



SURFACE VEHICLE RECOMMENDED PRACTICE

J2953™/3

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Plug-in Electric Vehicle Communication Interoperability with Electric Vehicle Supply Equipment

RATIONALE

The purpose of this recommended practice is to overview and clarify the requirements for digital communications and functions as defined in Plug-in Electric Vehicles charging standards, and then identify requirements for conformance and interoperability.

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1. SCOPE

This SAE Recommended Practice summarizes the conformance requirements for digital communication between the PEV and EVSE and establishes the interoperability requirements for successful charging sessions. This first version includes charging conformance summary for both the vehicle and EVSE and updates from CharIN with modifications, additions, and deletions to improve successful charging sessions. The summary of all existing charging/discharging standards, conformance, and functional categories will be updated in subsequent updates, and message/signal/values that would cause an interoperability issue will be clarified as this leads to diagnostic codes the vehicle/EVSE/Charge Point Operator and others can view to let the customer know what specific issue led to a failure to charge or discharge. This additional effort is ongoing and will be expanded in the next version update as this becomes more mature.

1.1 Purpose

This document assembles and clarifies the requirements for digital communications and functions as defined in related PEV charging standards (listed below). It provides support for charging, discharging, and Distributed Energy Resource systems, which are developed according to SAE J1772 and SAE J3400, and implements the digital communication requirements within the SAE J2836, SAE J2847, and SAE J2931 series of standards. There is also support for SAE J3072, which identifies the AC vehicle to grid requirements and protocols as various options are available to the consumer and utility. This document complements analog communication in SAE J2953/1 and SAE J2953/2 and clarifies conformance versus interoperability requirements.

1.2 Revision Information

This first revision addresses communications and functions for digital communication systems.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J1772	SAE Electric Vehicle and Plug-in Hybrid Electric Vehicle Conductive Charge Coupler
SAE J2836/1	Use Cases for Communication Between Plug-in Vehicles and the Utility Grid
SAE J2836/2	Use Cases for Communication Between Plug-in Vehicles and Off-Board DC Charger
SAE J2836/3	Use Cases for Plug-In Vehicle Communication as a Distributed Energy Resource
SAE J2847/1	Communication for Smart Charging of Plug-in Electric Vehicles Using Smart Energy Profile 2.0
SAE J2847/2	Communication Between Plug-in Vehicles and Off-Board DC Chargers
SAE J2847/3	Communication for Plug-in Vehicles as a Distributed Energy Source
SAE J2847/5	Communication Between Plug-in Vehicles and Customers
SAE J2847/6	Communication for Wireless Power Transfer Between Light-Duty Plug-in Electric Vehicles and Wireless EV Charging Stations
SAE J2931/1	Digital Communications for Plug-in Electric Vehicles

SAE J2931/4	Broadband PLC Communication for Plug-in Electric Vehicles
SAE J2953/1	Plug-in Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)
SAE J2953/2	Test Procedures for the Plug-in Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)
SAE J2954	Wireless Power Transfer for Light-Duty Plug-in/Electric Vehicles and Alignment Methodology
SAE J3072	Interconnection Requirements for Onboard, Grid Support Inverter Systems
SAE J3400	North American Charging System (NACS) for Electric Vehicles

2.1.2 DIN Publications

Copies of these documents are available online at <https://www.din.de/en/>.

DIN 70121	Digital Communication Between a D.C. EV Charging Station and an Electric Vehicle for Control of D.C. Charging in the Combined Charging System
DIN 70122	Conformance Tests for Digital Communication Between a D.C. Charging Station and an Electric Vehicle for Control of D.C. Charging in the Combined Charging System

2.1.3 IEC Publications

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

IEC 61850-7-420	Communication Networks and Systems for Power Utility Automation - Part 7-420, Basic Communication Structure - Distributed Energy Resources Logical Nodes
IEC 61851-1	Electric Vehicle Conductive Charging System - Part 1: General Requirements
IEC 61851-21-1	Electric Vehicle Conductive Charging System - Part 21-1: Electric Vehicle On-Board Charger EMC Requirements for Conductive Connection to an AC/DC Supply
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
IEC 61851-23	Electric Vehicle Conductive Charging System - Part 23: DC Electric Vehicle Supply Equipment

2.1.4 IEEE Publications

Available from IEEE Operations Center, 445 and 501 Hoes Lane, Piscataway, NJ 08854-4141, Tel: 732-981-0060, www.ieee.org.

IEEE 1547-2018	Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces
IEEE 1547.1-2020	Standard Conformance Test Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces
IEEE 1815	IEEE Standard for Electric Power Systems Communications - Distributed Network Protocol
IEEE 2030.5	IEEE Standard for Smart Energy Profile Application Protocol

2.1.5 ISO Publications

Copies of these documents are available online at <https://webstore.ansi.org/>.

ISO 15118	Road vehicles - Vehicle to grid communication interface
ISO 15118-1	Road vehicles - Vehicle to grid communication interface - Part 1: General information and use-case definition
ISO 15118-2	Road vehicles - Vehicle to grid communication interface - Part 2: Network and application protocol requirements
ISO 15118-3	Road vehicles - Vehicle to grid communication interface - Part 3: Physical layer and Data Link Layer requirements
ISO 15118-4	Road vehicles - Vehicle to grid communication interface - Network and application protocol conformance test
ISO 15118-5	Road vehicles - Vehicle to grid communication interface - Physical and data link layer conformance test
ISO 15118-8	Road vehicles - Vehicle to grid communication interface - Physical layer and data link layer requirements for wireless communication
ISO 15118-9	Road vehicles - Vehicle to grid communication interface - Physical layer and data link layer conformance test for wireless communication
ISO 15118-10	Road vehicles - Vehicle to grid communication interface - Physical layer and data link layer requirements for single-pair Ethernet
ISO 15118-20	Road vehicles - Vehicle to grid communication interface - Part 20: Network and application protocol Requirements
ISO 15118-21	Road vehicles - Vehicle to grid communication interface - Common 2nd generation network layer and application layer requirements conformance test plan
ISO 15118-23	Road vehicles - Vehicle to grid communication interface - Conductive AC/DC Charging 2nd generation network layer and application layer requirements conformance test plan

2.1.6 UL Publications

Available from UL, 333 Pfingsten Road, Northbrook, IL 60062-2096, Tel: 847-272-8800, www.ul.com.

UL 1741	Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources
UL 1741 SB	Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources: Supplement SB
UL 1741 SC	Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources: Supplement SC Bidirectional Electric Vehicle Supply Equipment (BEVSE)/Interconnection Systems Equipment (ISE) for EVs with Bidirectional Onboard Inverters
UL 2202	Standard for Safety for Electric Vehicle (EV) Charging System Equipment
UL 2594	Standard for Safety for Electric Vehicle Supply Equipment
UL 9741	Outline of Investigation for Bidirectional Electric Vehicle (EV) Charging System Equipment

2.1.7 Electric Power Research Institute (EPRI) Publications

Available from EPRI, 3420 Hillview Avenue, Palo Alto, California 94304, www.epri.com.

Common Functions for Smart Inverters: 4th Edition

Electric Transportation Standards Update for 2023

2.1.8 SunSpec Alliance Publications

Available from SunSpec Alliance, www.sunspec.org.

CSIPImplementationGuideV2.103-15-2018

IEEE 2030.5 V2G-AC Profile Implementation Guide for SAE J3072

SunSpecCSIPConformanceTestProceduresV1.2

3. DEFINITIONS

3.1 CEASE TO ENERGIZE

The DER ceases all active power output.

Allow active power output at the PCC.

Cease to energize is a different function from disconnect/connect. The definition is “the DER shall not export active power during steady-state or transient conditions. Reactive power exchange (absorb or supply) shall be less than x% of nameplate DER rating and shall exclusively result from passive devices.” There may be a time delay between receiving the command and the actual cease to energize.

3.2 CONFORMANCE

Conformance is testing the EV to requirements in the standards and the EVSE to the requirements in the standards.

3.3 DISCONNECT/CONNECT FUNCTION

Disconnect or connect the DER from the grid at its ECP.

The disconnect command initiates the galvanic separation (usually via switches or breakers) of the DER at its ECP or at the PCC. There may be a time delay between receiving the command and the actual disconnect.

The connect command initiates or allows the reconnection of the DER at its ECP or at the PCC. A permission to reconnect may also be issued.

3.4 DISTRIBUTED ENERGY RESOURCE (DER)

Distributed energy resources are small, modular generation and storage technologies that provide electric capacity or energy where needed on the distribution grid. Generation, which includes gensets, solar panels, and small wind turbines, only serve as a source of energy. Storage is a unique form of DER because, unlike pure generation, the unit can also provide variable demand. Plug-in vehicles are storage systems.

3.5 DROOP/FREQUENCY-ACTIVE POWER PRIMARY CONTROL OPERATIONAL FUNCTION

The active power output of a generator reduces as the line frequency increases above nominal frequency and vice versa.

Droop is a control mode used for AC electrical power generators to maintain the frequency within the normal operating zone, focused on returning the frequency to its nominal value (e.g., 50 Hz or 60 Hz). Specifically, the active power output of a generator reduces as the line frequency increases above nominal frequency and vice versa. It is commonly used as the speed control mode of the governor of a prime mover driving a synchronous generator connected to an electrical grid.

3.6 DYNAMIC REACTIVE CURRENT SUPPORT OPERATIONAL FUNCTION

The DER reacts against rapid voltage changes (spikes and sags) to provide dynamic system stabilization dV/dt .

The DER provides dynamic reactive current support in response to voltage spikes and sags, similar to acting as inertia against rapid changes. This operational function may be focused on emergency situations or may be used during normal operations.

When the dynamic reactive current support operational function is enabled, the DER monitors the voltage at the Referenced ECP and responds based on the parameters.

3.7 ELECTRICAL CONNECTION POINT (ECP)

Same as Point of Common Coupling (PCC).

3.8 FIXED (CONSTANT) POWER FACTOR OPERATIONAL FUNCTION

The DER power factor is set to a fixed value.

The DER power factor is set to the specified power factor. A leading power factor is positive and a lagging power factor is negative, as defined by the IEEE or IEC sign conventions.

3.9 FIXED (CONSTANT) REACTIVE POWER OPERATIONAL FUNCTION

The DER is requested to provide a fixed amount of reactive power.

3.10 FREQUENCY-ACTIVE POWER SENSITIVITY OPERATIONAL FUNCTION

The DER responds to large frequency excursions during abnormal events at a Referenced ECP by changing its production or consumption rate.

The DER is provided with frequency-active power curves that define the changes in its watt output based on frequencies around the nominal frequency during abnormal events.

When the frequency-active power sensitivity operational function is enabled, the DER monitors the frequency and adjusts its production or consumption rate to follow the specified emergency frequency-active power curve parameters.

3.11 HIGH/LOW FREQUENCY RIDE-THROUGH OPERATIONAL FUNCTION

The DER rides through temporary fluctuations in frequency.

The DER follows the utility-specified frequency ride-through parameters to avoid tripping off unnecessarily. The function would block tripping within the fault ride-through zones. Although normally enabled by default, this ride-through operational function may be updated, enabled, and disabled.

3.12 HIGH/LOW VOLTAGE RIDE-THROUGH OPERATIONAL FUNCTION

The DER rides through temporary fluctuations in voltage.

The DER follows the utility-specified voltage ride-through parameters to avoid tripping off unnecessarily. The function would block tripping within the fault ride-through zones.

Although normally enabled by default, this ride-through operational function may be updated, enabled, and disabled.

3.13 INTEROPERABILITY

Interoperability is testing the EV to EVSE for a successful charging/discharging session.

3.14 LIMIT ACTIVE POWER PRODUCTION OR CONSUMPTION OPERATIONAL FUNCTION

Limits the production and/or consumption level of the DER based on the Referenced ECP.

The production and/or consumption of the DER is limited at the Referenced ECP, indicated as absolute watts values. Separate parameters are provided for production or consumption limits to permit these to be different.

3.15 LOGICAL DEVICES (LD)

The device model composed of the relevant logical nodes for providing the information needed for a particular device. For instance, a circuit breaker could be composed of the logical nodes XCBR, XSWI, CPOW, CSWI, and SMIG. Logical devices are not directly defined in any of the documents since different products and different implementations can use different combinations of logical nodes for the same logical device.

3.16 LOGICAL NODES (LN)

Predefined groupings of data objects that serve specific functions and can be used as “bricks” to build the complete device. Examples of LNs include: MMXU, which provides all electrical measurements in 3-phase systems (voltage, current, watts, vars, power factor, etc.); PTUV for the model of the voltage portion of under voltage protection; and XCBR for the short-circuit breaking capability of a circuit breaker. These LNs are described in IEC 61850-7-420, Clause 5.

3.17 MONITORING FUNCTION

The DER provides nameplate, configuration, status, measurements, and other requested data.

