ermitted when a
ded.

DEKRA

Main differences – Main changes

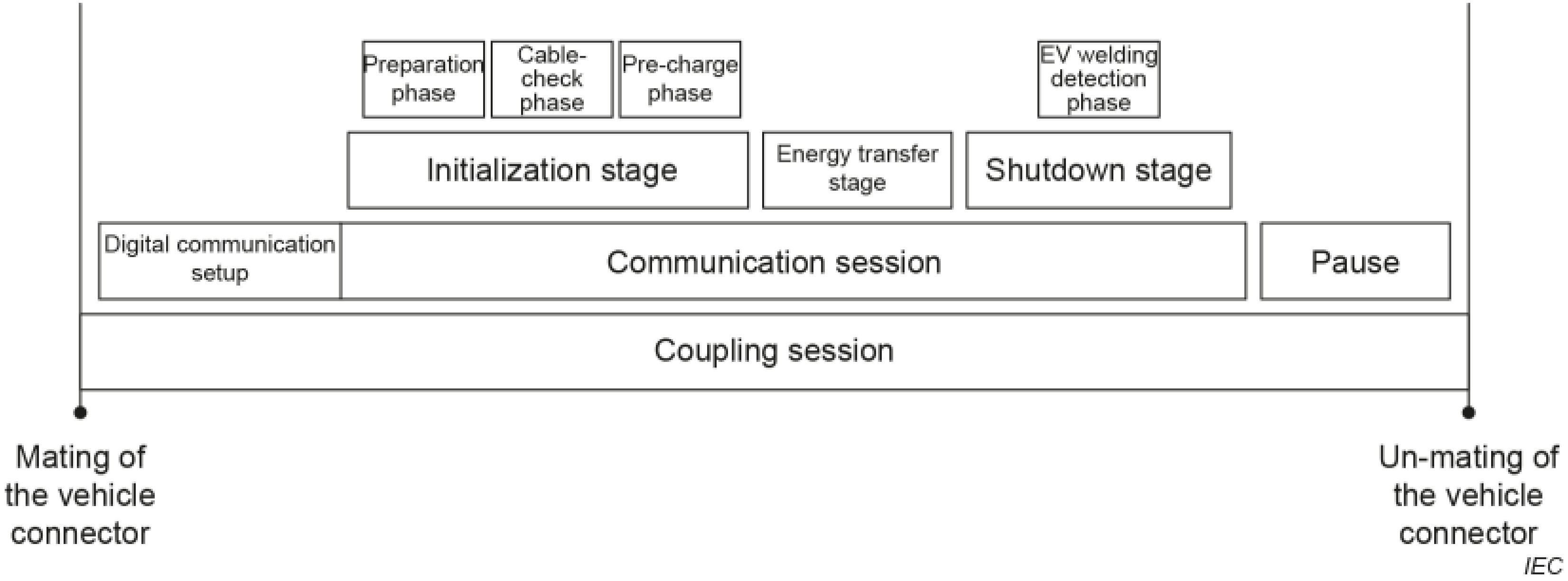
IEC 61851-23 Edition 2 (2023)

a) the structure has been rearranged according to IEC 61851-1:2017;
b) electrical safety requirements in Clause 8 and Clause 12 have been revised based on the requirements in IEC 62477-1 and inspired by the hazard based safety approach of IEC 62368-1;
c) test methods for checking conformity to the stated requirements have been mostly added; general provisions for compliance tests have been specified in Clause 102;
d) specific requirements and/or information for the following functions have been added: energy transfer with thermal management system (101.2), bi-directional power transfer control (Annex DD), multi- side B separated EV supply equipment (Annex FF), and communication and energy transfer process (Annex GG);
e) Annex AA (system A), Annex BB (system B) and Annex CC (system C) have been updated including additions in conjunction with b) and c). This document has been limited to be applicable to system A, system B and system C;
f) the former Annex DD and Annex EE have been deleted. A new Annex EE, with the requirements for the artificial test load, has been added.
g) a new informative annex for the touch current and the touch impulse current (Annex HH) has been added.

Main differences – Main changes

IEC 61851-23 Edition 2 (2023)

Definition of coupling session in replacement of charging session



Main differences – Important terms and definitions

IEC 61851-23 Edition 1 (2014)

controlled current charging – CCC

energy transfer method that the d.c. EV charging station regulates charging current according to the current value requested by the vehicle

controlled voltage charging – CVC

energy transfer method that the d.c. EV charging station regulates charging voltage according to the voltage value requested by the vehicle

IEC 61851-23 Edition 2 (2023)

controlled current mode – CCM

control mode of the EV supply equipment to control the present current at side B according to the target current of the EV supply equipment

controlled voltage mode – CVM

control mode of the EV supply equipment to control the present voltage at side B according to the target voltage of the EV supply equipment

Side A

supply network side

Side B

EV side

Rated boost current

upper limit of the current specified by the manufacturer up to which the EV supply equipment has been designed to operate for a limited period of time

Main differences – Functional requirements

IEC 61851-23 Edition 1 (2014)

verification that the vehicle is properly connected

protective conductor continuity checking (6.4.3.2)

energization of the system

de-energization of the system (6.4.3.4)

d.c supply for EV (6.4.3.101)

measuring current and voltage (6.4.3.102)

retaining / releasing coupler (6.4.3.103)

locking of the coupler (6.4.3.104)

compatibility assessment (6.4.3.105)

insulation test before charging (6.4.3.106)

protection against overvoltage at the battery (6.4.3.107)

verification of vehicle connector voltage (6.4.3.108)

control circuit supply integrity (6.4.3.109)

short circuit test before charging (6.4.3.110)

user initiated shutdown (6.4.3.111)

overload protection for parallel conductors (conditional function) (6.4.3.112)

protection against temporary overvoltage (6.4.3.113).

