Best Practices
on

Battery Charging Systems for Ships

November 2025

IRCLASS
Indian Register of Shipping

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November 2025

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Introduction

Background

In the marine industry growing concerns on GHG emissions is driving to the adoption of alternative sources of power such as alternative fuels, battery systems, solar and wind power systems. Among these Lithium-ion batteries, with their high energy density and fast charging capability compared to other available battery types, are being increasingly used for as main /auxiliary/emergency source of power. Vessel may be equipped with onboard power generation system for charging such batteries and these arrangements are required to comply with applicable IRS rules.

This document is intended to provide best practices for charging onboard lithium-ion batteries from an external power source. For the purpose of this document, the term Battery Charging Station (BCS) refers to shore-side or offshore installations (e.g. floating platforms) arranged to supply external power for charging ships' lithium-ion batteries. The term lithium-ion batteries, as used herein, covers various battery chemistries such as NMC, LTO, LFP, and others.

The charging mechanisms can broadly be categorized into two types: AC charging and DC charging. Among these, DC charging is the preferred method when fast charging of batteries is required. At present, the absence of marine standards for DC fast charging presents a challenge. Although IEC 80005-4, intended to address marine battery charging, is under development, the marine industry is currently adopting EV charging practices established in the automotive sector.

This document, in its initial section, provides an overview of the technologies presently used in EV systems, and in subsequent sections outlines best practices that may be adopted for charging onboard batteries from an external power source.

<u>Over view of Charging Technologies</u>

Transfer of electrical energy from an external power source to the onboard batteries requires dedicated charging equipment. Such a system comprises cables, connectors, and interface units that establish the connection between the utility power supply and the vessel's battery system. The critical aspects of the charging infrastructure are its system configuration, mode of operation, and the charging protocols employed

<u>Charging Modes</u>

This sub section provides a brief overview of EV charging methods. Internationally, four recognized modes of automotive battery charging are defined, which specify the power delivery, safety features, and communication between the vehicle and the charging equipment. The key distinctions among these modes lie in the type of power delivery (AC or DC), charging speed, and the level of integrated safety and communication features. Table 1 presents a summary of the principal characteristics of each mode.

Modes 1 and 2 are AC charging methods using standard sockets, with Mode 2 incorporating in-cable safety and communication functions. Mode 3 also operates with AC but employs dedicated charging stations that provide higher power and enhanced safety features. Mode 4 differs fundamentally, as it is a DC fast-charging method where the AC/DC conversion is performed within the charging station, enabling direct supply of high-power DC to the vehicle battery for rapid charging.

Considering the fast-charging requirements of electric vessel battery systems, this document will primarily emphasize Mode 4 charging, which is increasingly adopted in marine applications due to its capability to deliver high-power DC charging directly to the onboard batteries.

Mode	Description	Key Features & Safety	Typical EV Application	Marine Vessel Application
Mode 1	Simple AC connection to a standard outlet.	No communication. Obsolete and unsafe for high power.	Used for low-power vehicles like e-bikes.	Not used due to lack of safety and control.
Mode 2	AC connection with an In-Cable Control Device (IC-CPD).	Provides basic safety features; limited communication.	Portable charging for home or emergency use.	Rarely used for commercial vessels; sometimes for small recreational boats.
Mode 3	Dedicated AC charging station.	High-level communication (e.g., ISO 15118) and advanced safety features.	Home, workplace, and public AC charging stations.	Used for lower-power charging of auxiliary batteries or smaller electric ferries and tugs.
Mode 4	Dedicated DC fast charging station.	Bypasses the vessel's on-board AC/DC converter for high-power transfer. Robust communication protocols.	Public DC fast chargers, highway charging corridors.	The most common and essential mode for high-power charging of electric ferries and other commercial vessels.

Table 1: Summary of the principal characteristics of EV charging modes.

<u>Charging protocols</u>

Electric Vehicle (EV) charging protocols define the standardized communication and power transfer mechanisms between electric vehicles and charging infrastructure. These protocols ensure safe, efficient, and interoperable charging processes, enabling compatibility across diverse electric vehicles and charging networks globally.

