Combined Charging
the universal charging system

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**Current Status Charging Systems**

The main regions for e-Mobility have developed individual charging systems. One global solution needed.

1. **1st Step: start of e-Mobility with AC and DC**

   Regional, mutually incompatible connectors

2. **2nd Step: after migration**

   Combined Charging System for global AC and DC charging
**Costumer Expectations drive Charging Capabilities**

All DC fast-charging should be designed to meet customer needs and wants.

- **Long range travels**
  - ICE vehicles have a wide operating range
  - Operating range of current Battery EVs is comparably limited before refueling
  - Consumers expect convenient vehicle fueling/charging

- **Power access at multifamily homes**
  - Many consumers don’t have access at home to a convenient place to charge a plug-in EV.
  - Consumers still need a place to charge at/near home

- **Emergency charging**
  - Battery driving range is sufficient for the vast majority of everyday trips
  - Uncertainty of range limits to be overcome by fast charging spots
Design Requirements for the Combined Charging System

AC national standards remain the same. Two additional Pins allow DC charging in the same vehicle inlet while accepting the legacy AC connector.

How to speed up from up to 8 h charging to 20 min?
How the Combined Charging System Responds

AC national standards remain the same. Two additional Pins allow DC charging in the same vehicle inlet while accepting the legacy AC connector.
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</td>
<td>1-phase AC charging with Type 2</td>
</tr>
<tr>
<td>2</td>
<td>Integration into smart grid</td>
</tr>
<tr>
<td>Diagnosable lock</td>
<td>3-phase AC charging with Type 2</td>
</tr>
<tr>
<td>Proximity and control pilot</td>
<td>High power DC charging via dedicated pins</td>
</tr>
</tbody>
</table>
Charging Connectors for the Combined Charging System
The Combo inlet shall serve as a universal plug for all relevant charging scenarios.
Combined Charging Connector Concept

The Combined Charging System integrates the existing AC connectors, allowing for one standard global vehicle interface for AC and DC charging.

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

- AC 3,7
- AC 10
- AC 22
- DC 86
Comparison Combo 2 and alternative Approaches

Integration of AC and DC into a single inlet provides high freedom for vehicle design and in addition a reduction of size.
Impact on Vehicle Costs – Combined System vs Separate Systems

Separation of AC and DC charging systems has significant extra costs. Total cost for customer is reduced by application of Combined Charging System.

<table>
<thead>
<tr>
<th>Combined Charging System</th>
<th>CHAdeMO with separate charging systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Integrated electric architecture which implements all relevant AC and DC charging scenarios</td>
<td>▪ No integrated architecture for both AC and DC charging</td>
</tr>
<tr>
<td>▪ Integration of AC and DC in one single inlet</td>
<td>▪ Separate AC and DC connectors with two inlets in the vehicle</td>
</tr>
</tbody>
</table>

Consequences of a second separated charging system:
▪ Module costs much higher than 50€ according to expert evaluation*
▪ Loss of installation space and freedom of design through additional inlet

*depends on implementation

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Combined Charging Survey, V1.3
**Efficiency of Combined Charging**

Integration of AC and DC in the vehicle architecture may be applied to charging stations accordingly.
Combined Charging System

Low Complexity and Cost Optimized:
Cost efficient re-use of multiple parts, resulting in win – win situation.

Benefits

- One inlet
- No extra design required
- DC re-uses the complete AC communication and adds only DC specific data
- Extensive use of same parts
Design Combo Inlet
Easy Handling and Widely Spread User Acceptance: Single car design concept that enables fuel tank as well as combined AC/DC charging inlet.

The combo inlet fits behind typical fuel doors
No need for variants
Simplified Architecture
To focus on the relevant components for high power DC charging
High Power DC Charging

Pilot enters state B instantly (very fast hardware based communication).
Vehicle immobilized.
High Power DC Charging

Close lock. Establish PLC communication: Exchange operating limits and parameters of charging. In the end, pilot enters state C.
High Power DC Charging

EVSE performs isolation monitor self test and then initial internal isolation check.
EV performs initial internal isolation check.
High Power DC Charging
EVSE enables high power DC output. EV requests voltage to synchronize with battery level. Voltage plausibility check is performed. EV closes DC relays.
High Power DC Charging

EVSE transfers energy per EV request.
Continuous monitoring of lock, isolation, voltage and temperature.
High Power DC Charging

Per EV request and pilot state B, EVSE regulates current close to zero and voltage close to UBat (descending rate of 100 A/s).
High Power DC Charging

EV and EVSE open relays. EVSE disables high power DC supply. Any monitoring will be stopped. Lock is disabled. PLC communication is terminated.
High Power DC Charging
Mobilize vehicle.
Charging Communication for DC Charging

The charging communication between vehicle and charger is standardized in ISO/IEC 15118 in close cooperation with SAE.

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Charging control requires a permanent communication between vehicle and charge pump.</th>
<th>Current and voltage are adjusted continuously during charging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal</td>
<td>One communication system for all charging modes, world-wide:</td>
<td>Requirements and functionality</td>
</tr>
<tr>
<td>Solution</td>
<td>PLC-based communication ISO/IEC 15118 for all charging modes applying IEEE 1901 HomePlug Greenphy, IPV6 and data security</td>
<td></td>
</tr>
</tbody>
</table>
### One Charging Communication for all Charging Modes

The Charging Communication shall realize intelligent charging with high comfort by one implementation for both AC and DC charging.

