Combined Charging

Current status of the Combined Charging System

EPRI Infrastructure Working Council
December 14, 2011

Jeanette Clute (Ford)
Cliff Fietzek (BMW)
George Bellino (GM)

V1.5
Current Status Charging Connectors

Various regional connectors should be migrated into one global solution

1st Generation
- Regional, mutually incompatible connectors

2nd Generation
- Combined Charging System for global AC and DC charging
Benefits of Harmonization

- Reduces infrastructure planning complexity and cost.
- Provides a uniform standard reducing vehicle complexity and cost for global manufacturers.
- Provides customers increased confidence for charging expediency and extended driving use cases.
- Provides a uniform standard with identical electrical systems, charge controllers, safety mechanisms, and common sheet metal interface dimensions.
- Clear market signal facilitates growth of public charging infrastructure.
EU and US Harmonization: Transatlantic Economic Council

Jeanette Clute (Ford)
Cliff Fietzek (BMW)
George Bellino (GM)
Global OEMs Agree on Harmonized Approach for US and EU

- AUDI, BMW, DAIMLER, FORD, GENERAL MOTORS, PORSCHE and VOLKSWAGEN AGREED TO SUPPORT A HARMONIZED, SINGLE-PORT FAST CHARGING APPROACH FOR USE ON ELECTRIC VEHICLES IN EUROPE AND THE UNITED STATES.
Strategic Assessment of DC Charging Systems

7 OEMs have agreed to implement the combined charging systems.

- Audi, BMW, Daimler, Ford, GM, Porsche and Volkswagen agreed on combined charging
- One connector to support **AC/DC charging**
- One communication for AC/DC charging
- **Homeplug GreenPhy**
  - PLC communication between EV and EVSE to control DC charging and support integration into the smart grid.

### Seven Auto Manufacturers Collaborate on Harmonized Electric Vehicle Fast Charging Solution

- Audi, BMW, Daimler, Ford, General Motors (GM), Porsche and Volkswagen agreed to support a harmonized single-port fast charging approach for use on electric vehicles in Europe and the United States
- The system is a combined charging approach that integrates all charging scenarios into one vehicle inlet/charging connector and uses identical ways for the vehicle to communicate with the charging station
- The seven auto manufacturers also agreed to use HomePlug GreenPhy as the communication protocol. This approach will facilitate integration of the electric vehicle into future smart grid applications
- Agreeing upon a single, harmonized DC fast charging system, we believe will help infrastructure planning, reduce vehicle complexity and improve the ownership experience for electric vehicle customers

DEARBORN, Mich., Oct. 12, 2011 – Recognizing the importance of a single international approach for DC fast charging, Audi, BMW, Daimler, Ford, General Motors (GM), Porsche and Volkswagen have agreed on the combined charging system as an international standardized approach to charge electric vehicles (EV) in Europe and the United States.

The system is a combined charging approach integrating all charging scenarios into one vehicle inlet/charging connector and uses identical ways for the vehicle to communicate with the charging station. This allows electric vehicles from Audi, BMW, Daimler, Ford, GM, Porsche and Volkswagen can share the same fast charging stations.

The seven auto manufacturers believe the development of a common charging approach is good for customers, the industry and charging infrastructure providers. Standardization will reduce build complexity for manufacturers, accelerate the installation of common systems internationally and most importantly, improve the ownership experience for EV drivers.

The endorsement of the combined charging system was based on reviews and analysis of existing charging strategies, the ergonomics of the connector and the preferences of customers in both the United States and Europe. The harmonized approach – across both continents and all manufacturers – will provide a framework for future infrastructure planning as well as a communication protocol to assist in the integration of electric vehicles into the smart grids.

The seven auto manufacturers also agreed to use HomePlug GreenPhy as the communication protocol. This approach will facilitate integration of the electric vehicle into future smart grid applications.