The DER provides status, measurements, alarms, logs, and other data as authorized and requested by users. Examples include connect status, updated capacities, real and reactive power output/consumption, state of charge, voltage, and other measurements. Also of interest are forecast status and expected measurements.

3.18 NEGATIVE CURRENT

This is when power is flowing out the vehicle HV battery. The discharging term is not used since that has other requirements for the OBC to meet and is not applicable.

3.19 POINT OF COMMON COUPLING (PCC)

This is the point where the local (premises) and utility electric power systems connect. This would normally be at the electric meter.

3.20 POINT OF CONNECTION (PoC)

This is the point that the DER connects to the local electric power system. For V2G-AC, the PoC is the connection of the PEV to the EVSE charging cable.

3.21 POSITIVE CURRENT

This is when power is flowing into the vehicle HV battery. The charging term is not used since that has other requirements for the OBC to meet and is not applicable.

3.22 POWER FACTOR (PF)

Generally, the term power factor is used to mean displacement power factor, which is defined as the ratio of active (or real) power in watts to apparent power in volt-amps at the fundamental frequency (50 Hz/60 Hz). PF is a measure of the phase shift that occurs between line voltage and line current when the AC line is loaded with a linear load having reactive characteristics, such as an AC motor. The line current is sinusoidal in shape but either leads or lags the line voltage in phase.

3.23 REACTIVE POWER CAPABILITY OF THE DER

The DER shall be capable of injecting reactive power (over-excited) and absorbing reactive power (under-excited) for active power output levels greater than or equal to the minimum steady-state active power capability (P_{min}) or 5% of rated active power, P_{rated} (kW) of the DER, whichever is greater.

3.24 RETURN TO SERVICE

Return to service allows current flow at the PCC. A permission to return to service may also be issued.

This follows Cease to Energize.

3.25 VOLT-VAR

Voltage-reactive power mode (volt-var). The DER responds to changes in voltage at the Referenced ECP by supplying or absorbing reactive power in order to maintain the desired voltage level.

The DER is provided with volt-var curves that define the reactive power for voltage levels.

When the volt-var operational function is enabled, the DER receives the voltage measurements from a meter (or another source) at the Referenced ECP. The DER responds by supplying or absorbing reactive power according to the specified volt-var curve in order to maintain the desired voltage level.

3.26 VOLT-WATT

Voltage-active power mode (volt-watt). The DER responds to changes in the voltage at the Referenced ECP by changing its production or consumption rate.

The DER is provided with volt-watt curves that define the changes in its watt output based on voltage deviations from nominal as a means for countering those voltage deviations.

When the volt-watt operational function is enabled, the DER receives the voltage measurement from a meter (or another source) at the Referenced ECP. The DER adjusts its production or consumption rate to follow the specified volt-watt curve parameters.

3.27 WATT-VAR

Active power-reactive power mode (watt-var). The DER responds to changes in power at the Referenced ECP by changing its reactive power.

The DER is provided with watt-var curves that define the changes in its reactive power-based changes of power.

When the watt-var operational function is enabled, the DER modifies its reactive power setting in response to the power level at the Referenced ECP.

4. AC AND DC CHARGING COMMUNICATION INTEROPERABILITY REQUIREMENTS

Low level communication for Prox, Pilot, and mechanical items along with grid fluctuations are included in SAE J2953/1 and SAE J2953/2.

4.1 Conformance Summary

Conformance tests specify the testing of performance and behavior of an EV or the EVSE to the requirements in the standard. Charging conformance testing is well recognized as the most feasible “self-evaluation” method to identify issues and improve quality in the vehicle development cycle, and it could be carried out at any time in the lab (controlled environment) with test equipment, either on component level or vehicle level. However, conformance testing is to discover existing errors rather than to verify that there is no error; to simply rely on conformance testing can’t absolutely guarantee connectivity of all applications because lab testing doesn’t completely represent real-world complications. In the end, conformance testing is the most cost-effective way to improve the interoperability of an EV/EVSE charging system. Once EV is released to the market, the engineer must fight for enormously increased cost to fix the interoperability issues, which are found from customer complaints.

The Conformance Concept is shown in Figure 1. This does not include EV to EVSE testing.

Conformance is expected to be completed prior to proceeding to Interoperability.

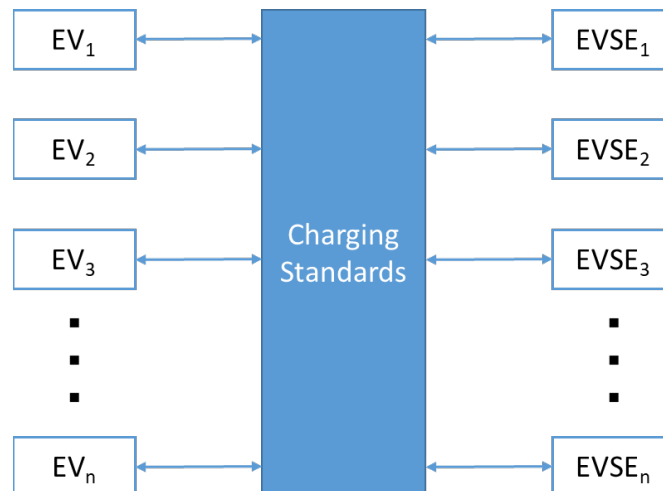


Figure 1 - Conformance equipment tests to the EV or EVSE

Charging standards and their respective Conformance standards are summarized in Table 1.

The base Conformance for DC charging is DIN 70122 and CharIN has updated test IDs with Modifications, Additions, and some Deletions. These are included in Appendix B, along with timing updates. CharIN updates are included from the file “CharIN Test Cases for DIN SPEC 70121:2014 Implementation Guide V.1.1.2.”

Table 1 - Conformance test standard summary

Charging Standard		Conformance Standard		Published
DIN 70121	Digital communication between a d.c. EV charging station and an EV for control of d.c. charging in the Combined Charging System	DIN 70122	Conformance tests for digital communication between a d.c. EV charging station and an EV for control of d.c. charging in the Combined Charging System	Yes
ISO 15118-2	Road vehicles - Vehicle to grid communication interface technical protocol description and Open Systems Interconnections (OSI) layer requirements	ISO 15118-4	Road vehicles - Vehicle to grid communication interface network and application protocol conformance test	Yes
		ISO 15118-5	Road vehicles - Vehicle to grid communication interface physical and data link layer conformance test	Yes
ISO 15118-8	Road vehicles - Vehicle to grid communication interface - Physical layer and data link layer requirements for wireless communication	ISO 15118-9	Road vehicles - Vehicle to grid communication interface - Physical layer and data link layer conformance test for wireless communication	Yes
ISO 15118-20	Road vehicles - Vehicle to grid communication interface - Part 20: Network and application protocol requirements	ISO 15118-21	Road vehicles - Vehicle to grid communication interface - Common 2nd generation network layer and application layer requirements conformance test plan	January 2025
		ISO 15118-22	Road vehicles - Vehicle to grid communication interface - Common Security 2nd generation network layer and application layer requirements conformance test plan	December 2025
		ISO 15118-23	Road vehicles - Vehicle to grid communication interface - Conductive AC/DC Charging 2nd generation network layer and application layer requirements conformance test plan	May 2025
		ISO 15118-24	Road vehicles - Vehicle to grid communication interface - WPT 2nd generation network layer and application layer requirements conformance test plan	June 2027
		ISO 15118-25	Road vehicles - Vehicle to grid communication interface - DC ACDP 2nd generation network layer and application layer requirements conformance test plan	June 2027

Charging Standard		Conformance Standard		Published
ISO 15118-10	Road vehicles - Vehicle to grid communication interface - Physical layer and data link layer requirements for single-pair Ethernet	ISO 15118-11		
ISO 15118-200	<i>Road vehicles - Vehicle to grid communication interface - Part 200: Extensible SECC Discovery Protocol and Error Information Protocol</i>			

Table 2 identifies the various standards and namespace, ServiceID, ServiceName, and ServiceCategory required to select the various protocol schemas.

The namespace and major/minor version is how the protocol schema used for the session is selected, and the ServiceID and ServiceName is the function that can be used from that protocol schema (e.g., SAE J2847/2 has two functions to be used by the EV and EVSE, ISO 15118-20 has several functions, and some EVs may not include the schema for ACDP, MCS, or WPT if the vehicle only connects to an AC or DC charging station).

NOTE: ServiceCategory and ServiceScope parameters in the ServiceDiscoveryReq message are optional and only used to filter the services sent by EVSE in the ServiceDiscoveryRes message. Therefore, the vehicle should send an empty ServiceDiscoveryReq; i.e., sending nothing in the ServiceDiscoveryReq, then the EVSE would respond with all the ServiceIDs it is capable of in the ChargeService parameter of the ServiceDiscoveryRes message. The EV can then process the match according to its capabilities.

Table 2 - Schema namespace and service summary

Standard	Namespace	Major/Minor Version	Service ID	ServiceName	ServiceCategory
DIN 70121	urn:din:70121:2012:MsgDef	2.0			
ISO 15118-2	urn:iso:15118:2:2013:MsgDef	2.0	1	AC_DC_Charging	EVCharging
SAE J2847/2	urn:iso:15118:2:2013:MsgDef	2.0	28472 & 1	SAE J2847/2 V2H AC_DC_Charging	OtherCustom EVCharging
	urn:iso:15118:2:2013:MsgDef	2.0	28473 & 1	SAE J2847/2 V2G AC_DC_Charging	OtherCustom EVCharging
SAE J2847/2 (ISO 15118-20 Light)	urn:iso:std:iso:15118:-20:DC	1.0	6	DC_BPT	
SAE J2847/3	urn:ieee:std:2030.5:ns				
SAE J2847/6	WECCP	0.1			
ISO 15118-20	urn:iso:std:iso:15118:-20:AC	1.0	1	AC	
	urn:iso:std:iso:15118:-20:AC	1.0	5	AC_BPT	
	urn:iso:std:iso:15118:-20:AC	1.0	10	AC_DER	
	urn:iso:std:iso:15118:-20:DC	1.0	2	DC	
	urn:iso:std:iso:15118:-20:DC	1.0	6	DC_BPT	
	urn:iso:std:iso:15118:-20:ACDP	1.0	4	DC_ACDP	
	urn:iso:std:iso:15118:-20:ACDP	1.0	7	DC_ACDP_BPT	
	urn:iso:std:iso:15118:-20:DC	1.0	8	MCS	
	urn:iso:std:iso:15118:-20:WPT	1.0	3	WPT	
	urn:iso:std:iso:15118:-20:DC	1.0	9	MCS_BPT	

Figure 2 shows the schema combinations in the first column and the associated functional combinations in the second column that are within each schema. ISO 15118-20 has a core function in addition to any or all or the SchemaID schema options for the EV and the EVSE to include.

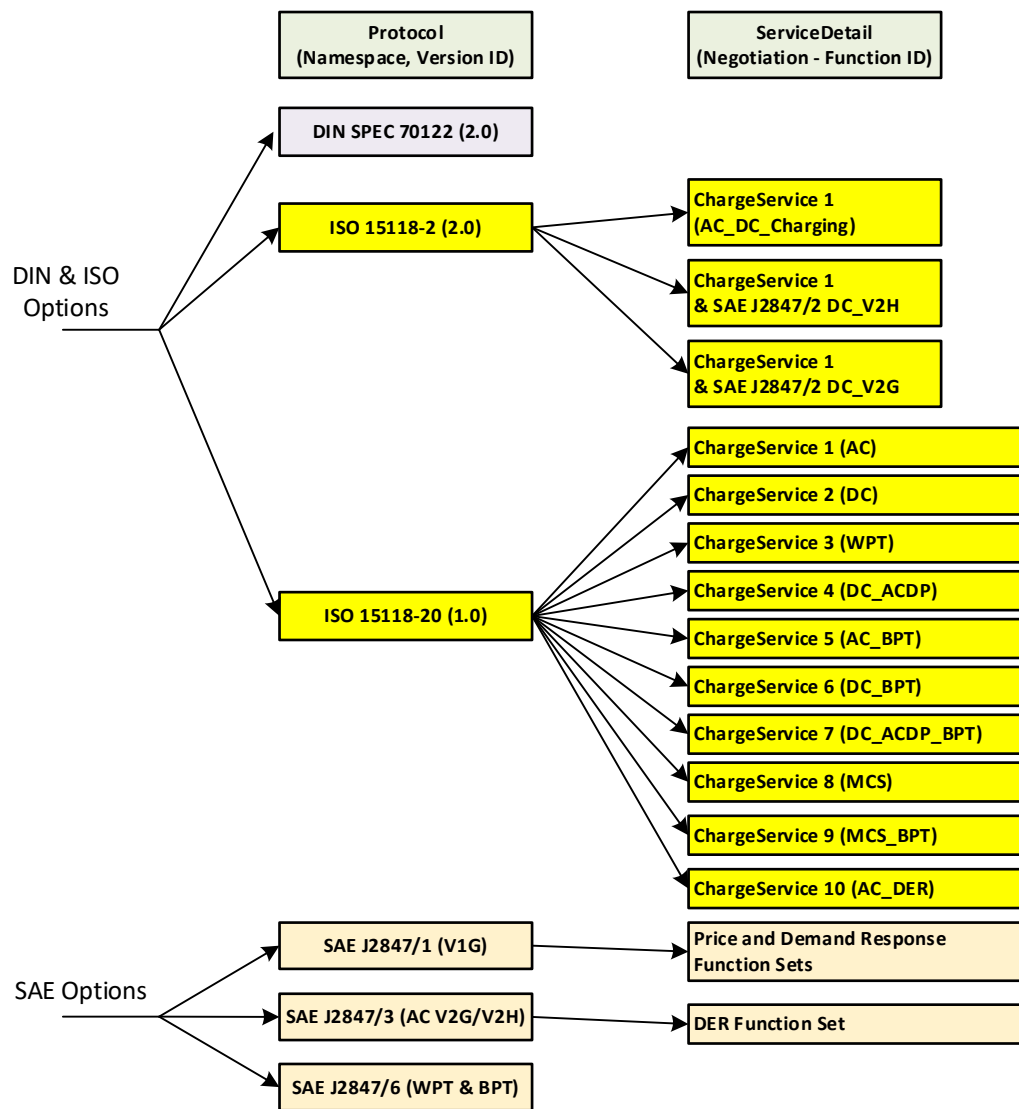


Figure 2 - Schema summary

4.2 Functional Combinations of Standards

Each of the charging and discharging functions start with a Base of initial standard and, as other standards were completed with added functions and implemented, become optional standards to also include in the vehicle and/or charging station. The first DC charging was DIN 17121; as ISO 15118-2 was published with more features, it is used for DC charging but also the base standard for AC charging.

