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CharIN – Harmonization of a global EV charging standard from vehicle to grid to high power and megawatt charging

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Summary

As an international standard for a reliable, safe, and powerful charging system to support basic charging as well as long range driving, many international stakeholders in the E-Mobility business support the Combined Charging System (CCS). To harmonize and further develop the holistic system approach of CCS, the CharIN e.V. was initiated by OEMs and market leaders in the E-Mobility value chain in 2015. With about 270 international members, the association is continuously growing and fostering CCS as *the* global charging standard. The holistic approach offers a solution for all charging use cases: From Alternating Current to Direct Current in different power classes, conductive charging as well as automated and wireless charging. It also addresses all kinds of vehicles: from bikes to cars to trucks. For high power charging of Commercial Vehicles, the requirements for a Megawatt Charging System (MCS) have been specified. The respective connector completes the range today and even allows to extend the CharIN scope to the aviation and marine sector.

Keywords: BEV, EVSE, fast charge, V2G, wireless charging, High Power Charging, Megawatt Charging System

1 The path to high-power charging and harmonization

A comprehensive high-power charging infrastructure, an adequate level of grid integration and the advancement of electric vehicles to a higher range play a pivotal role in the further establishment of electric vehicles on our streets and in the worldwide sustainable mobility progress.

Offering people to go on a long-distance trip (> 400 km) with an electric vehicle and having a comprehensive high-power charging infrastructure with a charging time of roughly 4 minutes for a 100 km electric range will open the opportunity to drive purely electric to additional user groups like business travelers.

Therefore, CharIN focuses on the requirements specification of a reliable, safe and powerful high-power charging system to support long distance E-mobility – the Combined Charging System (CCS). The challenge is to charge as fast as possible with high power as well as with normal charging power for home and workplace recharging, covering all aspects within the overall “one system for all” approach.

2 The CharIN Association

2.1 International Initiative

The Charging Interface Initiative (CharIN) e. V. is a registered association founded in 2015 to promote CCS as a worldwide standard. In 7 years, the association has grown to over 270 international members along the whole value chain of charging. 18 out of the top 20 car brands are already represented within CharIN as well as the top semiconductor companies and the leading EV charging station manufacturers.

Regional offices in Germany, Brussels, Hongkong, China, India, Japan, Korea and Washington DC are supporting the positive membership development. That means organizing regular meetings and calls, giving presentations at events and facilitating workshops as well as member meetings with respect to local requirements of the specific areas. The international presence of the association has been further extended by setting up the CharIN Ambassadors program and by extending influence and impact thanks to strategic cooperation with international organizations striving for the same goals.



Figure1: CharIN Offices around the world

2.2 Worldwide Solution

Most market leaders within the electromobility sector joined CharIN and support the rollout of CCS as *the* charging standard worldwide. In most parts of the world, CCS is the leading charging technology for combined AC and DC charging. In many countries and regions, it is mandatory for the installation of charging infrastructure to apply CCS, accompanied by the respective regulations referring to global standards.

2.3 Harmonization

In five different international working groups, CharIN members compile and discuss current challenges and develop common requirements regarding different topics of Charging Communication, Charging Infrastructure, Charging Connection, Grid Integration, and Conformance Test/Interoperability.

The path to EV fast charging includes an international standard of a reliable, safe and powerful charging system. A simple and consistent customer interface that is used all over the world from low to high power charging and that is suitable for bikes, cars, trucks as well as for ships and planes. The worldwide alignment of requirements for EVs, EVSEs and its infrastructure creates added value which will lead electro mobility to a success.

The harmonization of requirements of the international charging industry with a clear recommendation on technology and customer interface is a major deliverable of CharIN. Previously, various position papers, recommendations and commitments were published; further will follow to promote the harmonization of requirements of the international charging industry.

