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Draft 2	4/03/2024	Static charging methods via Plug-in connector added. General Requirements expanded. Previous comments addressed.
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Preface

This standard was prepared by the Wayside Electrical Charging Interface for Low Emissions Rollingstock Development Group, overseen by the RISSB Rolling Stock Standing Committee.

Objective

The purpose of this Standard is to specify the requirements for wayside electrical charging infrastructure for battery electric powered rolling stock within the ANZ rail industry to assist RSO's in developing, designing, acquiring, testing and integrating battery electric rail vehicles into their fleets as part of industry wide decarbonization initiatives.

Compliance

There are four types of provisions contained within Australian Standards developed by RISSB:

(a) Requirements.

(b) Recommendations.

(c) Permissions.

(d) Constraints.

Requirements – it is mandatory to follow all requirements to claim full compliance with the Standard. Requirements are identified within the text by the term 'shall'.

Recommendations – do not mention or exclude other possibilities but do offer the one that is preferred.
Recommendations are identified within the text by the term 'should'.

Recommendations recognize that there could be limitations to the universal application of the control, i.e. the identified control is not able to be applied or other controls are more appropriate or better.

Permissions – conveys consent by providing an allowable option. Permissions are identified within the text by the term 'may'.

Constraints – provided by an external source such as legislation. Constraints are identified within the text by the term 'must'.

For compliance purposes, where a recommended control is not applied as written in the standard it could be incumbent on the adopter of the standard to demonstrate their actual method of controlling the risk as part of their WHS or Rail Safety National Law obligations. Similarly, it could also be incumbent on an adopter of the standard to demonstrate their method of controlling the risk to contracting entities or interfacing organisations where the risk may be shared.

RISSB Standards address known hazards within the railway industry. Hazards, and clauses within this Standard that address those hazards, are listed in Appendix B.

Appendices in RISSB Standards may be designated either "normative" or "informative". A "normative" appendix is an integral part of a Standard and compliance with it is a requirement, whereas an "informative" appendix is only for information and guidance.

Commentary

Commentary *C Preface*

This Standard includes a commentary on some of the clauses. The commentary directly follows the relevant clause, is designated by 'C' preceding the clause number and is printed in italics in a box. The commentary is for information and guidance and does not form part of the Standard.

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Section 1 Scope and general

1.1 Scope

The Standard outlines a consistent approach to the electrical charging interfaces between wayside infrastructure and rolling stock to provide alignment between standards for traction power equipment, charging infrastructure design, solutions for different charging strategies and rolling stock with onboard traction energy storage systems for the purposes of charging onboard energy storage systems. The aim of this Standard is to promote seamless integration and interoperability across different ANZ rail networks to reduce cost and complexity.

The Standard provides requirements for the following charging systems:

(a) DC static charging via plug-in receptacle (both low and high-power charging);

(b) DC static charging via roof mounted conductors (via a reverse pantograph or similar interface) - with charging control and intelligence contained within the wayside charging equipment;

(c) overhead traditional pantograph static and dynamic charging via OHW/pantograph interface or 3rd rail (Up to 25 kV AC or 1,500 V DC, see note) with onboard charging control and intelligence;

(d) battery swap systems; and

(e) mobile charging systems.

The Standard excludes requirements for infrastructure upstream of the charging system input terminals (i.e. the wiring section isolator in the case of traditional pantograph), or downstream of the battery electric rail vehicle input terminals (i.e. collector bar/pantograph connection point or receptacle plug on rail vehicle)

The Standard also excludes ground-based charging systems including wireless inductive coupling.

NOTE:

A maximum of 25 kV AC and 1,500 V DC was specified based on systems considered, compatibility with existing OHW/rollingstock systems, and development group consensus at the time of writing this Standard.

1.2 Normative references

The following documents are referred to in the text in such a way that *some* or all of their content constitutes requirements of this document:

- AS 2067, Substations and high voltage installations exceeding 1 kV AC
- AS 4024, Safety of machinery
- AS 7505, Signalling detection interface
- AS 7507, Rolling stock outlines
- AS 7770, Rail cyber security
- AS 7722, EMC management
- AS 60529, Degrees of protection provided by enclosures (IP code)
- AS/NZS 3000, Electrical installations
- AS/NZS 61000 Series, Electromagnetic compatibility (EMC)
- IEC 61851 Series, Electric vehicle conductive charging system
- IEC 62196 Series, Plugs, socket-outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles

- ISO 13850, Safety of machinery – Emergency stop function – Principles for design
- ISO 17409, Electrically propelled road vehicles – Conductive power transfer – Safety requirements
- EN 50206 Series, Railway applications – Rolling stock – Pantographs: Characteristics and tests
- EN 50367, Railway applications – Fixed installations and rolling stock. Criteria to achieve technical compatibility between pantographs and overhead contact line
- IEEE Std 2030.1.1, IEEE Standard for Technical Specifications of a DC Quick and Bidirectional Charger for Use with Electric Vehicles
- CharIN Whitepaper Megawatt Charging System (MCS) – Recommendations and requirements for MCS related standards bodies and solution suppliers
- Energy Networks Association (ENA) EMF Management Handbook
- International Commission on Non-Ionizing Radiation Protection (ICNIRP)
- Institution of Electrical and Electronic Engineers (IEEE) International Committee on Electromagnetic Safety

NOTE:
Documents for informative purposes are listed in a Bibliography at the back of the Standard.

1.3 Defined terms and abbreviations

For the purposes of this document, the following terms and definitions apply:

1.3.1

adaptor
a device used for converting attributes from charging station to charging cable. Vehicle adaptors are only adaptors adapting from charging cable to vehicle inlet

1.3.2
AIMD
active implant medical device

1.3.3
alternating current (AC)
a form of electrical power known as alternating current

1.3.4
ANZ
Australia and New Zealand

1.3.5
battery electric rail vehicle (BERV)
any rail vehicle with propulsion powered by onboard batteries or alternate power sources like supercapacitors, including locomotives, maintenance vehicles, autonomous vehicles, and light or heavy rail vehicle

1.3.6
charger
a device used for supplying charging power to the battery intended to be onboard a BERV and/or capable of providing power for traction of the BERV

1.3.7
charging

the process of supplying power to a battery from an external power source, producing a chemical reaction of the active substances and storing electrical energy in the battery as chemical energy

1.3.8
charging cable
a cable that can be connected to a BERV for charging purposes

1.3.9
charging connector/plug
a connecting apparatus equipped with the charging cable to enable connection (plug-in) to the receptacle on a BERV

1.3.10
charging unit
an equipment enclosure containing a charger and associated charging equipment. See also 'charger'

1.3.11
CCS
combined charging system

1.3.12
direct current (DC)
a form of electrical power known as direct current

1.3.13
EIM
external identification means

1.3.14
EVSE
electric vehicle supply equipment

1.3.15
EMC
electromagnetic compatibility

1.3.16
EMF
electromotive force

1.3.17
fire resistance level (FRL)
also known as fire rating, FRL refers to the duration for which a particular material or element can resist the effects of fire and maintain its structural integrity

1.3.18
HMI
human machine interface

1.3.19
high power static charging system
a charging system capable of delivering greater than 350 kW of power, via plug-in cable. 'Megawatt charging systems' (MCS) fall into this category

1.3.20
low power static charging system
a charging system capable of delivering less than 350 kW of power to charge the system, via plug-in cable

1.3.21

MCS
megawatt charging system

1.3.22
OEM
original equipment manufacturer

1.3.23
OHW
overhead wire

1.3.24
PWM
pulse width modulation (signal type)

1.3.25
RFID
radio frequency identification

1.3.26
RIM
rail infrastructure manager

1.3.27
RSO
rolling stock operator

1.3.28
SIL
safety integrity level

1.3.29
SoC
state of charge

1.3.30
VCU
voltage converter unit

1.3.31
VTG
vehicle to grid

General rail industry terms and definitions are maintained in the RISSB Glossary. Refer to: https://www.rissb.com.au/products/glossary/

Section 2 General requirements

2.1 General compliance with applicable regulations and standards

Charging systems shall comply with relevant Australian regulations and standards governing electrical installations and railway operations as appropriate. In addition to the requirements defined in this Standard, a list of other applicable standards that may be utilized are provided in Appendix A.

2.2 Safety in design

Safety requirements for wayside electrical charging of BERVs shall adopt similar principles to those specified in ISO 17409.