B = Base Standard (Protocol): This is the protocol expected (recommended but not mandatory) as the basis for both the EV and EVSE.

O1 = 1st optional Standard: This is an optional protocol that the EV and EVSE may match and use for added features. The priority for Base or Option 1 is set by the EV. If the EVSE matches, then the priority option is used for the session.

O2 = 2nd optional Standard: This is an additional optional protocol that the EV and EVSE may match and use for more added features. Up to 20 priorities can be entered, and the one used is based on matching between the EV and EVSE.

The Base protocol is what was initially published for a particular function. Using DC charging as an example:

- DIN 70121 is the basis for DC charging.
- ISO 15118-2 updates DC charging and introduces AC charging.
- ISO 15118-20 updates both DC and AC charging and introduces BPT.

If the EV is capable of all three, the EV priority signal value to the EVSE would be ISO 15118-20 as Priority 1, ISO 15118-2 as Priority 2, and DIN 70121 as Priority 3, but this Priority does not change what is the basic progression of the protocols that were released and applied to legacy vehicles and charging stations.

1. AC charging is when the charger is on board the vehicle.
2. AC discharging is when the inverter is on board the vehicle.
3. DC charging is when the charger is in the EVSE.
4. DC discharging is when the inverter is in the EVSE.
5. BPT is when the inverter is capable of charging and discharging.
6. V2H is when the home has lost grid power, is islanded (disconnected from the grid), and the inverter is powering the home with the inverter functioning as Grid Forming or a voltage source.
7. V2G is when the grid is still connected to the home and the inverter is supplementing partial or full power to the home loads instead of using grid power. This may be during peak load periods when the customer is subject to a higher energy cost period.
8. DER is a regulatory requirement in several states for any inverter that exports to the grid. It includes additional grid stability functions be performed when the grid voltage, frequency, ride-through, and other stability items are present. IEEE 1547-2018 and UL 1741 SB identify the grid curves for these DER functions, and each state regulation may invoke some or all of these and establish the categories for the inverter to perform.
9. ACD is automatic connecting devices that provide the connection from the vehicle to the charging station without customer intervention. This is referring to conductive systems in ISO 15118-20. Combinations include Under, Side, and Overhead approaches.
10. WPT is static, semi-static, and dynamic wireless power transfer applications, and the system requirements are in SAE J2954 with the communication in SAE J2847/6 and ISO 15118-20.

Table 3 identifies the function for each protocol schema.

Table 3 - Protocol functional summary

Standard	Description	AC Charging	AC BPT (V2H)	AC BPT DER (V2G)	DC Charging	DC BPT (V2H)	DC BPT (V2G DER)	ACDP Charging	ACDP BPT	WPT Charging	WPT BPT (V2G/V2H)
DIN 70121	DC Charging				B						
ISO 15118-2	All charging services as defined by SupportedEnergyTransferMode in subclause 8.5.2.3.	B			O1						
SAE J2847/2 (Section 6, which applies ISO 15118-2 with negative signals)	DC Vehicle-to-Home - V2H (EVSE inverter is Grid forming). DC Charging					B					
	DC Vehicle-to-Grid - V2G (EVSE inverter is grid following). DC Charging						B				
SAE J2847/2 (Section 6.11 ISO 15118-20 Light, which allows TLS 1.2 security instead of TLS 1.3)	DC Charging with BPT, physical layer according to ISO 15118-3 and ISO 15118-8					O2	O2				
SAE J2847/3	IEEE 2030.5 - DER Function Set		B	B							
SAE J2847/6	WPT, physical layer according to ISO 15118-8									B	B
ISO 15118-20	Common messages	O1	O1	O1	O2	O1	O1	B	B	O1	
	AC energy transfer, physical layer according to ISO 15118-3 and ISO 15118-8	O1									
	AC Charging with BPT, physical layer according to ISO 15118-3 and ISO 15118-8		O1								
	AC Charging with DER, physical layer according to ISO 15118-3 and ISO 15118-8			O1							
	DC energy transfer, physical layer according to ISO 15118-3 and ISO 15118-8				O2						
	DC Charging with BPT, physical layer according to ISO 15118-3 and ISO 15118-8					O1	O1				
	DC Charging with ACDP, physical layer according to ISO 15118-8							B			
	DC Charging with ACDP and BPT, physical layer according to ISO 15118-8								B		
	MCS										
	WPT, physical layer according to ISO 15118-8									O1	

1. AC charging has the base schema in ISO 15118-2 with more features in ISO 15118-20.
2. DC charging has the base schema in DIN 70121 with more features in ISO 15118-2 than ISO 15118-20.
3. The base functions for AC V2G/V2H are in SAE J2847/3. ISO 15118-20, AC Charging with DER is an alternative.
4. The base functions for DC V2G/V2H are in SAE J2847/2, which describes using ISO 15118-2 schema with application-level software changes to initiate discharging. SAE J2847/2 also includes ISO 15118-20 Light as an option. ISO 15118-20, DC Charging with BPT is also an alternative.

4.3 Interoperability Summary

The Interoperability Concept is shown in Figure 3, where EVs and EVSEs are tested to each other.

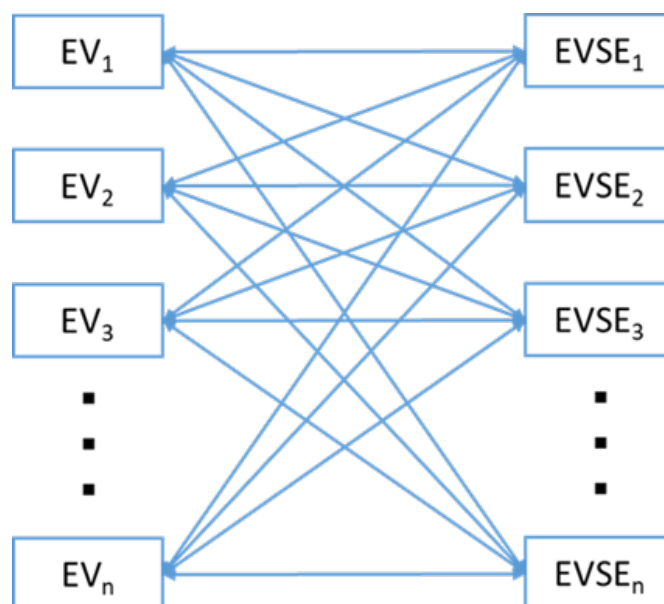


Figure 3 - Interoperability test between the EV and EVSE

4.3.1 Communication Error Code Summary

Table 4 summarizes the message and error codes listed in DIN 70121 and ISO 15118-2 standards. X indicates mandatory, and O means this is an optional signal.

Table 4 - EV and EVSE error codes

Stage	Message	AC ISO -2	DC DIN	DC ISO -2	EIM	PnC	EV Signal				EVSE Signal						
							Charge Progress (ISO Only)	Charging Session Type	EV Error Code	EV Ready	EVSE Isolation Status	EVSE Notification (AC ISO only)	EVSE Notification (DC ISO only)	EVSE Status Code	Fault Code (ISO only)	Response Code	Session Setup Code
Initialization	SupportedAppProtocol	X	X	X	X	X											X
	SessionSetup	X	X	X	X	X									X	X	X
	ServiceDiscovery	X	X	X	X	X									X	X	
	ServiceDetail	X		X	X	X									X	X	
	ServicePaymentSelection		X													X	
	PaymentServiceSelection	X		X	X	X									X		
	CertificateInstallation					X									X		
	Contract Authentication		X													X	
	CertificateUpdate	O		O		X									X		
	PaymentDetails					X									X		
	Authorization	X		X	X	X									X		
	ChargeParameterDiscovery	X	X	X	X	X			X	X	X	X		X	X	X	
	CableCheck		X	X					X	X	X		X	X	X	X	
Pre Charge	Pre-Charge		X	X					X	X	X		X	X	X	X	
	PowerDelivery	X	X	X			X		X	X	X	X		X	X	X	
Energy Transfer	CurrentDemand		X	X					X	X	X		X	X	X	X	
	ChargingStatus	X										X			X		
	MeteringReceipt					X						X			X		
	PowerDelivery	X	X	X			X		X	X	X	X		X	X	X	
Shut down	WeldingDetection		X	O					X	X	X		X	X	X	X	
	SessionStop	X	X	X				X							X	X	

The EV error code signals are summarized in Table 5 and EVSE signals in Table 6.

Table 5 - EV error code signals

EV Signals and Values		
Charge Progress	0	Start
	1	Stop
	2	Renegotiate
Charging Session Type	0	Terminate
	1	Pause
EV Error Code	0	NO_ERROR
	1	FAILED_RESSTemperatureInhibit
	2	FAILED_EVShiftPosition
	3	FAILED_ChargerConnectorLockFault
	4	FAILED_EVRESSMalfunction
	5	FAILED_ChargingCurrentdifferential
	6	FAILED_ChargingVoltageOutOfRange
	7	Reserved A-C
	8	FAILED_ChargingSystemIncompatibility
	9	NoData
EV Ready	0	False
	1	True

Table 6 - EVSE error code signals

EVSE Signals and Values		
EVSE Isolation Status	0	Invalid
	1	Valid
	2	Warning
	3	Fault
	4	No_IMD (ISO only)
EVSE Notification (ISO only)	0	None
	1	StopCharging
	2	ReNegotiation
EVSE Status Code	0	EVSE_NotReady
	1	EVSE_Ready
	2	EVSE_Shutdown
	3	EVSE_UtilityInterruptEvent
	4	EVSE_IsolationMonitoringActive
	5	EVSE_EmergencyShutdown
	6	EVSE_Malfunction
	7	Reserved 8-C (ISO only)
Fault Code (ISO only)	0	ParsingError
	1	NoTLSRootCertificateAvailable
	2	UnknownError
Response Code	0	OK
	1	OK_NewSessionEstablished
	2	OK_OldSessionJoined
	3	OK_CertificateExpiresSoon
	4	FAILED
	5	FAILED_SequenceError
	6	FAILED_ServiceIDInvalid
	7	FAILED_UnknownSession
	8	FAILED_ServiceSelectionInvalid
	9	FAILED_PaymentSelectionInvalid
	10	FAILED_CertificateExpired
	11 (B)	FAILED_SignatureError
	12	FAILED_NoCertificateAvailable (ISO only)
	13	FAILED_CertChainError (ISO only)
	14	FAILED_ChallengeInvalid (ISO only)
	15	FAILED_ContractCanceled (ISO only)
	16 (10)	FAILED_WrongChargeParameter
	17 (11)	FAILED_PowerDeliveryNotApplied
	18 (12)	FAILED_TariffSelectionInvalid
	19 (13)	FAILED_ChargingProfileInvalid
	20	FAILED_MeteringSignatureNotValid (ISO only)
	21	FAILED_NoChargeServiceSelected (ISO only)
	22 (16)	FAILED_WrongEnergyTransferMode



EVSE Signals and Values		
Session Setup Code	23	FAILED_ContactorError (ISO only)
	24	FAILED_CertificateNotAllowedAtThisEVSE (ISO only)
	25	FAILED_CertificateRevoked (ISO only)
	0	OK_SuccessfulNegotiation
	1	OK_SuccessfulNegotiationWithMinorDeviation
	2	Failed_NoNegotiation

4.3.2 Interoperability Issues with Diagnostic Codes

Diagnostic codes are summarized in Table 7 from ChargeX.