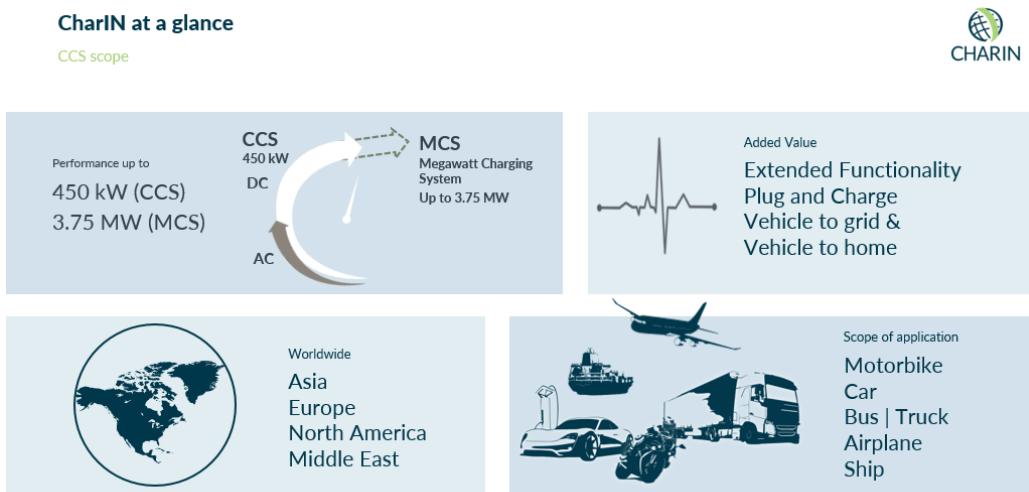


Figure 2: CCS Scope

2.4 The Holistic Charging System Approach

Charging infrastructure plays a pivotal role for the market uptake of EVs, and new technological developments need to be integrated quickly in order to shorten charging times.

The CCS charging communication standard between vehicles and the EVSE is ISO/IEC 15118. Current EVSEs are managing the compatibility with existing cars by supporting ISO 15118-2 ED1 and DIN SPEC 70121:2014. ISO 15118-20 has been recently published and lays the foundation for additional customer functionalities.

An implementation guide for High Power Charging (HPC) based on ISO/IEC 15118 was developed by the CharIN Focus Group Charging Communication. The Plug & Charge Implementation Guide is available for all CharIN members. This customer feature strongly improves the charging experience and makes electric driving on distances more convenient thanks to a smooth charging experience.

With respect to market requirements, CharIN and its members are currently working with high pressure on the following prioritized topics:

- higher charging currents ($> 500\text{A}$) and charging performance (up to 450 kW)
- the development of a charging System for commercial vehicles $> 1\text{MW}$
- vehicle to grid (V2G) integration
- automatic connection device interface for automatic conductive charging
- conformance tests and a respective certification body

Charging System Standards

Key facts for Combined Charging



- Single System approach for AC and DC combined in one connector
- Only one communication module for AC and DC charging
- Charging voltage up to 1.000 V and current up to 500 A
- Charging power up to 450 kW





- Interoperability secured CharIN CCS Test System
- Powerline Communication (PLC) for Charging and advanced services
- Certified payment and accounting system
- State of the art communication via HomePlug GreenPHY enables integration V2H and V2G

Figure 3: Charging System Standards

2.4.1 Increasing Charging Currents for Battery Electric Passenger Cars

As part of its ongoing process to provide guidance and support for the development of a battery electric vehicle charging eco system, the CharIN association endorses the initiative to increase the charging currents for battery electric vehicles, and specifically for passenger vehicles.

The currently specified DC Charging power is limited to 350kW. CharIN association and its members have been the leading proponents for the development of charging systems up to 450 kW. The results of which are currently being integrated into the international standards.

Following considerable performance testing, it has been demonstrated that current available charging systems are capable of charging currents over 500A. Therefore, CharIN is endorsing and supporting efforts to upgrade these standards from 200 A to over 500 A charging. CharIN will enhance the Combined Charging System 2.0 document to include $> 500\text{ A} / 450\text{ kW}$ charging for Combo 1 and Combo 2 CCS charging connectors to fulfill potential demands of future use cases.

Right now, several companies providing battery electric vehicles and charging infrastructure products are offering or announcing products, which can charge with a current of 500 A. Even though some manufacturers have already certified products for a charging current of 500 A, national and international standards are not yet available for all necessary components and sub-systems. In order to ensure safety, interoperability and reliability, CharIN and its members are endorsing and working diligently with the respective standardization committees to expedite the publication of these important standards.

