SAE International

**SURFACE VEHICLE RECOMMENDED PRACTICE**

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# Communication Between Plug-In Vehicles and Off-Board DC Chargers

## RATIONALE

The SAE J2847-1 document supports AC or DC energy transfer identifying communications from the utility to the charger. The SAE J2847-2 document supports the additional messages for DC energy transfer. The SAE J2847-3 document supports RPF and this series is based upon requirements jointly developed by vehicle manufacturers, electric utilities, grid operators, technology suppliers, and other stakeholders. These requirements are reflected in SAE Information Report SAE J2836-1™, *Use Cases for Communication between Plug-in Vehicles and the Utility Grid*. These requirements fulfill the use cases described in SAE J2836-2™, *Use Cases for Communication between Plug-in Vehicles and Off-Board DC Charger*.

Whereas SAE J2293 focused on communication between the vehicle and local, off-board electric vehicle supply equipment (EVSE) with optional grid interaction, SAE J2847-1, SAE J2847-2 and SAE J2847-3 focuses on communication between the vehicle and grid, with the EVSE playing the role of local intermediary. Additionally, while SAE J2293 included support for SAE J1773-based inductive charging and SAE J1850-based communication, these are obsolete and hence not supported by SAE J2847. In order to maintain information for existing systems, this task force has reaffirmed SAE J2293, preserving that specification at its last revision level.

This specification addresses major changes that have occurred since 1997 (when SAE J2293 was published) in the technologies of electric vehicles, the grid, and information processing, including: (1) support for bi-directional energy transfer between vehicle and grid (FPF and RPF, as defined above); (2) support for new local communications media between vehicle and EVSE (to replace SAE J1850), such as power line communication (PLC), Controller Area Network (CAN), and wireless transports (Zigbee, WiFi, etc.); (3) synchronizing with a major revision of SAE J1772™ which includes new connectors and signals between the vehicle and EVSE, and additional AC and DC power levels; (4) support for new vehicle architectures such as plug-in hybrid (PHEV) and plug-in fuel cell (PFCV) vehicles; (5) support for new rechargeable energy storage system (RESS) technologies and packaging methods; (6) support for vehicle telematic communication transports; and (7) support for new developments in both utility and customer premises equipment, such as advanced metering infrastructure (AMI) and home-area network (HAN) technologies.

The above changes and others require a new approach to vehicle-grid communications and provide the fundamental rationale for this specification.

In the context of this document, the DC Supply is considered an extension of the on-board vehicle systems. For the most part, the DC supply acts in response to vehicle requests; it does not act autonomously. The DC Supply does not contain intelligence about the RESS system or specific vehicle operation. It only mitigates some safety related concerns that it is able to self detect (isolation), and it conforms to the vehicle established charge session limits (from handshaking). Primary control of the charging output is dictated by the vehicle control system.

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## 1. SCOPE

This SAE Recommended Practice SAE J2847-2 establishes requirements and specifications for communication between plug-in electric vehicles and the DC Off-board charger. Where relevant, this document notes, but does not formally specify, interactions between the vehicle and vehicle operator.

This applies to the off-board DC charger for conductive charging, which supplies DC current to the vehicle RESS of the electric vehicle through a SAE J1772™ Hybrid coupler or SAE J1772™ AC Level 2 type coupler on DC power lines, using the AC power lines or the pilot line for PLC communication, or dedicated communication lines.

The specification supports DC energy transfer via Forward Power Flow (FPF) from source-to-vehicle.

This is the 1st version of this document and completes step 1 effort that captures the initial objectives of the SAE task force. The intent of step 1 was to record as much information on “what we think works” and publish. The effort continues however, to step 2 that allows public review for additional comments and viewpoints, while the task force also continues additional testing and early implementation. Results of step 2 effort will then be incorporated into updates of this document and lead to a republished version.

### 1.1 Purpose

The primary purpose of SAE J2847-2 is to provide the communication to achieve RESS pack charging control irrespective of RESS pack variations or energy storage technology.

SAE J2847-1 identifies the functional messaging for the Plug-In Electric Vehicle (PEV) to connect to the utility for Level 1 & 2 AC energy transfer. This document identifies the additional messages for DC energy transfer to the PEV.

The specification supports DC energy transfer via Forward Power Flow (FPF) from grid-to-vehicle, and DC Reverse Power Flow (RPF) from vehicle-to-grid is included in SAE J2847-3.[1] DC Forward Power Flow is used to charge the vehicle’s rechargeable energy storage system (RESS).

## 2. REFERENCES

### 2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, 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 724-776-4970 (outside USA), www.sae.org.



[1] In this specification, we use the terms FPF and RPF as precisely defined, and avoid the term V2G because its meaning has become ambiguous through divergent common usages.

2.1.2 Related Publications (Optional)

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

J1715 Hybrid Electric Vehicle (HEV) & Electric Vehicle (EV) Terminology

J1772™ SAE Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler (Surface Vehicle Recommended Practice).

J2836-1™ Use Cases for Communication between Plug-in Vehicles and the Utility Grid (Surface Vehicle Information Report).

J2836-2™ Use Cases for Communication between Plug-in Vehicles and the Supply Equipment (EVSE) (Surface Vehicle Information Report).

J2836-3™ Use Cases for Communication between Plug-in Vehicles and the Utility Grid for Reverse Power Flow (Surface Vehicle Information Report).

J2847-1 Communication between Plug-in Vehicles and the Utility Grid (Surface Vehicle Recommended Practice).

J2847-3 Communication between Plug-in Vehicles and the Utility Grid for Reverse Power Flow (Surface Vehicle Recommended Practice).

J1939 Recommended Practice for a Serial Control and Communications Vehicle Network

J2894 Power Quality Requirements for Plug In Vehicle Chargers - Part 1 (Recommended Practice)

2.2 ISO/IEC PUBLICATIONS

IEC61851-1 Electric vehicle conductive charging system - Part 1: General requirements (Under revision)

IEC61851-23 Electric vehicle conductive charging system - Part 23: D.C. electric vehicle charging station (Under development)

IEC61851-24 Electric vehicle conductive charging system - Part 24: Control communication protocol between off-board d.c. charger and electric vehicle (Under development)

IEC62196-3 Plugs, socket-outlets, and vehicle couplers – Conductive charging of electric vehicles - Part 3: Dimensional interchangeability requirements for d.c. pin and contact-tube vehicle couplers (Under development)

ISO 11898-1 Controller area network (CAN) -- Part 1: Data link layer and physical signaling

ISO 11898-2 Controller area network (CAN) -- Part 2: High-speed medium access unit

IEC Publications are also available from the American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

## 3. DEFINITIONS

### 3.1 ADVANCED METERING INFRASTRUCTURE (AMI)

AMI or Advanced Metering Infrastructure typically refers to the full measurement and collection system that includes meters at the customer site, communication networks between the customer and a service provider, such as an electric, gas, or water utility, and data reception and management systems that make the information available to the service provider.

### 3.2 BATTERY

See Electric Vehicle Storage Battery.

### 3.3 BATTERY ELECTRIC VEHICLE (BEV)

The BEV is a vehicle that receives its power solely from batteries, unlike a hybrid vehicle that may receive a portion of its power from an internal combustion engine (ICE). See also PEV.

### 3.4 BRANCH CIRCUIT

The circuit conductors between the final overcurrent device protecting the circuit and the equipment supplied by the circuit. It is typically an unswitched circuit from the service equipment (fuse box) to an appliance. For this application, the appliance is the Electric Vehicle Supply Equipment (EVSE).

### 3.5 CAN (CONTROLLER AREA NETWORK)

Common Automotive communications network as defined by SAE J1939.

### 3.6 ELECTRIC VEHICLE STORAGE BATTERY (BATTERY)

A group of electrochemical cells electrically connected in a series and/or parallel arrangement, the principal purpose of which is to provide DC electrical energy to propel the EV. May be called Rechargeble Energy Storage System (RESS), or Energy Storage System (ESS)

### 3.7 ELECTRIC VEHICLE SUPPLY EQUIPMENT (EVSE)

The equipment from the branch circuit to, and including, the connector that couples to the electric vehicle inlet, the purpose of which is to transfer electric energy to an EV. This equipment is located off-board the vehicle.

### 3.8 END-USE-MEASUREMENT-DEVICE (EUMD)

The End-Use-Measurement-Device (EUMD) is a revenue-grade submeter responsible for directly measuring energy delivered to a PEV. The PEV does not perform revenue-grade metering, and if a utility or electricity vendor wishes to offer a rate-advantaged program that requires specific metering of energy to a PEV, an EUMD must be installed in the appropriate circuit. The physical form and location of the EUMD may be unique for different applications.

### 3.9 ENERGY SERVICE COMMUNICATION INTERFACE (ESCI)

Energy Service Communication Interface (ESCI) communicates with and exchanges information between utility, PEV, and PEV End-Use-Measurement-Device (EUMD). ESCI shall provide PEV charging session information to the utility – PEV ID, interval kWhr consumption. It passes from utility to PEV the interval for metering kWhr consumption, rate tariff, and the day ahead hourly price table.

3.10 FORWARD POWER FLOW (FPF)

Forward Power Flow means the direction of energy for Charging a Vehicle from the source to the vehicle.

3.11 HEXADECIMAL NUMBER NOTATION

In some sections of the document the signal definitions use numerical values in Hexadecimal format for clarity. For example, a number '0x01' represents the decimal integer value '1'; the number '0x0C' represents the decimal equivalent of '12'.

3.12 HOME AREA NETWORK (HAN)

A HAN is a network contained within a user's home that connects a person's digital devices, from multiple computers and their peripheral devices to telephones, VCRs, televisions, video games, home security systems, "smart" appliances, fax machines and other digital devices that are wired into the network.

3.13 PLUG-IN ELECTRIC VEHICLE

Any class of vehicle BEV, PHEV, Electric Tug, etc. which can be plugged in to receive power from the Electrical Grid where this power is then used to apply traction to the vehicle wheels.

3.14 PRE-CHARGE

Precharging the DC bus ensures that the voltage supplied by the EVSE is nearly matched to the Vehicle RESS voltage prior to closing the vehicle contactors. This ensures that there is no possibility of a high in-rush current at the time of contactor closure.

3.15 RECHARGEABLE ENERGY STORAGE SYSTEM (RESS)

Means a system that stores energy for delivery of electric energy and which is rechargeable. See also Electric Vehicle Storage. See also 3.6 - ELECTRIC VEHICLE STORAGE BATTERY (BATTERY).

3.16 REVERSE POWER FLOW (RPF)

Reverse Power Flow means the direction of energy for Discharging a Vehicle from the vehicle to the load.

3.17 POWER FLOW

See Forward Power Flow and Reverse Power Flow.

3.18 POWER LINE COMMUNICATION (PLC)

Power line communication (PLC), also called power line carrier, mains communication, power line telecom (PLT), or power line networking (PLN), are terms describing several different systems for using electric power lines to carry information over the power line.