Table 7 - ChargeX diagnostic code summary

Summary of most frequently defined error codes			Responsibility Classification			
#	Diagnostic Code	Description	EV User	CSO	EVSE	EV
1	ConnectorLockFailure	Failure to lock or unlock connector on the vehicle side.	✓			✓
2	GroundFailure	Ground fault circuit interrupter has been activated.			✓	✓
3	HighTemperature	High temperature inside the EVSE is derating power delivery.			✓	
4	OverCurrentFailure	Over current protection device has tripped.			✓	✓
5	OverVoltage	Input voltage to the vehicle has risen above an acceptable level.			✓	✓
6	UnderVoltage	Input voltage to the vehicle has dropped below an acceptable level.			✓	✓
7	WeakSignal	Wireless communication device reported a weak signal.		✓	✓	
8	EmergencyStop	Emergency stop is pressed by the user (required if equipped).	✓		✓	
9	AuthorizationTimeout	The user plugs in but fails to authorize a charging session prior to the connection timeout between the vehicle and EVSE.	✓	✓	✓	✓
10	InvalidVehicleMode	The vehicle is in an invalid mode for charging.	✓			✓
11	CableCheckFailure	Isolation failure during cable check phase. Includes isolation failure.			✓	✓
12	PreChargeFailure	The EVSE did not reach the correct pre-charge voltage.			✓	✓
13	NoInternet	The EVSE has no internet connectivity.		✓	✓	
14	PilotFault	The control pilot voltage is out of range.			✓	✓
15	PowerLoss	The EVSE is unable to supply any power due to mains failure.			✓	

Summary of most frequently defined error codes			Responsibility Classification			
#	Diagnostic Code	Description	EV User	CSO	EVSE	EV
16	EVContactorFault	Contactors fail to open or close on the vehicle side. May also include welding-related errors.				✓
17	EVSEContactorFault	Contactors fail to open or close on EVSE's side. May also include welding-related errors.			✓	
18	CableOverTempDerate	Temperature of charging cable or connector assembly is too high, resulting in reduced power operation.			✓	
19	CableOverTempStop	Temperature of charging cable or connector assembly is too high, resulting in a stopped charging session.			✓	✓
20	PartialInsertion	Cable latch is raised due to incomplete insertion into the vehicle charging port.	✓		✓	✓
21	CapacitanceFault	An Isolation Monitoring Device tripped due to capacitance during active charging.			✓	✓
22	ResistanceFault	An Isolation Monitoring Device tripped due to low resistance to the chassis during active charging.			✓	✓
23	ProximityFault	The proximity voltage is out of range.			✓	✓
24	ConnectorVoltageHigh	The output voltage of EVSE is high before charging starts or after charging ends.			✓	
25	BrokenLatch	The latch on the connector is broken.		✓	✓	
26	CutCable	The output cable has been severed from the EVSE.		✓	✓	

Additional diagnostic codes from CharIN:

1. LLC (Low Level Communication)
 - a. ProximityPilotFault
 - b. ProximityPilotNotDetected
 - c. ProximityPilotValueChanged
 - d. ControlPilotFault
 - e. ControlPilotStateUnexpected
2. SLAC/PLC
 - a. PLCNotFound
 - b. PLCFault
 - c. SLACTimeout
 - d. PLCLinkDetectionTimeout
 - e. PLCLinkLost
 - f. PLCLinkLeaveTimeout
 - g. SLACTimeout
 - h. SLACSequenceError
 - i. SLACInvalidFieldValue
3. V2GTP
 - a. V2GTPInvalidProtocolVersion
 - b. V2GTPInvalidInverseProtocolVersion
 - c. V2GTPInvalidPayloadLength
 - d. V2GTPInvalidPayloadType
4. SDP
 - a. SDPInvalidPayloadLength
 - b. SDPInvalidFieldValue
 - c. SDPTimeout

5. TCP/TLS

- a. TCPTLSServerFault
- b. TLSHandshakeFault
- c. TCPTLSConnectionTimeout
- d. TCPTLSUnexpectedClose

6. EXI

- a. EXIEncodingFault
- b. EXIDecodingFault

7. V2G

- a. V2GParameterNotSupported
- b. V2GSequenceError
- c. V2GParameterInvalidValue
- d. V2GParameterNotAllowed
- e. V2GTimeout
- f. V2GPerformanceTime
- g. V2GExternalPayment

8. General

- a. InsulationFault
- b. InsulationWarning
- c. PowerModuleFailure
- d. ContactorFault

4.3.3 EV to EVSE Interoperability Test Plan

Baseline Functionality and Safety Tests

- Authentication types, methods, and timeouts
- Idle error faults (EVSE only)
- Session Initialization (SI) tests (from authentication to power transfer)
- Power Transfer (PT) tests

Advanced Charging Tests

- Simultaneous single dispenser charging (multiple EVs required)
- Seamless retry
- Pause and resume (contactors remain closed)
[DIN 70121 (telematics or other)]
- OCPP Smart Charge Profile (SCP)
[OCPP 1.6j base requirement]
- Smart Charge Scheduling (SCS)
[OCPP 2.0.1 and ISO 15118-2] or [OCPP 2.1 and ISO 15118-20] base requirements
- Scheduled Bidirectional Power Transfer (SBPT)
- Dynamic Bidirectional Power Transfer (DBPT)

Single PKI Testing

- Basic certificate validity tests
- Revocation: EVSE and contract certs (NREL Test Cases)
- Revocation: Sub-CA2 certs (NREL Test Cases)
- Fallback mechanisms (NREL test cases)
- Anomalous behavior (NREL test cases)

Multiple PKI

4.3.4 Tools to Use for Interoperability Testing

Placeholder for future editions.

4.3.5 Failure Summary from Test Events

The summary from Test Events is in Appendix E.

5. TECHNICAL REQUIREMENTS FOR VEHICLE TO GRID COMMUNICATION

5.1 IEEE 2030.5 Sequence of Interactions

The stages of PEV - EVSE Simplified Interactions is described in the SunSpec Specification “IEEE 2030.5 V2G-AC Profile Implementation Guide for SAE J3072” and outlined in SAE J2847/3, as shown in Table 8. These steps, along with the messages and signals, are expected to be included in the AC V2G Interoperability requirements.

Table 8 - Summary of communication steps for AC V2G (DER functions)

Step	Description
0	PEV plugs into EVSE and establishes communications.
1	PEV obtains site limits information from the EVSE.
2	Based on the EVSE site limits, PEV sends back its adjusted configuration settings.
3	EVSE provides Management Information (e.g., DER curves or controls) that are different than the IEEE 1547 defaults.
4	EVSE verifies PEV is properly configured for operation at this site.
5	EVSE authorizes PEV to discharge.
6	PEV continuously verifies that it is still authorized to discharge.
7	Session termination and teardown.

5.1.1 EVSE Management Information Requirements

The vehicle prioritizes the functions according to IEEE 1547-2018, section 4.7.

The Reactive power functions also need to be prioritized since the highest priority is used if more than one curve is transmitted.

The vehicle needs to perform the Dynamic Calibration Function as identified in Appendix H of SAE J3072. This establishes the voltage variation calculation between PoC and PCC.

IEEE 1547-2018, section 10.6 defines Management Information.

5.1.2 PEV Configuration Requirements

The information to be exchanged falls into the following four categories as specified in IEEE 1547-2018, section 10:

- Nameplate information: This information is indicative of the as-built characteristics of the DER. This information may be read.
- Configuration information: This information is indicative of the present capacity and ability of the DER to perform functions. This information may be read or written.
- Monitoring information: This information is indicative of the present operating conditions of the DER. This information may be read.
- Management information: This information is used to update functional and mode settings for the DER. This information may be read or written.

5.1.3 PEV Discharge Requirements

Placeholder for future editions.

5.1.4 Monitoring Information Requirements

Placeholder for future editions.

5.2 Vehicle to Grid Communication Interoperability Test Requirements

UL 1741 SB is to be used until IEEE 1547.1-2020 is updated.

5.2.1 DER Communication Protocol

IEEE 2030.5, IEEE 1815 (DNP3), or SunSpec Modbus are the supported protocols for DER devices to be supported. One of these protocols must be supported by the target DER device under test as a local communication interface.

5.2.1.1 Primacy

Primacy is one aspect of what also needs to be considered for interconnection requirements and is outside of the IEEE 1547 specification. These additional requirements are contained in the CSIP specification, and they can be broadly characterized as scheduling and group management. The DER model in IEEE 1547 envisions a memory-less atomic entity. By memory-less, the DER has no knowledge of the past or the future; it just continues to operate forever with its current configuration. By atomic, the DER has no knowledge of where it sits in the grid topology or the potential groups it may belong to.

Even though IEEE 1547 does not address scheduling or group management, CSIP and California Rule 21 requires them a necessary part of effective DER management. The IEEE 2030.5 protocol provides tools for both scheduling and group management, and CSIP defines exactly how to use those tools to enhance interoperability. Primacy is one aspect of group management where each group is assigned a priority value such that if the same control is issued to many groups, the DER has a clear algorithm on how to prioritize them based on their assigned primacy value.

Both ISO 15118-20 (AM1) and OCPP 2.1 claim to fully support the IEEE 1547 management information (i.e., grid codes). It is unclear if either of these protocols address the scheduling and group management requirements of CSIP and California Rule 21. This potential source of interoperability needs to be analyzed and addressed.

5.2.2 Nameplate Data Tests

Verifies that a set of nameplate data can be read from the target DER using one of the three supported protocols.

5.2.3 Configuration Information Tests

Verifies that a set of DER settings can be read and adjusted using one of the three supported protocols. The DER settings will be independently compared to the reported values from the connected test equipment.

5.2.4 Monitoring Information Tests

Verifies that a set of DER monitored data can be reported by the DER using one of the three supported protocols. The monitored data will be independently compared to the reported values from the connected test equipment.

5.2.5 Management Information Tests

Verifies that a set of grid support functions are able to be communicated through the use of the supported DER communication protocol and that the desired effect be implemented by the target DER as the power level. These tests leverage the IEEE 1547.1 Type tests that are defined for the required grid support functions.

5.2.6 Functional Testing

- Constant Power Factor Mode
- Voltage-Reactive Power Mode
- Active Power-Reactive Power Mode
- Constant Reactive Power Mode
- Voltage-Active Power Mode

- Voltage Trip Test
- Frequency Trip Test
- Frequency Droop Test
- Enter Service and Cease to Energize and Trip Tests
- Limit Maximum Active Power Test

6. VEHICLE TO HOME AND VEHICLE TO GRID SYSTEMS INTEROPERABILITY

6.1 AC V2G and V2H System Interoperability

These systems are described in SAE J2847/3.

6.1.1 AC V2G

If the customer has a utility variable rate program, as described in SAE J2836/1, they can program their vehicle to perform AC V2G for the EV to provide power to the home during high-price periods then recharge during low-cost periods.

If the customer enrolls in a utility program for DER functions, then SAE J2836/3 use cases and SAE J2847/3 messages apply. This would add grid support requirements such as volt/var to meet state regulations. DER is regulated by Rule 21 in California and applies to grid disturbance events, such as an undervoltage event.

If the customer does not permit AC V2G or AC DER, then charging would be as normally programmed into the vehicle, whether immediate charging or scheduled charging to delay the charge period until low prices are used for the home energy period.

If AC V2G is requested when the vehicle is charging, the vehicle must stop charging so its OBC can switch to a Current following (Grid following) function that starts with the OBC monitoring the grid voltage and frequency. It matches those, and then can ramp up the output current.

If the home also has solar, and it is exporting more energy than the home loads require, the vehicle OBC may be capable of switching between positive or negative current while still in the V2G operation mode as the Solar output exceeds the requirements of the home loads.

6.1.2 AC V2G, EVSE Oversight Requirements

UL 1741 SC is currently under development for a V2G AC system where the EV is compliant with SAE J3072.

The standard includes oversight requirements to ensure that the EVSE and EV together correctly meet critical grid safety and stability requirements.

Once UL 1741 SC is officially released, V2G AC-relevant SAE standards can consider adjusting clearing time to the EVSE.

6.1.3 AC V2H

If AC V2H is requested, the AC EVSE receives the signal from the home ATS that has islanded the home from the grid. The EVSE Pilot PWM frequency to the EV is 166 Hz, instead of the normal 1 kHz for charging or AC V2G, to identify that the home has lost power and is islanded from the grid. The OBC must also monitor for voltage on the AC circuits to determine if any other device in the home has started Grid forming, such as the ESS, if included in the home. If no voltage is present, then the OBC can start in Grid forming mode.