The wayside electrical charging system shall operate safely and continuously in any operational cycle. It shall be designed so that skilled personnel (e.g., electrical trade staff) are not required to enable charging.

> Commentary *C2.2*
>
> The intent of this requirement is that the charging interface can be connected and operated by a non-electrical specifically qualified person with the RSO upskilling the operator by providing appropriate safety training to identify and mitigate any risks related to charging.

Any switchgear used within the charging system, including the input supply circuit, shall be fully arc contained. An arc flash study, compliant to AS 2067 and ENA NENS 09, shall be carried out to appropriately identify and mitigate any residual risks associated with arc flash.

2.3 Fire safety

The fire life safety strategy and fire engineering report for wayside charging equipment shall be created and should include:

(a) NCC performance requirements and classification;

(b) individual railway operator requirements;

(c) local fire brigade requirements (including consultation);

(d) access, egress, exits and travel distances;

(e) function, use and height of building/enclosure or nearby buildings and number/mobility of occupants;

(f) fire sources, vehicle proximity and fire resistance level (FRL);

(g) fire load, potential fire intensity, temperatures, level of toxicity/visibility and hazards;

(h) active and passive fire safety systems; and

(i) fire brigade intervention.

> Commentary *C2.3*
>
> The fire safety for each BERV will have specific requirements not covered by this Standard. Refer to AS 7529.1.

2.4 Environmental considerations

The charging system shall be able to operate effectively as intended under the full range of environmental conditions that can be expected in the route/area of operation.

> Commentary *C2.4*
>
> The ambient temperatures of the Australian natural environment for the operation of trains can range from -10° C to +55° C. The Australian climate can produce conditions including relative humidity of 100 % at 25° C, heavy rain, hail, strong winds, solar radiation, frost, dew, dust, salt and corrosive/conductive contaminates.

2.5 Environmental impact and sustainability

The charging system should evaluate and minimize environmental impacts over the whole lifecycle of the asset for:

(a) energy use and greenhouse gas emissions;

(b) materials and waste; and

(c) end of asset life disposal and recycling.

Commentary *C2.5*

A method of managing environmental impact and sustainability can be through the use of an environmental management system (EMS). EMS elements can include management plans, procedures and protocols, checklists, training and awareness programs.

Depending on the environmental issues, risks and client (user) requirements, the EMS may be certified as consistent with standard AS/NZS ISO 14001. The EMS may also form part of a broader integrated management system, which can cover other aspects including safety and quality.

A full description of the requirements of an EMS is described in AS/NZS ISO 14001.

For further guidance on EMS and sustainability, refer to:

- *RISSB Requirements for the Procurement of Rolling Stock Guideline*; and
- *Australasian Railway Association - Sustainability Guide*

2.6 Reliability, availability, maintainability (RAMS)

The typical design life of the wayside electrical charging systems should be:

(a) 25 years for primary electrical systems; and

(b) 15 years for secondary electrical systems.

Wayside electrical charging systems shall have:

(c) a reliability target of 98% or greater (all weather); and

(d) an availability target of 92.5% or greater (target only as system dependent).

2.7 Traction return rail(s) and overhead line 'drop zone' considerations

DC static charging via plug-in receptacle or roof mounted conductors (with reverse pantograph or similar) shall not be recommended where:

(a) one or more of the rails is a traction return rail of a traction power system for an electrified rail line; and/or

(b) an overhead line 'drop zone' exists.

These systems shall only be recommended in defined non-electrified areas for reasons including:

(c) traction return current interference;

(d) effects of stray DC current; and

(e) possible interconnection of two different power systems or sources.

2.8 Standard gauge, narrow gauge and dual gauge track areas

In dual gauge areas, wayside electrical charging infrastructure shall be positioned to ensure necessary clearances to the standard gauge track kinematic envelope while making allowances in dimensional tolerances and functionality for both standard and narrow-gauge BERVs operating in dual gauge areas.

2.9 Signalling system interface

The BERV and the wayside electrical charging system shall be compatible with the signalling detection and indication systems used on Australian networks and shall be compliant to AS 7505.

2.10 Track circuit interference

A DC immunisation study shall be performed where traditional signalling track circuits exist and a DC charging system is to be implemented within the track circuited area.

2.11 Authenticity, confidentiality and integrity/cyber security

Before charging, the charger shall authenticate and authorize the BERV. If external identification means (EIM) are used such as radio frequency identification (RFID) cards, wireless communication, remote authorization and others, channels to communicate these credentials shall be secured separately.

The actual content of the monitoring systems shall only be readable by the intended recipient(s) and not by any unauthorized third parties.

An unauthorized modification of charging parameters and data communicated between the charger and the BERV shall be avoided or at least be detected.

The data exchange between the charger and BERV shall comply with AS 7770, or an equivalent standard to mitigate cyber security risks.

2.12 Preserving/maintaining battery integrity

Digital communication between the BERV and the charger shall be provided in accordance with IEC 61851-1 to allow the BERV to control the charger.

2.13 Harmonic limits, power factor, load balance and voltage fluctuations

2.13.1 Harmonic Limits

Harmonic emissions of charging systems shall be within allowable limits of the electrical network they are supplied from and include (as a minimum):

(a) Voltage harmonic emission severities:

- (i) Total harmonic distortion (%)
- (ii) Worst case (max) individual odd and even harmonic distortions (%)

(b) Current harmonic emission severities:

- (i) Total harmonic distortion (%)
- (ii) Individual harmonic distortions (%) for the odd harmonic orders “h” within the following ranges:
  - <11th order
  - 11 <= h < 17
  - 17 <= h < 23
  - 23 <= h < 35
  - 35 <= h

> Commentary *C2.13.1*
>
> IEEE Standard 519 ‘Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems’ can be used as a guide.

2.13.2 Power factor

The charging system shall ensure that demand for reactive power does not exceed the maximum level allowed by the electricity supplier.

> Commentary *C2.13.2*
>
> Power factor limits typically vary depending on the electrical supply voltage and the maximum demand of the installation.

2.13.3 Load balance

The charging system shall ensure that the current in each phase of a three-phase electrical installation does not deviate from the average of the three phase currents by more than amounts specified by the electricity supplier.

2.13.4 Voltage fluctuations

The charging system shall not cause voltage fluctuations at the point of common coupling greater than the levels specified in AS/NZ 61000.3.5 and AS/NZ 61000.3.7 as appropriate.

2.14 EMC/EMF/EMI

The BERV charging system shall be compliant to IEC 61851. Electromagnetic compatibility of the charging system shall be compliant with AS/NZS 61000 series and AS 7722.

> Commentary *C2.14*
>
> EN 50121-3 and EN 50155 applies to the onboard equipment.

The charging system, including cables, shall also follow the requirements of the Energy Networks Association (ENA) EMF Management Handbook, and comply with internationally recognized EMF guidelines and exposure limits:

(a) International Commission on Non-Ionizing Radiation Protection (ICNIRP); and

(b) Institution of Electrical and Electronic Engineers (IEEE) International Committee on Electromagnetic Safety.

Exposure limits for staff, public and persons equipped with AIMD (Active Implant Medical Devices) shall be considered.

An EMC management plan shall be developed for EMC management through the design, procurement and installation project phases. The EMC management plan should identify applicable standards, compliance verification and testing requirements and be used for compliance assurance.

At locations where it is possible electric field induction or radio frequency induction onto DC charging systems exists from external electrical sources, such as powerlines or dry-band arcing or micro-sparking from a faulty or polluted nearby insulator, a study shall be performed to ensure interference levels are below the charging equipment immunity levels.

2.15 Installation guidelines

Installation guidelines shall be provided by the OEM to enable seamless integration of the charging system with the BERVs it is intended to charge and the existing rail systems of the network it is added to.

2.16 Safety alarms

The OEM shall compile a comprehensive list of malfunctions, failures and faults that could prevent BERVs from being charged, and shall define suitable visible and audible alarms for both the charging system and the BERVs.

If multiple components or systems malfunction simultaneously, successive alarms shall be queued chronologically, and the queue displayed on the HMI panel.

Section 3 Static charging via plug-in receptacle

3.1 System components and specifications

> Commentary *C3.1-1*

Static charging via plug-in receptacle is classified as:

- a low power static DC charging system, defined by this standard as any single charger, also known as electric vehicle supply equipment (EVSE), with output power below 350kW to charge the connected battery system.

- a high-power static DC charging system, often referred to as megawatt charging system (MCS), defined by this Standard as any charger capable of producing more than 350 kW of output power.