Electrical power is transmitted over high voltage transmission lines, distributed over medium voltage, and used inside buildings at lower voltages. Power line communications can be applied at each stage. Most PLC technologies limit themselves to one set of wires (for example, premises wiring), but some can cross between two levels (for example, both the distribution network and premises wiring).

All power line communications systems operate by impressing a modulated carrier signal on the wiring system. Different types of power line communications use different frequency bands, depending on the signal transmission characteristics of the power wiring used. Since the power wiring system was originally intended for transmission of AC power, the power wire circuits have only a limited ability to carry higher frequencies. The propagation problem is a limiting factor for each type of power line communications.

Data rates over a power line communication system vary widely. Low-frequency (about 100-200 kHz) carriers impressed on high-voltage transmission lines may carry one or two analog voice circuits, or telemetry and control circuits with an equivalent data rate of a few hundred bits per sec; however, these circuits may be many miles (kilometers) long. Higher data rates generally imply shorter ranges; a local area network operating at millions of bits per sec may only cover one floor of an office building, but eliminates installation of dedicated network cabling.

3.19 SIGNAL

A signal refers to the individual data elements that are communicated between the Plug In Vehicle and the Off Board charger. The signals are listed in Section 4.2 and in the Table in Appendix B.

3.20 MESSAGE

A message may include several signals packaged together in a group such that the entire group can be sent together over a physical layer interface. The physical layer will be defined in J2931 documents.

3.21 SIGNAL UPDATE RATE

This defines the expected frequency at which a periodic signal must be received over the communications bus for proper system control. If a particular signal is missing for more than ten full rate cycles, (based on section 4.1.3.2) then the system should enter a faulted state, and proceed to shutdown energy transfer.

3.22 SIGNAL RANGE

The Range defines the signal limits in engineering units.

3.23 SIGNAL RESOLUTION

The resolution determines how much a signal can change with each bit step in the integer representation.

3.24 SIGNAL DEFAULT VALUE

The default value is what is assumed if a signal has not yet been received over the communications bus.

3.25 SIGNAL BIT SIZE

The bit size defines how many digital bits are needed to represent the full range signal, including no data

3.26 SIGNAL OFF-SET

Signal Offset defines how an integer is adjusted to achieve the full range at the defined resolution. Offset can be positive or negative.

3.27 NO DATA PARAMETER

This defines a means for the Vehicle or DC Supply to indicate that a signal is not available (i.e.: hasn't been read yet).

3.28 DC SUPPLY

It converts AC energy from the grid to the DC energy for the rechargeable energy storage system (RESS). It is also referred as the off-board charger.

3.29 COMPATIBILITY CHECK

The PEV and the off-board charger should check if they are compatible. For example, the PEV RESS voltage may be higher than what the DC supply can support. Another example is where the PEV RESS maximum voltage is lower than what the DC supply can regulate down to. The vehicle will evaluate the DC supply limit parameters and the vehicle decides whether to proceed with charging.

3.30 HANDSHAKING COMPLETE

This is not a signal but it is a state from a combination of several signals between the PEV and the off-board charger. The DC off-board charger must receive: vehicle ready, vehicle maximum current limit, vehicle voltage upper limit and vehicle status code. The PEV must receive: charger maximum current limit, charger maximum voltage limit, charger minimum current limit, and charger minimum voltage limit and charger status code. After all of these signals have been exchanged between the PEV and the off-board DC charger then handshaking complete state is reached.

# 4. TECHNICAL REQUIREMENTS

## 4.1 Charging Phases

The signals within this document apply to the use case off board DC charging. The expectation is that the system behaves similarly as the on-board charger.

### 4.1.1 Normal Charging Session

A charging session is when a plug is inserted until when it is unplugged. Each charging session has three phases:

#### 4.1.1.1 Handshaking (Initialization)

During this phase, the vehicle and DC Supply exchange their operating limits and parameters for the upcoming charging session. Some signals are required, such as the voltage and current limitations. Each side uses these values to perform a compatibility check and to ensure that the limits are maintained during the charge session.

After negotiating the charging session parameters, according to J1772 the vehicle will lock the Charge cord connector into the vehicle inlet if the two systems are compatible. If incompatible, the information broadcasted can be used by a display unit on either side to inform the customer. Once locked, the vehicle and DC Supply must be stopped by the end of the charging session, or by a user initiated shutdown before the connector can be removed. The connector lock will be released by the vehicle when the onboard sensors determine that voltage and currents at the inlet port are within safe limits.

To ensure no damage (welding) to the vehicle side contactors, charger must be enabled and controlled to a voltage that the vehicle can measure. Closing of vehicle side contactors when there is a voltage differential present can result in damaged or welded contactors. Vehicle side welding of the contactor is a reliability concern. When the contactors are welded, high voltage could be exposed at the touchproof inlet pin.

Using the Vehicle Maximum Voltage Limit signal, the vehicle will control the Pre-Charge process. The power is delivered by the EVSE to reduce the voltage difference between the Vehicle RESS and the Charging Supply output. When the vehicle determines the voltage measured at the DC supply is within acceptable difference to the RESS (exact tolerance threshold is at the discretion of the OEM), the vehicle can then close contactors in the vehicle to connect the DC supply output to the RESS.

When all the Initialization and pre-charge steps have completed, the system (vehicle and charger) will transition to the Energy Transfer phase. The vehicle charging algorithm may establish maximum current, voltage and power limits at a fixed value at the beginning of the charging session, and proceed through the whole charge session without changing the limits. This method might be used if the algorithm uses a fixed voltage controlled charging algorithm.

4.1.1.2 Energy Transfer

During Energy Transfer, the vehicle and the DC Supply will continuously monitor the voltage and current readings independently to ensure that the system remains within the negotiated limits. The vehicle can reduce consumption to protect the RESS. The DC Supply can reduce the output level to ensure that its voltage and current limits will not be violated.

The DC supply will indicate the status of the energy transfer and will be able to signal to the vehicle when it is operating at its maximum output capability. The Vehicle will communicate the expected charge completion time so the information can be presented to the user on a display in the DC charging station.

There are two modes of energy transfer: Bulk Charging and Full Charging. During Bulk Charging, the vehicle will request energy transfer at or near the negotiated limitations of the charging session. This will continue for the requested charging session time. When the Bulk threshold has been reached, the vehicle will end the charging session, or it will reduce the energy consumption to allow charging the RESS to full. While charging to Full, the energy transfer requests will be limited by the vehicle to ensure the maintenance of the RESS. Charging to Full may last for a duration that continues for several hours.

The vehicle will control charge level based on vehicle RESS and other vehicle conditions. When the vehicle determines that the charging session is complete, it will send a unique signal to the DC Supply. At that point, the vehicle will reduce its requested energy transfer to near zero, and may open the charging contactors in the vehicle.

When the vehicle has determined that it has reached Full or Bulk charge level, the system will transition to Normal Shutdown. It's up to the vehicle manufacturer when to switch from bulk to full charge.

4.1.1.3 Normal shutdown

Normal shutdown occurs when the RESS reaches the desired State of Charge limit and any accessory load consumption of the vehicle has completed. After completion of the charge session, the Shutdown phase allows the vehicle and DC Supply to return to a safe condition so the user can handle the charging cord. The vehicle will have reduced its charge current request to zero, and will be indicating Charge complete. When the current is near zero (exact tolerance threshold is at the discretion of the OEM), the vehicle will open its onboard charge contactors, and wait for the inlet voltage to drop to a safe level. Once at the safe level (below 60V DC as defined by SAE J2344), the charging port connector can be unlocked by the vehicle. The user can then remove the charge coupler from the inlet.

The vehicle and DC Supply may exchange some signals that can be used for energy reporting and consumption displays.

Normal shutdown can be entered by an action from the user. For example, a "Stop" button on the DC Supply could have been pressed which will immediately cause the vehicle to reduce the request even if the RESS has not reached Full or Bulk level. Then the vehicle will enter the normal shutdown state, which will lead to the charge coupler being unlocked for the user.

Based on user preferences, the vehicle will keep the charge coupler locked in the inlet until the user is ready to remove the charge cord connector. The vehicle may remain in this state for a long time period. If necessary, the vehicle system can restart the charging process by asserting the "Vehicle Ready Signal" and De-asserting the "Charge Complete" signal(s). The DC Supply should recognize the state transition, and will enter the initialization sequence so that the isolation check and pre-charge will be done.

Each signal is transmitted at fixed periodic rate. Some signals are transmitted during the start of the session (handshaking). Critical signals are transmitted throughout the energy delivery phase. Some messages close out the session at the end of charging process (normal shutdown).

#### 4.1.2 Examples of Emergency Shutdown

Certain fault conditions will cause the charging system to shutdown before the normal shutdown. Either the Vehicle will initiate the shutdown, or the charging station might initiate shutdown. Some examples would be:

##### 4.1.2.1 Loss of safety ground

It occurs when continuity of the safety ground is lost.

##### 4.1.2.2 Loss of high voltage isolation

It occurs when there is current leak between the chassis and the high voltage charging system including the vehicle RESS.

##### 4.1.2.3 Loss of communication

In the event that reliable data communication between the PEV and the off board DC charger cannot be established, it is understood that the PEV or the off board charger shall stop energy transfer.

##### 4.1.2.4 Loss of power

It happens when the off-board charging system stops delivering power to the PEV.

#### 4.1.3 Examples of System Faults

##### 4.1.3.1 Welded Contactors

In case the vehicle contactors are welded, the vehicle should provide a fault indication and request zero current and voltage. Through the in-vehicle display system or a hidden switch (as directed by the user manual), the charge cord connector could be manually unlocked in a safe manner. That manual switch could break the HV connection to the inlet, or pull the HV contacts out of harms way, or light an indicator within view of the inlet pins showing that there could be high voltage present at the inlet. In this case, the vehicle controls should not allow start, or be in some very limited operating state such that the owner is directed to get the vehicle in for service.

In the normal shutdown sequence, the vehicle will be able to test the contactor status for welded contactor fault reporting. In the event that the charging session is shut down in an emergency situation, there is no opportunity for the welded contactor check. In this situation, the vehicle should record that an abnormal shutdown has occurred, and then the next charging opportunity, the vehicle should perform a welded check before entering charge. The method for welded check during startup is described below.

<u>Welded Contactor Check at Startup</u>

Referring to sections 5.2.1 & 5.2.2, which show the startup and shutdown sequences, the vehicle will start a new charging session as normal. The sequence will work just as shown until step T6, where the vehicle has given the DC Supply opportunity to check for HV isolation in the charging station and into the connector. Then the vehicle will skip to the normal shutdown sequence step T12, where the vehicle will perform the welded contactor check through step T16. If there are no issues found, the vehicle will keep the connector locked, and return to the startup sequence at step T2, which will again perform all the isolation and safety checks prior to entering normal charging at step T9. Normal charging would proceed, and a welded check would be performed at the end of the charging session when following the normal shutdown sequence.