The OBC is expected to wait 1 minute before outputting in Grid forming, allowing it to detect voltage from the ESS then proceed to Grid following.

- If the home includes an ESS, it is expected to be the Grid forming device since it is hardwired into the home. The EV is then Grid following.
- If solar is also in the home, it is always expected to be a Grid following device. If PV output power exceeds the power required for the home loads, the vehicle (and ESS) could switch between negative current (discharging) to positive current (charging) as the home loads are met with the solar output. Positive current to the EV and EVSE would occur when the PV raises the home voltage above the set voltage of the Grid forming device (EV or ESS). It is always expected for the home to include an HEMS to manage home loads to not exceed the OBC output or the combination of solar, ESS, and OBC. The PV system also needs to be self-regulated so that it will curtail its output when the home maximum voltage is met as to not exceed the voltage rating of the home loads.
- Since the home is still islanded from the grid while the EV is Grid following, while the ESS is performing the Grid forming function, the EV is not expected to perform any AC V2G (DER) functions but merely provide the primary power to the home loads.
- The summary of AC V2H use cases are as follows:
 1. EV only:
 - a. EV is Grid forming
 2. EV and ESS:
 - a. ESS is Grid forming
 - b. EV is Grid following
 3. EV and PV:
 - a. EV is Grid forming
 - b. PV can charge EV if excess power is available
 4. EV and ESS and PV:
 - a. ESS is Grid forming
 - b. EV is Grid following
 - c. PV can charge EV and/or ESS if excess power is available

Figure 4 shows the communication and power if only the EV is performing AC V2H.

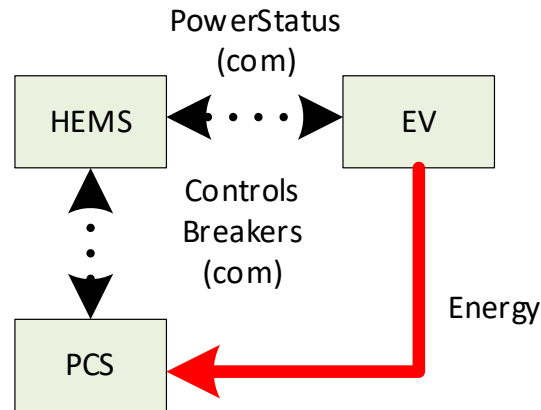


Figure 4 - AC V2H - EV only - EV is Grid forming

1. The system starts with the signal from the ATS to the AC EVSE per SAE J2847/3 that identifies the home has lost power and is islanded from the grid.
2. The AC EVSE provides the 166-Hz Pilot frequency and PWM value per home CBR and wiring size for Available Line Current per SAE J1772.
3. OBC monitors voltage on power circuits and, with no voltage detected, starts in Grid forming mode (voltage source) to power the home.
4. The digital communication message (PowerStatus) from EV to HEMS identifies OBC maximum power limit, energy available from the EV for the session, and departure time.
 - a. The HEMS then controls the PCS smart breakers to only turn on the ones that do not exceed OBC output. Critical loads first, then others.
 - b. Additional loads are powered as critical loads are “off” and control to them is also turned off until other loads are also off, allowing critical loads to be turned on again.
 - c. The HEMS is expected to profile the home loads for expected power and duration so it can anticipate how to manage the home loads as to not exceed the OBC power limit (e.g., once the AC turns off, power can be directed to other loads until the AC is expected to be powered for the next cycle).

6.1.3.1 ESS is also in the home.

Figure 5 shows the communication and power for the EV and ESS for AC V2H

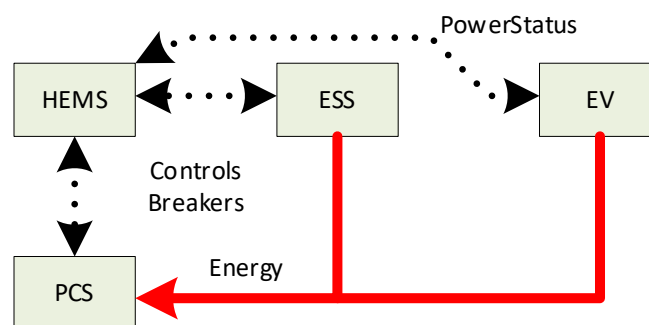


Figure 5 - AC V2H - EV and ESS - ESS is Grid forming

1. The ATS signals both the ESS and AC EVSE per SAE J2847/3 that the home has lost power and is islanded from the grid.
2. The ESS should be set to be the Grid forming device since it is always connected to the home.
 - a. The OBC detects the voltage and frequency from the ESS along with the 166-Hz Pilot frequency and starts to operate as AC V2G (Grid following) inverter instead of Grid forming.
 - b. This provides stable power to the home from the ESS in case the EV disconnects so it can be used for transportation.
 - c. The OBC should be the primary power source for the home loads since the ESS will still be fully charged when the EV disconnects and can then continue to provide power to the home until the EV returns and resumes providing power to the home and recharges the ESS.
3. The EV communication to the HEMS could be direct or pass through the AC EVSE.

6.1.3.2 If PV is also in the home.

It almost always includes a Grid following inverter, not Grid forming. It will then operate if the OBC is generating the Grid forming function.

The goal is to always capture PV power so the OBC may switch from discharging to charging if the PV is providing full power to all the home leads and still has excess output.

The OBC stays in Grid forming mode, and there may be a pause in switching from discharging to charging and vice versa.

The higher voltage output of the PV (higher than the OBC output) provides the function to switch to charging.

The PV should communicate directly with the HEMS since it may be using a different protocol than the EV and there is no need for the PV signals to be passed through (or processed) by the EV.

Figure 6 shows the communication and power for the EV and PV for AC V2H.

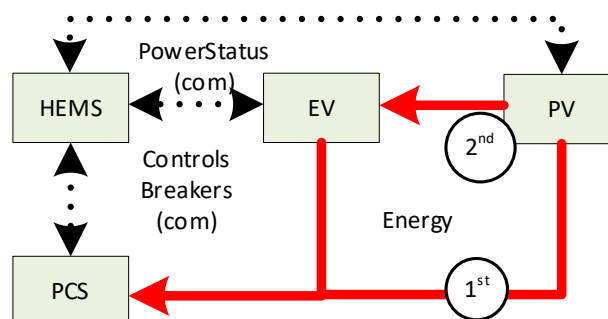


Figure 6 - AC V2H - EV and PV - EV is Grid forming

1. If PV is also in the home, it almost always includes a Grid following inverter, not Grid forming.
 - a. It will then operate if the OBC is generating the Grid forming function.
 - b. The goal is to always capture PV power so the OBC may switch from discharging to charging if the PV is providing full power to all the home leads and still has excess output.
 - i. The OBC stays in Grid forming mode, and there may be a pause in switching from discharging to charging and vice versa.
 - ii. The higher voltage output of the PV (higher than the OBC output) provides the function to switch to charging.
2. The PV should communicate directly with the HEMS since it may be using a different protocol than the EV and there is no need for the PV signals to be passed through (or processed) by the EV.

6.1.3.3 ESS and PV are also in the home.

Figure 7 shows the communication and power for the ESS, PV, and EV for AC V2H.

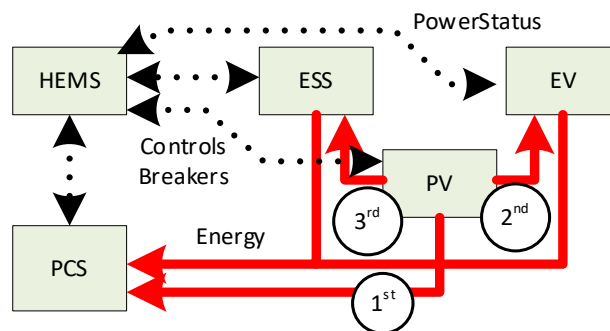


Figure 7 - AC V2H - PV, ESS, and EV - ESS is Grid forming

1. The ATS signals both the ESS and AC EVSE per SAE J2847/3 that the home has lost power and is islanded from the grid.
 - a. The ESS should be the Grid forming device since it is permanently installed in the home.
 - b. The PV almost always includes a Grid following inverter.
 - c. The PV should be the primary power source for all the home loads. If there is excess, then the EV should be recharged, then the ESS.
 - d. If the PV cannot provide sufficient power to the home, the EV should be the next source and finally the ESS.
 - i. Conserving the power in the ESS should be a priority since PV could go away with a cloud cover and the EV could disconnect for transportation needs. In this case, the ESS needs to provide the power to the home, and potentially only critical loads may be powered as to maximize the time the home has power. The HEMS would manage this and would realize the PV may have disconnected and the total power available through the ESS is low.

The EV communicates to the ESS since its power may be combined if the PV is not able to provide sufficient power to the home loads.

Figure 8 identifies the home configuration for AC V2H where the home loads need to be controlled to match the vehicle onboard charger power level and vehicle battery energy remaining.

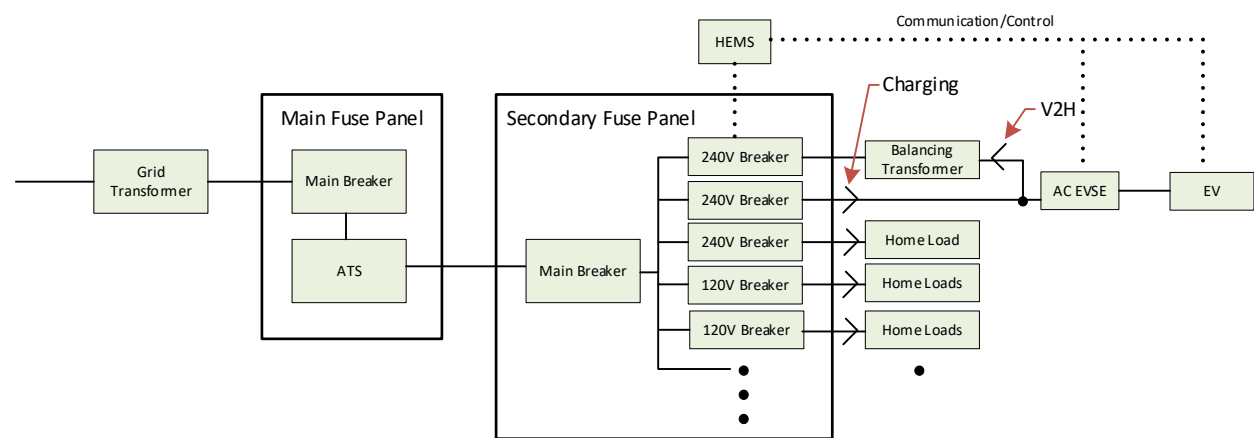


Figure 8 - AC V2H schematic

AC V2G communication from the EV to the grid aggregator is described in SAE J2847/3. AC V2H includes a subset of this, and only the PowerStatus message between the EV and HAN is required. PEVInfo is a signal within PowerStatus. This is shown in Table 9, Step 2 for HAN communications. Step 0 is also required to establish communication, same as with AC V2G, along with Step 6 for continued exchange as energy and departure time varies for the session.

Table 9 - HAN to EV communication

Step	Description	Sub #	Action	Signals
0	PEV plugs into EVSE and establishes communications	5.1	Service Discovery	
		5.2	Resource Discovery	PEV gets Device Capability.
				PEV gets Time.
				PEV gets EndDeviceList.
2	Based on the EVSE site limits, PEV sends back its adjusted configuration settings	5.4	PEV Sends Info to EVSE	PEV gets its DERList.
				PEV put its Device Information.
				PEV put its PowerStatus, which contains the PEVInfo resource.
				PEV put its DER Capability.
				PEV put its adjusted settings based on the site limits it got from the EVSE.
				PEV put its DER Availability.
6	PEV continuously verifies that it is still authorized to discharge	5.11	PEV Sends Periodic Information	PEV put its DERStatus.
				PEV put its PowerStatus, which contains the PEVInfo resource.

PowerStatus parameters:

BatteryStatus - Simple attribute to indicate whether battery is available to use for V2H.

ChangedTime - When this reading was taken; this adds value to know when the data was sampled.

CurrentPowerSource - This value will be fixed for devices powered by a single source. This value may change for devices able to transition between multiple power sources (mains to battery backup, etc.).

PEVInfo parameters:

ChargingPowerNow,

EnergyRequestNow,

MaxForwardPower

MinimumChargingDuration

TargetStateOfCharge,

TimechargelsNeeded

TimeChargingStatusPEV

6.2 DC V2H System and HAN Communication and Controls

The DC V2H system is described in SAE J2847/2.

This includes the HAN and main utility panel updates.

With DC V2H, the inverter is in the DC EVSE and home output established when installed. The home circuit breakers are separated as needed with critical loads in a secondary panel and remaining loads controlled in the main panel that is not powered during the power outage. The critical loads are established to match the power output of the EVSE inverter, the same as a home generator is installed. The HAN then may not be required if the secondary panel contains sufficient critical circuit breakers for the customer desires.