Key charging protocols widely implemented across various regions are summarised as follows:

<u>CHAdeMO Protocol</u>

CHAdeMO (short for CHArge de MOve) is a DC fast charging protocol originally developed in Japan, which was one of the first widely adopted standards for rapid DC charging of electric vehicles which is based on IEC 61851 standards. The protocol facilitates direct DC power delivery to the vehicle's battery pack. Communication between the charging station and vehicle occurs over a Controller Area Network (CAN) bus, negotiating key parameters including charging voltage, current limits, and battery management system (BMS) status, ensuring safe and optimized fast charging.

<u>GB Standard</u>

This charging standard developed in China defines both AC and DC charging, with dedicated connectors and communication protocols. DC fast charging under GB/T employs CAN bus or power line communication (PLC) to manage charging sessions. The DC connector supports high-voltage, high-current transfer directly to the battery, tailored to Chinese grid and vehicle specifications. The Chinese standard is based on GB/T 20234.

Combined Charging System (CCS)
The CCS standard extends Type 1 and Type 2 connectors by integrating two additional DC power pins to enable high-power DC fast charging, thus providing a unified AC/ DC interface. CCS, utilizing Power Line Communication (PLC) defines communication protocols, for features such as Plug and Charge authentication, load balancing, smart charging etc. CCS1 (Combo 1) is prevalent in North America, while CCS2 (Combo 2) is dominant in Europe and increasingly adopted worldwide.

Given its high-power capacity, robust communication, and modular design, CCS2 is rapidly becoming the preferred protocol for electric maritime vessels including ferries and service boats. The CCS2 is based on IEC 62196. For CCS2 charging, the most relevant IEC standards are IEC 62196-3:2022 (for the physical connector design) and the IEC 61851 series (for the overall charging system safety and control).

A summary of various protocols is presented at table 2 below

Protocol / Standard	Description	Key Features	Marine Vessel Application
Combined Charging System (CCS)	Dominant fast-charging standard in Europe and North America. Uses a single port for both AC and DC charging.	Relies on **Power Line Communication (PLC)**. Supports "Plug & Charge," smart charging, and high-power delivery.	The **most common and growing standard** for marine charging infrastructure in the West.
GB/T	The national standard for EV charging in China. Uses **separate connectors** for AC and DC charging.	Employs a **CAN bus** for communication. Vital for vehicles built in China.	The **primary standard for electric vessels built and operating in China** and other countries that have adopted this system.
CHAdeMO	A DC fast-charging standard originating from Japan.	Known for high power capabilities and support for **bidirectional charging (V2G)**.	Found in some **Asian-built vessels** and ports. Its V2G capability is highly relevant for marine applications.
ISO 15118	**Vehicle-to-Grid (V2G) Communication Interface.**	The most advanced standard for digital communication. Enables "Plug & Charge" and complex energy management.	The **underlying protocol for smart charging** in both CCS and GB/T systems, crucial for grid-friendly operations.
IEC/IEEE 80005	Under development for DC charging .		.

Table 2 : A summary of EV charging protocols

<u>Connectors</u>

IEC 62196 : specifies the requirements for **Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles**. The standard covers the following Connector types:
<u>Type 1</u> : A single-phase AC charging connector widely used in North America.
<u>Type 2</u> : A connector that supports both single-phase and three-phase AC charging, prevalent in Europe. support AC charging with integrated control pilot (CP) functionality. The CP line facilitates real-time communication between the vessel and the external power Supply Equipment enabling control over charging current, state monitoring, and safety interlocks.

<u>**Combined Charging System (CCS)**</u>**:** Combines the Type 2 connector with additional pins for high-power DC charging.
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CP - Control Pilot: (CP)This pin is part of the communication system between the vessel and the charging station. The charging station uses CP line to communicate the maximum charging current the station can provide and to initiate or terminate charging. The CP line is also used to communicate from the vessel to the charging station.

PE - Physical Earth: This pin is the safety ground connection, ensuring that the vehicle and charging station are properly grounded to prevent electrical shock hazards.

PP - Proximity Pin/ Plug Present: This pin is used to detect the presence of the connector and whether it is properly plugged.. It signals the charging system about the connection status, allowing the charging process to begin or preventing it if the connection is not secure.