It consists of an external charging unit (charger) that can be connected to the BERV with a plug-in connection cable via an onboard receptacle unit. The plug-in connection cable is intended to be permanently connected to the charger. The receptacle is permanently connected to the battery system (intended to be onboard the BERV and capable of providing power for traction of the vehicle).

For low power static DC charging systems, the external DC charger system with cable permanently connected to the charger (mode 4 charging and Case "C" connection as defined by BS EN 61851-1) is to be adopted for BERV. While mode 1, 2, and 3 EV charging systems are possible, including onboard chargers and AC power connection from EV to supply network, they are not recommended for rollingstock applications covered in this Standard.

The charger shall be able to indicate to the user the status of the charging process and take corrective actions if required.

Both the charger and the BERV shall be equipped with a means to confirm they remain physically and/or electrically connected with each other during charging.

To ensure interoperability, the combined charging system (CCS) combo 2 connector with uni-directional power flow shall be adopted for low power static charging of BERVs in Australia. Bi-directional power flow systems/vehicle to grid (VTG) may be accepted in the future.

The insulation requirements for high power static DC charging system shall be in accordance with CharIN Whitepaper 'Megawatt Charging System (MCS)'.

Commentary *C3.1-2*

It is not recommended to install static charging equipment in railway electrified corridors i.e. where traction power systems are in operation.

3.2 External charging unit

The external charging unit (charger) shall deliver power to the BERV via the cable and plug-in connector via the onboard receptacle.

The voltage, current and power quality delivered to the battery of an electric rail vehicle shall be compatible with the battery (intended to be onboard the BERV and capable of providing power for traction of the vehicle).

The following shall be applicable for low power static DC charging:

(a) the charger shall be able to detect loss of isolation, short circuit, or earth faults;

(b) the charger shall be equipped with a means to stop charging if communication between the vehicle and the charger (via the communications interface) is interrupted; and

(c) the charger shall be equipped with an overvoltage protection function.

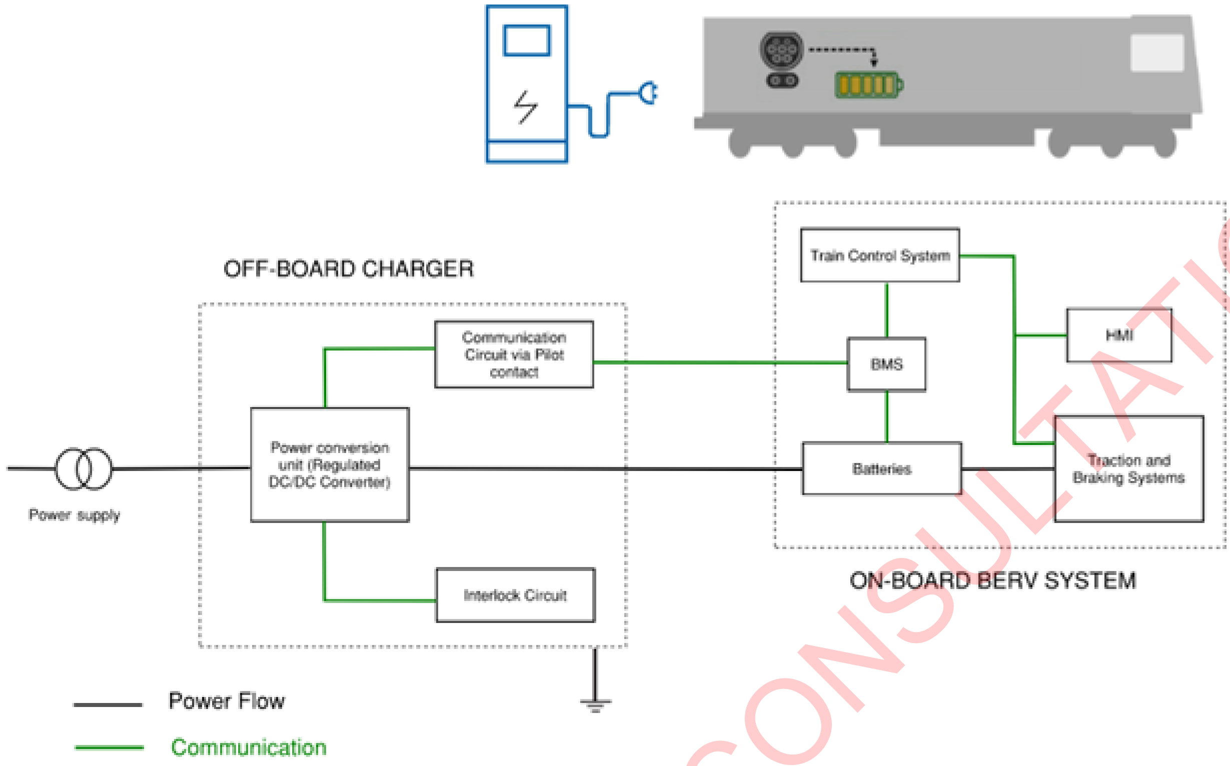

Figure 1 Typical interface between regulated plug-in charger and on-board BERV system

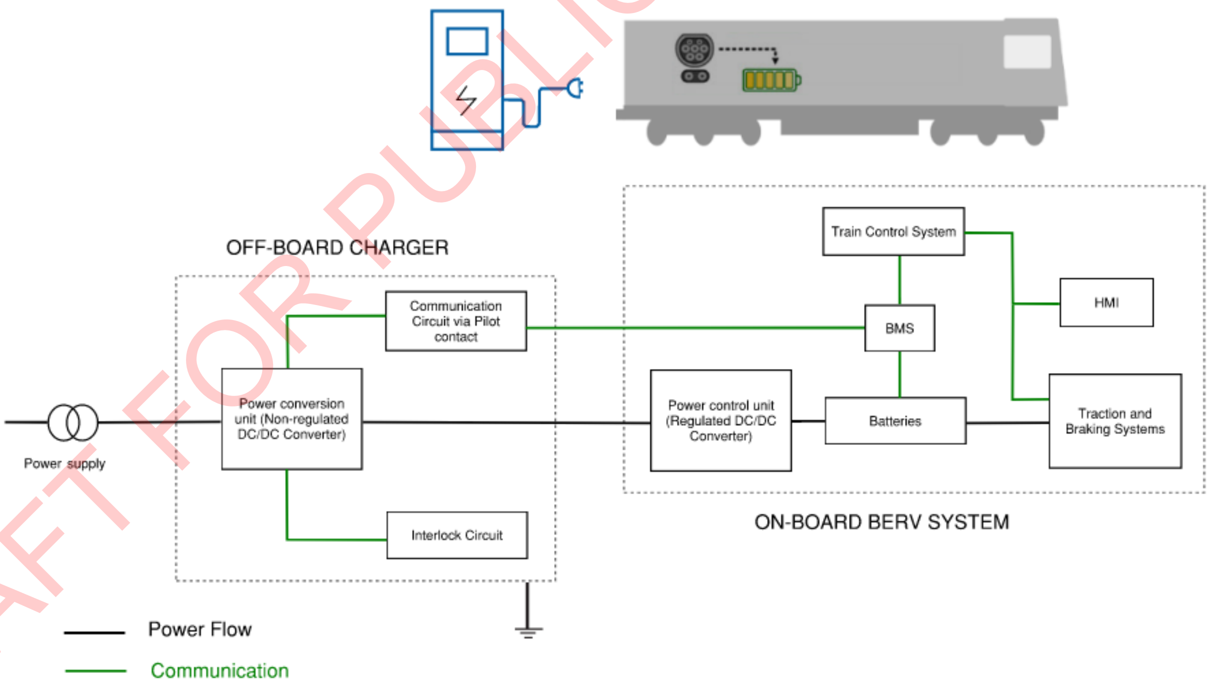

Figure 2 Typical interface between un-regulated plug-in charger and on-board BERV system

Commentary *C3.2*

The design of the BERV will be affected by the onboard DC-to-DC converters. The onboard converters and their additional systems, necessitate heat dissipation methods, create space constraints, limit power capacity and increase the weight of the BERV.

3.3 Voltage converter unit (VCU) ratings and components

Based on CCS development, typical operating voltages for low power static DC charging shall be 200 to 920 V DC.

The output operating voltage for high power static DC charging should be up to a maximum of 1500 V DC with a continuous output current range of 0 - 3000 A DC.