The AC V2H system, however, has the inverter in the vehicle. With the AC EVSE installed to UL 1741 SC, it is sized for the circuit breaker and wiring, providing power to it, but there may not be any consistency on the vehicle onboard charger size, which may be less than the AC EVSE rating connected during the power outage.

The AC HAN then includes signals from the EV when connected that are in the IEEE 2030.5 PowerStatus message. This provides the Power, Energy, and TCIN along with other signals for the HAN to manage the home loads.

Figure 9 shows the home panel configuration for DC V2H. This shows not all of the loads supported by the DC EVSE inverter. If all loads can be supported, then the main panel would only include the main breaker and ATS.

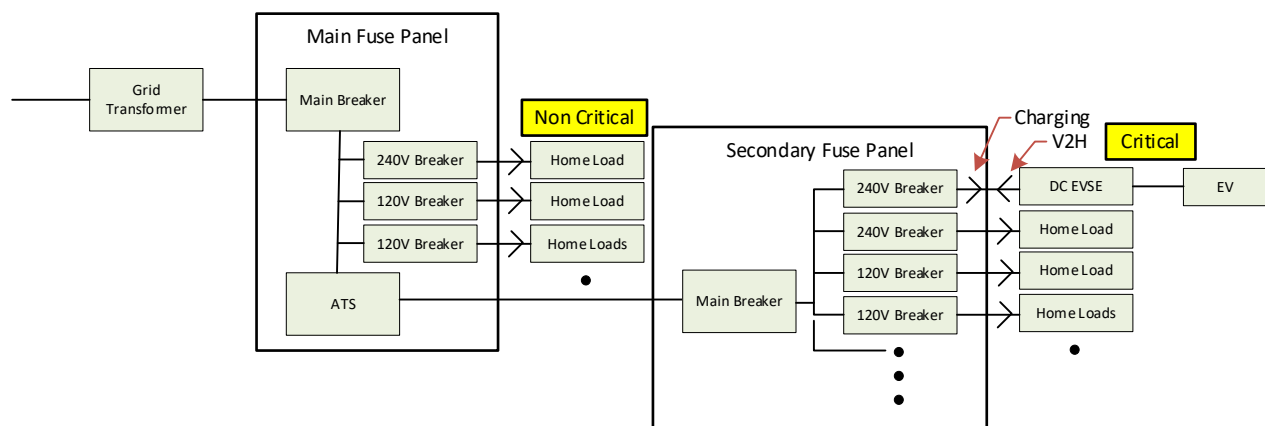


Figure 9 - DC V2H schematic

7. AC VEHICLE TO LOAD (V2L) AND VEHICLE TO VEHICLE (V2V)

SAE J2847/5 identifies the requirements for both AC V2L and V2V. The off-board cable can be designed with the software approach using a variation to the Pilot frequency or a hardware approach using variations to the Prox resistor values. The EV needs to include both options.

AC V2L and AC V2V includes two options, with the first being a software solution with a variation to the SAE J1772 Pilot frequency indicating the OBC needs to discharge to an AC V2L or V2V cable.

The second option is a hardware solution where the Prox value uses previously unused values, and some include a Power switch for additional input to the OBC for these functions. In this case, there is no Pilot from the cable that would have indicated the maximum current to discharge with the PWM value.

SAE J3400 has also added values to the Prox measurements that overlap with the AC V2L/V2V values for Thermal warning and shutdown if an adapter is used in the charging system. This, however, also includes the Pilot PWM with this Prox, so the OBC can clearly detect if a NACS adapter is being used or AC V2L/V2V is being requested.

8. TEST TOOLS

Placeholder for future editions.

9. TEST SCRIPTS - SOFTWARE

Placeholder for future editions.

PREPARED BY SAE HYBRID - EV COMMITTEE

APPENDIX A - ABBREVIATIONS

For this document, the following abbreviations apply:

ATS	Automatic Transfer Switch
DER	Distributed Energy Resource
DNP3	IEEE Std 1815 Protocol
EIM	External Identification Means
EV	Electric Vehicle
EVCC	Electric Vehicle Communication Controller
ESS	Energy Storage System
EVSE	Electric Vehicle Supply Equipment
EXI	Efficient XML Interchange
HAN	Home Area Network
HEMS	Home Energy Management System
IOP	Support for ISO 15118
ITB	Invalid Test Behavior
OBC	Onboard Charger
PCS	Power Control System
PICS	Protocol Implementation Conformance Statement
PIXIT	Protocol Implementation eXtra Information for Testing
PLC	Power Line Carrier
PnC	Plug and Charge
PV	Photovoltaic (Solar)
PWM	Pulse Width Modulation
SECC	Supply Equipment Communication Controller
SDP	Service Discovery Protocol
SEP 2.0	Smart Energy Profile 2.0
SLAC	Signal Level Attenuation Characteristic
TCP	Transmission Control Protocol
TLS	Transport Layer Security

V2G	Vehicle to Grid
V2H	Vehicle to Home
V2GTP	V2G Transfer Protocol
V2L	Vehicle to Load
V2V	Vehicle to Vehicle
VTB	Valid Test Behavior

APPENDIX B - DIN 70121 AND CharIN CONFORMANCE SUMMARY

Table B2 includes DIN 70122 test cases and CharIN modified test cases from 2018. These test cases focus on conformance and might not lead to interoperability. With current ongoing developments in ChargeX and CharIN regarding interoperability, the test cases in Table B2 may be modified in the future by removing and/or changing specific DIN cases that are problematic to interoperability and keeping only those that lead to best interoperability experience. Table B1 identifies the initial timer values and updates for DIN 70121 requirements.

Table B1 - Timer default values

Timer	Default Value (Old)	Default Value (New)	Reason
par_T_match_leave	1.0	25.0	Current PLC nodes are not able to leave the logical network within defined timing according to DIN 70121.
par_transmission_delay	0.01	0.1	Transmission delay might be higher than 0.01 second.
par_SECC_B1_B2_Timeout	8.0	9.0	EVSE shall apply a CP duty cycle of 5% no later than 1 second after its Green PHY node is ready for communication and T_conn_max_comm = 8 seconds (see [V2G-DC-507] and [V2G-DC-564]).
par_SECC_CPOscillator_Shutdown_Timeout	0.2	4.5	Shutdown time is not defined in DIN 70121. If the timing is too short, it is not clear if the SUT will shut down the oscillator after timeout. NOTE: Some SUTs need more time for oscillator shutdown after error detection.
par_EVCC_StateB_Shutdown_Timeout	0.2	4.5	Shutdown time is not defined in DIN 70121. If the timing is too short, it is not clear if the SUT will signal CP State B after timeout. NOTE: Some SUTs need more time for CP State B signalization after error detection.
par_CMN_TCP_Connection_Termination_Timeout	1.0	5.0	Shutdown time is not defined in DIN 70121. If the timing is too short, it is not clear if the SUT will terminate the TCP connection after timeout. NOTE: Some SUTs need more time for TCP termination after error detection.
par_CMN_waitForConnectionLoss	5.0	15.0	Current PLC nodes are not able to reset a connection (set new NMK/NID) directly after link detection (SLAC process).
par_CMN_remainingTime2Timeout	1.0	3.0	The time for TCP connection establishment should also be considered for remaining time.
par_SECC_attenuationDeviation	N/A	7.0	This parameter value was not defined in DIN 70122.

Table B2 identifies Conformance for the EVCC (EV Communication Controller) and Table B3 for the SECC (Supply Equipment Communication Controller). Table B1 identifies updated Timer default values.

NOTE: The Modified IDs have replaced the initial test ID by adding the prefix "CharIN." The intent is to include the complete list of DIN Conformance Test IDs and replace ones that have been updated while adding new ones and showing ones that need to be deleted.

It is expected the EV and EVSE test to each of these.

Table B2 - EVCC conformance test summary

#	Action	DIN plus CharIN
1	Mod	CharIN_TC_EVCC_VTB_PSDMeasurement_001
2		TC_EVCC_VTB_CmSlacParm_001
3		TC_EVCC_VTB_CmSlacParm_002
4		TC_EVCC_VTB_CmSlacParm_003
5		TC_EVCC_VTB_CmSlacParm_004
6		TC_EVCC_VTB_CmSlacParm_005
7		TC_EVCC_VTB_CmSlacParm_006
8		TC_EVCC_VTB_CmSlacParm_007
9		TC_EVCC_VTB_CmSlacParm_008
10		TC_EVCC_VTB_CmSlacParm_009
11		TC_EVCC_VTB_CmSlacParm_010
12	Mod	CharIN_TC_EVCC_VTB_AttenuationCharacterization_001
13		TC_EVCC_VTB_AttenuationCharacterization_002
14		TC_EVCC_VTB_AttenuationCharacterization_003
15	Mod	CharIN_TC_EVCC_VTB_AttenuationCharacterization_004
16		TC_EVCC_VTB_AttenuationCharacterization_005
17		TC_EVCC_VTB_AttenuationCharacterization_006
18		TC_EVCC_VTB_AttenuationCharacterization_007
19		TC_EVCC_VTB_AttenuationCharacterization_008
20		TC_EVCC_VTB_AttenuationCharacterization_009
21		TC_EVCC_VTB_AttenuationCharacterization_010
22		TC_EVCC_VTB_AttenuationCharacterization_011
23		TC_EVCC_VTB_AttenuationCharacterization_012
24	Mod	CharIN_TC_EVCC_VTB_AttenuationCharacterization_013
25		TC_EVCC_VTB_AttenuationCharacterization_014
26		TC_EVCC_VTB_AttenuationCharacterization_015
27		TC_EVCC_VTB_CmValidate_001
28		TC_EVCC_VTB_CmValidate_002
29		TC_EVCC_VTB_CmValidate_003
30		TC_EVCC_VTB_CmValidate_004
31		TC_EVCC_VTB_CmValidate_005
32		TC_EVCC_VTB_CmValidate_006
33		TC_EVCC_VTB_CmValidate_007
34	Del	TC_EVCC_VTB_CmValidate_008
35		TC_EVCC_VTB_CmValidate_009
36		TC_EVCC_VTB_CmValidate_010
37		TC_EVCC_VTB_CmValidate_011
38		TC_EVCC_VTB_CmValidate_012
39		TC_EVCC_VTB_CmValidate_013
40		TC_EVCC_VTB_CmValidate_014
41		TC_EVCC_VTB_CmValidate_015
42	Mod	CharIN_TC_EVCC_VTB_CmValidate_016

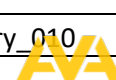
#	Action	DIN plus CharIN
43	Mod	CharIN_TC_EVCC_VTB_CmValidate_017
44	Add	CharIN_TC_EVCC_VTB_CmValidate_018
45	Add	CharIN_TC_EVCC_VTB_CmValidate_019
46	Add	CharIN_TC_EVCC_VTB_CmValidate_020
47		TC_EVCC_VTB_CmValidateOrCmSlacMatch_001
48		TC_EVCC_VTB_CmSlacMatch_001
49		TC_EVCC_VTB_CmSlacMatch_002
50		TC_EVCC_VTB_CmSlacMatch_003
51		TC_EVCC_VTB_CmSlacMatch_004
52		TC_EVCC_VTB_CmSlacMatch_005
53		TC_EVCC_VTB_CmSlacMatch_006
54		TC_EVCC_VTB_CmSlacMatch_007
55		TC_EVCC_VTB_CmSlacMatch_008
56		TC_EVCC_VTB_CmSlacMatch_009
57		TC_EVCC_VTB_CmSlacMatch_010
58		TC_EVCC_VTB_CmSlacMatch_011
59		TC_EVCC_VTB_CmSlacMatch_012
60		TC_EVCC_VTB_CmSlacMatch_013
61	Mod	CharIN_TC_EVCC_VTB_CmSlacMatch_014
62		TC_EVCC_VTB_PLCLinkStatus_001
63		TC_EVCC_VTB_PLCLinkStatus_002
64	Mod	CharIN_TC_EVCC_VTB_PLCLinkStatus_003
65		TC_EVCC_VTB_PLCLinkStatus_004
66	Add	CharIN_TC_EVCC_VTB_PLCLinkStatus_005
67	Add	CharIN_TC_EVCC_VTB_PLCLinkStatus_006
68	Add	CharIN_TC_EVCC_VTB_PLCLinkStatus_007
69	Add	CharIN_TC_EVCC_VTB_PLCLinkStatus_008
70	Mod	CharIN_TC_EVCC_VTB_CmAmpMap_001
71	Mod	CharIN_TC_EVCC_VTB_CmAmpMap_002
72	Mod	CharIN_TC_EVCC_VTB_CmAmpMap_003
73	Mod	CharIN_TC_EVCC_VTB_CmAmpMap_004
74	Mod	CharIN_TC_EVCC_VTB_CmAmpMap_005
75	Mod	CharIN_TC_EVCC_VTB_CmAmpMap_006
76	Mod	CharIN_TC_EVCC_VTB_CmAmpMap_007
77		TC_EVCC_VTB_V2GTPSessionSetup_001
78		TC_EVCC_VTB_V2GTPSessionSetup_002
79		TC_EVCC_VTB_V2GTPSessionSetup_003
80		TC_EVCC_VTB_V2GTPSessionSetup_004
81		TC_EVCC_VTB_V2GTPSDP_001
82	Mod	CharIN_TC_EVCC_VTB_SDP_001
83	Del	TC_EVCC_VTB_SDP_002
84		TC_EVCC_VTB_SDP_003
85		TC_EVCC_VTB_SDP_004