Section 1

General requirements

1.1 Battery Charging station (BCS) in general would consist of :

a) External Power supply along with associated power supply components to provide AC , DC power
b) BCS to ship cable connection system

1.2 The establishment of power substation including associated cabling and power convertors should be carried out as per applicable rules and regulations.

1.3 Monitoring and logging

Each BCS system must have calibrated meters to measure the total kWh supplied to vessels. and should have facility for data logging and should have procedures established to verify the accuracy of recorded data.

1.4 Risk assessment

A risk assessment should be carried out to identify and mitigate various risks associated with provision of external power from BCS which should include continuity of supply, situations which could result in loss of power supply or providing supply continuity considering the effect due to such risks on environment, safety of persons and assets. The risk assessment should include a criticality and reliability analysis. It is important to ensure that a recognized methodology is applied with the involvement of risk assessment specialists. During the planning and designing stage, a general overview of the possible hazards and the means to address them is required taking into account the equipment, on-site conditions and user requirements. This risk assessment should be reviewed and updated at the detailed design stage and prior to actual implementation.

1.5 Carbon Certificate

A carbon certificate refers to a document that verifies the reduction of carbon emissions achieved by ships through the use of shore-side electricity (Onshore Power Supply or OPS) while docked at Indian ports. This certification process is structured to ensure transparency and accuracy in reporting carbon savings and enables ships to earn carbon credits.

Section 2

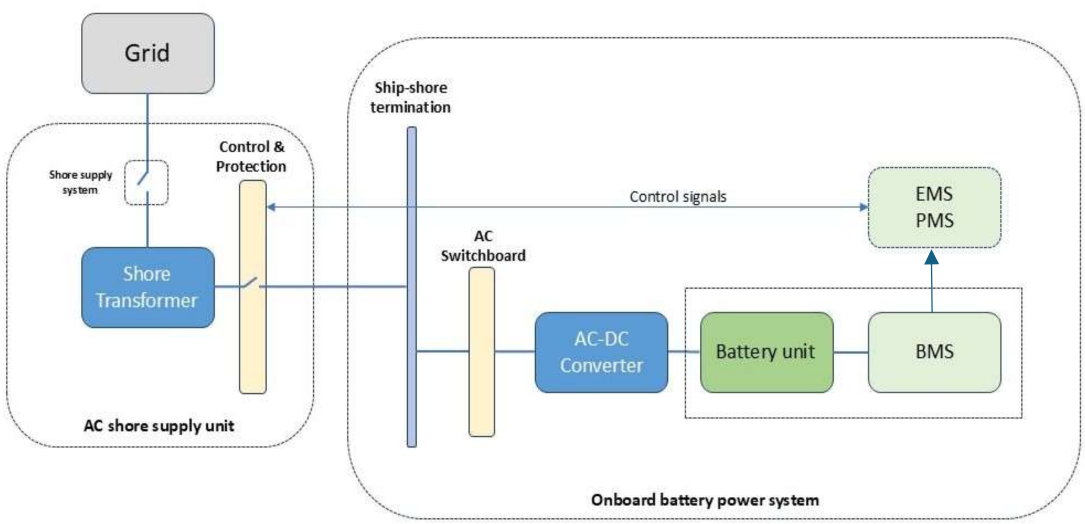
System requirements

2.1 Battery Charging Types

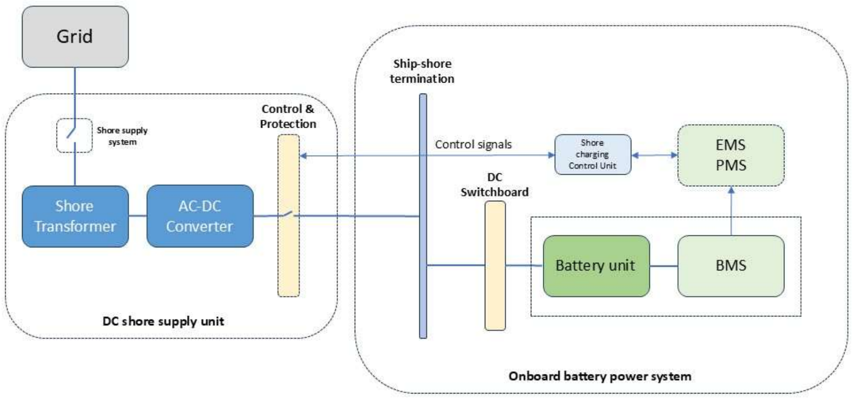
2.1.1 The external AC or DC power supply can be used for ship battery charging, the power requirement being mainly dependent on ship-specific power supply arrangement including battery charging system. The voltage variations including system protections are to comply with the Class requirements.