Commentary *C3.3*

Based on CharIN Whitepaper 'Megawatt Charging System (MCS)', output operating voltage for high power static DC charging supports the range of 500 to 1,250 V DC. Note this is primarily for road vehicles.

For a rail application, a dual output system where both plug in and OHW charging is available can be of benefit.

3.4 Ingress protection and access to electrically energised areas

The charging system shall prevent access to electrically energised areas and be able to withstand direct rain/water, dust exposure and anticipated atmospheric conditions with no harmful effects. Appropriate IP ratings shall be determined in accordance with AS 60529 (IEC 60529 Ed 2.1) and shall meet or exceed ingress protection according to IEC 62196 and IEC 61851.

Commentary *C3.4*

For high power static DC charging system, IEC 62196 is expected to be superseded by IEC 63379 for MCS in the future.

3.5 Internal wiring

Internal wiring of the charger shall be in accordance with AS/NZS 3000.

3.6 Adaptors and extension cords

As per IEC 61851-1, adaptors shall not be used for charging of BERVs with CCS charging interface or for incompatible plug-in connectors/receptacles (couplers) onboard the BERV.

Adaptors at the charging station outlet should only be allowed under certain conditions:

(a) the liability for safe operation shall be with the respective manufacturer based on applicable Australian laws and regulations; and

(b) the adaptor design shall ensure that its current rating is not exceeded.

In accordance with BS EN 61851-1, extension cords shall not be used for the connection of BERVs to the charger.

3.7 Earthing provisions

The charging connection cable and plug-in connector shall have a protective earthing conductor and connection pin that ensures a safe earthing connection between the charger and the BERV.

If the protective earthing conductor becomes disconnected, the charger shall stop charging within 10 seconds in accordance with IEEE Std 2030.1.1.

3.8 Charging connection cable

The charging connection cable shall be capable of delivering the required charging power to the BERV via a cable plug-in connector and onboard receptacle compliant to IEC 62196 series.

The charging connection cable should consist of power wires and signal wires. The power wires and signal wires shall have conductor size and electric wire coating material that is appropriately designed for the charging current and applied voltage.

The signal wires that are applicable to CAN communication shall be twisted pair wires in order to reduce conductive noise of differential mode signals.

The charging connection cable should exhibit following properties:

(a) withstand harsh environmental conditions such as temperature extremes;

(b) be resistance to abrasion and impacts; and

(c) withstand mechanical deformation due to bending, twisting, vibration and other physical forces generally associated with rail operating environment.

In accordance with CharIN Whitepaper 'Megawatt Charging System (MCS)', the protective earth/potential equalization wire for high power static DC charging included in the MCS connector shall be capable of withstanding a short circuit current of 11 MA^2s, which typically results in a minimum cross section of 25 mm^2.

In accordance with BS EN 61851-1, the maximum permissible temperature of exposed parts of the accessory and cable assembly that can be grasped during normal operation carrying the rated current shall not exceed:

(d) 50^o C for metal parts; and

(e) 60^o C for non-metal parts.

For parts which can be touched but not grasped, the permissible temperatures are:

(f) 60^o C for metal parts; and

(g) 85^oC for non-metal parts.

3.9 Plug-in connector (charger outlet/vehicle connector)

The charger and plug-in connector shall be equipped with measures to reduce the risk of contact with exposed live parts as a measure against exposure to any residual electric charge on the charging plug-in connector.

In accordance with CharIN Whitepaper 'Megawatt Charging System (MCS)', the protective earth pin shall be 6 mm diameter for low power static DC charging and 8 mm diameter for high power static DC charging.

Commentary *C3.9*

Mating Durability - It is recommended that the plug-in connectors must undergo a minimum of 10,000 mating cycles, regardless of the application for low power static DC charging.

Depending on the region, UL 2251 No-Load Endurance Test and/or IEC 62196 mating cycles with pollution tests should apply for high power static DC charging. It is recommended that 20,000 mating cycles is considered for these tests due to the duty cycle of commercial applications.

Insertion/removal force (with latching device deactivated) shall be as follow:

(a) for low power static DC charging - 80 N in accordance with BS EN 61851-1; and

(b) for high power static DC charging - 100 N in accordance with IEC 62196

The system shall fail safe in the event of an accidental BERV breakaway or in an emergency such as a runaway rail vehicle/collision.

A dummy socket (receptacle) shall be provided in the vicinity of the charging connection cable to accommodate the plug-in connector while not being used for charging. The dummy socket (receptacle) shall be designed to prevent dust, debris and water ingress to the plug-in connector.

3.10 Plug-in receptacle (vehicle inlet/outlet)

For low power static DC charging, the charging connection interface to the BERV shall include a plug-in receptacle with male pinouts compatible with the charger plug-in connector and compliant with IEC 62196-3.

For high power static DC charging, the charging connection interface to the BERV shall include a plug-in receptacle compatible with the charger plug-in connector.

In accordance with CharIN Whitepaper 'Megawatt Charging System (MCS)' for high power static DC charging, the plug-in receptacle (coupler) shall include an electrically activated/actuated lock to ensure the plug-in connector remains engaged with the inlet during all normal operation and also in case of short circuit. This electrically activated retaining means shall provide feedback to the EV and shall be controlled independently of buttons or switches used for either normal user requested shutdowns or emergency shutdowns. The retaining means shall be integrated into the inlet side of the coupler on at least one location, and up to 3 locations. The lock shall have a pin or slot design that operates consistently in all expected operating conditions, especially considering temperature and weather variations for charging operations in extreme environments, and with expected tolerances and wear.

3.11 Communication and control system

A secure data communications interface shall be used to transmit parameters required for charging control. The charger and BERV shall exchange the parameters through the interface.

A control pilot circuit shall be the primary control means when connecting the BERV to the charger. The control pilot circuit shall be in accordance with BS EN 61851-1, Annex B, and perform the following functions:

(a) verification that the BERV is properly connected;
(b) continuous protective earth conductor integrity checking;
(c) energization of the system;
(d) de-energization of the system;
(e) supply rating recognition by the Battery Electric Rail Vehicle; and
(f) determine ventilation requirements (optional).

3.12 Interface with BERV

The charger should be compatible with the energy storage type and chemistry in use, rated for the appropriate charging rate, and compatible with different operating conditions.

3.13 Safety measures

The static plug-in DC charging system shall be designed to prevent the presence of voltages dangerous to the human body on the connection cable (plug) when it is not connected to the BERV.

The charging system shall be designed to prevent contact with electrically energized parts on the charger, charging connection cable, cable connection (plug), onboard receptacle and BERV.

The charger shall be equipped with the following safety functions:

(a) earth leakage current detection (insulation monitoring) and automatic disconnection to prevent electric shock;

(b) overcurrent and overvoltage protection;

(c) reverse power (BERV to Charger);

(d) an emergency stop switch;

(e) an open door electrical/mechanical interlock (to ensure power is disconnected when charging unit door is opened); and

(f) for low power static charging, disconnection be restricted while under load. In the case of disconnection under load due to a DC fault, no hazardous condition shall occur.

Touch current protection for a high power static DC charging system shall be in accordance with CharIN Whitepaper 'Megawatt Charging System (MCS)'.

Commentary *C3.13*

It is recommended that the static DC charging equipment is installed only in very low speed track areas such as at maintenance facilities (e.g., <8 km/hr) and as approved by the RSO.

3.14 Human factors

The external charging unit shall be equipped with a display providing a human-machine interface capable of performing the following functions:

(a) display status and set-up charger parameters;

(b) calibrate peripherals;

(c) select charging process arrangement;

(d) enable charging process start/stop;

(e) display fault events or reduced capability;

(f) display input voltage, output voltage and output current;

(g) charger temperature;

(h) contactor and critical power supply status;

(i) state of charge (SoC) of the BERV's battery; and

(j) confirm charging process finish.

An emergency stop button shall also be provided separate to the HMI display.

3.15 Spacing and connection location

Charging equipment spacing shall be as per OEM recommendations and local regulations. There should be adequate space for personnel to safely operate and maintain the charging equipment.

The charging connection cable manoeuvrability shall be restricted by the cable size, i.e. minimum voltage drop or on communication protocols.

The charging connection location shall cater for the plug-in receptacle location which can be on either side of the BERV, approximately midway along the vehicle, with a plug-in height at approximately 1.2 m above rail level.

NOTE:

This dimension is a guide only and needs to be confirmed with the BERV manufacturer for compatibility assurance.