IEC 61851-23 Edition 2 (2023)

verification that the EV is properly connected to the EV supply equipment (6.3.1.3)

continuous continuity checking of the protective conductor (6.3.1.2)

energization of the power supply to the EV (6.3.1.4)

de-energization of the power supply to the EV (6.3.1.5)

maximum allowable current (6.3.1.6)

DC supply for EV (6.3.1.101)

measuring current and voltage (6.3.1.102)

latching of the vehicle coupler (6.3.1.103)

compatibility check (to 6.3.1.104)

insulation resistance check before energy transfer (6.3.1.105)

protection against overvoltage between DC+ and DC– (6.3.1.106)

verification of vehicle connector latching (6.3.1.107)

control circuit supply integrity (6.3.1.108)

short-circuit check before energy transfer (6.3.1.109)

user initiated shutdown (6.3.1.110)

overload protection for parallel conductors (conditional function) (6.3.1.111)

voltage limitation between side B (according to 6.3.1.112)

shutdown of EV supply equipment (6.3.1.113)

Main differences – Output Current regulation

IEC 61851-23 Edition 1 (2014)

Limit	Target current
± 2,5 A	EVTargetcurrent < 50A
± 5 %	$EV_{Targetcurrent}$ when $EV_{Targetcurrent}$ ≥ 50 A

IEC 61851-23 Edition 2 (2023)

Limit	Target current
± 150 mA	$EV_{Targetcurrent}$ < 5 A DC
± 1,5 A	$EV_{Targetcurrent}$ ≥ 5 A DC but ≤ 50 A
± 3 %	$EV_{Targetcurrent}$ when $EV_{Targetcurrent}$ > 50 A DC

Main differences – Current / Voltage Ripple Limits (CCM / CVM)

IEC 61851-23 Edition 1 (2014)

Frequency	Limit
below 10Hz	1.5A (peak-peak) at maximum rated power and maximum rated current
below 5 kHz	6A (peak-peak) at maximum rated power and maximum rated current
150 kHz	9A (peak-peak) at maximum rated power and maximum rated current

IEC 61851-23 Edition 2 (2023)

Frequency	**Present current at side B (I)**		
	I ≤ 200 A DC	**200 A DC < I ≤ 400 A DC**	**I > 400 A DC**
10 Hz	**1,5**	**I × 0,75 %**	**3,0** **I × 0,75 %**
5 kHz	**(I × 1,5 % + 3)** **6.0**	**6,0**	**I × 1,5 %**
150 kHz	**9.0**	**I × 4,5 %**	**18,0** **I × 4,5 %**

Limits are in A peak-to-peak

Controlled voltage mode (CVM)

± 5 % during pre-charge and charging of requested voltage for EV < 500V

± 1 % during pre-charge and charging of requested voltage for EV > 500V

Main differences – Thermal management and Over Temperature Protection

IEC 61851-23 Edition 1 (2014)

Temperature monitoring

The station shall shutdown when the lower of the following 2 limits is exceeded:

– the vehicle connector contact temperature limit is exceeded; or

– the vehicle connector cable temperature rating is exceeded.

For vehicle connectors designed to operate with contact temperature greater than 120 °C, the d.c. EV charging station shall shutdown when the vehicle connector contact temperature reaches or exceeds 120 °C.

IEC 61851-23 Edition 2 (2023)

Overtemperature handling

If the contact temperature of the DC contact accessory is > 90 °C for 8 consecutive seconds, the EV supply equipment shall trigger an error shutdown in 1 s or less according CC.3.4 for system C.
If the contact temperature of the DC contact accessory is > 95 °C for 1 s, the EV supply equipment shall trigger an error shutdown in 1 s or less

Compliance is checked by test In 101.2.4.3. (extensive test case)

Extensive tests for thermal sensing (connector, cable) devices before and during energy transfer while the later shall to be performed at rated continuous current

Main differences – Thermal management and Over Temperature Protection

IEC 61851-23 Edition 1 (2014)

IEC 61851-23 Edition 2 (2023)

Thermal management system

- cable assembly according to IEC TS 62196-3-1

- Tests for thermal management system performance of the EV supply equipment
- Tests executed at 40 °C ± 4 °C ambient temperature and at rated continuous current of the EV supply equipment at side B
- temperature-controlled energy transfer (see 101.3), the test shall be performed including the rated boost current of the EV supply equipment at side B
- After reaching thermal stabilization – to be operated at the rated continuous current of the EV supply equipment at side B for an additional 60 min

Main differences – Cable check voltages (Cable Check Phase)

IEC 61851-23 Edition 1 (2014)

The d.c. supply shall perform insulation monitoring between DC+ and PE and DCand PE during the supply process and communicate the current state (Invalid, Valid, Warning, Fault) of the system periodically to the EV.

Prior to each supply cycle the following tests shall be performed. During these tests the d.c. output voltage shall not exceed 500 V at vehicle connector.

IEC 61851-23 Edition 2 (2023)

During the cable-check phase, the EV supply equipment shall perform the following checks.

- Perform and finish the functional check of the IMD under a controlled voltage at side B
- Perform the insulation resistance check under a controlled voltage at side B
- Perform the short-circuit check before energy transfer
- Optional: perform a welding check of the EV supply equipment disconnection device during the cable-check phase. If the EV supply equipment performs a welding detection, then the EV supply equipment shall still comply with the requirements of 6.3.1.112 (Voltage limitation btw side B (+/-) and ground).

  If the results of all the checks during the cable-check phase are "Passed" or "Valid", the EV supply equipment shall send message CableCheckRes with parameters "EVSEIsolationStatus" = ‘Valid’ and "ResponseCode" = ‘OK’, and "EVSEProcessing" = ‘Finished’ in the last "CableCheckReq" message.