The power supply arrangement to meet the onboard requirements can be broadly categorized as below

a)AC power for ship battery charging: The battery charger would be located on board and in general the arrangements are suitable for slow charging unless the DC switchboard along with associated rectifier and charger are designed to handle high charging currents. Relevant requirements should be as specified in IRS "Best practises Shore-side Equipment for Low Voltage Connection Systems for Ships"



a) DC power for ship battery Charging: This method is suitable for DC fast charging. The power system infrastructure requirement on the ship is comparatively less as compared to AC battery charging. For vessels with shorter voyage duration, this mode of charging arrangement will result in optimizing the battery capacity with consequent advantage of reduced weight and space optimization.



General block diagram for DC shore charging system

2.1.2 In addition to the above two configurations, there could be combination of both AC and DC supply depending on vessel specific design to meet its operational requirements. Suitable interlocks are to be provided to prevent simultaneous operation of both AC and DC external power supplies.

2.2 Power system Accessories

2.2.1 These requirements apply to plug, socket-outlet, ship connector and ship inlet (herein referred to as accessories), intended to connect ships to dedicated shore supply systems. When BCS is a floating platform requirements as per relevant Class rules are applicable

- Accessories should have ingress protection of IP66/ IP67.
- One type of plug, socket-outlet, ship connector and ship inlet should be used for all types of ships.
- The accessories should be rated with min prospective short circuit current withstand of 16kA (rms) for 1 second.
- Accessories should be marked with:
    - rated current in amps
    - rated voltage in volts
    - symbol for nature of supply
    - either the name or trademark of the manufacturer or of the responsible vendor
    - type reference, which may be a catalogue number
    - degree of protection

The contacts should clearly specify the AC, DC and control signal pins. Accessories should be so designed that live parts of socket-outlets and connectors, when they are wired as in normal use, and live parts of plugs and inlets, when they are in partial or complete engagement with the complementary accessories; are not accessible.

Accessories with earthing contact should be provided with an earthing terminal.

2.2.2 An interlock should be incorporated in socket-outlets and connectors not complying with the tests for breaking capacity and normal operation. Interlocks should be linked with the operation of a switching device so that the plug can neither be withdrawn from the socket-outlet or connector while the contacts are alive, nor be inserted while the switching device is in the “ON” position.

2.2.3 The insulation resistance should be not less than 5 megaohm.

2.2.4 Accessories and their mounting means should be constructed to resist the corrosion induced by a seawater environment. Ferrous parts, including enclosures, should be adequately protected against rusting.

2.2.5 IEC 62196-3, may be referred for DC fast charging systems until specific standards for marine applications are available.

2.3 Power system Requirements

2.3.1 The BCS system should be able to determine that the charger plug is properly connected to the socket. Proper connection is assumed when the continuity of the control pilot circuit is detected. Once charger detected, all propulsion system should be in OFF condition and propulsion system power should be disconnected. The socket-outlet should not be energized unless the control pilot function between the BCS and the ship has been established correctly with signal states allowing energization.

2.3.2 Maximum allowable current

A means should be provided to inform the ship system of the value of the maximum current it is allowed to draw. The value of the maximum current permitted should be transmitted and should not exceed any of the following:

- the rated output current of the BCS
- the rated current of the cable assembly

The transmitted value may change, without exceeding the maximum allowed current, to adapt to power limitations, e.g. for load management.

2.3.3 De-energization of the power supply

If the control pilot signal is interrupted, the power supply to the sockets should be interrupted.

The BCS should disconnect the supply in case of:

- loss of electrical continuity of the protective earthing conductor (i.e. open control pilot circuit)
- incapacity to verify the continuity of the protective conductor (i.e. short circuit between pilot wire and protective conductor)

If the control pilot signal status no longer allows energization, the power supply should be interrupted but the control pilot signalling may remain in operation.