Automakers point to the success of Level 1 and Level 2 (for 220V charging in the U.S.) as an example of how standardization will increase the adoption of electric vehicles and increase customer satisfaction. The harmonized electric vehicle charging solution is backward compatible with the J1772 connector standard in the U.S. Backward compatibility also has been achieved in Europe where the system is based on the IEC 62196 Type 2. The approval of the J1772 standard has given electric vehicle owners the comfort of knowing they can charge at all Level 2 charging stations. Prior to standardization an EV owner had no way of knowing if the charge port they were pulling up to was compatible with their vehicle.

Jeanette Clute (Ford)
Cliff Fietzek (BMW)
George Bellino (GM)
SAE J1772 or IEC 62196-1 Type 1 for North America and Japan
Type 1 supports all infrastructure scenarios in North America, Japan and meets OEM requirements.

- J1772 applicable for
  - charging modes AC Level 1, AC Level 2

- J1772 is proven
  - introduced to the market
  - accepted by all major OEM’s and EVSE suppliers
Combined Charging: Benefits

Addressing the needs of CONSUMERS and planting the seeds for a SMART future for vehicle electrification

- DC Fast Charging offers 80% charge in less than 15 min
- It is the electric equivalent to a commercial fuel pump.

US TYPE 1 COMBO

- AC and DC Fast Charging with One Inlet
- Standard Communications with the Charging Station
- Light Weight
- Standard Safety Mechanisms
- “State-of-the-Art” User Friendly Design
DC Charging: Customer Benefits

DC charging offers confidence in driving range and extends customers driving use cases due to its ability to charge faster.

- DC charging satisfies customer expectations for fast and ultra-fast charging.
Charging Connectors for the Combined Charging System

The Combo inlet shall serve as a universal plug for all relevant charging scenarios.
DC Combination Charging: Vehicle Inlet Design

The DC Charging combination inlet provides comprehensive functionality at a high level of safety.

<table>
<thead>
<tr>
<th>Safety features</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Diagnosable lock</td>
<td>1. 1-phase AC charging with Type 1</td>
</tr>
<tr>
<td>2. Charging control</td>
<td>2. Integration into smart grid</td>
</tr>
<tr>
<td>communication with PLC</td>
<td></td>
</tr>
<tr>
<td>3. Proximity and control</td>
<td>3. High power DC charging via</td>
</tr>
<tr>
<td>pilot</td>
<td>dedicated pins</td>
</tr>
<tr>
<td>4. Protective covers</td>
<td></td>
</tr>
</tbody>
</table>
Availability of Combo DC-Chargers

Sample chargers for the Combined Charging System are ready.

- Two-box design: charge pump and separate converter
- Network connection to AC 3ph 125A 480V
- Charging communication via PLC (HPGP)
- Charging connector DC Type 2
- Safety measures according to IEC 61851-23

Charging Station

- Two sample vehicles with integration of DC Type 2 or Combo 2 Inlet respectively
- Charging current up to 70A DC
- Alternatively, charging with AC 1ph via the same inlet possible
- Vehicles used for permanent tests
- Handling with high comfort
- Acceptable temperature rise at connector
Combined Charging System

Combined Charging: the universal charging system for electric vehicles has been demonstrated at vehicles of German OEMs at the 15th international conference on „Electronics in Vehicles“ at Baden-Baden on October 12-13.
Availability of Vehicles

Vehicles have been announced and are under development.

Production vehicles with the combined charging system will be available in 2013.

Jeanette Clute (Ford)
Cliff Fietzek (BMW)
George Bellino (GM)
Backup
Comparison Combo 2 and separated Inlets
Combo inlet optimizes charging and increases robustness.

<table>
<thead>
<tr>
<th>Combo 2</th>
<th>DC China + AC Type 2 China</th>
</tr>
</thead>
</table>

Jeanette Clute (Ford)
Cliff Fietzek (BMW)
George Bellino (GM)

General EV Charging System, V1.0
Design DC Combo 2 Inlet
The Combo 2 inlet provides comprehensive functionality at a high level of safety.