Main differences – Cable check voltages (Cable Check Phase)

IEC 61851-23 Edition 1 (2014)

Prior to each supply cycle the following tests shall be performed. During these tests the d.c. output voltage shall not exceed 500 V at vehicle connector.

IEC 61851-23 Edition 2 (2023)

In the cable-check phase, during the functional check of the IMD and the insulation resistance check, the EV supply equipment shall apply a controlled present voltage at side B according to the rated maximum voltage values communicated in the last set of ChargeParameterDiscoveryReq/Res messages. See Formula (CC.1).

If $V_{EV\_MAX\_CPD} \leq 500$ V (EV_MaximumVoltage)

$V_{EVSE\_CableCheck} = \min(V_{EV\_MAX\_CPD} + 50\text{ V}, V_{EVSE\_MAX\_CPD}, 500\text{ V})$

If $V_{EV\_MAX\_CPD} > 500$ V (EV_MaximumVoltage)

$V_{EVSE\_CableCheck} = \min(1.1 \times V_{EV\_MAX\_CPD}, V_{EVSE\_MAX\_CPD})$

The voltage deviation of the $V_{EVSE\_CableCheck}$ shall be between ±5 % of the $V_{EV\_MAX\_CPD}$, or ±2 % of the $V_{EVSE\_MAX\_CPD}$, whichever deviation is less,

Main differences – Emergency shutdown

IEC 61851-23 Edition 1 (2014)

DC supply initiated emergency shutdown

An emergency shutdown of the output current to less than 5 A within 1s with a current descending rate of 200 A/s or more shall be applied by the d.c. supply.

DC supply shall indicate supply initiated emergency shutdown by turning off CP oscillator.

EV initiated emergency shutdown

EV triggers emergency shutdown by opening S2 and changing CP state from C/D to B. DC supply shall acknowledge emergency shutdown request from the EV by performing emergency shutdown

IEC 61851-23 Edition 2 (2023)

DC supply initiated emergency shutdown

After the emergency shutdown is triggered by the EV supply equipment, the EV supply equipment shall reduce and maintain:

– the present current at side B ≤ 5 A in 20 ms or less for system C, and

– the present voltage at side B ≤ 60 V DC between DC+ and DC–, between DC+ and the protective conductor, and DC– and the protective conductor in 1 s or less for system C

Reaction time	Trigger reason
10 ms or less	Loss of electrical continuity of the control pilot conductor
10 ms or less	Loss of electrical continuity of the proximity detection conductor
500 ms or less	Overcurrent protection
1 ms or less	Protection against overvoltage at side B between DC+ and DC– (if voltage exceeds threshold for more than 9 ms)
150 ms	Loss of electrical continuity the protective conductor
1 s or less	Short-circuit protection
10 ms or less	EV reaction for EV initiated emergency shutdown

Main differences – Pre-Charge

IEC 61851-23 Edition 1 (2014)

For CVC, the maximum voltage deviation during pre-charge state and during charging of the vehicle/traction battery shall not exceed ±5 % of the requested voltage. The maximum voltage ripple in normal operation shall not exceed ±5 V. The maximum voltage slew rate in normal operation shall not exceed ±20 V/ms.

IEC 61851-23 Edition 2 (2023)

For CVM, the maximum voltage deviation, during the pre-charge phase and during the energy transfer stage of the battery system shall be between ±5 % of the target voltage requested by the EV, or ±2 % of the rated maximum voltage of the EV supply equipment at side B, whichever deviation is smaller

During the pre-charge phase, the EV supply equipment shall operate in CVM to follow the target voltage of the EV according to 101.1.2.2 and 101.1.6. The EV supply equipment shall

- be able to pre-charge the circuit defined in Figure CC.14 with the values according to Table CC.19 for its entire operating range in 3 s or less, and
- subsequently follow a change in the target voltage of the EV of a maximum of ±50 V DC in 1 s or less.

Main differences – Wake up

IEC 61851-23 Edition 1 (2014)

The d.c. supply may support a standby mode to minimize power consumption as described as optional function in 6.4.4.101. In this case it is mandatory for the d.c. supply to wake up and resume energy supply according to the following method.

- If the vehicle attached to the d.c. supply has not changed the control pilot from state B2 to C2 or D2 for more than 2 min, the station may go to sleep. The control pilot signal B1 shall be supplied continuously by the d.c. supply to enable a wake up of the station triggered by the EV changing into state C1 or D1.

IEC 61851-23 Edition 2 (2023)

Sleep mode is an operating mode of the EV supply equipment or EV designed for reduced energy consumption when a communication session is not occurring. In this case, the EVCC or SECC are permitted to not communicate via digital communication.