#### 4.1.3.2 Missing Signal Messages

The PEV will allow occasional missing signal messages. When the PEV has not detected a Required Signal message after 10 intervals of the Expected Data Rate (according to table in Appendix B), then the PEV should consider this a loss of communications fault condition and initiate a shutdown. Additionally, the PEV might log a diagnostics error code, which can be retrieved from the normal dealership diagnostics procedures using a vehicle testing tool.

The DC Supply will allow occasional missing signal messages. When the DC Supply has not detected a Required Signal message after 10 intervals of the Expected Data Rate (according to table in Appendix B), then the DC Supply should consider this a fault condition and initiate a shutdown.

## 4.2 Signal Definitions

This section describes the details of the signals used to control an off-board charger. Several Signals may be combined together to form a binary packed Message for more efficient use of the communications medium. The Message packaging structure is outside the scope of this document in this current revision.

Refer to table in Appendix A for the signal phases. Refer to table in appendix B for signal details.

### 4.2.1 Bulk Charging Complete

*Source: PEV*
*Destination: DC Supply*
*Phase: End of the charging process*

This is the signal that indicates that the RESS has reached the bulk charge level (generally up to 80 to 100% SoC). This is optional, and is used for display purposes on the charging station. See “Normal Charging Session” above for more details.

### 4.2.2 Charging Complete

*Source: PEV*
*Destination: DC Supply*
*Phase: End of the charging process*

This is the signal that indicates that the RESS has reached the full charge level (up to 100% SoC).

### 4.2.3 Vehicle Energy Capacity

*Source: PEV*
*Destination: DC Supply*
*Phase: Hand shaking*

This signal indicates the maximum designed energy capacity allowed by the vehicle manufacturer. The DC Supply could use this signal for safety mitigation from the charger side. Charger may optionally stop after delivering this amount of energy the vehicle would accept. That value includes RESS capacity and vehicle auxiliary energy.

### 4.2.4 Vehicle RESS SOC

*Source: PEV*
*Destination: DC Supply*
*Phase: Periodic in any phase*

This signal is defined by the vehicle manufacture to represent the relative charge level as a percentage of the full energy storage of the Vehicle RESS. It’s primary used for display on the charging Supply. If the vehicle uses a battery for energy storage, then this would be Battery SOC.

4.2.5 Vehicle Maximum Current Limit

*Source: PEV*
*Destination: DC Supply*
*Phase: Hand shaking and as needed*

It's a signal from the vehicle to the DC Supply indicating its maximum allowed current. In other words, it's the maximum current limit allowed by the vehicle. It may depend on RESS temperature, SoC, etc. The charger shall not exceed the minimum of this signal and the Charger Maximum Current Limit. The primary purpose of the Current Limit signal is for the DC charger to regulate its fast internal (ms) regulation loops. The DC Supply hardware and software shall control the output so that there will be no violations of this limit. The vehicle may optionally change this signal dynamically throughout the charging session.



4.2.6 Vehicle Maximum Power Limit

*Source: PEV*
*Destination: DC Supply*
*Phase: Hand shaking and as needed*

It's the maximum power limit allowed by the vehicle. It may depend on RESS temperature, SoC, etc. The charger shall not exceed the minimum of this signal and the Charger Maximum Power Limit. The primary purpose of the Power Limit signal is for the DC charger to regulate its fast internal (ms) regulation loops. The vehicle may optionally change this signal dynamically throughout the charging session.

4.2.7 Vehicle Maximum Voltage Limit

*Source: PEV*
*Destination: DC Supply*
*Phase: Hand shaking, Pre Charge and as needed*

It's the maximum voltage limit allowed by the vehicle. It may depend on RESS temperature, SoC, etc. The charger shall not exceed the minimum of this signal and the Charger Maximum Voltage Limit. The primary purpose of the Voltage Limit signal is for the DC charger to regulate its fast internal (ms) regulation loops. The vehicle may optionally change this signal dynamically throughout the charging session.

4.2.8 Charger Maximum Power Limit

*Source: DC Supply*
*Destination: PEV*
*Phase: Hand shaking and as needed*

It's the maximum power that can be delivered to the PEV. The charger should regulate this value. The charger shall not exceed the minimum of this signal and the Vehicle Maximum Power Limit. This DC Supply can dynamically change this value throughout the charging session (as in the case where a utility demand reduces the available power).

4.2.9 Charger Maximum Current Limit

*Source: DC Supply*
*Destination: PEV*
*Phase: Hand shaking and as needed*

It's the maximum current that can be delivered to the PEV. The charger should regulate this value. The charger shall not exceed the minimum of this signal and the Vehicle Maximum Current Limit. This value can change dynamically through the charging session.

4.2.10 Charger Maximum Voltage Limit

*Source: DC Supply*
*Destination: PEV*
*Phase: Hand shaking and as needed*

It's the maximum voltage that can be maintained by the charger. The charger should regulate this value. The charger shall not exceed the minimum of this signal and the Vehicle Maximum Voltage Limit. This value can change dynamically through the charging session.

4.2.11 Charge Current Request

*Source: PEV*
*Destination: DC Supply*
*Phase: Periodic at 25mSec rate*

This signal is the instantaneous charging current request from the vehicle. The request should be within the established charger and vehicle limits from handshaking. In accordance with section 4.4.7, the current request is allowed to be higher than the Charger Maximum Current Limit (4.2.9), but the DC Supply will reduce the output to maintain the limit. The DC supply is allowed to overshoot or undershoot around this target as long as it doesn't violate sections 4.2.5, 4.4.1, 4.4.6, and 4.4.9. In the case where any of the charging limits have been achieved (sections 4.2.24, 4.2.25, 4.2.26), the charge current request may be higher than the actual measured current reading. Since the vehicle is controlling charge current and reading on-vehicle current sensors, the vehicle will ensure that the request is adjusted to achieve the vehicle control target.

4.2.12 Vehicle RESS Voltage

*Source: PEV*
*Destination: DC Supply*
*Phase: Periodic as needed.*

It's the vehicle RESS instantaneous (actual) voltage value as read by the vehicle. It can be used for diagnostic purposes.

4.2.13 Vehicle Ready

*Source: PEV*
*Destination: DC Supply*
*Phase: Handshaking and periodic at 25mSec rate.*

It informs the charger that the PEV is ready to be charged. It is needed if there is no control pilot signal. It's redundant to control pilot signal.



4.2.14 Vehicle Status Code

*Source: PEV*
*Destination: DC Supply*
*Phase: Periodic or when state changes.*

It indicates the PEV internal charging sequence state. That could be vehicle gear shift not in P, IGN key ON, etc. Optionally PEV could report more info to be display on the charger.
In situations where a vehicle might have more than one state from the list below, the vehicle (or OEM) will determine the highest priority item to send to the charger for display. Only one item from the list can be sent in this signal.

This is an enumerated type signal defined by:

| Enumeration | Definition | Comments / Description |
|---|---|---|
| 0x0 | Vehicle Not Ready | Key is On, etc. |
| 0x1 | Vehicle Charging or Energy Transfer | Energy Transfer is active |
| 0x2 | RESS Temperature Inhibit | RESS too hot/cold to accept charge |
| 0x3 | Vehicle Shift Position | Vehicle is not in Park |
| 0x4 | Charger Connector Lock Fault | Vehicle has not detected the Charge cord connector locked into the inlet or failure where connector cannot be unlocked from the charging inlet. |
| 0x5 | Vehicle Cabin Conditioning | The PEV is using energy from the DC supply to heat or cool the passenger compartment. *This state is Optional, as an alternative, the vehicle can use 0x1 (charging)* |
| 0x6 | Vehicle RESS Conditioning | The vehicle using energy from the DC charger to condition the RESS to a target temperature. *This state is Optional, as an alternative, the vehicle can use 0x1 (charging)* |
| 0x7 | Vehicle RESS Malfunction | Any non-recoverable fault or error condition of the Vehicle RESS. |
| 0x8 | Charging current differential | Indication that vehicle has stopped the charging session after detecting that the charging station is not able to maintain the current request. |
| 0x9 | Charging voltage out of range | Indication that vehicle has stopped the charging session after detecting that the RESS is either under or above normal operating voltage range. |
| 0xA – 0xC | Reserved | |
| 0xD | Charging System Incompatibility | If the vehicle determines that the charging station is incompatible. *This state is Optional, as an alternative, the vehicle can use 0x0 (not ready)* |
| 0xE | Other Vehicle Faults | Faults not covered above. Vehicle Emergency Shutdown |
| 0xF | No Data | Only used when vehicle has not yet determined its operating state. |

4.2.15 Charger Status Code

*Source: DC Supply*
*Destination: PEV*
*Phase: Periodic or when state changes.*

It indicates the charger internal charging sequence state. That could be charger mal function, AC phase lost, EVSE ready, EVSE on maintenance, EVSE standby, etc. Optionally charger could report more info to be displayed on the PEV or cell phone.

In situations where a charger might have more than one state from the list below, the charger will determine the highest priority item to send to the vehicle for display.

This is an enumerated type signal defined by:

| Enumeration | Definition | Comments / Description |
|---|---|---|
| 0x0 | Charger Standby / Not Ready | Not authorized, On maintenance, etc. |
| 0x1 | Charger Ready / Charging | |
| 0x2 | Charger Prepaid Limits Exceeded | Maximum negotiated time limit exceeded<br>Maximum negotiated energy limit exceeded. |
| 0x3 | Charger Shutdown | Customer Initiated Shutdown |
| 0x4 | Utility Interrupt Event | Utility or Equipment operator has requested a temporary reduction in load. |
| 0x5 | Isolation Monitoring Internal | Charging station is actively testing its internal isolation monitoring circuit. (optional) |
| 0x6 | Isolation Monitoring Active | After the Charging Station has confirmed HV isolation internally, it will remain in this state until the cable isolation integrity is checked. |
| 0x7 | Charger Emergency Shutdown | Emergency Shutdown or 'E-Stop' button pressed at charging station. |
| 0x6 – 0xC | Reserved | |
| 0xD | Charging System Incompatibility | e.g. If requested voltage range is not supported. If not capable of DC charging. Transfer type mismatch, etc. |
| 0xE | Charger Malfunction | Any type of non-recoverable charger fault.<br>Ex: Coupler overtemperature, Isolation Failure, etc. |
| 0xF | No Data | Only used when charger has not yet determined its operating state. |

4.2.16 Remaining Charging Time to Bulk SoC

*Source: PEV*
*Destination: DC Supply*
*Phase: Periodic in all phases.*

This signal from the vehicle allows the charging station to display a time remaining count. This value is the Remaining time to charge PEV up to the bulk SoC. The time represents how much time it will take to get from the actual SoC to the bulk SoC. The DC Supply may optionally use this periodic signal from the vehicle in order to display information to the user. The DC Supply will not stop the charging session based on this time; the vehicle always controls the charging session stop time.

4.2.17 Bulk SoC

*Source: PEV*
*Destination: DC Supply*
*Phase: Hand shaking only*

It's the end point (SoC) where optimum fast charge ends. Each vehicle OEM will decide the bulk level value (80% for example). The display SoC could indicate this from actual SoC to bulk percent if desired.