#	Action	DIN plus CharIN
86		TC_EVCC_VTB_SDP_005
87	Add	CharIN_TC_EVCC_VTB_SDP_006
88		TC_EVCC_VTB_SupportedAppProtocol_001
89		TC_EVCC_VTB_SupportedAppProtocol_002
90	Mod	CharIN_TC_EVCC_VTB_SupportedAppProtocol_003
91	Add	CharIN_TC_EVCC_VTB_Reliability_001
92	Add	CharIN_TC_EVCC_VTB_Reliability_002
93	Add	CharIN_TC_EVCC_VTB_Reliability_003
94	Mod	CharIN_TC_EVCC_VTB_SessionSetup_001
95		TC_EVCC_VTB_SessionSetup_002
96		TC_EVCC_VTB_SessionSetup_003
97	Mod	CharIN_TC_EVCC_VTB_SessionSetup_004
98		TC_EVCC_VTB_SessionSetup_005
99		TC_EVCC_VTB_SessionSetup_006
100		TC_EVCC_VTB_SessionSetup_007
101		TC_EVCC_VTB_SessionSetup_008
102		TC_EVCC_VTB_SessionSetup_009
103		TC_EVCC_VTB_SessionSetup_010
104	Add	CharIN_TC_EVCC_VTB_SessionSetup_011
105		TC_EVCC_VTB_ServiceDiscovery_001
106		TC_EVCC_VTB_ServiceDiscovery_002
107		TC_EVCC_VTB_ServiceDiscovery_003
108		TC_EVCC_VTB_ServiceDiscovery_004
109	Mod	CharIN_TC_EVCC_VTB_ServiceDiscovery_005
110		TC_EVCC_VTB_ServiceDiscovery_006
111		TC_EVCC_VTB_ServiceDiscovery_007
112		TC_EVCC_VTB_ServiceDiscovery_008
113		TC_EVCC_VTB_ServiceDiscovery_009
114		TC_EVCC_VTB_ServiceDiscovery_010
115		TC_EVCC_VTB_ServiceDiscovery_011
116		TC_EVCC_VTB_ServiceDiscovery_012
117	Add	CharIN_TC_EVCC_VTB_ServiceDiscovery_013
118	Add	CharIN_TC_EVCC_VTB_ServiceDiscovery_014
119	Add	CharIN_TC_EVCC_VTB_ServiceDiscovery_015
120		TC_EVCC_VTB_ServicePaymentSelection_001
121		TC_EVCC_VTB_ServicePaymentSelection_002
122		TC_EVCC_VTB_ServicePaymentSelection_003
123		TC_EVCC_VTB_ServicePaymentSelection_004
124		TC_EVCC_VTB_ServicePaymentSelection_005
125		TC_EVCC_VTB_ServicePaymentSelection_006
126	Mod	CharIN_TC_EVCC_VTB_ServicePaymentSelection_007
127		TC_EVCC_VTB_ServicePaymentSelection_008
128		TC_EVCC_VTB_ServicePaymentSelection_009

#	Action	DIN plus CharIN
129		TC_EVCC_VTB_ServicePaymentSelection_010
130		TC_EVCC_VTB_ServicePaymentSelection_011
131		TC_EVCC_VTB_ServicePaymentSelection_012
132		TC_EVCC_VTB_ServicePaymentSelection_013
133	Add	CharIN_TC_EVCC_VTB_ServicePaymentSelection_014
134		TC_EVCC_VTB_ContractAuthentication_001
135		TC_EVCC_VTB_ContractAuthentication_002
136		TC_EVCC_VTB_ContractAuthentication_003
137		TC_EVCC_VTB_ContractAuthentication_004
138	Mod	CharIN_TC_EVCC_VTB_ContractAuthentication_005
139		TC_EVCC_VTB_ContractAuthentication_006
140	Mod	CharIN_TC_EVCC_VTB_ContractAuthentication_007
141		TC_EVCC_VTB_ContractAuthentication_008
142		TC_EVCC_VTB_ContractAuthentication_009
143		TC_EVCC_VTB_ContractAuthentication_010
144		TC_EVCC_VTB_ContractAuthentication_011
145		TC_EVCC_VTB_ContractAuthentication_012
146		TC_EVCC_VTB_ContractAuthentication_013
147	Add	CharIN_TC_EVCC_VTB_ContractAuthentication_014
148		TC_EVCC_VTB_ChargeParameterDiscovery_001
149	Mod	CharIN_TC_EVCC_VTB_ChargeParameterDiscovery_002
150	Mod	CharIN_TC_EVCC_VTB_ChargeParameterDiscovery_003
151	Mod	CharIN_TC_EVCC_VTB_ChargeParameterDiscovery_004
152	Mod	CharIN_TC_EVCC_VTB_ChargeParameterDiscovery_005
153	Mod	CharIN_TC_EVCC_VTB_ChargeParameterDiscovery_006
154	Mod	CharIN_TC_EVCC_VTB_ChargeParameterDiscovery_007
155		TC_EVCC_VTB_ChargeParameterDiscovery_008
156		TC_EVCC_VTB_ChargeParameterDiscovery_009
157		TC_EVCC_VTB_ChargeParameterDiscovery_010
158		TC_EVCC_VTB_ChargeParameterDiscovery_011
159		TC_EVCC_VTB_ChargeParameterDiscovery_012
160		TC_EVCC_VTB_ChargeParameterDiscovery_013
161		TC_EVCC_VTB_ChargeParameterDiscovery_014
162		TC_EVCC_VTB_ChargeParameterDiscovery_015
163		TC_EVCC_VTB_ChargeParameterDiscovery_016
164	Add	CharIN_TC_EVCC_VTB_ChargeParameterDiscovery_017
165	Add	CharIN_TC_EVCC_VTB_ChargeParameterDiscovery_018
166	Mod	CharIN_TC_EVCC_VTB_CableCheck_001
167	Mod	CharIN_TC_EVCC_VTB_CableCheck_002
168	Mod	CharIN_TC_EVCC_VTB_CableCheck_003
169	Mod	CharIN_TC_EVCC_VTB_CableCheck_004
170	Mod	CharIN_TC_EVCC_VTB_CableCheck_005
171		TC_EVCC_VTB_CableCheck_006

#	Action	DIN plus CharIN
172	Mod	CharIN_TC_EVCC_VTB_CableCheck_007
173		TC_EVCC_VTB_CableCheck_008
174	Mod	CharIN_TC_EVCC_VTB_CableCheck_009
175		TC_EVCC_VTB_CableCheck_010
176		TC_EVCC_VTB_CableCheck_011
177		TC_EVCC_VTB_CableCheck_012
178		TC_EVCC_VTB_CableCheck_013
179		TC_EVCC_VTB_CableCheck_014
180	Add	CharIN_TC_EVCC_VTB_CableCheck_015
181	Add	CharIN_TC_EVCC_VTB_CableCheck_016
182	Add	CharIN_TC_EVCC_VTB_CableCheck_017
183	Add	CharIN_TC_EVCC_VTB_CableCheck_018
184	Add	CharIN_TC_EVCC_VTB_CableCheck_019
185	Add	CharIN_TC_EVCC_VTB_CableCheck_020
186	Add	CharIN_TC_EVCC_VTB_CableCheck_021
187	Add	CharIN_TC_EVCC_VTB_CableCheck_022
188	Add	CharIN_TC_EVCC_VTB_CableCheck_023
189	Add	CharIN_TC_EVCC_VTB_CableCheck_024
190	Add	CharIN_TC_EVCC_VTB_CableCheck_025
191	Add	CharIN_TC_EVCC_VTB_CableCheck_026
192	Mod	CharIN_TC_EVCC_VTB_PreCharge_001
193	Mod	CharIN_TC_EVCC_VTB_PreCharge_002
194	Mod	CharIN_TC_EVCC_VTB_PreCharge_003
195	Mod	CharIN_TC_EVCC_VTB_PreCharge_004
196	Mod	CharIN_TC_EVCC_VTB_PreCharge_005
197	Mod	CharIN_TC_EVCC_VTB_PreCharge_006
198		TC_EVCC_VTB_PreCharge_007
199	Mod	CharIN_TC_EVCC_VTB_PreCharge_008
200		TC_EVCC_VTB_PreCharge_009
201		TC_EVCC_VTB_PreCharge_010
202		TC_EVCC_VTB_PreCharge_011
203		TC_EVCC_VTB_PreCharge_012
204		TC_EVCC_VTB_PreCharge_013
205	Mod	CharIN_TC_EVCC_VTB_PreChargeOrPowerDelivery_001
206	Mod	CharIN_TC_EVCC_VTB_PreChargeOrPowerDelivery_002
207	Mod	CharIN_TC_EVCC_VTB_PreChargeOrPowerDelivery_003
208	Mod	CharIN_TC_EVCC_VTB_PreChargeOrPowerDelivery_004
209	Mod	CharIN_TC_EVCC_VTB_PreChargeOrPowerDelivery_005
210	Mod	CharIN_TC_EVCC_VTB_PreChargeOrPowerDelivery_006
211	Mod	CharIN_TC_EVCC_VTB_PreChargeOrPowerDelivery_007
212	Mod	CharIN_TC_EVCC_VTB_PreChargeOrPowerDelivery_008
213		TC_EVCC_VTB_PreChargeOrPowerDelivery_009
214	Mod	CharIN_TC_EVCC_VTB_PreChargeOrPowerDelivery_010



#	Action	DIN plus CharIN
215		TC_EVCC_VTB_PreChargeOrPowerDelivery_011
216		TC_EVCC_VTB_PreChargeOrPowerDelivery_012
217		TC_EVCC_VTB_PreChargeOrPowerDelivery_013
218		TC_EVCC_VTB_PreChargeOrPowerDelivery_014
219		TC_EVCC_VTB_PreChargeOrPowerDelivery_015
220	Del	TC_EVCC_VTB_PreChargeOrPowerDelivery_016
221		TC_EVCC_VTB_CurrentDemand_001
222	Mod	CharIN_TC_EVCC_VTB_CurrentDemand_002
223	Mod	CharIN_TC_EVCC_VTB_CurrentDemand_003
224	Mod	CharIN_TC_EVCC_VTB_CurrentDemand_004
225	Mod	CharIN_TC_EVCC_VTB_CurrentDemand_005
226		TC_EVCC_VTB_CurrentDemand_006
227		TC_EVCC_VTB_CurrentDemand_007
228	Mod	CharIN_TC_EVCC_VTB_CurrentDemand_008
229		TC_EVCC_VTB_CurrentDemand_009
230		TC_EVCC_VTB_CurrentDemand_010
231		TC_EVCC_VTB_CurrentDemand_011
232		TC_EVCC_VTB_CurrentDemand_012
233		TC_EVCC_VTB_CurrentDemand_013
234		TC_EVCC_VTB_CurrentDemand_014
235		TC_EVCC_VTB_CurrentDemand_015
236	Mod	CharIN_TC_EVCC_VTB_CurrentDemandOrPowerDelivery_001
237	Mod	CharIN_TC_EVCC_VTB_CurrentDemandOrPowerDelivery_002
238	Mod	CharIN_TC_EVCC_VTB_CurrentDemandOrPowerDelivery_003
239	Mod	CharIN_TC_EVCC_VTB_CurrentDemandOrPowerDelivery_004
240	Mod	CharIN_TC_EVCC_VTB_CurrentDemandOrPowerDelivery_005
241		TC_EVCC_VTB_CurrentDemandOrPowerDelivery_006
242	Mod	CharIN_TC_EVCC_VTB_CurrentDemandOrPowerDelivery_007
243		TC_EVCC_VTB_CurrentDemandOrPowerDelivery_008
244		TC_EVCC_VTB_CurrentDemandOrPowerDelivery_009
245		TC_EVCC_VTB_CurrentDemandOrPowerDelivery_010
246		TC_EVCC_VTB_CurrentDemandOrPowerDelivery_011
247	Add	CharIN_TC_EVCC_VTB_CurrentDemandOrPowerDelivery_012
248	Add	CharIN_TC_EVCC_VTB_CurrentDemandOrPowerDelivery_013
249	Add	CharIN_TC_EVCC_VTB_CurrentDemandOrPowerDelivery_014
250	Add	CharIN_TC_EVCC_VTB_CurrentDemandOrPowerDelivery_015
251	Add	CharIN_TC_EVCC_VTB_CurrentDemandOrPowerDelivery_016
252	Add	CharIN_TC_EVCC_VTB_CurrentDemandOrPowerDelivery_017
253	Add	CharIN_TC_EVCC_VTB_CurrentDemandOrPowerDelivery_018
254	Add	CharIN_TC_EVCC_VTB_CurrentDemandOrPowerDelivery_019
255		TC_EVCC_VTB_WeldingDetection_001
256	Mod	CharIN_TC_EVCC_VTB_WeldingDetection_002
257	Mod	CharIN_TC_EVCC_VTB_WeldingDetection_003