Restart methods

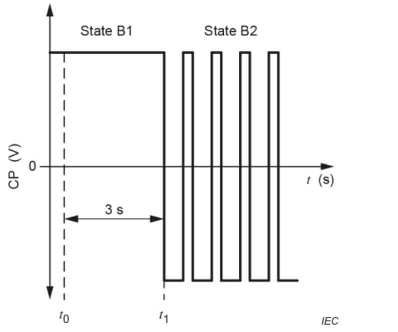


Figure CC.17 – Example of a B1 – B2 transition

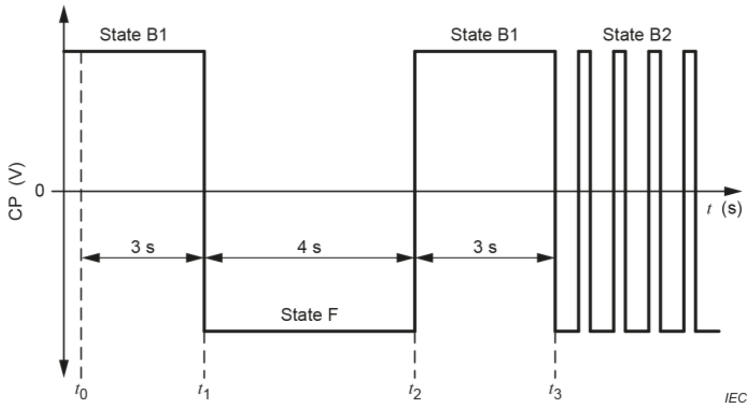


Figure CC.19 – Example of a B1 – F – B1 – B2 transition

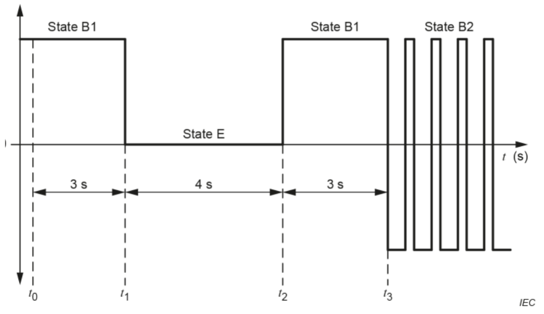


Figure CC.18 – Example of a B1 – E – B1 – B2 transition

Main differences – Wake up

IEC 61851-23 Edition 1 (2014)

IEC 61851-23 Edition 2 (2023)

Restart methods

B1 – B2 transition

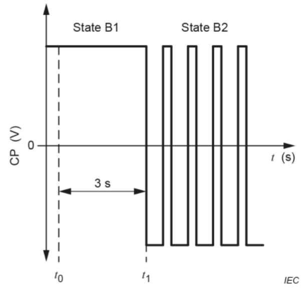


Figure CC.17 – Example of a B1 – B2 transition

B1 – E – B1 – B2 sequence

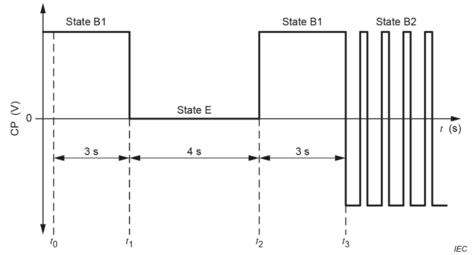


Figure CC.18 – Example of a B1 – E – B1 – B2 transition

B1 – F – B1 – B2 sequence

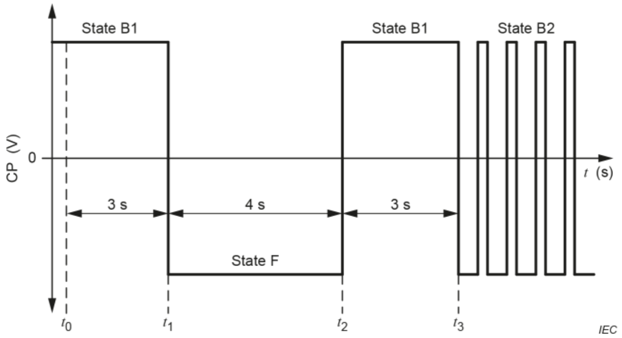
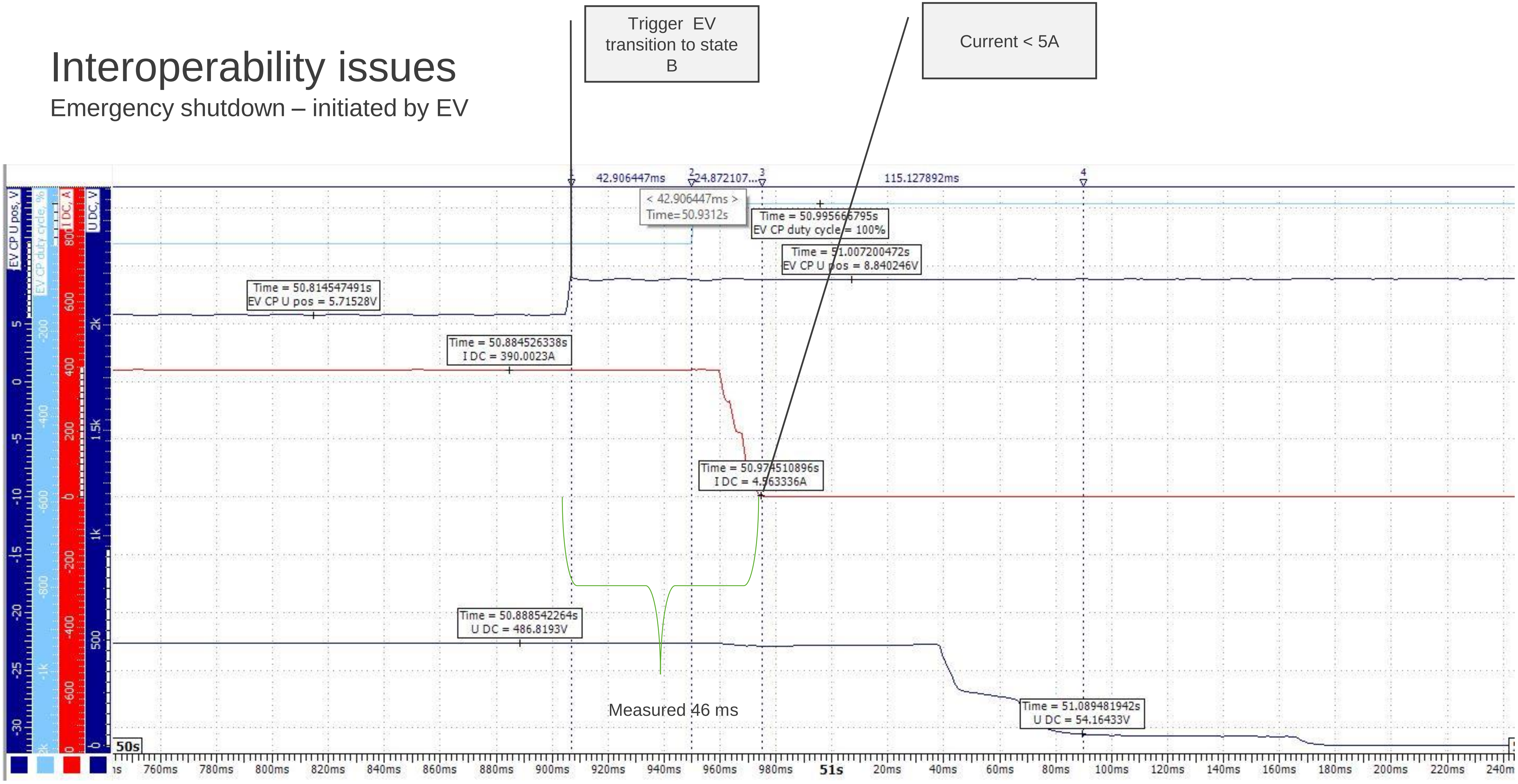