2.4.2 Megawatt Charging System with beyond 1 MW of charging power

To expand the scope of applications within the holistic system approach to CCS, CharIN established the Megawatt Charging System (MCS) group to define a new commercial vehicle high power charging solution to maximize customer flexibility when using fully electric commercial vehicles.

The scope of the technical recommendation is to be limited to the connector and any related requirements for the EVSE, the vehicle, communication, and related hardware. The standard focuses on Class 6, 7, & 8 commercial vehicles but could easily be used for buses, aircrafts, boats or other large battery electric vehicles (BEVs).

Separate subgroups (communication and safety) were formed to explore the requirements from their unique point of view: customers, truck & bus OEMs, utilities, site selection and permitting firms, EVSE manufacturers, service providers, hardware manufacturers and cyber security experts. From their input, one single requirements document was created which was further refined by the working group.

The MCS system is in its final stage of development and respective tests are ongoing to ensure reliable, safe and secure charging for the customer. The Electromagnetic Compatibility (EMC) tests on the communication layer ensure a proper signal transfer even at a power level of more than 1 MW.. As the current within the MCS system reaches up to 3000A, the temperature behavior is carefully considered within the test scope of CharIN.

This unique working group with the bundled know-how of the entire charging ecosystem supports the enhancements and the progress of further future-oriented developments to charge all kinds of vehicles with large batteries. The MCS technology can be applicable to a variety of industries and supports the path to clean transportation and zero emission mobility.

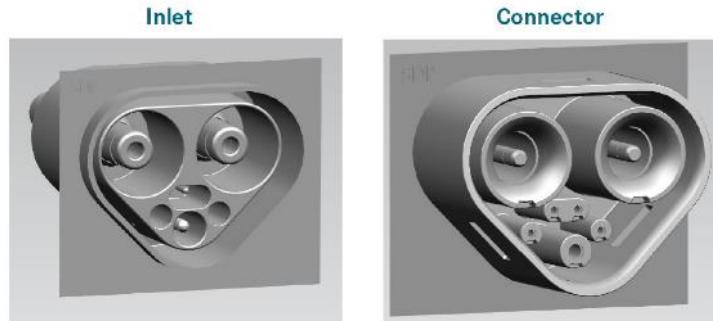


Figure 4: MCS Inlet and Connector shape

2.4.3 Grid Integration

One of the current major challenges is the integration of E-Mobility into the power grid. The energy network faces three major challenges in the years to come:

- The increasing decentralized production of energy from renewable sources
- The balancing of volatile renewable energy production, grid capacities, and energy demands
- Increasing numbers of Battery Electric Vehicles (BEVs) of all kinds, and the need to charge them at locations where the grid was originally designed for much lower energy demand (e.g. in residential areas)

These challenges can be solved only partly by conventional grid expansion. The solution requires major investments in the electrical infrastructure and digitization which will take considerable time. Short-term solutions for optimized use and the chance to use as much renewable energy as possible are urgently required.

CCS with its elaborated communication capabilities enables Grid Integration. It uses ISO/IEC 15118 as communication standard, and the upcoming next edition will provide the most advanced features for Bidirectional Power Transfer (BPT).

Secured, open and non-proprietary data exchange between driver/vehicle and infrastructure/energy system, including:

- For charging execution: charging power can be restricted remotely during a specific time period, thus allowing interventions from energy providers
- For charging planning: tariff tables and load profile registration allow EV drivers to benefit from demand-driven energy price advantages, and energy providers can use this information in advance for their load planning
- For AC and DC charging support
- For ease-of-use with Plug & Charge for authentication and billing

Grid Integration Levels

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- There are many levels of Grid Integration that can generate value.
- CCS with ISO/IEC 15118-20 is the key enabler of Grid Integration and is ready for V2G.
- This technology is prepared for a wide range of use cases.