Electrical and mechanical interlocks shall be employed to isolate and safeguard the active pins of plug-in receptacles on both sides of BERVs, to ensure that if one side is in use, the incorrect side cannot be accessed. Energization of the system shall not be performed until the interlock function between both sides of the plug-in receptacles has been established.

3.16 Manual handling

Cable handling and plug-in connection shall be possible by a single operator.

Cable hangers may be included to reduce manual handling effort and prevent 'dropped' connectors. The design of any such system shall incorporate the rail environment and rail operator requirements including but not limited to proximity of rollingstock kinematic envelope and robustness of supporting structure.

The following shall be incorporated in the design of high power static charging system:

(a) cable length shall be a maximum of 15 m. For liquid cooled cables it is recommended to keep the length as short as possible in order to avoid excessive performance requirements on the cooling system and the manual handling of the cable;

(b) automated connection can be possible with sufficient optical recognition features implemented; and

(c) manual handling for installation and maintenance purposes shall follow principles provided under the jurisdiction workplace health and safety act and the rail operators safety management system.

3.17 Process of operation

To prevent damage to the charger, cable and coupler and provide a safe and orderly system start-up sequence of the charge process, a complete sequence of control events shall take place as described in BS EN 61851-1, Annex B, and summarised below:

(a) proximity detection – prior to any electrical contact is established, the vehicle shall provide a means to detect the presence of the plug-in connector at the point where damage could occur to the coupler if the vehicle moved. The means shall provide a signal to activate the vehicle control system and interlock the vehicle traction system. The charger shall initiate charging only when the traction motor of BERV is switched off;

(b) verification the BERV is properly connected;

(c) continuous protective earth conductor integrity checking;

(d) energization of the system (if no fault conditions exist, any installed off-peak time delay has expired and vehicle has successfully performed internal charge ready checks);

(e) supply rating recognition by the vehicle (data communication shall be established before charger main power contactor is closed and charger system energized. If communication cannot be established the process shall be terminated at this point). Power can now be drawn at the rate established by the data communications;

(f) de-energization of the system – Conditions in steps (a) to (d) above shall be continuously monitored during charge process. If any of the conditions in these steps do not satisfy the specified requirements, the charger shall terminate the charge process by opening the main contactor and S1 (control pilot contact) and display a fault condition; and

(g) determination of ventilation requirements of the charging area (optional – if vehicles require it for indoor charging).

Commentary *C3.17*

If a vehicle has a low voltage battery problem such that it can't begin charging, it is recommended to follow the industry standard of using "jumper" cables or a "jump box" to temporarily provide low voltage power to that vehicle until it can begin charging.

3.18 Emergency stop

In the event of a power failure, fault, or emergency stop command, a built-in-fail-safe function shall automatically seize power flow from the charger to the BERV. The plug-in connector shall remain engaged with the inlet until the fault is cleared.

Emergency E-stop button/s that comply to ISO 13850 shall be provided to cut power from the charging process in the event of an emergency. A risk assessment shall be conducted to determine the location and quantity of emergency E-stop button/s required. These may be located in close proximity to the charging equipment and/or charging tower.

The E-stop push button shall be clearly marked, immediately accessible and be red in colour. It should have a minimum diameter of between 22 mm to 30 mm.

Section 4 DC static charging via roof mounted conductors (via reverse pantograph or similar interface)

4.1 System components and specifications

A DC static charging system, via roof mounted conductor bars or contacts (current collector) on BERV shall be integrated with a wayside reverse pantograph (or similar interface) charging system located above the vehicle, via a tower structure or fixed to other existing overhead infrastructure along the track and/or depot.

Commentary *C4.1*

This is also known as a top-down or inverted pantograph system.

The reverse pantograph (or similar interface) shall automatically extend down to make contact with the roof mounted current collector once alignment is achieved and handshaking is completed via a communication protocol between the BERV and the reverse pantograph charging system.

Both the charger and the BERV shall be equipped with a means to confirm they remain physically and/or electrically connected with each other during charging.

4.2 Charging unit

The charging unit shall deliver power to the BERV via the reverse pantograph (or similar interface) and roof mounted current collector.

The voltage, current and power quality delivered to the battery of an electric rail vehicle shall be compatible with the battery (intended to be onboard the vehicle during operation).

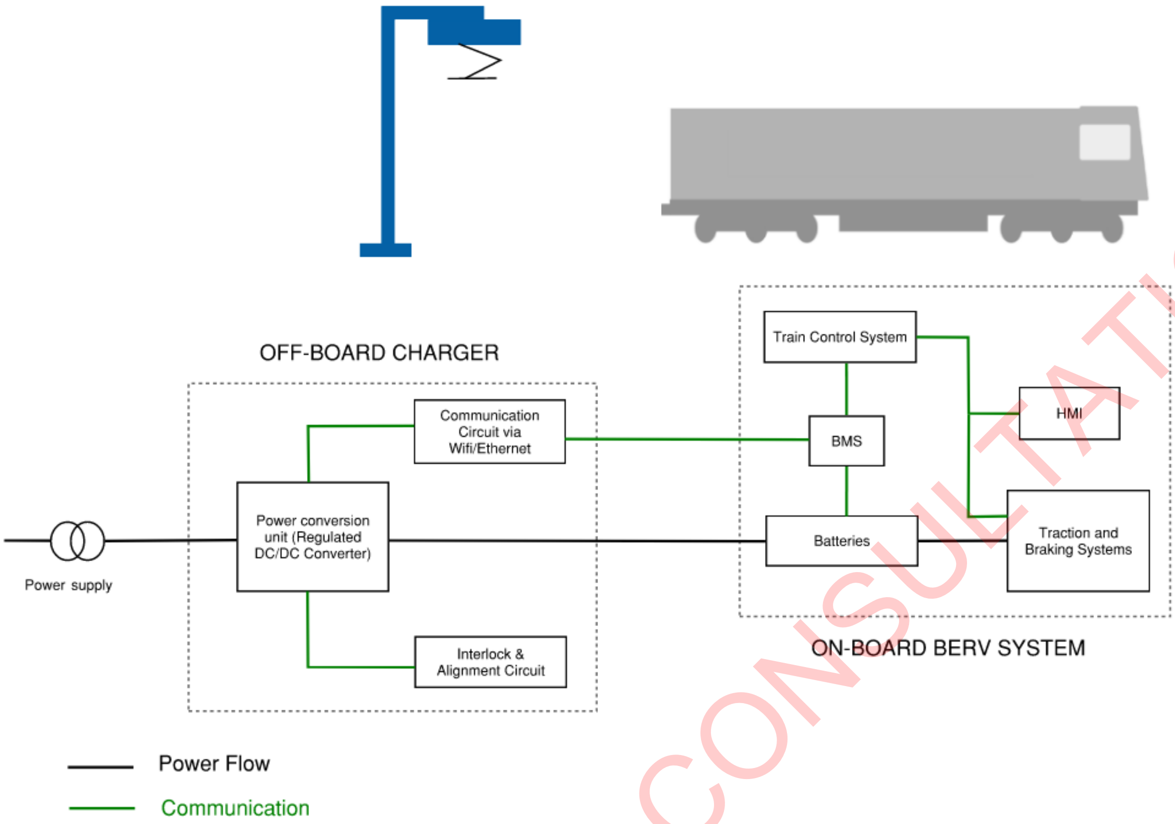

Figure 3 Typical interface between regulated DC static charging via roof mounted conductors and on-board BERV system

Following handshake between the charger and the BERV, the charging unit control system and DC converter(s) shall control the charging voltage and current throughout the charging process.

The reverse pantograph shall be motorised in both directions enabling safe connection and disconnection from the current collector on the BERV.