4.2.18 Remaining Time to Full SoC

*Source: PEV*
*Destination: DC Supply*
*Phase: Periodic in all phases.*

Remaining time to charge PEV to full SoC; that is, the interval in time when no more energy is needed to charge the RESS. Display time to charge from actual SoC to full SoC. The DC Supply may optionally use this periodic signal from the vehicle in order to display information to the user. The DC Supply will not stop the charging session based on this time; the vehicle always controls the charging session stop time.

4.2.19 Full SoC

*Source: PEV*
*Destination: DC Supply*
*Phase: Hand shaking only.*

This signal defines the SOC where the vehicle considers the RESS is full. It's from bulk SoC to Full. It is defined by each vehicle OEM.

4.2.20 Vehicle Energy Request

*Source: PEV*
*Destination: DC Supply*
*Phase: Hand shaking and as needed.*

It's the RESS residual capacity before or during charging. This allows the PEV to limit the charging session by limiting the energy transfer (i.e. for partial charge)

4.2.21 Charger Energy to be delivered

*Source: DC Supply*
*Destination: PEV*
*Phase: Hand shaking and as needed.*

It's the allowed or requested units of energy to be delivered during charging. This allows public charging stations to limit charging session by limiting the energy transfer (i.e., for a prepaid amount).

4.2.22 Voltage Output

*Source: DC Supply*
*Destination: PEV*
*Phase: Hand shaking and as needed.*

It's the measured High Voltage DC voltage at the output of the DC Supply. It's used by the PEV during charging for diagnosis of on board sensors.

4.2.23 Current Output

*Source: DC Supply*
*Destination: PEV*
*Phase: Hand shaking and as needed.*

It's the measured High Voltage DC current at the output of the DC Supply. It's used by the PEV during charging for diagnosis of on board sensors.

4.2.24 Charger Current Limit Achieved

*Source: DC Supply*
*Destination: PEV*
*Phase: Hand shaking and as needed.*

The charger is at the limit of its source capability (saturation). The charger becomes saturated when either the charger limits (4.2.9) are achieved or the vehicle limits (4.2.5) from handshaking have been achieved. It's used by the PEV control to compensate for reaching the limit.

4.2.25 Charger Voltage Limit Achieved

*Source: DC Supply*
*Destination: PEV*
*Phase: Hand shaking and as needed.*

The charger is at the limit of its source capability (saturation). The charger becomes saturated when either the charger limits (4.2.10) are achieved or the vehicle limits (4.2.7) from handshaking have been achieved. It's used by the PEV control to compensate for reaching the limit.

4.2.26 Charger Power Limit Achieved

*Source: DC Supply*
*Destination: PEV*
*Phase: Hand shaking and as needed.*

The charger is at the limit of its source capability (saturation). The charger becomes saturated when either the charger limits (4.2.8) are achieved or the vehicle limits (4.2.6) from handshaking have been achieved. It's used by the PEV control to compensate for reaching the limit.

4.2.27 Vehicle Protocol Version

*Source: PEV*
*Destination: DC Supply*
*Phase: Hand shaking only.*

This is sent at the beginning of the charging session in order to coordinate which signals can be used. This is only necessary if a new protocol with enhanced features is developed. Devices will fall back to a lower protocol as needed to support a limited set of messaging.

4.2.28 Charger Protocol Version

*Source: DC Supply*
*Destination: PEV*
*Phase: Hand shaking only.*

This is sent at the beginning of the charging session in order to coordinate which signals can be used. This is only necessary if a new protocol with enhanced features is developed. Devices will fall back to a lower protocol as needed to support a limited set of messaging.

4.2.29 Connector Locked

*Source: PEV*
*Destination: DC Supply*
*Phase: All States and periodic at 100mSec rate.*

It informs the charger that the PEV has locked the charge cord connector into the inlet. When locked, the vehicle and charger can both commence to transfer energy. This would be used for charging systems which do not have the Proximity detect button (such as IEC Type 2 connector).

4.2.30 Charger Minimum Voltage Limit

*Source: DC Supply*
*Destination: PEV*
*Phase: Hand shaking and as needed.*

It informs the PEV that the DC supply can only regulate its voltage output down to this level. If a vehicle has RESS that must operate below this level, then the vehicle will determine that the charging station is incompatible. The vehicle will not start charging or will stop a charging session if the target RESS voltage falls below this value.

4.2.31 Charger Minimum Current Limit

*Source: DC Supply*
*Destination: PEV*
*Phase: Hand shaking and as needed.*

It informs the PEV that the DC supply can only regulate its current output down to this level. If a vehicle has RESS that must operate below this level, then the vehicle will determine that the charging station is incompatible. The vehicle will not start charging or will stop a charging session if the target RESS current falls below this value.

4.2.32 Charger Peak Current Ripple

*Source: DC Supply*
*Destination: PEV*
*Phase: Only in Hand shaking.*

This signal informs the PEV what peak-to-peak magnitude of the DC Supply current ripple can be expected at any charge level. This is dependent on the charger filter and control design. It is expected that quick chargers will have higher ripple, and may not be suitable for low current topoff charging (Bulk level to Full level). The vehicle may modify its charging strategy using this information. The vehicle may chose not to initiate the charging session if the value is not compatible with the RESS charging strategy.

4.2.33 Charger Current Regulation Tolerance

*Source: DC Supply*
*Destination: PEV*
*Phase: Only in Hand shaking.*

This signal informs the PEV what absolute magnitude of the DC Supply regulation tolerance can be expected at any charge level. This is dependent on the charger filter and control design. It is expected that quick chargers will have larger tolerance, and may not be suitable for low current topoff charging (Bulk level to Full level). The vehicle may modify its charging strategy using this information. The vehicle may chose not to initiate the charging session if the value is not compatible with the RESS charging strategy

4.2.34 Vehicle Requested Energy Transfer Type

*Source: PEV*
*Destination: DC Supply*
*Phase: In Hand shaking*

This signal informs the DC supply that the Vehicle wishes to request AC Energy transfer from an EVSE that supports digital communications. This allows a vehicle to connect to an EVSE that can do either DC or AC energy transfer.
Note: For an EVSE capable of supplying DC, the system must also have a Proximity or Pilot circuit change and potentially keyways on the connector that allows the vehicle to identify a EVSE that is only capable of DC supply.

This signal allows the Vehicle to select its desired energy transfer type in the case that both the EVSE and Vehicle support multiple energy transfer types and J1772™ connector variations (AC, DC type 1, DC Combo). If the DC Supply cannot support the requested transfer type, it shall respond with a Charger Status Code enumeration 0x0D "Charging System Incompatibility".

This is an enumerated type signal defined by:

| Enumeration | Definition | Comments / Description |
|---|---|---|
| 0x00 | (reserved for) AC Type 1/Type 2 – single phase on core pins | Vehicle is requesting single phase AC energy transfer as specified through the SAE 1772 type 1 or type 2 connector. |
| 0x01 | (reserved for) AC Type 2 – three phase on Type 2 core pins | Vehicle is requesting three phase AC energy transfer as specified through the SAE 1772 type 1 or type 2 connector. |
| 0x02 | DC Type 1/Type 2 on core pins | Vehicle is requesting DC energy transfer as specified through the SAE 1772 type 1 or type 2 connector using the standard core connector pins. (couple type C1) |
| 0x03 | DC combo 1/combo 2 on extended pins | Vehicle is requesting DC energy transfer as specified through the SAE 1772 type 1 or type 2 combo connector over the additional pins outside the core (coupler type C2) |
| 0x04 | DC combo 1/combo 2 on core pins | Vehicle is requesting DC energy transfer as specified through the SAE 1772 type 1 or type 2 combo connector over the core pins (coupler type C2) |
| 0x05 | (reserved for) Dedicated DC on unique connector | In the case of a dedicated coupler for Level 3 DC charging (coupler type C3) |
| 0x06 | (reserved for) Reverse Energy Flow DC | |
| 0x07 | (reserved for) Reverse Energy Flow AC | |
| 0x08 – 0x0E | Reserved for future use | |
| 0x0F | Undetermined | Vehicle may transmit this enumeration at startup before selecting a compatible energy transfer type. |

4.2.35 Charger Supported Energy Transfer Type

*Source: DC Supply*
*Destination: PEV*
*Phase: In Hand shaking*

This signal informs the Vehicle of all Energy transfer types supported by the EVSE. Since an EVSE may support multiple types of energy transfer (AC, DC type 1, DC combo) this signal allows a vehicle know all options of charging that are supported by the EVSE to determine if it is compatible and select the desired energy transfer type. If the vehicle cannot use any of the supported charging types from the DC supply, it shall respond with Vehicle Status Code enumeration 0x0D "Charging System Incompatibility".

This is an enumerated type signal defined by:

| **Enumeration** | **Definition** | **Comments / Description** |
|---|---|---|
| 0x00 | (reserved for) AC Type 1/Type 2 – single phase on core pins | The EVSE supports single phase AC energy transfer as specified through the SAE 1772 type 1 or IEC type 2 connector. |
| 0x01 | (reserved for) AC Type 2 – three phase on Type 2 core pins | The EVSE supports three phase AC energy transfer as specified through the IEC type 2 connector. |
| 0x02 | DC Type 1/Type 2 on core pins | The EVSE supports DC energy transfer as specified through the SAE 1772 type 1 or type 2 connector on the core pins. |
| 0x03 | DC combo 1/combo 2 on extended pins | The EVSE supports DC energy transfer as specified through the SAE 1772 type 1 or type 2 combo connector on the extended pins. |
| 0x04 | DC combo 1/combo 2 on core pins | The EVSE supports DC energy transfer on a combo connector core pins (but not on the extended pins) |
| 0x05 | DC combo 1/combo 2 dual | The EVSE supports DC energy transfer on a combo connector core pins and on the extended pins (but not at the same time) |
| 0x06 | (reserved for) AC on core pins / DC on extended pins | The EVSE supports AC energy transfer on a combo connector core pins and DC energy transfer on the extended pins (but not at the same time) |
| 0x07 | (reserved for) AC and DC capable on core pins | The EVSE supports single phase AC or DC energy transfer on Type 1/Type 2 connector core pins (but not at the same time) |
| 0x08 | (reserved for) AC single phase on core combo 1/combo 2 pins<br>AND<br>AC three phase on combo 1/combo 2 core + extended pins | The EVSE supports single phase AND three phase AC energy transfer on a combo connector using combination of core pins and extended pins (but not both at the same time) |
| 0x09-0x0E | Reserved for future use | |
| 0x0F | Undetermined | Supply may send this enumeration while executing its startup sequence. |

## 4.3 Measurement Accuracy

The off-board DC charger is equipped with current and voltage sensors, and is responsible for reporting measured current and voltage to the vehicle using the messages described in the Section 4.2. The following defines the accuracy requirements for the values measured and reported to the vehicle.

### 4.3.1 Measured Current Accuracy

The measured current reported by the DC Supply shall be within +/-1.5% of reading (but not better than +/- 0.5A).