Figure CC.19 – Example of a B1 – F – B1 – B2 transition

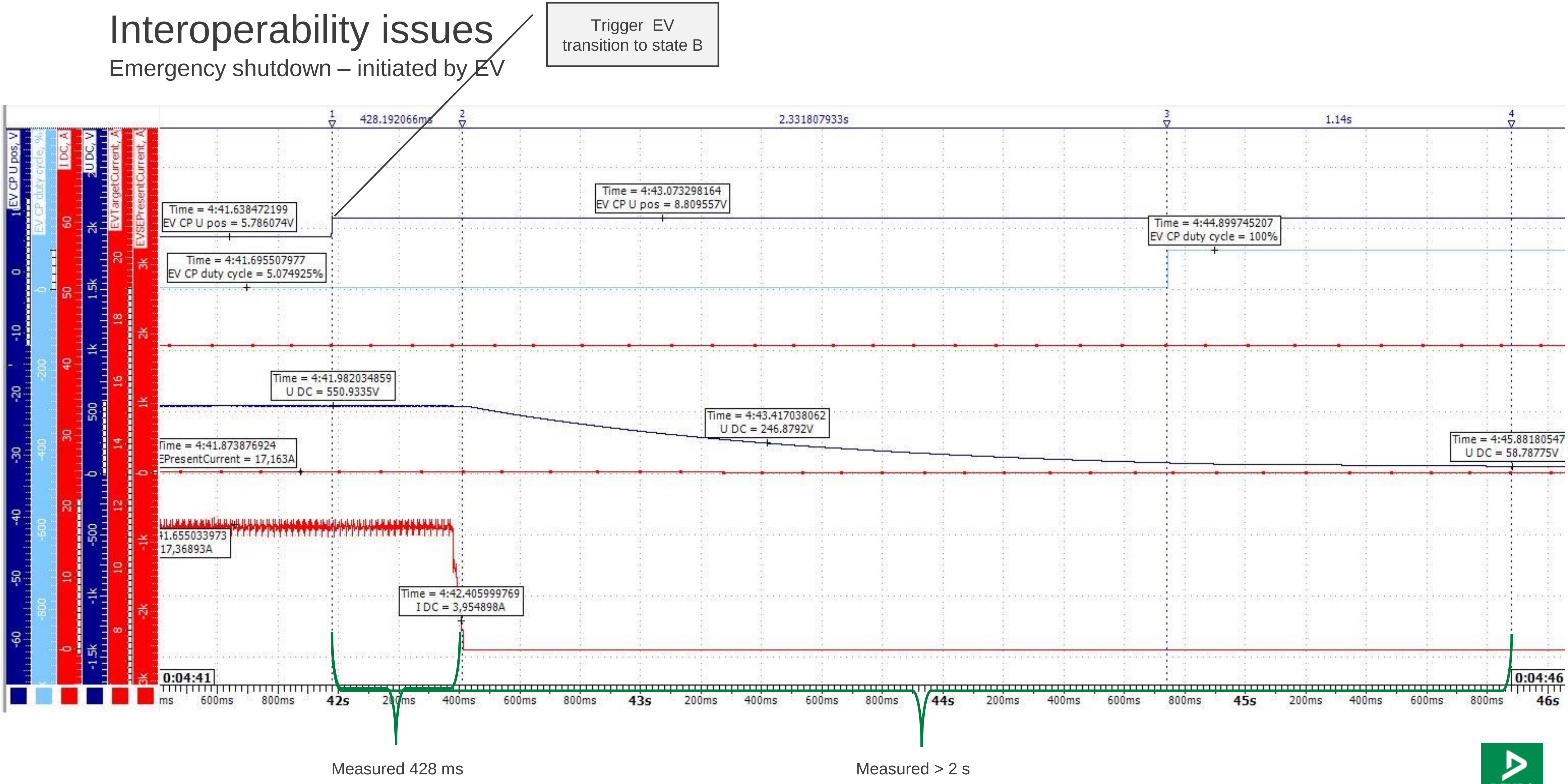
Interoperability issues

Emergency shutdown – initiated by EV



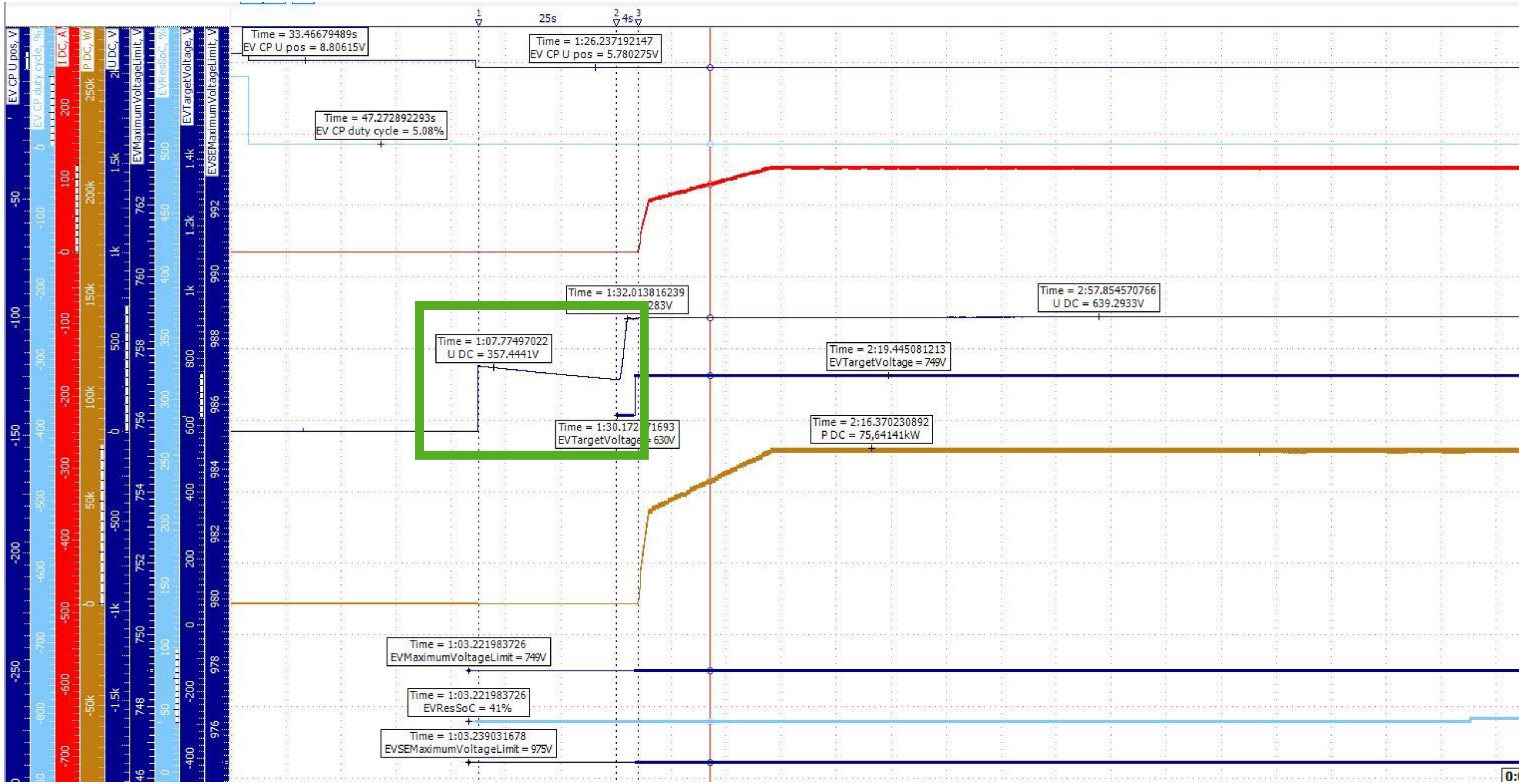
Interoperability issues

Emergency shutdown – initiated by EV



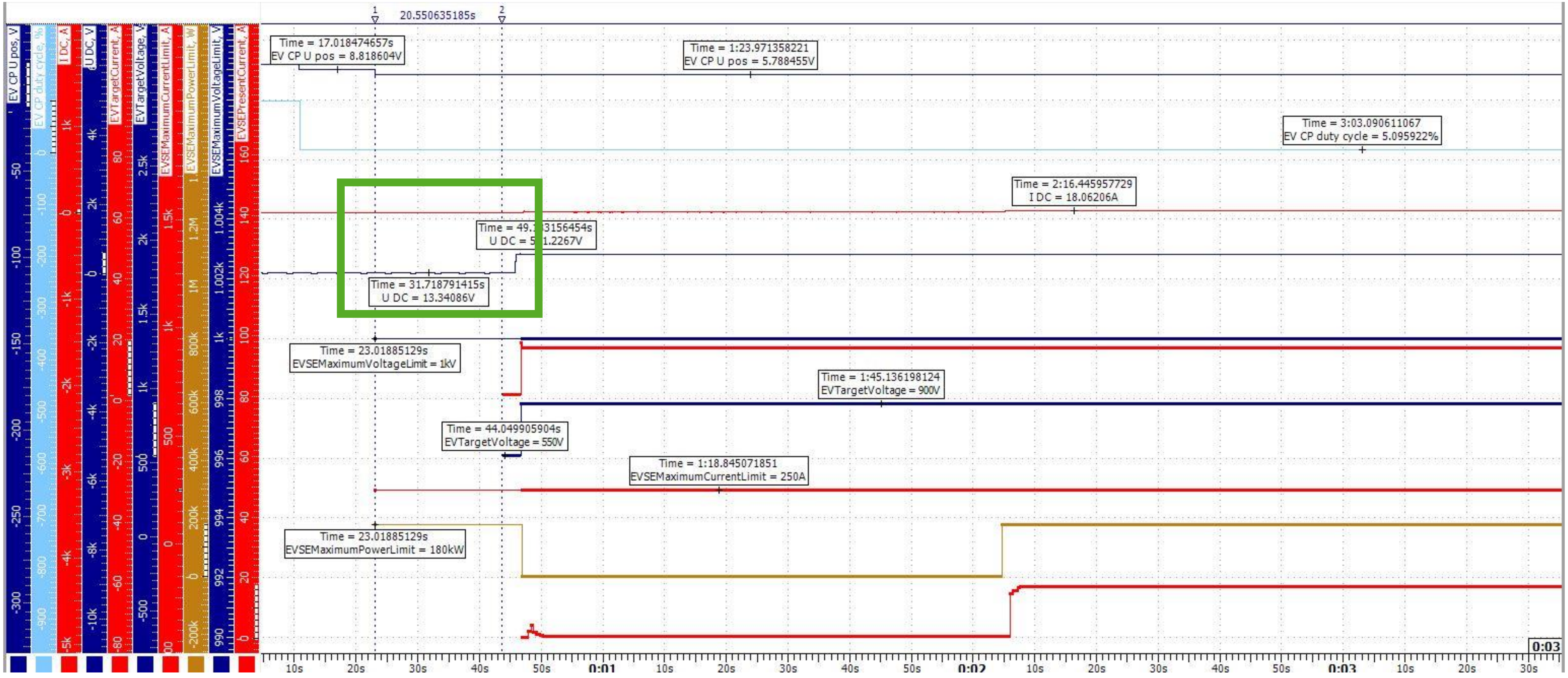
Interoperability issues

Cable Check Voltage



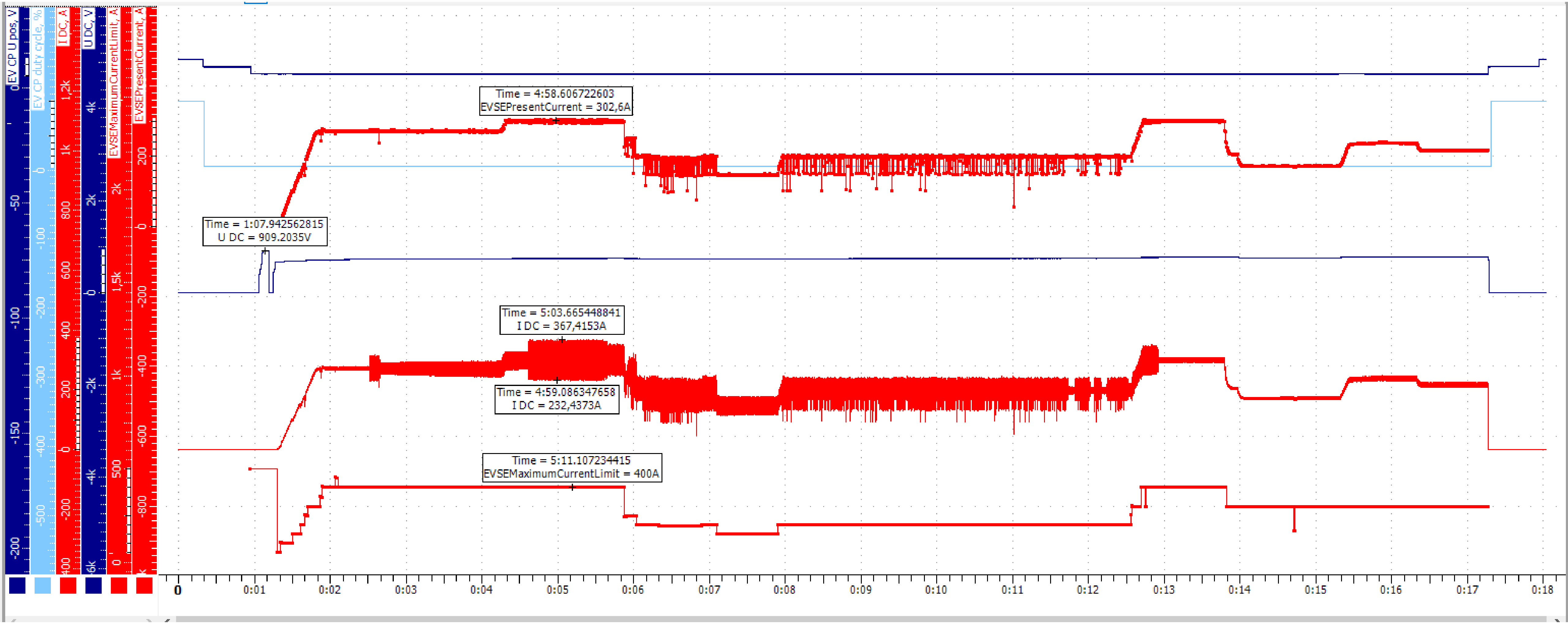
Interoperability issues

Cable Check Voltage



Interoperability issues

Ripple Current



Summary IEC 61851-23 Ed. 2

a) The IEC standard improves reliability of charging infrastructure
b) Each functional and performance requirements has now a clearly defined test case to confirm compliance with the requirements
   a) Compatibility check
   b) Normal start up
   c) Wake up of EV supply equipment by EV
   d) Loss of electrical continuity of the control pilot
   e) Protective conductor continuity checking
   f) Rated EV supply equipment value at side B
   g) Protection against overvoltage at the vehicle connector (emergency shut down and error shutdown, temporary overvoltage)
   h) Emergency shutdown in case of proximity pilot disconnection
   i) Load dump
   j) Limiting inrush current by EV supply equipment
   k) Side B current regulation in CCM including static deviation and ripple
   l) 0A mode during energy transfer
   m) Side B voltage regulation in CVM during pre-charge
   n) Control delay of present current at side B in CCM
   o) Insulation resistance checks before pre-charge (cable-check)
   p) Insulation resistance check to detect fault state during energy transfer
   q) Short-circuit between the control pilot conductor and the protective conductor
   r) Test of measured voltage values during welding detection
   s) Normal shutdown by EV supply equipment
   t) Short-circuit check before energy transfer
   u) Functional check of the insulation monitoring device