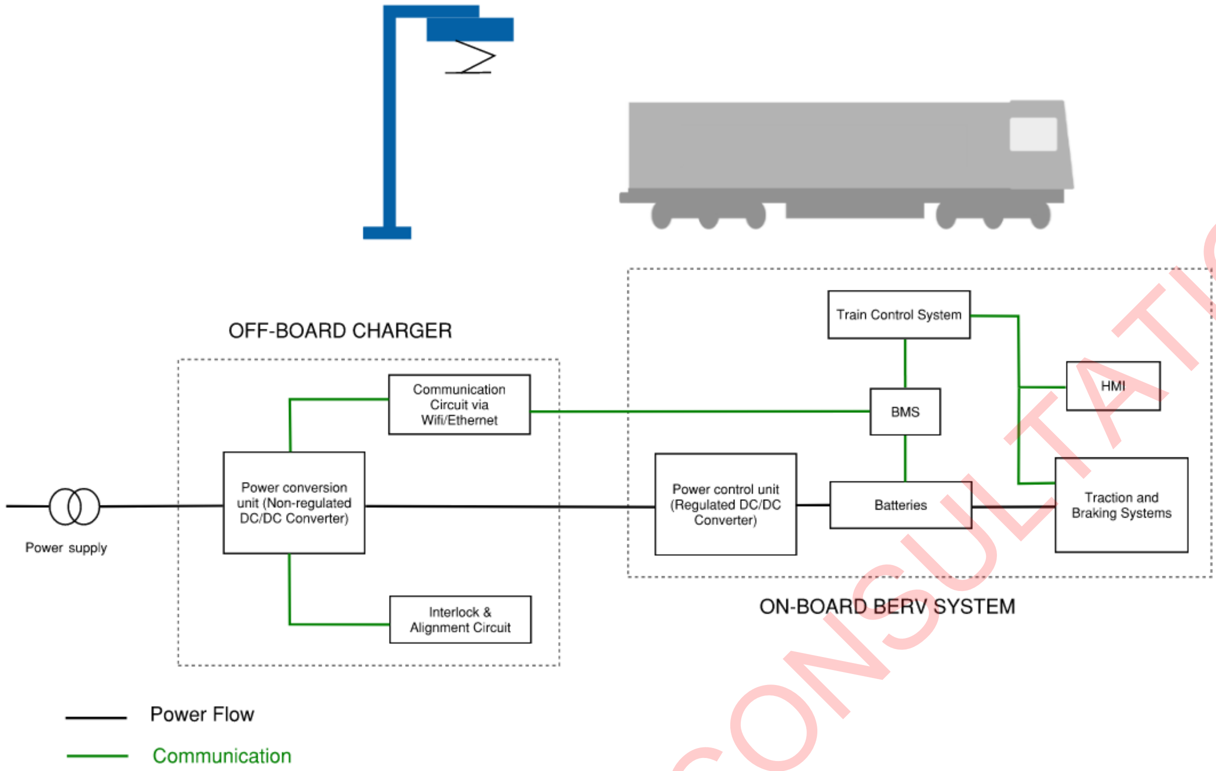

Figure 4 Typical interface between un-regulated DC static charging via roof mounted conductors and on-board BERV system

4.3 VCU ratings

Output operating voltage for static DC charging via roof mounted conductors shall be less than 1,500 V DC with a continuous output current range of 0 to 3,000 A DC.

Back-to-back charge cycles in any 24 hour period shall be possible unless specified otherwise (i.e. essentially continuous operation with short duration breaks of approx. 2 to 30 mins between charge cycles)

The desired output power and rate of charge may be achieved with multiple charging units and charging towers/reverse pantographs combined to charge a single BERV.

4.4 Ingress protection and access to electrically energised areas

The charging system shall prevent access to electrically energised areas and be able to withstand direct rain/water, dust exposure and anticipated atmospheric conditions with no harmful effects and be in accordance with AS 4024. Appropriate IP ratings shall be determined in accordance with AS 60529 and shall meet or exceed ingress protection according to IEC 62196 and IEC 61851.

> Commentary *C4.4*
>
> A typical IP rating for DC static charging system equipment is IP 65.

4.5 Cooling system and moisture control

Cooling of the charging unit may take the form of passive ventilation, forced mechanical ventilation or liquid cooling. If forced mechanical ventilation or liquid cooling is implemented, risks associated with reliability, dust or moisture ingress, maintenance, and leaks shall be assessed.

4.6 Internal wiring

Internal wiring of the charger and reverse pantograph system shall be in accordance with AS/NZS 3000.

4.7 Reverse pantograph

The reverse pantograph (or similar interface) shall be robust and designed to provide the required reliability and power (duty cycle) rating. Allowance shall be made for derating due to the arrangement and environmental conditions across the design life.

4.8 Earthing provisions

The charger and reverse pantograph shall have a protective earthing conductor to ensure safe earthing connection between the charger and the pantograph. The nearest rail adjacent the charging tower shall be connected to the same earth at the charger to ensure protective earthing of the BERV via the rail.

Risks of signalling system interference and rail voltage rise shall be investigated and mitigated when designing and implementing this earthing arrangement. AS 7505 principles shall be adhered to.

4.9 Reverse pantograph physical specifications

The contact noise emission shall be less than 70 db (A).

Static contact forces during lowering and raising the reverse pantograph shall lie within the boundaries defined in EN 50367, or as specified by the RSO.

4.10 Safety measures

The DC static reverse pantograph charging system shall be designed to prevent the presence of voltages dangerous to the human body on the pantograph when it is not connected to the BERV.

The charging system shall be designed to prevent contact with electrically energized parts on the charger or reverse pantograph. Live part clearances shall be compliant to AS 2067, climbing aids shall be avoided and the charging tower shall be non-climbable.

The charger shall be equipped with the following safety functions:

(a) earth leakage current detection (insulation monitoring) and automatic disconnection to prevent electric shock;

(b) overcurrent and overvoltage protection;

(c) reverse power (BERV to Charger) protection;

(d) ability for the operator to stop the charging process via communication system at any time;

(e) a hard-wired emergency stop switch direct to control system;

(f) an open door electrical/mechanical interlock (to ensure power is disconnected when charging unit door is opened);

(g) isolation and lockout provisions;

(h) alignment detection;

(i) time delay for pantograph operation - minimum 5 sec;

(j) status light indication;

(k) HMI indication; and

(l) automatic retraction and isolation in the event of fault.

Commentary *C4.10*

It is recommended that DC static reverse pantograph charging equipment is installed only in very low speed track areas such as at maintenance facilities (e.g., < 8km/hr), where the BERV can stop for extended duration underneath the charging tower, as approved by the RSO.

4.11 Communication and control system

Communication between the charging system and the BERV may be via:

(a) Wi-Fi/ethernet link communication; and/or

(b) radio frequency identification (RFID)

In case of Wi-Fi malfunction, a backup communication channel shall be provided in order to enable charging process between the charging system and the BERV.

The type of communication system and communication protocol used shall be in accordance with a recognized international and industry accepted standard.

4.12 Interface with BERV

Alignment of reverse pantograph with roof mounted conductor is critical for static DC reverse pantograph charging systems and shall be incorporated in the design. For multiple reverse pantographs systems feeding a single BERV, spacing and alignment of reverse pantographs with roof mounted conductors shall be incorporated in the design.

The charger should be compatible with the energy storage type and chemistry in use, rated for the appropriate charging rate, and compatible with different operating conditions.

4.13 Human factors

The charger shall be installed and configured to enable:

(a) charger ID;

(b) HMI user interface screen; and

(c) selection of charger ID on the BERV HMI screen.

4.14 Connection location

The reverse pantograph tower(s) shall be installed on straight track sections and the roof mounted conductor (collector) location on the BERV chassis shall be located in the mid-section of the vehicle/bogie, and, for multiple reverse pantograph systems, the subsequent conductors and charging towers are spaced at appropriate intervals along the track centreline to allow alignment between the reverse pantograph and the roof mounted conductor (collector).

4.15 Manual handling

The charging system shall be arranged such that manual handling effort for operational purposes is limited to a single operator selecting functions and performing commands from a HMI screen, switch or push button. Manual handling for installation and maintenance purposes shall follow principles provided under the jurisdiction workplace health and safety act and the rail operators safety management system.

4.16 Process of operation

The system shall be capable of one-person (or automatic via onboard battery management system) start-up and shutdown, with the driver (or automated vehicle) to position the BERV underneath the charging tower. The system shall be designed so the necessary operational requirements can be performed from within the cab of the BERV or from the charging unit.

The operational modes shall be as follows:

(a) Standby/idle mode: The locomotive is not ready to connect or is not in alignment with the reverse pantograph (or similar). The charging system is on standby waiting for a BERV to commence the pre-charging process.

(b) Pre-charge mode: The BERV is parked underneath the charging tower(s). Once the brakes are applied and the BERV is secured from movement, an onboard interlock is released allowing the BERV operator to request and establish communication between the BERV and the charger via the communication system (HMI/WiFi interface or similar). Once the communication is established, and alignment is confirmed, the system shall initiate physical connection of the reverse pantograph.