### 4.3.2 Measured Voltage Accuracy

The measured voltage reported by the DC Supply shall be within +/-1% (of full scale) or less.

## 4.4 Charger Control Accuracy

The vehicle issues current and voltage commands to the off-board DC charger using the messages defined in Section 4.2. The following requirements define the performance of the off-board charger.

### 4.4.1 Charger Current Regulation

The actual RMS output of the charger shall meet the following conditions:

Requested Current 0-5A: Actual output is equal to requested current +/-150mA or less.

Requested Current 5-50A: Actual output is equal to requested current +/-1.5A or less.

Requested Current >50A: Actual output is equal to requested current less than +/- 3% of the rated full scale.

### 4.4.2 Descending Current Output Slew Rate

Normal Shutdown or Zero Current Request: -100A/sec or greater.

Malfunction or Emergency Shutdown (Vehicle Ready flag = FALSE): -200A/sec or greater.

### 4.4.3 Control Delay to Vehicle Request

At the beginning of energy transfer, the charger shall begin to respond to a vehicle request within 2.5 sec. During energy delivery, the charger should follow the change rate as in 4.4.2 and 4.4.9.

### 4.4.4 Charger Current Ripple

During Regulation the charging system shall maintain a peak-to-peak ripple no greater than +/-3% of the rated full scale output. The requirement only applies to ripple at a frequency below 1000 hertz.

Examples:

a.) 120A charger at full current with 3% ripple would result in no better than +/-3.6A ripple.

b.) 200A charger with a 40A target output request would result in +/-4.0A ripple.

c.) 10A charger with 1A request would result in a +/-300mA ripple.

### 4.4.5 Voltage Ripple – No Load Voltage Regulation

Under no load conditions, for example during Pre-charge, the actual output of the charger will be +/- 5V of the vehicle's request within 2 sec.

### 4.4.6 Charger Current Overshoot time

If Vehicle Maximum Current Limit is exceeded by more than the amount specified in section 4.4.1 for more than 400mSec the charging station will shut down due to a fault condition. This is the case where the current output is no longer under the control of the vehicle, and the charging station will use its conversion circuitry to cleanly reduce current flow.

### 4.4.7 Vehicle Response to Charge Station Limits

The Vehicle should respond to a change in the Charging Station Limits within 10 sec. For example, the charger will allow the vehicle to continue requesting higher current for a short time so that the vehicle can adjust its internal controls for battery maintenance such as cell balancing. The charging station will reduce the delivered current throughout this time period towards the new charge limits. The vehicle should reduce the request in order to meet the charging station limits. The charge limit achieved signals (4.2.24, 4.2.25, & 4.2.26) would indicate the charger status. When the vehicle does not respond to the charging station limits after 10 sec, the charger may optionally consider this a fault and initiate emergency shutdown to force the vehicle to stop.

### 4.4.8 Charger Isolation Impedance

The isolation between the HV DC bus wiring and the vehicle chassis and earth ground must be controlled. The requirements here are assuming a system with worst case of 500V bus, and 10 devices connected to the HV bus. According to SAE J2344, the total of the combined Vehicle, DC Supply, and other HV loads will have impedance higher than 100 ohm/volt after the vehicle has gone to Ready state. Therefore, the DC supply isolation should be greater than 1.0Meg-ohm to ensure system compliance. These requirements apply until end of service for the product.

### 4.4.9 Vehicle Request Change Rate

The maximum change rate for the current request from the PEV shall be 20 A/sec (or 10% of the Full rated current per sec). The charger current output should be within 80% of the PEV current request within 1 sec.

In Normal and Emergency Shutdown, the request can make a step change directly to zero as described in Section 4.4.2.

Where the DC Supply is limited by grid restriction in power delivery, the actual rate of change may be lower. This is related to the power quality restrictions in J2894.

Charging station may not be able to honor this request all the time due to thermal foldback or other reduced operating modes. In the case where the DC supply is not able to produce the request, it will use the charger maximum voltage and current limits to indicate the limitations.

### 4.4.10 Loss of communications DC Supply

When communications loss is detected by the EVSE, the EVSE shall use the EVSE initiated shutdown sequence. After the current output achieves zero, the EVSE must allow 500mSec for the PEV to open its charge contactors before discharging the HV bus. See Section 5.2.4.

### 4.4.11 Loss of communications Vehicle

When communications loss is detected by the Vehicle, the vehicle shall use the Vehicle initiated shutdown sequence. After the current output achieves zero, the vehicle must open contactors no later than 500mSec to allow for the DC Supply to discharge the HV bus. See Sections 5.2.3 & 5.2.4.

## 5. SEQUENCE DIAGRAM

### 5.1 DC Charging System State Diagram

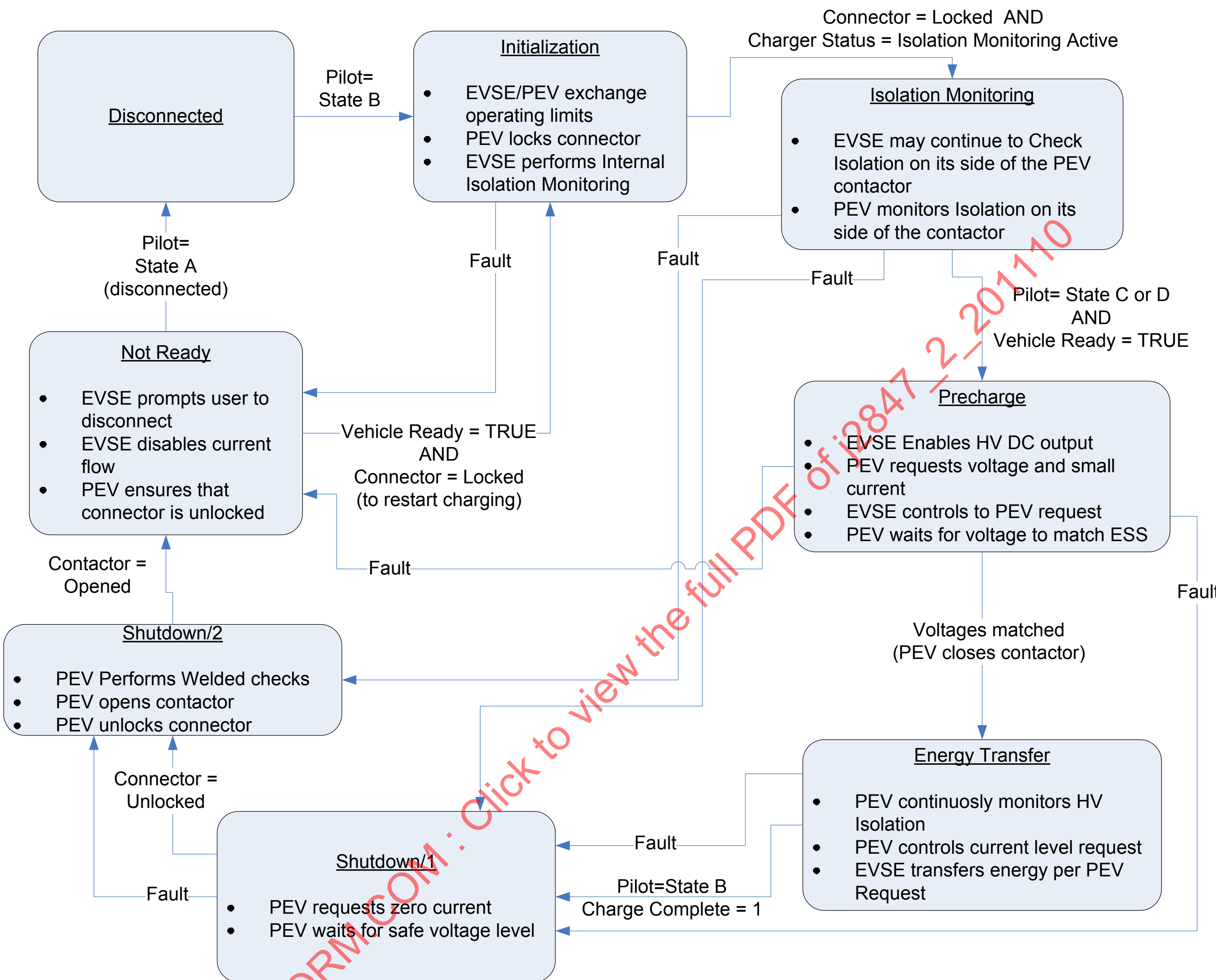



FIGURE 5.1 – DC CHARGING SYSTEM STATE DIAGRAM

## 5.2 Charging System Sequence Diagram

Notes:
- Items in *Italics* are optional as per table in Appendix A.
- The signals in the table below are transmitted at a regular interval; change of state occurs when a signal value has been updated.



TABLE 5.2 – CHARGING SYSTEM SEQUENCE DIAGRAM

| Time | Action | Off-Board Charger Signals | Vehicle Signals | Stage | Duration |
|---|---|---|---|---|---|
| T0 | PEV is plugged in<br><br>Pilot Change from State A to State B causes transition to T1 | None | None | Disconnected | n/a |
| T1 | PEV Begins Isolation Monitoring on Vehicle RESS side of PEV contactor<br><br>Handshaking is complete after appropriate messages have been exchanged between PEV and DC Supply<br><br>After Handshaking complete, transition to T2 | Charger Status Code =<br>Charger Not Ready<br>Charger Maximum Current Limit<br>Charger Maximum Voltage Limit<br>Charger Supported Energy Transfer Type<br>Charger Peak Current Ripple<br>Charger Minimum Voltage Limit<br>Charger Minimum Current Limit<br><br>*Charger Energy to be Delivered*<br>*Charger Protocol Version*<br>*Charger Maximum Power Limit*<br>*Charger Current Regulation Tolerance* | Vehicle Ready = Not Ready<br>Vehicle Status Code = Not Ready<br>Vehicle Connector Lock = Not Locked<br>Vehicle Requested Energy Transfer Type<br>Vehicle Connector Lock = NOT Locked<br><br>*Vehicle Protocol Version*<br>*Bulk SOC*<br>*Full SOC*<br>*Vehicle Energy Request*<br>*Vehicle Energy Capacity* | Initialization | 250mSec or less |
| T2 | PEV Locks Connector into Inlet<br><br>DC Supply Can Start Isolation Monitoring<br><br>After connector has locked, and the DC Supply has finished initial Isolation Monitoring transition to T3 | Charger Status Code =<br>Isolation Monitoring<br>Charger Maximum Current Limit<br>Charger Maximum Voltage Limit<br><br>*Charger Energy to be Delivered*<br>*Charger Protocol Version*<br>*Charger Maximum Power Limit* | Vehicle Ready = Not Ready<br>Vehicle Status Code = Not Ready<br>Vehicle Connector Lock = Locked | Initialization | 100mSec or less |
| T3 | DC Supply continues Isolation Monitoring (on Supply side of PEV contactor)<br><br>After Charger isolation Monitoring is Active then transition to T4 | Charger Status Code = Passed<br>Charger Maximum Current Limit<br>Charger Maximum Voltage Limit<br><br>*Charger Energy to be Delivered*<br>*Charger Protocol Version*<br>*Charger Maximum Power Limit* | Vehicle Ready = Not Ready<br>Vehicle Status Code = Not Ready<br>Vehicle Connector Lock = Locked | Initialization to Pre-charge | First pass of isolation monitoring must complete in 2 sec or less |