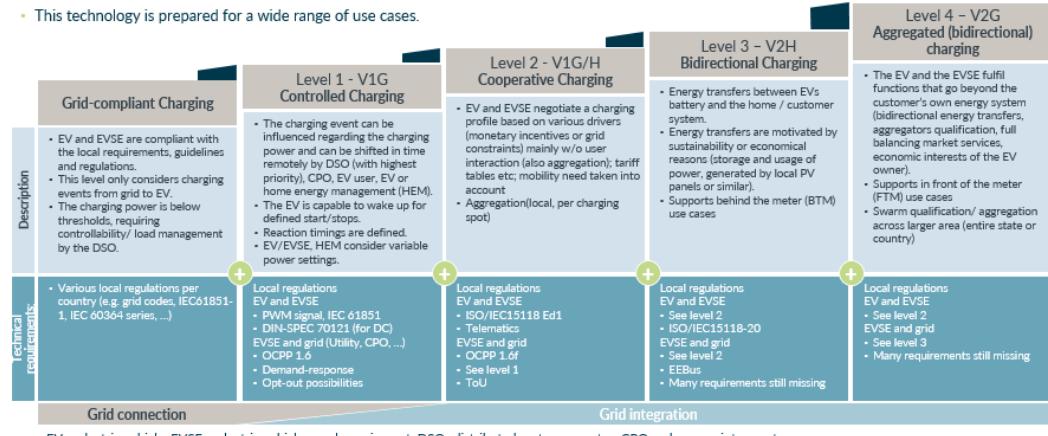


Figure 5: CharIN's five levels of grid integration

2.4.4 Vehicle to Grid Communication

By today's CCS definition, the vehicle to grid communication ideally includes a unified AC/DC charging control system, an optimized load management system as well as a simple payment/billing method and additional customer services. The seamless integration of a wireless charging control system, bidirectional power flow as well as extended smart grid functionalities will make charging of electric vehicles even more comfortable and offer additional business opportunities and value-added services.

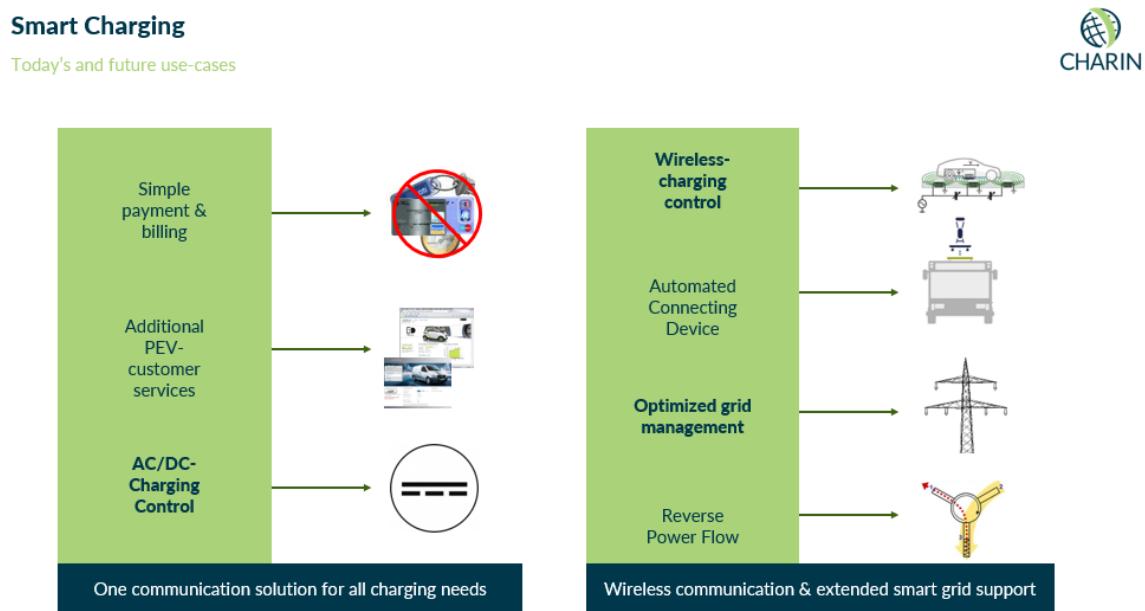


Figure 6: Vehicle to Grid communication

2.4.5 ACD

As autonomous driving is about to hit the consumer market, which enables new possibilities for a fully automated customer experience, there is a need to harmonize requirements and to provide guidance for automated charging. As electromobility is further penetrating the global markets, also the convenience of automated charging will get more attraction. In addition to wireless charging systems two additional subgroups were formed and re-initiated in 2021 within CharIN to work on recommendations for the two different forms of automated conductive connection: ACD-S (Automatic Connection Device for the conventional Side connection interface) and ACD-U (Automatic Connection Device for vehicle Underbody connection).