Conformance & Interoperability testing & certification

completed | ongoing | open

CCS Basic v1.1.x 30.07.2021

Requirements	DC EVSE	AC EVSE 40TC open
Test Cases	DC EVSE 207 TC*	AC EVSE

CharIN is responsible for fixing the Implementation baseline to ensure a competitive CCS charging system in SYNC with directives and homologation requirements

EVSE products can be **tested** and **certified** for **CCS Basic DC EVSE v1.1.6**

CCS Basic v1.2 is being evaluated

CCS Extended 21.09.2022 (Start)

Requirements	DC EVSE	AC EVSE	AC EV	AC EVSE
Test Cases	DC EVSE	AC EVSE	AC EVSE	AC EVSE

CharIN is responsible for fixing the Implementation baseline to ensure a competitive CCS charging system in SYNC with directives and homologation requirements

On basis of ISO 15118 incl. PnC

EVSE products can be **validated** and **certified** for **CCS Extended by end of 2024**

EV products can be **validated** and **certified** for **CCS Extended by ???**

***Test cases implemented in CCTS**

What elements are included in CharIN CCS Basic DC EVSE

EVSE IEC 61851-1

9 Test Cases

- **Control Pilot**
- **Proximity Pilot**

Tested parameters

Frequency
Duty Cycle
Voltages
Tolerances

What elements are included in CharIN CCS Basic DC EVSE

EVSE IEC 61851-23

29 Test Cases

- **Control Pilot**
- **Proximity Pilot**
- **High Voltage**
- **Communication**

Tested parameters

Short Circuit
Protection against overvoltage
Interrupts of CP and PP
Load Dump
Charging Performance
Cable Check voltage levels
Pre-charge voltage levels
Insulation Monitor checks valid and error
Emergency Shutdown
Charging Reliability
Reverse Power Flow
Compatibility Assessment
Power Class
Etc.

What elements are included in CharIN CCS Basic DC EVSE

EVSE **CharIN Implementation Guide to DIN 70121/22**

72 Test Cases

- **PLC Link Layer**
- **V2G communication**

Tested parameters

SLAC match process
BCB validation
Protocol support
V2G handshake
Contract authentication
Charge parameter
Energy transfer cycle
Terminating energy transfer
Terminating charge session
Unlock and unplug
ISO 15118 interoperability
Charging reliability
Charging robustness
PIXIT

What elements are included in CharIN CCS Basic DC EVSE

EVSE **DIN 70122**

59 Test Cases

- **PLC Link Layer**
- **V2G communication**

Tested parameters

SLAC match process
BCB validation
Protocol support
Contract authentication
Charge parameter
Energy transfer cycle
Terminating energy transfer
Terminating charge session
Unlock and unplug

What elements are included in CharIN CCS Extended DC EVSE

EVSE **ISO 15118 (incl. PnC)**

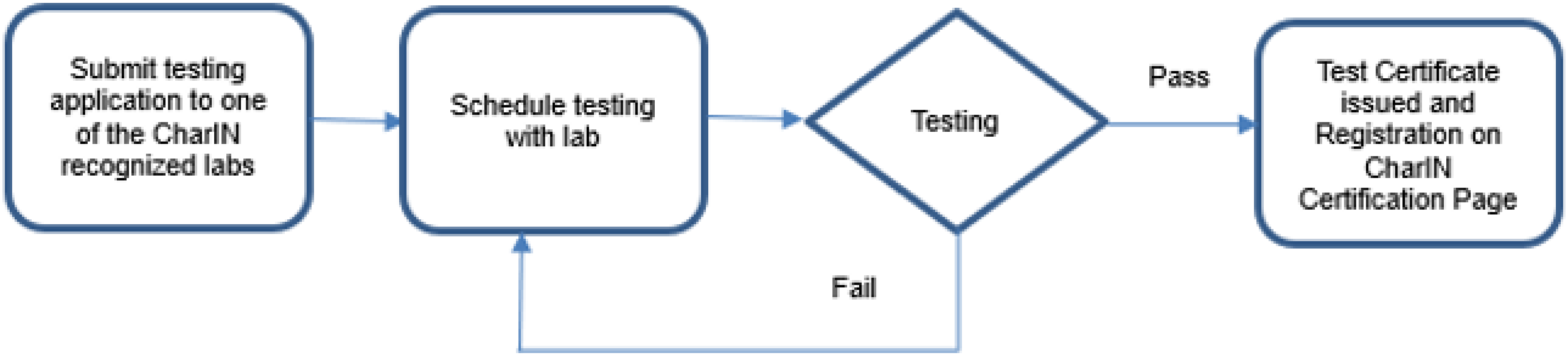
XX Test Cases

- **PLC Link Layer**
- **V2G communication**

Tested parameters

SLAC match process
BCB validation
Protocol support
Contract authentication
Charge parameter
Energy transfer cycle
Terminating energy transfer
Terminating charge session
Unlock and unplug
Plug and Charge

Certification Process



1. Applicants submit testing application including PIXIT information to CharIN recognized lab (https://www.charin.global/technology/charin-conformance-testing/)
2. Applicant coordinates with test lab about test date, technical and financial arrangements.
3. Test labs executes conformance testing using latest CharIN Conformance Test document
4. If product fails, retesting maybe scheduled (refer also to section 7)
5. Test lab issues CharIN Test Certificate and registers product on CharIN database

https://www.charin.global/technology/charin-conformance-testing/

Thank you,

for taking care of

SAFETY