(c) Reverse pantograph connection: The reverse pantograph is lowered onto the roof mounted conductor. The charger controller acknowledges the roof mounted conductor is physically connected. An insulation check is performed with the connection engaged.

(d) Pre - charging: Closing of a pre-charge contactor is followed by a main contactor a few seconds later. The pre-charge contactor shall open, leaving the main contactor closed.

(e) Polarity check and voltage equalization: This shall be performed by the charger control system and establish voltage and current setpoints on the converters to ensure output capacitors are charged to a voltage equal to the battery voltage on the BERV to avoid sparks upon closing output contactors.

(f) Start command: Once output capacitors are fully charged, the charge process is ready to begin via a start command communicated from the BERV via the communication system. On receipt of the start command, charging commenced. Output power contactors shall be activated and any ventilation or cooling system contactors shall be closed. The transfer of energy shall be controlled by the charger.

(g) Battery charging: Charging of the batteries on the BERV shall continue automatically until the batteries are fully charged. It shall be possible to stop the charging process in the following situations:

    (i) due to a failure or fault detection;

    (ii) operator stop request via communication system; or

    (iii) emergency stop.

(h) End charging: The BERV requests the charger to stop charging once the batteries are fully charged or by request or intervention of the operator via communication system or emergency stop switch.

4.17 Emergency stop

In the event of a power failure, fault, or emergency stop command, a built-in-fail-safe function shall automatically disconnect the reverse pantograph (or similar interface) from the current collector contacts on the BERV and return the reverse pantograph to the rest position.

Emergency E-stop button/s that comply to ISO 13850 shall be provided to cut power from the charging process in the event of an emergency. A risk assessment shall be conducted to determine the location and quantity of emergency E-stop button/s required. These may be located in close proximity to the charging equipment and/or charging tower.

The E-stop push button shall be clearly marked, immediately accessible and be red in colour. It should have a minimum diameter of between 22 mm to 30 mm.

4.18 Security

Charging equipment for the reverse pantograph located at ground level shall be supplied with physical locking facilities on all external doors. Specific details including lock type, barrel and key shall be specified by the RSO.

A camera shall be provided, enabling the driver or operator to view the reverse pantograph operation and position, including the roof of the locomotive.

A light shall be provided to ensure the driver or operator can view the reverse pantograph operation and position, including the roof of the locomotive, in any day or night conditions.

Section 5 Static and dynamic charging via traditional OHW/pantograph interface or third rail (Up to 25 kV AC or 1500V DC)

5.1 OHW/Pantograph interface specifications

The BERV may be charged through OHW interface via a BERV mounted pantograph through either of the methods below:

(a) Static charging – BERV is stationary (no traction/park brakes applied) and pantograph is raised; or

(b) Dynamic charging – BERV is in motion and pantograph is only raised during charging or section of tracks.

The pantograph(s) in their lowered position, including all parts of the pantograph and associated equipment shall not exceed the appropriate rolling stock static outline as defined in AS 7507.

The technical requirements such as pantograph working range, force requirements, collector head parameters and tests shall be in accordance with EN 50206 series.

EN 50367 shall be used to achieve technical compatibility between pantographs and overhead contact line. The pantograph design, position and dimensional characteristics shall be defined by the RIMs route and interface standards where the BERV will operate.

The OHW and pantograph shall be rated to carry the maximum combined power of the charger (charging power), vehicle auxiliary power and any traction power used simultaneously (in the case of dynamic systems).

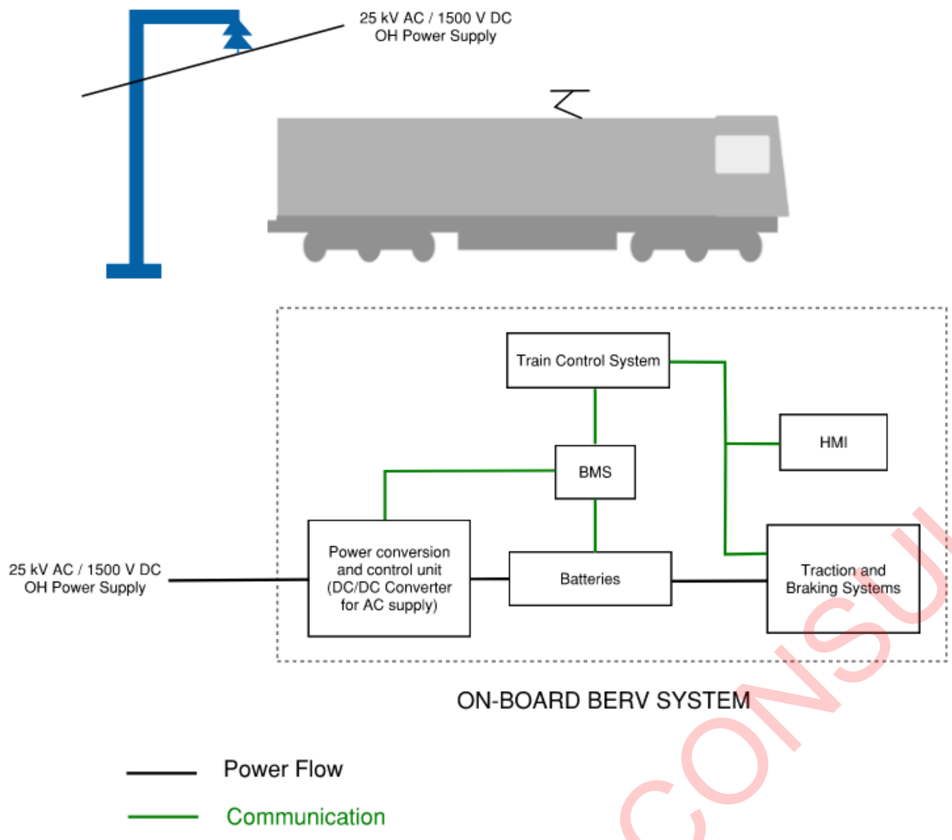

Figure 5 Typical interface between OHW and BERV via on-board pantographs

5.2 Third rail interface specifications

The third rail conductor and collector shoe shall be rated to carry the maximum combined power of the charger (charging power), vehicle auxiliary power and any traction power used simultaneously (in the case of dynamic systems).

Commentary *C5.2*
Traditional third rail systems can take the form of a third rail laid on ballast/track slab parallel to running rails or raised alongside the rail line outside the kinematic envelope and running at height parallel to the running rails with a collector shoe mounted on the rail vehicle which is used to collect power from the third rail. At the time of writing this standard, third rail systems were identified as being used in light rail systems in Australia. Proprietary systems used for catenary free solutions and utilising technologies such as induction or ground-based static charging systems is not covered by this Standard.

5.3 Requirements for dynamic charging/discharging

Where overhead/third rail contact charging is used in conjunction with onboard energy storage, the pantograph(s) shall be raised and lowered automatically as the BERV enters and leaves the charging position. Automatic raising and lowering of the pantograph(s) shall be initiated in response to track magnets, balises, or inductive loops.

Under normal operating conditions, the traditional pantograph/third rail system design shall provide sparkless operation during charging for the range of speeds up to the maximum operating speed of the BERV.

During dynamic charging, current collection from the OHW generates heat due to electrical resistance and it shall be dissipated in an efficient manner to prevent excessive temperature rise in the pantograph conductive strips.

The BERV's pantograph shall be monitored periodically for any conductive strip defects that can reduce contact area with the OHW, affecting the current collection efficiency. It includes broken conductive strip, abnormal wear and tear, edge chips, vertical cracks, reduced conductor thickness and deformed angle of pantograph relative to the BERV.

Vehicle to grid/power supply system via battery discharging shall be managed via the energy management system, however, this Standard does not cover discharging/reverse power schemes such as back to the grid.

The RSO and BERV OEM shall determine how batteries will be discharged for safety reasons prior to maintenance, removal, storage or transportation. Discharging of onboard batteries is not covered by this Standard.

5.4 Cooling system and moisture control

Not applicable.

> Commentary *C5.4*
>
> It is not expected that any specific cooling system other than ambient air for static and dynamic charging via traditional OHW/pantograph interface or third rail systems will be required.

5.5 Safety measures

The static and dynamic traditional pantograph/third rail charging infrastructure shall be designed to prevent the presence of voltages dangerous to the human body where accessible and prevent contact with electrically energized parts.