2.3.4 Arrangement

2.3.4.1 BCS system is not to be installed in hazardous spaces.

2.3.4.2 Adequate space is to be provided around BCS system to enable the operator to perform connection and disconnection operations.

2.3.5 Safety and operational precautions onboard the vessel should be as required for low voltage shore supply would be applicable where the power requirement is less than 1MVA . In the event of any emergency during the charger supply to battery should be interrupted.

2.4 Control and Communication

2.4.1 Onboard battery systems are to be controlled and monitored by the ship’s own Battery Management System (BMS). The BMS is responsible for State of Charge (SOC), State of Health (SOH), thermal management and cell balancing. Necessary communication to the BCS should be made available between onboard BMS and External charger.

2.4.2 While providing DC fast charging it is essential to have control data exchange between the shore station and the vessel prior to initiating charging and during charging. The control signals from vessel BMS, Power Management Systems (PMS) and Energy Management System (EMS), which are necessary for safe operation of the charging system, would be required to be transmitted. Similarly critical substation parameters e.g. voltage, power limit etc. are to be shared with the vessel.

2.4.3 The controller should establish low-level communication via CP with the charger. The onboard controller should continuously monitor the power requirement. The controller should continuously monitor battery for cell over-temp, over-charge, over-discharge. The controller should disconnect the battery when such command is initiated by the Battery management system.

2.4.4 A typical control signals handshake could be (including, but not limited to) as follows:

a. Control of the Converters and respective modes of operation.

b. Current control

c. Control of power flows

d. Voltage Control

e. Power Variation control during charging process

g. Battery safety parameters from BMS to BCS (state of charge, faults, etc)

h. current limits of shore power station

i. BCS faults

j. Emergency shutdowns

Section 3

Ship-to-BCS Connection

3.1 The BCS -side of the connection cable should be fitted with a shore plug which is arranged to protect all contacts. The ship-side of the connection cable should be fitted with a ship connector. Ship-to-BCS connection cable extensions should not be used.

3.2 A cable management system should be provided on the BCS -side. A portable High Voltage to Low Voltage system including but not limited to a transformer and cable management may be utilized to provide a Low Voltage connection interface.

3.3 Cables should be at least of a flame-retardant type. The outer sheath should be oil-resistant, resistant to sea air, seawater, solar radiation (UV) and should be non-hygroscopic.

3.4 A cable assembly should be constructed such that it cannot be used as a cord extension set. The cable assembly may include one or more cables, which may be in a flexible tube, conduit or wire way.

3.5 The cable may be fitted with an earth-connected metal shielding.

3.6 The cable insulation should be wear resistant and flexible over the full temperature range required by the classification of the BCS.

3.7 Prevention of overheating of cables or cable assemblies used in stored or partially stored position should be ensured.

Section 4

Compatibility Assessment and Testing

4.1 Compatibility Assessment

4.1.1 A compatibility assessment should be carried out for each vessel. The following aspects are to be considered as a minimum:

- Battery charging rate
- Communication with BMS for safety interlocks
- Charging mode
- Charging communication protocols
- Battery charger capacity
- Manufacturer recommendations for bcs side fast charging.
- Compatibility of ship side power sockets
- Suitable cable ratings.
- Maximum and minimum prospective short circuit current
- Monitoring and alarm functions during charging

The compatibility assessment or technical analysis, as appropriate, should be performed, prior to the first arrival of a vessel. Both BCS and ship sides should cross-review the initial test reports before the tests at the first call at a BCS supply point.

4.2 Verifications & Tests

4.2.1 Before connecting to external power, the following tests and verifications must be carried out, depending on whether it is a first or subsequent visit of a vessel.

<u>4.2.2 Integration tests at the first visit</u>

The following should be performed as an integration test at BCS and ship-sides before the BCS System connection:

- visual inspection,
- power frequency test for switchgear assemblies and voltage test for cable,
- insulation resistance measurement,
- measurement of the earthing resistance,
- function test of the protection devices,
- function test of the interlocking system,
- function test of the control equipment,
- equipotential bond monitoring test or equivalent,
- function test of the cable management system,
- integration tests to demonstrate that the BCS - and ship-side installations work properly together, and
- function test of the emergency stops.