<table>
<thead>
<tr>
<th>Safety features</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Diagnosable lock</td>
<td>1. 1-phase AC charging with Type 2</td>
</tr>
<tr>
<td>2. Proximity and control pilot</td>
<td>2. Integration into smart grid</td>
</tr>
<tr>
<td>3. Charging control communication with PLC</td>
<td>3. DC charging with Type 2</td>
</tr>
<tr>
<td></td>
<td>4. 3-phase AC charging with Type 2</td>
</tr>
<tr>
<td></td>
<td>5. High power DC charging via dedicated pins</td>
</tr>
</tbody>
</table>

17
Standardization of AC Connectors (IEC 62196-2)

International Standardization defines 3 options for AC connectors. European Commission promotes the selection of one connector for Europe.

- **Type 1: 1-phase**
- **Type 2: 1- to 3-phase**
- **Type 3: 1- and 3-phase**

- One AC connector to be applied in Europe to ensure unrestricted mobility
- National regulations need to comply with overall decision
- Rule of subsidy does not apply due to cross-border traffic

Jeanette Clute (Ford)
Cliff Fietzek (BMW)
George Bellino (GM)
## Combined Charging Connector Concept

The Combo Connector Concept integrates the existing AC connectors into a single system, allowing for a single global vehicle interface for AC and DC.

<table>
<thead>
<tr>
<th>Connector</th>
<th>Application range</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>Europe</td>
</tr>
<tr>
<td>5 kW</td>
<td>5 kW</td>
</tr>
<tr>
<td>50 kW</td>
<td>100 kW</td>
</tr>
</tbody>
</table>

- **AC 1-phase**
- **AC 1-phase plus**
- **AC 3-phase**
- **DC (Type 1 up to 36 kW)**
- **DC (Combo System)**

---

Jeanette Clute (Ford)
Cliff Fietzek (BMW)
George Bellino (GM)

Current_status_of_the_Combined_Charging_System_V1.0
Design DC Combo Inlet

Integration of AC and DC into a single inlet provide high freedom for vehicle design. Mechanical dimensions of package are highly optimized.

- Combo Connector based on Type 1 and Type 2 have been jointly submitted to IEC by Germany and the US. Both Combo Connectors have identical package and fixation.

Jeanette Clute (Ford)
Cliff Fietzek (BMW)
George Bellino (GM)
Charging Protocol defined by ISO/ IEC 15118

DC Charging communication is standardized based on existing AC Charging communication.

**DC Charging and AC Charging use the same protocol stack**
- IPv6 based protocol
- Transport layer with dedicated security measured
- Flexible XML-based messages
- AC as well as DC messages

**ISO/IEC15118-3 focus on HomePlug GreenPhy as Layer 1 & Layer 2 solution**
- HomePlug GreenPhy on Control Pilot
- Uses GreenPhy StateLess Address AutoConfiguration for EV/EVSE Association
- Common Layer1 / Layer2 solution for AC and DC-Charging

### Protocol Stack

<table>
<thead>
<tr>
<th>Layer 7 – Application</th>
<th>Smart Charge Protocol (Application Layer + Session Layer)</th>
<th>SLAAC (Stateless Address Autoconfiguration)</th>
<th>Optional: DHCP (Dyn. Host Conf. Protocol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layer 6 – Presentation</td>
<td>EXI – Efficient XML interchange</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layer 5 – Session</td>
<td>V2GTP (Vehicle to Grid Transfer Protocol)</td>
<td>Optional: HTTP (Hypertext Transfer Protocol)</td>
<td></td>
</tr>
<tr>
<td>Layer 4 – Transport</td>
<td>TLS (Transport Layer Security 1.0)</td>
<td>TCP (Transmission Control Protocol)</td>
<td>UDP (User Datagram Protocol)</td>
</tr>
<tr>
<td>Layer 3 – Network</td>
<td>IPv6 (Internet Protocol)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layer 2 – Data Link</td>
<td>IEEE1901</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layer 1 – Physical</td>
<td>HomePlug GreenPHY</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Relevant Standards for the Charging Interface

The charging system is comprised by a set of related standards.