2.4.6 Conformance Tests, Certification, and Standardization

The worldwide distribution of the global CCS standard is supported by the activities within the international standardization bodies as well as local governmental regulations. The engagement of universities and research institutes in the field of interoperability and conformance helps to develop it further.

CharIN organizes the international “CCS Testing Symposium” format, initiated by the University of Dortmund. It brings together major stakeholders to improve the systems’ communication protocol implementations for a better interoperability. Other similar events are organized by CharIN North America and the Korean Smart Grid Association.

The Joint Research Centre (JRC) as the European Commission's science and knowledge service and the Argonne National Laboratory (ANL) as the American science and engineering research center are supporting the system evaluation and enhancement with their broad expertise.

A significant aspect to enhance the quality of charging is the common agreement on expected conformance. CharIN currently recognized two test laboratories to run the CCS Basic conformance tests and issue CCS Basic certificates for charging stations.

The test system vendors have gone through an extensive test case validation. They have shown their capabilities to provide reliable tests and measures for the CharIN Conformance Tests. These test cases have been defined by the Focus Group experts. The CharIN recognized Conformance Test Systems (CCTS) can be used for CharIN CCS conformance testing and for individual product development testing.

The Korea Electrotechnology Research Institute (KERI) and DEKRA are the first two test houses officially appointed by CharIN as recognized test laboratories. Both have shown their expertise in the field of test execution and results analysis according to the CharIN Quality Assurance Process (QAP). A Peer Assessment Committee consisting of experts from CharIN member companies confirmed that both companies have the required technical capabilities and quality control process to produce repeatable and consistent test results.

A first EVSE Test Certificate is already issued, more in preparation within the membership base of CharIN. This Conformance Approval by CharIN as a “Label of Quality” will support to fulfil the customer expectation of a seamless charging session.



Figure 7: Main elements of the Quality Assurance Program

3 Summary

CCS is currently the world's only charging system that covers all charging scenarios with one single product. Drivers of any type of electric vehicle can choose between normal and fast charging as well as AC and DC, with a single interoperable system for all these options. CCS has the advantage of being used and supported by a significant number of major global companies from different industries, as well as having the support of being respected as the global standard from governments in different regions of the world.

The CharIN association is unique as it is comprised of multiple experts across a variety of international industries who work together as a team to make this future-oriented system design possible. CharIN is a non-profit organization and is open to all interested parties.

Rather than reinventing the wheel, the CCS team focuses on an innovative approach: rethinking existing systems and defining requirements while incorporating and supporting the relevant international standards. The result is an ingenious and future-proof solution that is universal for all electric vehicles and charging scenarios while remaining safe and easy to use. That's what qualifies CCS and MCS as *the* global standard.

The vision of CharIN is to develop and establish the Combined Charging System (CCS) and the Megawatt Charging System (MCS) as *the* global technologies for charging battery powered electric vehicles of all kinds. Therefore, the association continuously works on expanding its worldwide network by integrating companies on each level of the defined value chain to support and promote CCS and MCS. Moreover, drafting requirements to accelerate the evolution of charging related standards plays an important role. Based on this, defining a certification system for all manufacturers implementing CCS and MCS in their products is an additional ongoing topic the association is working on together with its members from all over the world.

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5 Authors



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He joined BMW in March 2005 and held various senior management positions in research and development with focus on E/E-architectures, system design, hardware/software components and in car networking. Before his current position in the powertrain development he was in charge of body electronics development. He started his career at Mercedes Benz and Daimler in the development of data bus systems. He led several teams and departments in the area of system test, E/E-architecture and ECU-development.

Claas Bracklo holds a degree in Electrical Engineering from the University of Dortmund.



Michael Keller is member of the Executive Board of the Charging Interface Initiative (CharIN) and heading the Volkswagen Group development coordination for Charging and charging infrastructure. He has more than 18 years' experience in the automotive industry at suppliers and OEMs.

Before joining Volkswagen in 2010 as head of “energy systems and functions development”, he was heading the traction battery technology and battery development at a Tier 1 (Continental).

Michael Keller received his engineer degree for electric in Karlsruhe and was awarded with the “Professor Ferdinand Porsche Preis” of the Technical University in Vienna in 2009 for the “first automotive application of a lithium-ion hybrid battery”