<u>4.2.3 Routine tests at all subsequent visits</u>

If the time between port calls (the same BCS supply point) does not exceed 12 months and if no modifications have been performed either on the BCS -side or ship-side installations, the following verification should be conducted:

- visual inspection.
- confirmation that no earth fault is present.
- an authorized switching and connection procedure; and
- function test of the emergency stops.

Section 5

System operation

System operation should be in accordance with a defined procedure identifying the roles, responsibilities and requirements of all parties involved. The procedures should be documented, reviewed periodically and renewed (as required) by the port.

During the operation of external battery charging systems, the person(s) in charge (PIC) should be identified at the BCS facility and on board the vessel for the purposes of communication.

The PIC(s) should be provided with sufficient information, instructions, tools and other resources for safety and efficiency of these activities. An independent means of voice communication should be provided between the vessel and the BCS facility PIC (e.g. two-way radios).

The operation procedures should address the following, as a minimum:

5.1 Pre-connection and connection:

.1 a pre-connection safety inspection, which in turn should include:

a) a visual inspection
b) the definition of restricted access areas on both ship-side and BCS -side connection
c) verification of the locations of the communication devices, i.e. walkie-talkie and telephone, fire-fighting equipment and first aid devices
d) verification of the PPE of the personnel involved; and
e) confirmation that both BCS and ship-side circuit breakers are open, and power circuits are de-energized.

.2 cross-check of communication equipment

.3 the PIC should confirm that there are no ongoing safety-critical operations on the ship prior to connecting to the external power supply

.4 operation of the cable management system fit for the intended purpose; and

.5 simulation of the "safety circuit pilot loop operation" by both BCS and ship-sides to confirm the appropriate breakers will trip.

5.2 Disconnection:

5.2.1 External power disconnection from the BCS system should include the following detailed procedures:

.1 a safety inspection, which in turn should include:

a) verification of the locations of communication devices, i.e. walkie-talkie and telephone, fire-fighting equipment and first aid devices; and
b) verification of the PPE of the personnel involved

.2 the PIC should confirm that there are no ongoing safety-critical operations on the ship prior to disconnecting from the external power supply

.3 when the ship-side requires disconnection from BCS system, the ship-side should communicate with PIC indicating that it is safe to open the ship-side and BCS side circuit breakers

.4 to ensure that the power circuit is de-energized, both parties should confirm that both ship- andBCS side circuit breakers are open, circuits are isolated,

.5 the power and control cable (if applicable) should be disconnected.

Section 6

Documentation

6.1 The following documentation should be developed and maintained at the port, as a minimum:

a) Complete system description, including circuit diagrams, operation instructions, charger protocol , mode and specification of set points of protection, monitoring, alarms and shutdown Records of ship specific completed compatibility assessments including any port-specific information
b) Operational procedures including details of Person(s) In Charge (PIC)
c) Maintenance plan to establish periodic tests and maintenance procedures for the system
d) Pre-connection checklist
e) Connection check list
f) Disconnection check list
g) Emergency response procedures
h) Records of power supplied to each vessel
i) Where the port is required to issue carbon certificate, procedure should be prepared on the process including data logging, data accuracy and issuance of certificates. The procedure should also include process for submitting the reports to Administration and periodic review of the procedure.
j) Risk Assessment Report (as updated).

References:

1. IEC 80005-3:2014 Utility Connections in Port - Part 3: Low Voltage Shore Connection (LVSC) Systems - General Requirements

2. IEC 60309-1:2021 – Plugs, socket-outlets and couplers for industrial purposes – Part-1: General Requirements

3. IEC 60309-5:2017 – Plugs, socket-outlets and couplers for industrial purposes – Part-5: Dimensional compatibility and interchangeability requirements for plugs, socket-outlets, ship connectors and ship inlets for low-voltage shore connection system

4. IMO MSC.1/Circ.1675 - Interim guidelines on safe operation of Onshore Power Supply (OPS) service in port for ships engaged on international voyages

5. IRS Guidelines on Shore connection Systems on Ships, Rev 1, July 2025 (as may be amended)

6. IEC 61851-1:2017 Electric vehicle conductive charging system - Part 1: General requirements

7. EMSA Guidance on Shoreside Electricity Part 1 and Part 2

8. IEC 62196 : Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles