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CharIN e.V. – Charging heavy duty electric vehicles with the Megawatt Charging System (MCS)

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Executive Summary

Under the CharIN umbrella, cross-industry stakeholders are advancing interoperable charging solutions for electric vehicles (EVs). CharIN's international community, comprising leading global companies, collaborates to define requirements for Megawatt Charging System (MCS) standards and certification, based on the experience of Combinedd Charging System (CCS). The association's efforts did create in the last years the MCS specification as basis for the standardization of MCS and is now focusing on enhancing the user experience through reliable, easy, and smooth charging processes. The development of the Megawatt Charging System (MCS) is pivotal for rapid and efficient charging of heavy-duty electric vehicles, supporting the transition to sustainable transportation. Through rigorous testing and industry alignment, CharIN aims to establish CCS and MCS as global standards, fostering innovation and interoperability in EV charging solutions.
CharIN promotes the harmonization of standards, addressing challenges in charging communication, infrastructure, and grid integration.

Keywords: Fast and Megawatt charging infrastructure, Standardization, Electric Ships &Airplanes, Heavy Duty electric Vehicles & Buses, Mining

1 Introduction

The Charging Interface Initiative e.V. - abbreviated to CharIN e. V. - is a registered non-profit association founded in 2015 to promote Combined Charging System (CCS) as a standard worldwide, to define requirements for the evolution of CCS related standards and for the certification of CCS based products, besides the development of the Megawatt Charging System (MCS). Since then, the association has grown to more than 300 international members along the whole e-mobility value chain.

Under the CharIN umbrella, cross-industry stakeholders like automakers, charging station manufacturers, component suppliers, energy providers, grid operators, and many others continue moving towards interoperable charging, where vehicles, chargers, and software systems work together and to make the user experience reliable, easy and smooth.

Through collaborative efforts and industry expertise, CharIN drives innovation and interoperability in EV charging solutions, fostering a more connected and efficient ecosystem for electric mobility worldwide.

Table 1 Comparison CCS and MCS specification

Feature / Parameter	CCS (Combined Charging System)	MCS (Megawatt Charging System)
Max Charging Power	Up to 500 kW	Up to 3.75 MW
Target Application	Passenger cars, light-duty EVs	Heavy-duty trucks, buses, aviation, maritime
Connector Type	Combo Type 1 / Type 2	Dedicated MCS connector
Communication Protocol	ISO 15118-2/-20 (limited)	ISO 15118-20 (full)
Cooling	Liquid (optional)	Mandatory liquid cooling
Physical Layer	PLC	10BASE-T1S mandatory
Cybersecurity	TLS 1.2	TLS 1.3, multi-PKI supported
Vehicle-to-Grid (V2G)	Pilot stage	Supported via ISO 15118-20

1.1. Harmonization of Standards

In five different international working groups as well as subgroups, task forces and project groups, members compile and discuss current challenges and develop common requirements regarding different topics on Charging Communication, Infrastructure, Connection, Grid Integration and Conformance Test/Interoperability.

The path to EV 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 applicable for bikes, cars, trucks, ships, and planes. The worldwide alignment of requirements for EVs, EVSEs and its infrastructure is creating added value which will lead electro mobility to 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 and further will follow to promote the harmonization of requirements of the international charging industry. The position papers and recommendations can be found on the website of CharIN e.V. [1]

The Figure 1 below shows the current status of the standardization of the MCS. The most important part of the system specification of connector and infrastructure standard is expected to be finalized within 2025. Whereas CharIN is supporting further activities like working group meetings and testing activities described later in the document.

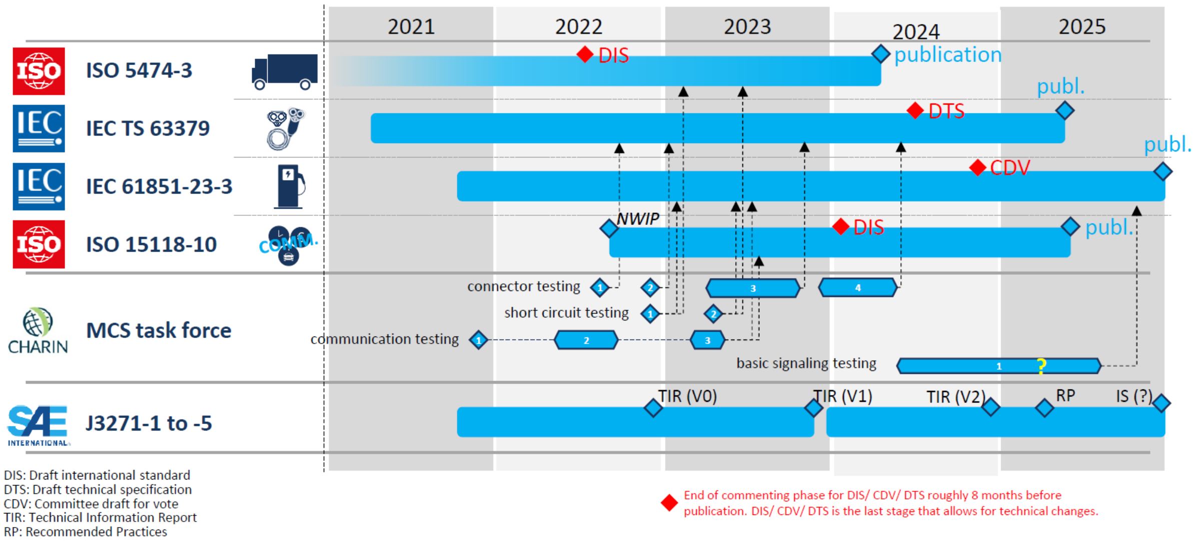

Figure 1 Standardization timeline of MCS

1.2. Extended features for Charging EVs and new players

EV charging introduces numerous advanced features beyond simply recharging the battery. As new players enter the market, some developing solutions from scratch, this presents both opportunities and challenges. In response, CharIN e.V. focuses on recommending requirements for reliable, safe and powerful high-power charging system to support long-range e-mobility – specifically CCS, MCS amd NACS (North American Charging Standard).

Furthermore, CharIN e.V. focuses on advancing features such as Plug and Charge, smart charging, and wireless charging to enhance the overall charging experience. With increasing digitalization, the integration of advanced diagnostics and cybersecurity measures is paramount. The extension of ISO 15118 protocols—beyond enabling plug-and-charge functionalities—provides a robust framework for real-time system monitoring, remote diagnostics, and threat mitigation. This not only enhances operational efficiency but also safeguards critical infrastructure against emerging cyber threats.

2 Megawatt Charging System (MCS)

As urban areas continue to expand and the demand for sustainable transportation solutions grows, the electrification of freight transport has become increasingly important. MCS represent a transformative advancement in this domain, enabling rapid and efficient charging for heavy-duty electric trucks. These systems are essential for facilitating the transition to electric logistics, particularly in urban corridors where time-sensitive deliveries are paramount.

By significantly reducing charging times, megawatt charging not only enhances operational efficiency but also supports the broader goal of reducing greenhouse gas emissions in the transportation sector. The implementation of such infrastructure is vital for meeting the rising expectations of both consumers and regulatory bodies, ensuring that electric trucks can operate seamlessly within city environments.

Moreover, the relevance of megawatt charging extends beyond trucks to encompass a wide range of vehicles equipped with large batteries, including tractors, trains, boats, and planes. As industries increasingly adopt electric alternatives, the need for high-capacity charging solutions becomes paramount. For instance, electric tractors can enhance agricultural efficiency, while electric trains can significantly reduce emissions in public transport. Similarly, boats and planes are exploring electrification to minimize their environmental impact.

Megawatt charging systems can provide the necessary power to support these diverse applications, enabling faster turnaround times and greater operational flexibility. By establishing a robust charging infrastructure, we can accelerate the transition to electrified transport across multiple sectors, paving the way for a more sustainable future.

2.1 Industry alignment

CharIN was established to promote the global adoption of battery electric vehicles (EVs) through standardized charging solutions. Recognizing the growing need for efficient and rapid charging systems, particularly for medium- and heavy-duty vehicles, CharIN initiated the development of the Megawatt Charging System (MCS) back in 2018. This system was conceived to address the unique challenges posed by vehicles with large batteries, such as trucks, buses, and even maritime and aviation applications.

The primary purpose of the MCS is to enable high-power charging capabilities that significantly reduce charging times, thereby enhancing the operational efficiency of electric commercial vehicles. Traditional charging standards were insufficient for the demands of heavy-duty vehicles, which require higher power levels to facilitate quick turnaround times. By increasing the charging power to levels up to 3.75 megawatts, the MCS aims to maximize customer flexibility and support the widespread adoption of electric transport solutions.

CharIN has played a pivotal role in this initiative by bringing together stakeholders from across the automotive and energy sectors to collaborate on the MCS. In 2018, CharIN formed a dedicated task force to develop a comprehensive approach based on the CCS. This task force includes representatives from various industries, ensuring that all perspectives are considered in the design and implementation of the MCS. Through rigorous testing and consensus-building, CharIN has established the technical specifications and standards necessary for the MCS, positioning it as a potential global standard for high-power charging.

By fostering collaboration and innovation, CharIN is not only advancing the technology behind megawatt charging systems but also paving the way for a more sustainable and efficient future in transportation.

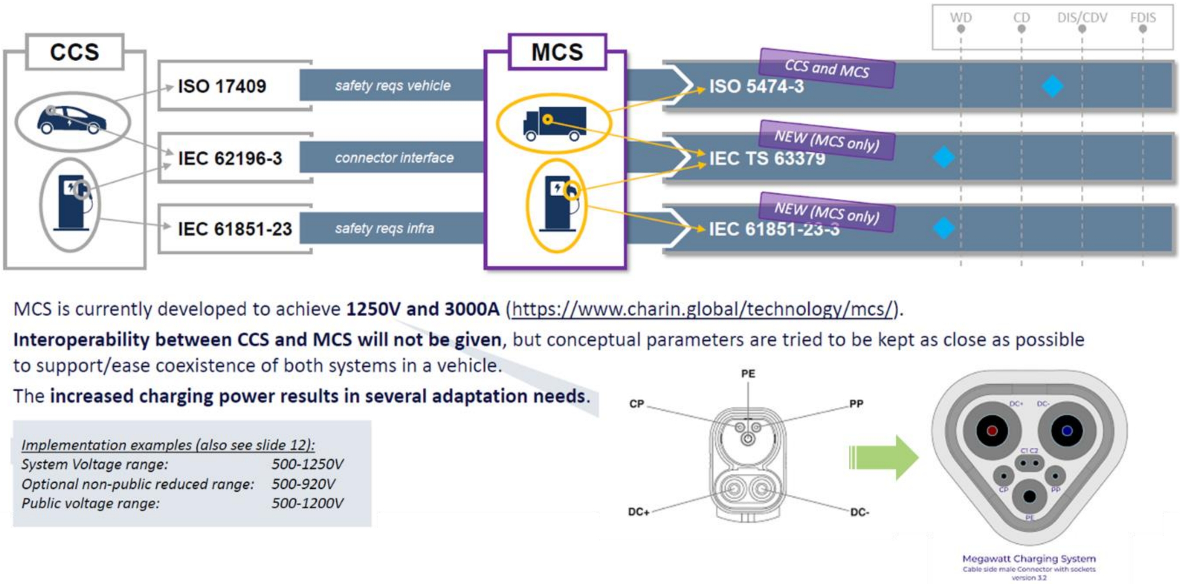

Figure 2 MCS standardization derived from CCS specification

One example of practical implementation is the coordination of early MCS field trials involving logistics operators and OEMs. These pilots not only validate the interoperability of charging components but also provide operational insights into charger availability, turnaround time improvements, and thermal management during repeated high-power sessions. The feedback from these trials is channeled directly into CharIN’s working groups to inform updates to standards and certification processes.

2.2 Transnational testing activities

CharIN has been instrumental in facilitating transnational testing activities for the MCS, ensuring its reliability and safety from the outset. Notably, connector tests conducted in collaboration with the National Renewable Energy Laboratory (NREL) at 3000 amperes demonstrated the system's capacity to handle high power levels effectively. Additionally, communication tests carried out at the University of Zwickau were crucial in validating the noise immunity of the system, confirming its robustness in real-world conditions. Furthermore, short circuit tests performed with CharIN members provided essential insights into the safety mechanisms of the MCS. Additionally, the further testing conducted during the CharIN MCS Controller Testival—held for the first time—revealed implementation gaps and software bugs in ISO 15118-20 within a simulated environment. These comprehensive testing initiatives not only enhance the technical performance of the system but also build confidence among stakeholders regarding its reliability and safety in various operational scenarios.

2.2.1 Connector Testing

The National Renewable Energy Laboratory (NREL), in collaboration with CharIN, conducted comprehensive evaluations of MCS connectors and inlets from May 2023 to January 2024. This testing aimed to assess compliance with the draft IEC 63379 and SAE J3271 standards. The evaluations included thermal interoperability tests at various current levels (350A, 1000A, and 3000A), mechanical tests for insertion and withdrawal forces, and touch-safety assessments. The results demonstrated that most devices met the thermal performance criteria, validating the MCS standard's viability for high-power charging applications. However, some mechanical refinements were identified to ensure full compliance with insertion/withdrawal force and touch-safety requirements.

2.2.2 Communication Testing

The University of Zwickau, in collaboration with CharIN, conducted extensive electromagnetic compatibility (EMC) tests on communication systems for MCS using Single Pair Ethernet (SPE). The tests focused on immunity to broadband RF disturbances, evaluating different implementations of 10BASE-T1S and 100BASE-T1 Ethernet standards. The test setup included a 17-meter data line, exceeding the IEEE 802.3bw specification, and involved point-to-point connections with unshielded twisted pair cables. The results demonstrated that 10BASE-T1S exhibited higher immunity to RF disturbances compared to 100BASE-T1, with up to 4 dB better performance. The study provided valuable insights into the robustness of Ethernet-based communication systems in high-power charging environments, ensuring reliable data transmission under various interference conditions. ￼

2.2.3 Interoperability Testing

Interoperability testing, a cornerstone of CharIN's initiatives, involved coordinated evaluations where multiple manufacturers' Electric Vehicle Communication Controllers (EVCC) and Supply Equipment Communication Controllers (SECC) interfaced in controlled test scenarios. The inaugural MCS Controller Testival elucidated significant implementation gaps and protocol inconsistencies—particularly within the ISO 15118-20 framework—which are imperative for identifying avenues of refinement to ensure seamless communication across systems. In parallel, the testing framework incorporated rigorous assessments of multi Public Key Infrastructure (PKI) and Transport Layer Security (TLS) 1.3 protocols, underscoring the commitment to robust cybersecurity measures and secure data transmission in high-power charging scenarios.

The comprehensive results derived from these testivals are intended to serve as a baseline for subsequent working group discussions. By systematically analyzing performance data and the identified deficiencies, industry experts can collaboratively address technical shortcomings, standardize communication protocols, and iteratively enhance the MCS specifications. This structured feedback loop not only informs immediate technical improvements but also lays the foundation for the evolution of global charging standards, thereby advancing interoperability and fortifying overall system resilience.

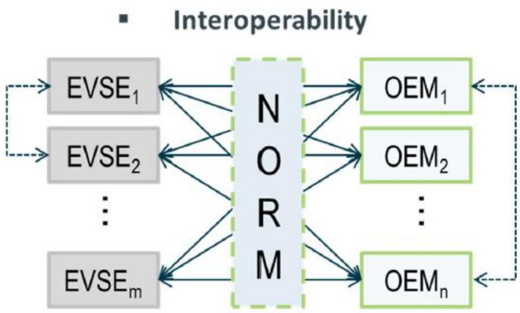

Figure 3 Interoperability Testing Scenario

Recent progress includes successful pilot implementations at logistics terminals, where early MCS hardware and controllers have been deployed in operational scenarios. These installations have tested the integration of thermal management strategies, connector locking mechanisms, and automated communication handshakes using ISO 15118-20. Furthermore, CharIN has contributed to the definition of test cases now under discussion at IEC TC69 and ISO/IEC JWG1, helping to mature the standards beyond draft status.

2.3 Grid Integration and Energy Management

The deployment of high-power charging infrastructure such as the MCS introduces new challenges and opportunities for grid integration. MCS charging sessions can impose substantial transient loads on local and regional electricity grids. This necessitates coordinated planning between infrastructure operators and grid utilities to ensure the availability of sufficient capacity without compromising grid stability.

To address these issues, CharIN's Grid Integration Focus Group supports the development of standards and best practices for dynamic load balancing, demand response, and integration with on-site energy storage and renewable energy sources. Smart charging strategies and energy management systems are being explored to align charging activities with grid conditions, reduce operational costs, and enable vehicle-to-grid (V2G) applications.

Integrating MCS with distributed energy resources and intelligent grid services is critical for minimizing peak loads, especially in logistics hubs and along long-haul freight corridors. These strategies will be key in ensuring the economic and environmental sustainability of megawatt-scale charging infrastructure.