| Time | Action | Off-Board Charger Signals | Vehicle Signals | Stage | Duration |
|---|---|---|---|---|---|
| T4 | PEV pulls S2 switch (to go to State C or D) and sends Vehicle Ready signal<br><br>Vehcle provides a target voltage level to allow DC supply to enable charger output.<br><br>After vehicle Ready transition to T5 | Charger Status Code = Passed<br>Charger Maximum Current Limit<br>Charger Maximum Voltage Limit<br><br>*Charger Energy to be Delivered*<br>*Charger Protocol Version*<br>*Charger Maximum Power Limit* | Vehicle Ready = Vehicle Ready<br>Vehicle Status Code = (various)<br>Vehicle Maximum Current Limit<br>Vehicle Maximum Voltage limit = (non zero)<br>Vehicle Connector Lock = Locked<br><br>*Vehicle RESS Voltage*<br>*Vehicle Maximum Power Limit*<br>*Vehicle Protocol Version*<br>*Vehicle Energy Capacity* | Pre-charge | indefinitely |
| T5 | DC Supply Closes charging Contactors or Enables its Supply output<br><br>After DC Supply output enabled (or contactors closed), transition to T6 | Charger Status Code = Passed<br>Charger Maximum Current Limit<br>Charger Maximum Voltage Limit<br><br>*Charger Energy to be Delivered*<br>*Charger Protocol Version*<br>*Charger Maximum Power Limit* | Vehicle Ready = Vehicle Ready<br>Vehicle Status Code = (various)<br>Vehicle Maximum Current Limit<br>Vehicle Maximum Voltage limit<br>Vehicle Connector Lock = Locked<br><br>*Vehicle RESS Voltage*<br>*Vehicle Maximum Power Limit*<br>*Vehicle Protocol Version*<br>*Vehicle Energy Capacity* | Pre-charge | At most 3 sec |
| T6 | DC Supply must finish Isolation Monitoring (including isolation check of the cable)<br><br>After DC Supply has finished isolation checks (including the cable), then transistion to T7 | Charger Status Code = Charger Ready | Vehicle Connector Lock = Locked | Pre-charge | PEV must allow at least 500mSec but not more than 2 sec |
| T7 | PEV sets up Voltage Limit<br><br>After Voltage limit sent, transition to T7' | Charger Status Code = Charger Ready<br>Charger Maximum Current Limit<br>Charger Maximum Voltage Limit<br><br>*Charger Energy to be Delivered*<br>*Charger Protocol Version*<br>*Charger Maximum Power Limit* | Vehicle Ready = Vehicle Ready<br>Vehicle Status Code, = Ready<br>Charge Current Request = 0<br>Vehicle Maximum Voltage limit = (RESS voltage)<br>Vehicle Connector Lock = Locked<br><br>*Vehicle RESS Voltage* | Pre-charge | PEV must request voltage limit within 2 sec or less |

| Time | Action | Off-Board Charger Signals | Vehicle Signals | Stage | Duration |
|---|---|---|---|---|---|
| T7' | Charge Current Request increases to above 0 but less than 1A to get the charger to bring up the bus voltage.<br><br>PEV adjusts the bus voltage to slightly above the pack voltage.<br><br>PEV is responsible to ensure that the measured charger supplied bus voltage is at appropriate level before it closes its contactors to avoid welding vehicle side contactors.<br><br>When the bus voltage matches, transition to T8 | Charger Status Code = Charger Ready<br>Charger Maximum Current Limit<br>Charger Maximum Voltage Limit<br><br>*Charger Energy to be Delivered*<br>*Charger Protocol Version*<br>*Charger Maximum Power Limit* | Vehicle Ready = Vehicle Ready<br>Vehicle Status Code = Ready<br>Charge Current Request = (small amount)<br>Vehicle Connector Lock = Locked<br>Vehicle Maximum Voltage limit = (RESS voltage)<br><br>*Vehicle RESS Voltage*<br>*Vehicle Maximum Power Limit*<br>*Vehicle RESS SOC*<br>*Bulk SOC*<br>*Full SOC*<br>*Vehicle Energy Request* | Pre-charge | No minimum (but cannot happen before T7) |
| T8 | When the bus voltage matches the RESS voltage, the PEV closes contactors<br><br>Vehicle adjusts the Bus voltage to match RESS voltage<br><br>The DC Supply must limit in-rush current to below the target Charge Current Request from the PEV.<br><br>After the PEV contactors close, transition to T9 | Charger Status Code = Ready<br>Charger Maximum Current Limit = (update as needed)<br>Charger Maximum Voltage Limit = (update as needed)<br><br>*Charger Energy to be Delivered*<br>*Charger Protocol Version*<br>*Charger Maximum Power Limit* | Vehicle Ready = Vehicle Ready<br>Vehicle Status Code<br>Charge Current Request = (small amount)<br>Vehicle Connector Lock = Locked<br>Vehicle Maximum Voltage limit = (RESS voltage)<br><br>*Vehicle Maximum Power Limit*<br>*Vehicle RESS Voltage*<br>*Remaining Charge Time to bulk SOC*<br>*Remaining Charge Time to Full SOC*<br>*Vehicle RESS SOC* | Pre-charge to Energy Transfer | Voltage must match request in 2 sec or less |
| T9 | EV regulates Charge Current Request based on internal control algorithms.<br><br>Voltage limit will be adjusted to match charging algorithm maximum parameter.<br><br>This step continues into charging. | Charger Status Code<br>Charger Current Limit Achieved<br>Charger Voltage Limit Achieved<br>Charger Power Limit Achieved<br><br>*Charger Maximum Current Limit*<br>*Charger Maximum Voltage Limit*<br>*Voltage output*<br>*Current output*<br>*Charger Maximum Power Limit* | Vehicle Ready = Vehicle Ready<br>Vehicle Status Code<br>Charge Current Request = (regulating)<br>Vehicle Maximum Voltage limit = (regulating)<br>Charging Complete = False<br>Vehicle Connector Lock = Locked<br><br>*Bulk Charge Complete*<br>*Vehicle RESS SOC*<br>*Vehicle RESS Voltage*<br>*Remaining Charge Time to bulk SOC*<br>*Remaining Charge Time to Full SOC*<br>*Vehicle Maximum Power Limit* | Energy Transfer | No minimum |
| | | | | | |

| Time | Action | Off-Board Charger Signals | Vehicle Signals | Stage | Duration |
|---|---|---|---|---|---|
| T10 | Vehicle will reduce current request as it nears charge completion.<br><br>EV determines charging goal reached (either bulk or full)<br><br>Vehicle requests energy flow reduced to zero | Charger Status Code = Ready<br>Charger Current Limit Achieved<br>Charger Voltage Limit Achieved<br>Charger Power Limit Achieved | Vehicle Ready = Vehicle Ready<br>Vehicle Status Code<br>Charge Current Request = (reducing)<br>Charging Complete = False<br>Vehicle Connector Lock = Locked<br><br>*Vehicle RESS SOC*<br>*Bulk Charge Complete*<br>*Remaining Charge Time to bulk SOC*<br>*Remaining Charge Time to Full SOC* | Energy Transfer | n/a |
| T11 | Vehicle Indicates Charging Complete | Charger Status Code = Ready | Vehicle Ready = Vehicle Ready<br>Vehicle Status Code<br>Charge Current Request = 0.0<br>Charging Complete = True<br>Vehicle Connector Lock = Locked<br><br>*Vehicle RESS SOC*<br>*Bulk Charge Complete*<br>*Remaining Charge Time to bulk SOC*<br>*Remaining Charge Time to Full SOC* | Normal Shutdown | Defined by vehicle charging strategy. |
| T12 | Vehicle Changes the Pilot Signal state to Not Ready (State B)<br><br>Voltage Request from PEV is reduced to zero | Charger Status Code = Ready | Vehicle Ready = False<br>Vehicle Status Code = Not Ready<br>Charge Current Request = 0.0<br>Charging Complete = True<br><br>*Vehicle RESS SOC*<br>*Bulk Charge Complete*<br>*Remaining Charge Time to bulk SOC*<br>*Remaining Charge Time to Full SOC* | Normal Shutdown | No minimum time from contactor open to reduction in request. |
| T13 | DC Supply Changes to not ready in response to vehicle changing Pilot State<br><br>DC Supply stops power flow to output bus. | Charger Status Code = Not Ready | Vehicle Ready = False<br>Vehicle Status Code = Not Ready<br>Charge Current Request = 0.0<br>Charging Complete = True<br>Vehicle Connector Lock = Locked<br><br>*Vehicle RESS SOC*<br>*Bulk Charge Complete*<br>*Remaining Charge Time to bulk SOC*<br>*Remaining Charge Time to Full SOC* | Not Ready | DC Supply must stop delivering power (open EVSE contactor) in 3 sec or less |

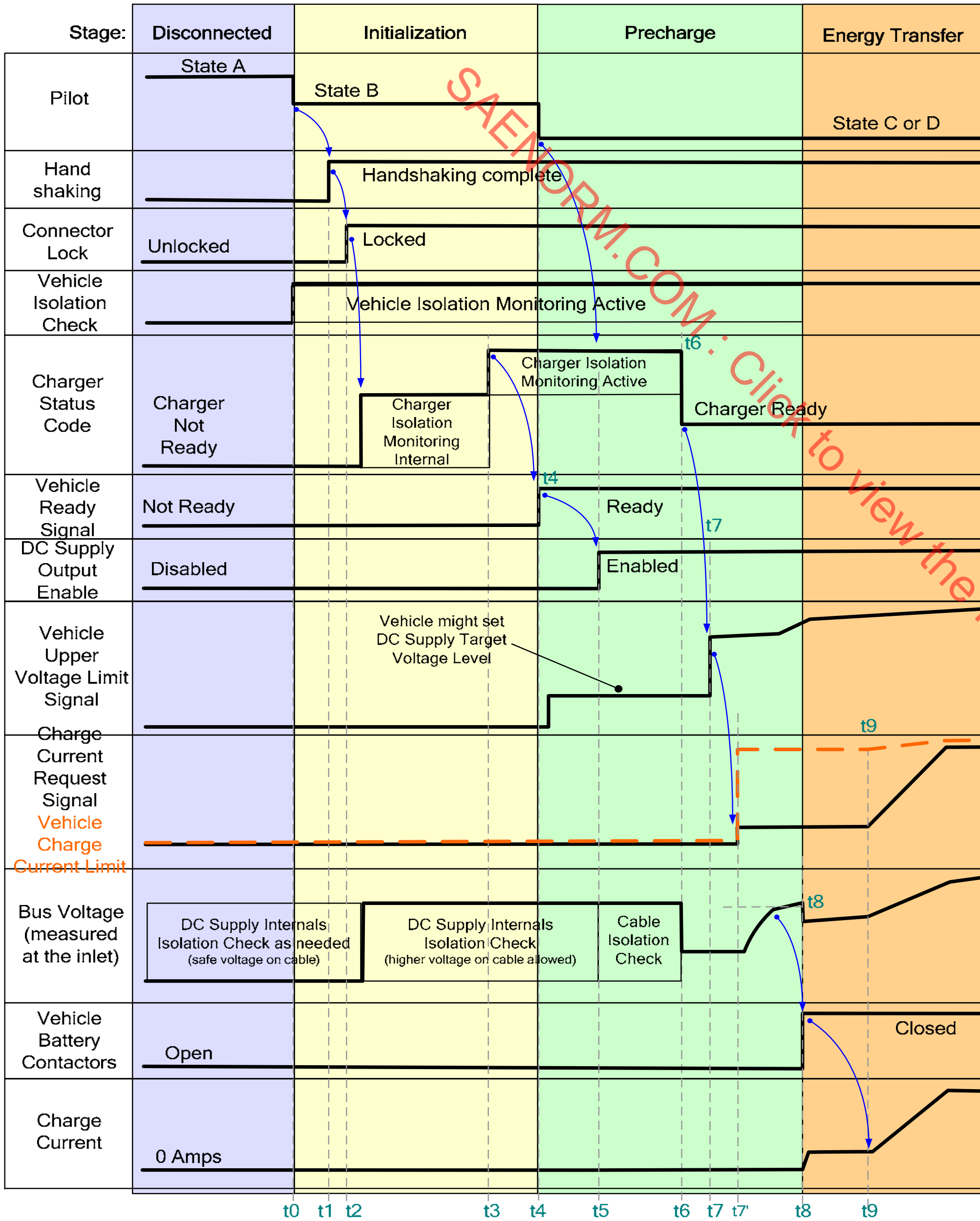
| Time | Action | Off-Board Charger Signals | Vehicle Signals | Stage | Duration |
|---|---|---|---|---|---|
| T14 | Vehicle Performs Welded contactor tests.<br><br>When current is below acceptable level, the vehicle opens charging contactors on-vehicle<br><br>DC Supply should allow Bus voltage to drop if not held up by vehicle RESS (when vehicle contactors open) | Charger Status Code = Not Ready | Vehicle Ready = Not Ready<br>Vehicle Status Code<br>Charge Current Request = 0.0<br>Charging Complete =True<br>Vehicle Connector Lock = Locked<br><br>*Vehicle RESS SOC*<br>*Bulk Charge Complete*<br>*Remaining Charge Time to bulk SOC*<br>*Remaining Charge Time to Full SOC* | Welded Check | Vehicle should complete welded contactor testing within 3 sec after going to not ready (t15-t12). |
| T15 | Vehicle finishes Welded contactor check and opens all vehicle charging contactors.<br><br>DC Supply will allow Bus voltage toward zero. | Charger Status Code = Not Ready | Vehicle Ready = Not Ready<br>Vehicle Status Code<br>Charging Complete = True<br>Vehicle Connector Lock = Locked<br><br>*Vehicle RESS SOC*<br>*Bulk Charge Complete*<br>*Remaining Charge Time to bulk SOC*<br>*Remaining Charge Time to Full SOC* | Not Ready | Vehicle could remain in this state indefinitely as determined by connector locking strategy |
| T16 | Voltage Drops below safe voltage (60V DC as defined by J2344) level as determined by PEV<br><br>When vehicle determines the connector is safe to handle (voltage below a threshold), then vehicle release connector lock<br><br>Some vehicle manufacturers may hold the connector locked in the inlet until the customer has returned to the vehicle and unlocked the connector for removal (see T15). | Charger Status Code = Not Ready | Vehicle Ready = Not Ready<br>Vehicle Status Code<br>Charging Complete<br>Vehicle Connector Lock = Not Locked<br><br>*Vehicle RESS SOC*<br>*Bulk Charge Complete*<br>*Remaining Charge Time to bulk SOC*<br>*Remaining Charge Time to Full SOC* | Normal Shutdown complete | Vehicle will release lock on connector within 100mSec after finishing Welded Check |
| T17 | Connector can be removed from inlet<br><br>If the vehicle strategy wishes to restart charging, then the lock would be applied, and the startup sequence would commence. | (None) | (none) | Disconnected | Connector can remain plugged in while unlocked indefinitely. |
| | | | | | |

| Time | Action | Off-Board Charger Signals | Vehicle Signals | Stage | Duration |
|---|---|---|---|---|---|
| T18 | Vehicle Initiates shutdown by changing the Pilot signal State C/D "Ready" to B "Not Ready"<br><br>The Charge Current Request (and Charge Current Limit) will be set to zero immediately by the vehicle.<br><br>The Vehicle State will change to Faulted.<br><br>Current from charger starts to reduce to zero. | Charger Status Code = Ready | Vehicle Ready = Ready<br>Vehicle Status Code = Faulted<br>Charge Current Request = 0.0<br>Charging Complete<br>Vehicle Connector Lock = Locked | Emergency Shutdown | n/a |
| T19 | DC Supply should open its Charging contactors (if equipped). The DC supply should attempt to regulate current to zero as quickly as possible. | Charger Status Code = Ready | Vehicle Status Code = Faulted | Emergency Shutdown | 500mSec after Not Ready |
| T20 | When the vehicle has determined that current is low enough to safely open its vehicle RESS charging contactors, the vehicle contactors will open.<br><br>The vehicle might open the vehicle contactors while current is still flowing after a vehicle manufacturer determined timeout period any time after T18. | Charger Status Code = Ready | Vehicle Ready = Ready<br>Vehicle Status Code = Faulted<br>Charge Current Request = 0.0<br>Charging Complete<br>Vehicle Connector Lock = Locked | Emergency Shutdown | 1000mSec maximum |
| T21 | The vehicle will reduce the voltage request to zero. This must occur after the vehicle contactors are open to reduce the possibility of reverse power flow (on chargers that are not equipped with a blocking diode). | Charger Status Code = Ready | Vehicle Ready = Ready<br>Vehicle Status Code = Faulted<br>Charge Current Request = 0.0<br>Vehicle Maximum Voltage Limit = 0.0<br>Charging Complete<br>Vehicle Connector Lock = Locked | Emergency Shutdown | No minimum time |
| T22 | If the DC charger is still regulating the voltage output (where DC supply contactors are not present), then the voltage will follow the command from the line above. | Charger Status Code = Ready | Charging Complete = True<br>Vehicle Connector Lock = Locked | Emergency Shutdown | 500mSec |
| T23 | When the vehicle detects the voltage below a safe threshold, then it will change the Vehicle Ready Signal state to "Not Ready" The vehicle may keep the connector locked until the user "unlocks" the vehicle (via the Key FOB or other means).<br><br>The DC Supply can start the Isolation monitoring after the vehicle is not ready. | Charger Status Code = Ready | Vehicle Ready = Not Ready<br>Vehicle Connector Lock = Locked | Not Ready | Indefinitely as needed by vehicle strategy. |

| Time | Action | Off-Board Charger Signals | Vehicle Signals | Stage | Duration |
|---|---|---|---|---|---|
| T24 | The Vehicle will unlock the connector as specified by the user preferences defined in the vehicle.<br><br>The Vehicle may continue to perform its HV system isolation monitoring after complete. | Charger Status Code = Not Ready | Vehicle Connector Lock = Not Locked | Not Ready | 500 mSec |
| T25 | When connector is removed, the Pilot signal returns to the state A "Disconnected" state | (None) | (None) | Not Connected | Connector can remain plugged in while unlocked indefinitely. |
| | | | | | |
| T26 | DC Supply initiates shutdown by turning off the Control Pilot PWM oscillator. | Charger Status Code = Ready | Vehicle Ready = Ready<br>Vehicle Status Code = Ready<br>Charge Current Request = (as before)<br>Vehicle Maximum Voltage Limit = (as before)<br>Charging Complete = (as before)<br>Vehicle Connector Lock = Locked | Emergency Shutdown | n/a |
| T27 | The vehicle detects the loss of control pilot, and goes to not ready status (State B).<br><br>Vehicle Ready Signal (not the Pilot) will remain True until end of shutdown sequence.<br><br>The current request will immediately go to zero.<br><br>The DC supply will attempt to reduce the current output towards zero. | Charger Status Code = Ready | Vehicle Ready = Ready<br>Vehicle Status Code = Not Ready<br>Charge Current Request = 0.0<br>Vehicle Maximum Voltage Limit = (as before)<br>Charging Complete<br>Vehicle Connector Lock = Locked | Emergency Shutdown | Up to 3 sec maximum after Pilot changed |
| T28 | The DC Supply will indicate "Not Ready" and report that current (and power) limits are at zero. | Charger Status Code = Shutdown<br>Charger Maximum Current Limit = 0.0<br>Charger Maximum Voltage Limit = 0.0 | Vehicle Ready = Ready<br>Vehicle Status Code = Not Ready<br>Charge Current Request = 0.0<br>Vehicle Maximum Voltage Limit = (as before)<br>Charging Complete<br>Vehicle Connector Lock = Locked | Emergency Shutdown | 1 sec maximum |
| T29 | When the vehicle has determined that current is low enough to safely open its vehicle RESS charging contactors, the vehicle contactors will open.<br><br>The vehicle might open the vehicle contactors while current is still flowing after a vehicle determined timeout period. | Charger Status Code = Shutdown<br>Charger Maximum Current Limit = 0.0<br>Charger Maximum Voltage Limit = 0.0 | Vehicle Ready = Ready<br>Vehicle Status Code = Not Ready<br>Charge Current Request = 0.0<br>Vehicle Maximum Voltage Limit = 0.0<br>Charging Complete<br>Vehicle Connector Lock = Locked | Emergency Shutdown | n/a |

| Time | Action | Off-Board Charger Signals | Vehicle Signals | Stage | Duration |
|---|---|---|---|---|---|
| T30 | The DC Supply will disable its output to the HV bus (if it has contactors, they will open).<br><br>The DC Supply might open the contactors while current is still flowing after a DC Supply manufacturer determined timeout period any time after step T26. | Charger Status Code = Shutdown<br>Charger Maximum Current Limit = 0.0<br>Charger Maximum Voltage Limit = 0.0 | Vehicle Ready = Ready<br>Vehicle Status Code = Not Ready<br>Charge Current Request = 0.0<br>Vehicle Maximum Voltage Limit = 0.0<br>Charging Complete<br>Vehicle Connector Lock = Locked | Emergency Shutdown | Up to 5 sec after pilot changed state in T26 |
| T31 | When the vehicle detects the voltage below a safe threshold, then it will change the Vehicle Ready Signal state to "Not Ready" The vehicle may keep the connector locked until the user "unlocks" the vehicle (via the Key FOB or other means). | Charger Status Code = Shutdown<br>Charger Maximum Current Limit = 0.0<br>Charger Maximum Voltage Limit = 0.0 | Vehicle Ready = Ready<br>Vehicle Status Code = Not Ready<br>Charge Current Request = 0.0<br>Vehicle Maximum Voltage Limit = 0.0<br>Charging Complete<br>Vehicle Connector Lock = Locked | Emergency Shutdown | 500mSec |
| T32 | Vehicle Ready Signal will go "Not Ready" after the voltage threshold has been reached. | Charger Status Code = Shutdown | Vehicle Ready = Not Ready<br>Vehicle Status Code = Not Ready<br>Charge Current Request = 0.0<br>Vehicle Maximum Voltage Limit = 0.0<br>Charging Complete<br>Vehicle Connector Lock = Locked | Not Ready | Indefinitely as needed by vehicle strategy. |
| T33 | The Vehicle will unlock the connector as specified by the user preferences defined in the vehicle.<br><br>The Vehicle may continue to perform its HV system isolation monitoring after complete. | Charger Status Code = Shutdown<br>Charger Maximum Current Limit = 0.0<br>Charger Maximum Voltage Limit = 0.0 | Vehicle Ready = Not Ready<br>Vehicle Status Code = Not Ready<br>Charge Current Request = 0.0<br>Vehicle Maximum Voltage Limit = 0.0<br>Charging Complete<br>Vehicle Connector Lock = Not Locked | Not Ready | 500mSec |
| T34 | When connector is removed, the Pilot signal returns to the state A "Disconnected" state | (None) | (None) | Disconnected | Connector can remain plugged in while unlocked indefinitely. |