<table>
<thead>
<tr>
<th>Controlled charging</th>
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<tbody>
<tr>
<td>- Support of controlled intelligent charging based on dynamic rates</td>
<td></td>
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<tr>
<td>- Forecast of network load through planned charging</td>
<td></td>
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<tr>
<td>- Support of fleet- and load-management</td>
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<tr>
<td>- Active control of network load</td>
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<table>
<thead>
<tr>
<th>AC and DC charging control</th>
<th></th>
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<tbody>
<tr>
<td>- Authentication with the same methods for AC and DC Charging</td>
<td></td>
</tr>
<tr>
<td>- DC Charging takes control over voltage and status information</td>
<td></td>
</tr>
<tr>
<td>- Same communication technology for AC and DC Charging</td>
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<th>Value added services</th>
<th></th>
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<tbody>
<tr>
<td>- Certified payment and accounting system</td>
<td></td>
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<tr>
<td>- Future integration of vehicles in home networks or cloud services</td>
<td></td>
</tr>
<tr>
<td>- Integration of Electric Vehicles into Smart Grid</td>
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<table>
<thead>
<tr>
<th>Simple realisation</th>
<th></th>
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<tbody>
<tr>
<td>- Using existing connections</td>
<td></td>
</tr>
<tr>
<td>- One implementation for all charging modes</td>
<td></td>
</tr>
</tbody>
</table>
**Charging Protocol defined by ISO/IEC 15118**

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

<table>
<thead>
<tr>
<th>DC Charging and AC Charging use the same protocol stack</th>
</tr>
</thead>
<tbody>
<tr>
<td>- IPv6 based protocol</td>
</tr>
<tr>
<td>- Transport layer with dedicated security measured</td>
</tr>
<tr>
<td>- Flexible XML-based messages</td>
</tr>
<tr>
<td>- AC as well as DC messages</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>ISO/IEC15118-3 focus on HomePlug GreenPhy as Layer 1 &amp; Layer 2 solution</th>
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<tbody>
<tr>
<td>- HomePlug GreenPhy on Control Pilot</td>
</tr>
<tr>
<td>- Uses GreenPhy SLAAC for EV/EVSE Association</td>
</tr>
<tr>
<td>- Common Layer1 / Layer2 solution for AC and DC-Charging</td>
</tr>
</tbody>
</table>

<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</td>
<td></td>
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**Combined Charging Survey, V1.3**
Station for (Semi-)Public Infrastructure in Europe

Minimal infrastructure should be realized with a dedicated charging station. No specific equipment requirements for semi-public or private areas.

Strategic Impact

- DC charging station without discrimination of AC charging as required by ACEA
- Backward compatible design of public infrastructure
Relevant International Standards for the Charging Interface

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

1. Connector
   - IEC 62196-1
   - IEC 62196-2
   - SAE J1772
   - ISO/IEC 15118
   - SAE J2847
   - SAE J2931
   - IEC 61851-1
   - IEC 61851-21
   - IEC 61851-22

2. Communication
   - IEC 62196-3
   - IEC 61850
   - IEC 61851-24
   - IEC 61851-23
   - IEC 61851-22

3. Safety
   - IEC 60529
   - IEC 60364-7-722
   - ISO 6469-3
   - SAE J1766
   - ISO 17409

4. Charging topology
### Standardization

Standards for DC charging are ready and implementation baseline defined.

#### Scope
- DC systems according to Combined Charging Systems will be created according to existing standards:
  - Connector: IEC 62196-3 CDV
  - Topology: IEC 61851-23 CDV
  - Communication: DIN Spec 70121
  - DIN SPEC 70121 refers to ISO / IEC 15118-1 DIS, -2 DIS and 15118-3

#### Benefits
- Series production of DC-Charging ongoing, Transparent requirements for all products on the market
- Common agreement by all stakeholders
- Standards aligned with SAE

#### Implementation Baseline
- Series products available End of 2012
- Vehicles on the market in 2013 with DC option will comply to implementation baseline 2012 defined by IEC CDV 62196-3, IEC CDV 61851-23 and DIN SPEC 70121
Summary of using DC Charging in Modellregion Munich

Final project presentation.

**Impressions**

- 17.10.2011 in Munich
- Ca. 100 guests
  - stakeholder from industry and government
  - national press, customers
- LIVE CHARGING DEMONSTRATION
- DC-Type 2 with PLC
  - with 70A (up to 28kW)
  - 85km e-range in 30min
- Press echo:

**Facts**

E-Cars mit Gleich- und Wechselstrom laden
Siemens präsentiert flexibles Schnellladesystem
Schnellladen für Autos mit Gleich- und Wechselstrom
Electric Cars with Combo Inlet.
Announced cars for 2013.

- GM Chevy Spark
- BMW i3
- Volkswagen e-up!
All members of the European Association of Automotive Manufacturers ACEA support the Combined Charging System for Europe:


SAE has developed the Combined Charging System in the U.S.

The Combined Charging System is the US solution for electric vehicle charging – from AC charging to ultra-fast DC charging.

Nearly all global automotive companies support the Combined Charging System including US manufacturers Chrysler Group LLC, Ford Motor Company, and General Motors.
Combined Charging System

Combined Charging: the universal charging system for electric vehicles has been demonstrated with vehicles of German OEMs at the 15th international conference „Electronics in Vehicles“ at Baden-Baden on October 12-13, 2011.
Combined Charging System at EVS 26
Combined Charging System at eCarTec