3 Conclusion and outlook

CharIN e.V. aims to establish MCS as the global standards for charging heavy duty electric vehicles. To achieve this, CharIN is expanding its global network by integrating companies across the entire value chain to support and promote CCS and MCS. They focus on drafting requirements to accelerate the evolution of charging standards and envision extending the ISO 15118 communication protocol. CharIN also promotes the Conformance approved label as a quality indicator for CCS and MCS products, which, with the help of global experts, will be crucial for their success.

The importance of MCS lies in its ability to support fast charging for heavy-duty electric vehicles, such as trucks and buses, which require significantly higher power levels than passenger vehicles. This capability is essential for the widespread adoption of electric vehicles in commercial and industrial sectors, contributing to the reduction of greenhouse gas emissions and the advancement of sustainable transportation.

Future functionalities beyond the charging interface, integrating various standards to enhance the ecosystem (e.g., Plug & Charge) will be implemented. CharIN serves as a platform for discussions to improve quality beyond the connector interface. Additionally, CharIN considers monitoring field issues to improve the standards and to facilitate solutions through cross-committee discussions, leveraging its comprehensive involvement in the value chain.

As governments and regulatory bodies worldwide adopt increasingly stringent decarbonization targets, scalable and standardized charging infrastructure becomes an essential enabler for achieving zero-emission freight and public transport. MCS, with its capacity to deliver up to 3.75 MW, plays a pivotal role in decarbonizing sectors that have historically been hard to electrify.

To support widespread adoption, coordinated policy frameworks and targeted financial incentives—such as grants for infrastructure development, subsidies for heavy-duty EV acquisition, and grid upgrade support—will be critical. Moreover, CharIN is promoting the CharIN Conformance Label as a trusted indicator of compliance and interoperability, facilitating procurement decisions and reinforcing quality assurance across the supply chain.

Future work will focus on aligning international standards, enhancing cybersecurity measures, and exploring new functionalities such as dynamic MCS charging and real-time grid participation through V2G, positioning MCS as not just a charging solution but a cornerstone of intelligent transport energy systems.

While the Megawatt Charging System (MCS) has been primarily developed with a focus on European and North American long-haul applications, CharIN remains committed to supporting global interoperability and regional adaptation. Recognizing that regions such as China and India are pursuing parallel paths with battery swapping and hydrogen-based solutions for heavy-duty transport, CharIN emphasizes a technology-neutral approach to decarbonization. MCS aims to complement—not compete with—regional preferences, and its specifications are publicly accessible to support alignment or hybridized integration. For example, MCS interfaces could be adapted for modular or swappable battery packs, while ongoing collaboration with international standards bodies ensures harmonization across markets.

Acknowledgments

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Additionally, we appreciate the participation of industry collaborators—specifically the manufacturers of EVCC and SECC—in the inaugural MCS Controller Testival, including their evaluations of multi PKI and TLS 1.3 security measures. Their insights have been pivotal in refining the communication protocols and strengthening the cybersecurity framework, thereby supporting the continuous advancement of globally interoperable charging standards.

Nomenclature

AC - DC:	Alternating current - Direct Current
CCS:	Combined Charging System
EVCC:	Electric Vehicle Communication Controller
IEC:	International Electrotechnical Commission
ISO:	International Standards Organization
JWG:	Joint Working Group
MCS:	Megawatt Charging System
NACS:	North American Charging Standard
NREL:	National Renewable Energy Laboratory
OEM:	Original Equipment Manufacturer
PKI:	Private Key Infrastructure
PLC:	Power Line Communication
SAE:	Society of Automotive Engineers
SECC:	Supply Equipment Communication Controller
TLS:	Transport Layer Security
V2G:	Vehicle to Grid

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Presenter Biography

Michael Keller

Before he joined 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”

Semih Tetik is Projectmanager at CharIN e. V.

Tetik serves as a Project Manager at CharIN. The association also engages in special projects related to charging interoperability issues, where he represents CharIN. As an electric mobility enthusiast, Tetik is passionate about shaping the future of technology.

Since joining CharIN, he has led the Focus Groups on charging connection, grid integration, and energy. Additionally, he manages the MCS and cybersecurity working groups, contributing to industry advancements.

His background includes a master’s degree in automotive engineering from the Technical University of Berlin. Early in his career, he gained experience in project management for electric car development at Mercedes Benz. Afterwards, he was involved in vehicle testing activities with Bosch.