5.2.1 Figure 5.2a –Normal Startup Sequence



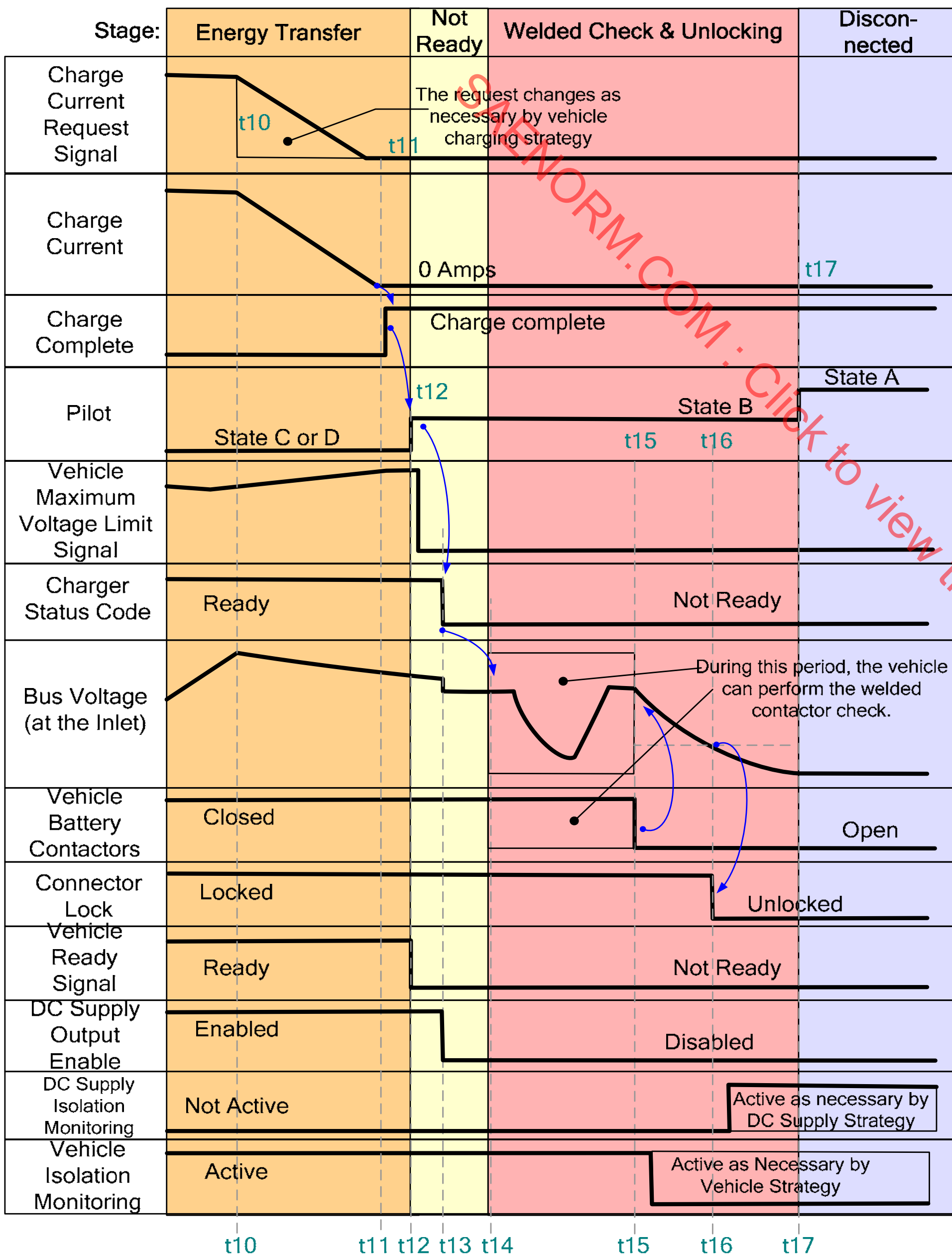

**Comments**

J1772™ Pilot Signal states:

- State A (12V) is Disconnected
- State B (9V) on connect
- State C (6V) or D (3V) when Vehicle Ready (S2 switch closed by EV)

- (t1) Handshaking should complete within 250mSec (t1 - t0) Seconds after plug in
- The Pilot signal changes to state C/D when the Vehicle is ready to Precharge.
- (t2) After handshaking is complete and conditions are okay to proceed with charge, the Vehicle will lock the Charge Connector into the Inlet within 100mSec. (t2 - t1)
- Vehicle may be performing HV Isolation at any time after it wakes up (starting just after connector has been plugged into the inlet)
- Prior to t2, the DC supply can check internal isolation as long as no voltage is applied to the connector. The DC Supply can start checking Isolation on the Cable after the cord is locked in the inlet.
- (t3) The initial DC Supply Isolation Monitoring step must complete within 2 seconds (t3 - t2).
- The DC Supply will continue to monitor its Isolation status including the cable in the "Isolation Monitoring Active" state. (it could remain in this state t3 to t4 indefinitely)
- After handshaking is complete Connector is confirmed as Locked and all other charging conditions are OK, PEV sends ready and a request for a minimum voltage.
- (t4) After EV signals Ready with Pilot, the DC Supply output is enabled within 3 Seconds (t5 - t4) according to transition 5 in Table 8 of J1772.
- (t5) DC Supply output is enabled after the vehicle enters the Precharge step.
- The DC Supply is allowed to test the HV Isolation of the cable for a minimum of 500 mSeconds (t6 - t5). This allows the Charging Station time to complete its last Isolation check. After that, it must stop the cable Isolation check to ensure it has stopped prior to the Vehicle voltage target request (t7).
- When the DC Supply Output is Enabled, the cable voltage will settle to the lowest voltage that the supply can effectively regulate on its output.
- (t6) After the DC supply has finished its isolation checks, the DC Supply then transitions to "Charger Ready"
- (t7) After the DC Supply output is enabled and "Charger Ready" signal is received, The Vehicle sets the Voltage Limit slightly above the pack voltage. Note the vehicle may have to regulate this based on its voltage sensor readings.
- While the PEV requests 0Amps, the charger shall not charge up the HV bus capacitance since it would be violating the PEV current request. Bus voltage remains at the lowest voltage where the DC Supply can maintain control.
- The "Vehicle Charge Current Limit" establishes how the DC Supply fast control loop must protect from current overshoot; the "Charge Current Request Signal"
- (t7') The PEV must make a request for current to get charger to bring up the bus voltage. This request would be a very small current (such as 1Amp). For DC Supplies with a blocking diode, this step may not be necessary.
- As soon as the EV requests current (t7' - after the voltage request), the charger should charge bus capacitors and limit voltage to the the Vehicle Voltage Upper Limit within 2 seconds (t8 - t7).
- (t8) The EV will close its contactors when the bus voltage is appropriate. Note that the EV may have to regulate the Vehicle Upper Voltage Limit signal to properly match the pack voltage.
- The DC Supply hardware current control must limit inrush current below the requested Target current from the PEV (such as 1A).
- (t9) After EV contactors are closed then the EV can ramp up current according the charging algorithm defined by the vehicle manufacturer.

5.2.2 Figure 5.2b – Normal Shutdown Sequence




**Comments**

- (t10) The PEV will reduce the current request as it completes the charging process.
- The PEV charging strategy determines how to reduce current after the battery is full at t10.
- Charge station always follows charge current request
- The PEV will stop request for current output; No minimum time required between signals (t13 - t12).
- (t11) PEV determines that Energy Transfer is complete (based on battery SOC level, customer preferences or pre-negotiated conditions)
- (t12) The PEV will change to Not Ready after charge complete when the vehicle has read the current to be below an OEM determined level.
  (Note: there is no defined amount of time that the vehicle will remain in this state)

J1772™ Pilot States:

- o State A Disconnected
- o State B on connect (S2 open, Not Ready)
- o State C or D when Vehicle Ready (S2 switch closed by PEV)

- The Voltage Limit is no longer needed after Not Ready; the charger should disable its output control (it may also open contactors if it has them).
- (t13) The DC Supply will disable its output (open its contactors) within 3 Sec (t13 - t12) after the vehicle changes the state of the Pilot. (Per J1772, Table 8, Line 6)
- The DC Supply status code is 'Not Ready' to indicate it has opened its contactors.
- The Supply Bus Voltage should fall toward the battery voltage.
- (t14) The vehicle can perform its on-board contactor tests (welded contactor check) prior to unlocking the connector
- (t15) The PEV must complete the welded contactor check within 4 seconds (t15 - t14) of charger going Not Ready.
- (t16) The PEV will release the lock within 100 milliseconds (t16 - t15) of completing the Welded contactor check.
- The PEV can unlock the connector after the bus voltage has dropped below a safe value (60V DC as defined by J2344).
- The discharge time (t16 - t15) shall be no less than TBD (500mSec)
  Note: The vehicle may remain in Locked state (t16 - t15), even after the voltage has dropped to safe levels so the PEV can keep the connector locked in the inlet until the customer unlocks the vehicle.
- If the vehicle wishes to restart charging, it will lock the connector, then assert "Vehicle Ready", after which it shall start from the initialization phase (t2) requiring the DC Supply isolation check and Precharge
- The DC Supply might continue to monitor the HV isolation on the charging station side (excluding cable isolation check) as long as its strategy dictates even after the coupler has been released from lock.
- The PEV will continue to monitor the HV isolation on vehicle systems as long as its strategy dictates.