#	Action	DIN plus CharIN
258	Mod	CharIN_TC_EVCC_VTB_WeldingDetection_004
259	Mod	CharIN_TC_EVCC_VTB_WeldingDetection_005
260		TC_EVCC_VTB_WeldingDetection_006
261	Mod	CharIN_TC_EVCC_VTB_WeldingDetection_007
262		TC_EVCC_VTB_WeldingDetection_008
263		TC_EVCC_VTB_WeldingDetection_009
264		TC_EVCC_VTB_WeldingDetection_010
265		TC_EVCC_VTB_WeldingDetection_011
266		TC_EVCC_VTB_WeldingDetection_012
267		TC_EVCC_VTB_WeldingDetectionOrSessionStop_001
268	Mod	CharIN_TC_EVCC_VTB_WeldingDetectionOrSessionStop_002
269	Mod	CharIN_TC_EVCC_VTB_WeldingDetectionOrSessionStop_003
270	Mod	CharIN_TC_EVCC_VTB_WeldingDetectionOrSessionStop_004
271	Mod	CharIN_TC_EVCC_VTB_WeldingDetectionOrSessionStop_005
272		TC_EVCC_VTB_WeldingDetectionOrSessionStop_006
273		TC_EVCC_VTB_SessionStop_001
274		TC_EVCC_VTB_SessionStop_002
	Mod	72
	Add	39
	Del	3
	Total	271

The new CharIN requirements are shown below since these are in the detail test cases that follow.

New requirements	[V2G-DC-CharIN-001] EV and EVSE: The max. PLC transmission power shall be -73 dBm/Hz for all carriers from 2-30 MHz. [V2G-DC-CharIN-002] EV and EVSE: The min. PLC transmission power shall be -80 dBm/Hz for 80% of the carriers from 2-30 MHz. [V2G-DC-CharIN-003] EV and EVSE: The typ. PLC transmission power shall be -75 dBm/Hz for 80% of the carriers from 2-30 MHz. [V2G-DC-CharIN-004] EVSE: The EVSE shall respond with 0x03=Failure in CM_VALIDATE.CNF message if it does not support Validation of Matching. NOTE "Failure" state: This is an indication from the EVSE that it does not support the validation process. The EV decides to either terminate the matching process with the current EVSE and go on with the next EVSE or to skip the validation process with the current EVSE. [V2G-DC-CharIN-005] EV: If the NUM_SOUNDS field in a CM_ATTEN_CHAR.IND is <7, then the ATTEN_PROFILE has no significance and the EVCC shall stop the SLAC communication. It is up to the EV to decide what number of M-SOUNDS used for the attenuation profile is sufficient for its decision (i.e., whether to discard CM_ATTEN_CHAR.IND if NUM_SOUNDS is less than C_EV_match_MNBC). [V2G-DC-CharIN-006] EVSE: To wake up the EV, the pilot function controller on EVSE side shall be configured to the last known parameter set NMK and NID and the oscillator shall perform a E-> B1 -> B2 transition.
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[V2G-DC-CharIN-007] EV: After waking up, the PLC node on EV side shall be configured to the last known logical parameter set of NMK AND NID.) ".

[V2G-DC-CharIN-008] EV: If the EV is asleep, it shall wake up by detecting a control pilot state B1/B2 transition and shall configure the communication module to the last known logical network parameter of NMK and NID.

[V2G-DC-CharIN-009] EV: The attenuation of the section between EV inlet to the EV Green PHY Chipset (AttnRxEV / AttnTxEV in Figure 16 of DIN SPEC 70121) shall be:

- 0dB < Average over all carrier groups < 8dB
- 0dB < Maximum per single carrier groups < 12dB

[V2G-DC-CharIN-010] EVSE: The Attenuation of the section between EVSE connector to the EVSE Green PHY Chipset (AttnRxEVSE / AttnTxEVSE in Figure 16 of DIN SPEC 70121) shall be:

- 0dB < Average over all carrier groups < 12dB
- 0dB < Maximum per single carrier groups < 14dB

NOTE: For DC charging stations the cable is always attached to the station (Case C according to IEC 61851-1).

NOTE: The EVSE connector is the interface between the charger and the vehicle. This can be a cable connector, pantograph mechanism, or other design types.

[V2G-DC-CharIN-011] EVSE: At a DC Charging Station with permanently attached Cable (Case C according to IEC 61851-1) the reference for all PSD and Attenuation values shall be the Vehicle Connector including the cable.

[V2G-DC-CharIN-012] EV: AMLen = 0x3A in message CM_AMP_MAP.REQ shall be used.

NOTE: Given in Table 6 of DIN SPEC 70121 and [V2G-DC-585].

[V2G-DC-CharIN-013] EVSE: An EVSE that supports only DC charging according to DIN SPEC 70121 on a connector shall apply a CP duty cycle of 5% on this connector.

- Not before its Green PHY node becomes ready for communication (receive first SLAC message) and no later than 1s after its Green PHY node is ready for communication.

[V2G-DC-CharIN-014] EV and EVSE: Little endian byte ordering shall be used for SLAC messages.

NOTE: This is specified in HomePlug GreenPHY specification.

Example:

Table 2 MVFLen (CM_SLAC_MATCH.REQ) ->0x003E

Table 2 MVFLen (CM_SLAC_MATCH.CNF) ->0x0056

[V2G-DC-CharIN-015] EV: The EV may send any value in EVReady according [V2G-DC-639]

[V2G-DC-CharIN-016] EVSE: The EVSE shall not use the parameter EVReady to have any impact on the charging process according to **[V2G-DC-639]**

[V2G-DC-CharIN-017] EV and EVSE: The implementation must consider the time-out requirements in chapter “9.6 Session timing and error handling” of DIN SPEC 70121:2014 (V2G_EVCC_Msg_Timeout (MessageType)).

[V2G-DC-CharIN-018] EV and EVSE: The implementation may consider the performance time in chapter “9.6 Session timing and error handling” of DIN SPEC 70121:2014 for further internal decisions (V2G_SECC_Msg_Performance_Time) and error handling.

NOTE: For details, see Table 75 in DIN SPEC 70121:2014

[V2G-DC-CharIN-019] EV and EVSE: If an implementation stores a physical value type as defined in chapter 9.5.2.4 as unsigned datatype internally (and not as float), it shall apply a datatype of at least 32bit.

NOTE: The Maximum and Minimum transmittable values are calculated using the boundaries of the PhysicalValueType. They are given through the signed 16-bit Integer (Range: -32768 to +32767) of the Value and the Exponent which ranges from -3 to +3. This Results in a transmittable Value Range from -32768000 to 32767000 in the PhysicalValueType.

To ensure backward compatibility to existing implementations for EVs:

[V2G-DC-CharIN-020] EVSE: If the EVMaximumPowerLimit in ChargeParameterDiscoveryReq is smaller than the power which the EVSE can provide, the EVSE shall send an EVSEMaximumPowerLimit equal to EVMaximumPowerLimit in ChargeParameterDiscoveryRes. This also applies for all other V2G messages, where EVSEMaximumPowerLimit is sent.

[V2G-DC-CharIN-021] EVSE: If the EVMaximumVoltageLimit in ChargeParameterDiscoveryReq is smaller than the voltage which the EVSE can provide, the EVSE shall send an EVSEMaximumVoltageLimit equal to EVMaximumVoltageLimit in ChargeParameterDiscoveryRes. This also applies for all other V2G messages, where EVSEMaximumVoltageLimit is sent.

[V2G-DC-CharIN-022] EVSE: If the EVMaximumCurrentLimit in ChargeParameterDiscoveryReq is smaller than the current which the EVSE can provide, the EVSE shall send an EVSEMaximumCurrentLimit equal to EVMaximumCurrentLimit in ChargeParameterDiscoveryRes. This also applies for all other V2G messages, where EVSEMaximumCurrentLimit is sent.

[V2G-DC-CharIN-023] EV: An EV supporting DIN+ISO that wants to use TCP shall send TCP in the SDP request (see ISO 15118-2:2014, 7.3.4 Support and Application of TLS).

[V2G-DC-CharIN-024] EV: An EV supporting DIN+ISO that wants to use TLS shall send TLS in the SDP request (see ISO 15118-2:2014, 7.3.4 Support and Application of TLS).

[V2G-DC-CharIN-025] EVSE: An EVSE supporting DIN+ISO that only supports TCP (no TLS) shall send TCP in an SDP response (see ISO 15118-2:2014, 7.3.4 Support and Application of TLS).

[V2G-DC-CharIN-026] EVSE: An EVSE supporting DIN+ISO that supports TLS (TLS+TCP) shall send the same security level (TLS or TCP) as requested by the EV in the SDP Request (see ISO 15118-2:2014, 7.3.4 Support and Application of TLS).

[V2G-DC-CharIN-027] EVSE: An EVSE shall always send an SDP response with its supported security level according to [V2G-DC-CharIN-025] or [V2G-DC-CharIN-026] even if this does not meet the requested security level of the EV.

For DIN+ISO support:

[V2G-DC-CharIN-028] EV: Requirement [V2G-DC-546] is only valid for a DIN only implementation and an ISO implementation that supports TCP only.

[V2G-DC-CharIN-029] EVSE: Requirement [V2G-DC-618] is not applicable for a DIN+ISO implementation with support of TLS. It is replaced by the behavior described in [V2G-DC-CharIN-026].

[V2G-DC-CharIN-030] EV: For a DIN only and a DIN+ISO EV implementation, the definition of the ISO 15118-2:2014 shall be applied ([V2G2-161]).

[V2G-DC-CharIN-031] EVSE: For a DIN only and a DIN+ISO EVSE implementation, the SDP Server could expect 50 incoming SECC Discovery Request Messages and shall wait for at least 12.5s (see [V2G2-159]) before stopping the charge session due to a time-out.

[V2G-DC-CharIN-032] EVSE: If an EVSE receives a corrupted SDP request, it shall disregard the message and shall not send an SDP response.

[V2G-DC-CharIN-033] EV: If an EV receives a corrupted SDP response it shall disregard the message. The EV shall continue SDP process as defined in ISO 15118-2:2014, chapter 7.10.1 (see also [V2G-DC-CharIN-030]).

[V2G-DC-CharIN-034] EVSE: If a DIN only EVSE receives a payload that indicates “reserved” for the transport protocol, it shall reply with TCP.

[V2G-DC-CharIN-035] EVSE: If a DIN+ISO EVSE receives a payload that indicates “reserved” for the transport protocol in the SDP response.

[V2G-DC-CharIN-036] EVSE: If a DIN+ISO EVSE receives a payload that indicates “reserved” for the security field, it shall send 0xFF for supported security level in the SDP response.

[V2G-DC-CharIN-037] EV: If a DIN+ISO EV receives a payload that indicates “reserved” for the transport protocol field in the SDP response, it shall disregard the message. The EV shall continue SDP process as defined in ISO 15118-2:2014, chapter 7.10.1 (see also [V2G-DC-CharIN-030]).

[V2G-DC-CharIN-038] EV: If a DIN+ISO EV receives a payload that indicates “reserved” for the security field in the SDP response, it shall disregard the message. The EV shall continue SDP process as defined in ISO 15118-2:2014, chapter 7.10.1 (see also [V2G-DC-CharIN-030]).

[V2G-DC-CharIN-039] EV: If a DIN+ISO EV receives a payload that indicates “0xFF” for the transport protocol field in the SDP response, it shall disregard the message. The EV shall select a different transport protocol.

[V2G-DC-CharIN-040] EV: If a DIN+ISO EV receives a payload that indicates “0xFF” for the security field in the SDP response, it shall disregard the message. The EV shall select a different security protocol.

[V2G-DC-CharIN-041] EVSE: An EVSE shall at least wait for 20s after first CM_SLAC_PARM.REQ received for SDP request, before it is allowed to switch off the SDP server.

NOTE: For EVSEs supporting ISO15118 and DIN SPEC 70121 wake up might cause the SDP Server to be active after pausing.

[V2G-DC-CharIN-042] EVSE: The EVSE shall support at least 20 namespaces according to XML-Schema of DIN SPEC 70121.

[V2G-DC-CharIN-043] EV: A DIN+ISO EV shall not send an "AppProtocol" element referring to DIN in SupportedAppProtocolReq if a TLS connection is established.