The wayside static and dynamic charging system shall incorporate the following safety functions:

(a) onboard earth leakage current detection and automatic disconnection to prevent electric shock;

(b) overcurrent and overvoltage protection;

(c) reverse power (BERV to charger) protection;

(d) ability for the operator to stop the charging process via onboard communication system at any time;

(e) a hard wired emergency stop switch direct to onboard control system;

(f) an open door electrical/mechanical interlock provided at substations supplying the power (to ensure power is disconnected when charging unit door is opened); and

(g) OHW or third rail systems compliant with the RSO standards and safety management system.

> Commentary *C5.5*
>
> AS/NZS 3000 and AS 2067 apply to the substation supplying the power, although electrical network upstream on the charger is excluded from this Standard.

5.6 Communication & control system

Not applicable.

> Commentary *C5.6*

There will be no communication link between the OHW (or third rail) and the BERV. On-board communication and control are through vehicle control and management system.

5.7 Interface with BERV

The onboard charger shall be compatible with both the wayside charging supply and the onboard energy storage type and chemistry in use, rated for the appropriate charging rate, and compatible with different operating conditions.

5.8 Human factors

The charger shall be installed and configured to enable:

(a) onboard HMI user interface screen; and

(b) onboard emergency stop button

5.9 Connection/charging location

Connection location is dependent on the traditional system employed (i.e. via pantograph or third rail collector shoe). Standards governing these systems shall be adopted based on individual RSO requirements.

Commentary *C5.9*

For static charging systems, the charging location(s) is recommended to be in slow traffic areas (i.e. <8 km/hr).

For dynamic charging systems, the charging location is dependent on individual rail operator requirements and can be throughout their electrified line or network. In dynamic systems, it is recommended that a traction power/charging demand study is performed to appropriately identify charging locations some or all of which can be on-route.

In 25 kV AC networks containing neutral sections, charging locations shall avoid the neutral sections.

5.10 Manual handling

The charging system shall be arranged such that manual handling effort for operational purposes is limited to a single operator selecting functions and performing commands from a HMI screen, switch or push button.

Manual handling for installation and maintenance purposes shall follow principles provided under the jurisdiction workplace health and safety act and the rail operators safety management system and existing standards, procedures, and guidelines.

5.11 Process of operation

Static or dynamic charging system via traditional OHW/pantograph interface or third rail, shall be capable of automatic start-up and shutdown for battery charging (e.g., initiated via track magnets, balises, or inductive loops).

In static and dynamic systems, the driver (or automated vehicle) shall position the BERV underneath the overhead wire (or align the vehicle above or to the side of the third rail in the case of third rail systems). In dynamic systems, the vehicle may be in position with pantograph up at all operational times (e.g., continuous electrified lines). The system shall be designed so the necessary operational requirements can be performed from within the cab of the BERV.

The charging operational modes shall be as follows:

(a) Standby mode: The OHW or third rail is energized. The locomotive is not ready to charge as it is either not positioned, has not raised the pantograph (or released the collector shoe in the case of third rail), or the battery or pantograph is disconnected from the DC bus of the rail vehicle. The charging system is electrified and on standby waiting for a BERV to be positioned and ready to commence the pre-charging process.

(b) Pre - charge mode: The BERV is parked (static system) or moving (dynamic system) underneath the overhead wire (or the vehicle aligned above or to the side of the third rail in the case of third rail systems). The system requires the onboard automation system to raise the pantograph (or release the collector shoe) once positioned which can be confirmed via track magnets, balises, or inductive loops.

(c) Battery charging: Once the pantograph (or collector shoe) has made contact with the energized system, an onboard interlocked contactor changes state allowing the BERV to charge. Onboard voltage equalization and transfer of energy shall be performed by the onboard automation and battery control system. Charging of the batteries on the BERV shall continue automatically until the batteries are fully charged. It shall be possible to stop the charging process in the following situations:

(i) due to an onboard failure;

(ii) operator stop request;

(iii) onboard emergency stop;

(iv) external failure or power supply trip; and/or

(v) overtemperature event or fire detection.

(d) End charging: The BERV energy management system requests the charger to stop charging via the onboard automation system once the batteries are fully charged or by request or intervention of the operator or via an emergency event detected in the onboard energy management system or if an emergency stop switch is pressed.

5.12 Emergency stop

An emergency stop shall be initiated via an emergency event detected in the onboard energy management system or activation of an emergency stop switch. A risk assessment shall be conducted to determine the location and quantity of emergency stop switches required

5.13 Handshaking

Robustness of handshaking is important and shall be performed via proven technology typically used onboard rolling stock to perform emergency control and signalling duties, including:

(a) track magnets;

(b) balises;

(c) inductive loops;

(d) RFID tags; and/or

(e) SIL rated control systems.

Section 6 Battery swap systems

Commentary *C6*

For the purposes of this Standard, battery swap systems involving batteries stored on wagons or battery electric tenders that can be disconnected from or coupled to a locomotive for re-charging and connected or re-coupled, in singular or multiple units as required. The intention of this system is to supply power (or additional power reserve) to a BERV utilizing similar charging methods as detailed in the sections above.

This Standard excludes battery swap systems that involve replaceable batteries intended to be physically removed from the BERV for the purposes of charging and reinstated on the vehicle once charged. Off rail and vehicle-to-vehicle charging systems are also excluded from this Standard.

6.1 On-rail static charging for battery swap systems

On rail static charging for battery swap systems shall be performed in the same manner as for BERVs as outlined in this Standard, however, the following additional requirements shall be included in the design:

(a) the battery electric tender (or batteries stored on wagons) must be compatible with the wayside static charging system;

(b) if an uncontrolled rectifier is used to supply DC power for static charging, the charge receive system onboard the battery electric tender (or wagons with batteries) shall be able to control charging voltage and current, via DC/DC converters (or similar), to each battery or battery string ensuring charging power is maintained within the tolerances of the installed batteries throughout the charging process; and

(c) control of charging must be via either the locomotive charging control system that the battery electric tender (or wagons with batteries) is connected to or a local trained operator (in the case of charging a de-coupled battery swap system).

6.2 On-rail dynamic charging for battery swap systems

On rail dynamic charging for battery swap systems shall be performed in the same manner as for BERVs as outlined in this Standard, however, the following additional requirements shall be included in the design:

(a) the battery electric tender (or batteries stored on wagons) must be compatible with the wayside dynamic charging system;

(b) the battery electric tender (or batteries stored on wagons) shall remain connected to a BERV (e.g., locomotive) when dynamic charging is in progress (i.e. Dynamic charging shall not be possible unless coupled to a drive vehicle); and

(c) the control of charging must be via the locomotive charging control system that the battery electric tender (or wagons with batteries) is connected to.

6.3 Safety measures

An emergency stop of charging shall be enabled by an E-stop button provided on both the battery electric tender (or wagons with batteries) and the locomotive for which it is intended to supply power to and the charging system itself.

An isolation and interlocking system shall be employed to prevent electric shock while coupling, decoupling or storing a battery swap system (battery electric tender or batteries stored on wagons).

When charging a coupled or de-coupled battery swap system, means shall be provided to maintain the same level of safety and protection as for a BERV utilizing charging methods and associated safety and protection functions as detailed in the sections above.

This includes items such as:

(a) interlocking with the braking system of the battery electric tender (or wagon with batteries) before charging;

(b) handshaking/pilots;

(c) emergency stops;

(d) electrical protection;

(e) overtemperature event or fire detection;

(f) safety alarms, sounds and alerts; and

(g) manual handling.

6.4 Communication system

Communication between the battery swap system and the charging system shall be via the coupled BERV (drive vehicle) when coupled. When charging a de-coupled battery swap system direct, means shall be provided for communication between the battery swap system and the charger.

6.5 Interface with BERV

The interface between the battery swap system (battery electric tender or batteries stored on wagons) and the BERV (drive vehicle) shall include the following in the design:

(a) adequate power rating of cables and connectors that interconnect between the battery swap system and the drive vehicle; and

(b) A communication system between the battery electric tender (or batteries stored on wagons) and the drive vehicle.

6.6 Human factors

Safety/operational signage and operating and maintenance instructions shall be provided to prevent incidents while operating or coupling or decoupling battery swap systems (battery electric tender or batteries stored on wagons).

6.7 Connection location

The cables and connectors from battery electric tender (or batteries stored on wagons) shall be level with the coupler. These cables and connectors shall not impact operation of rolling stock coupler, brake pipes or any other electrical connections.

AS 7524 should be used to determine the height of the coupler.

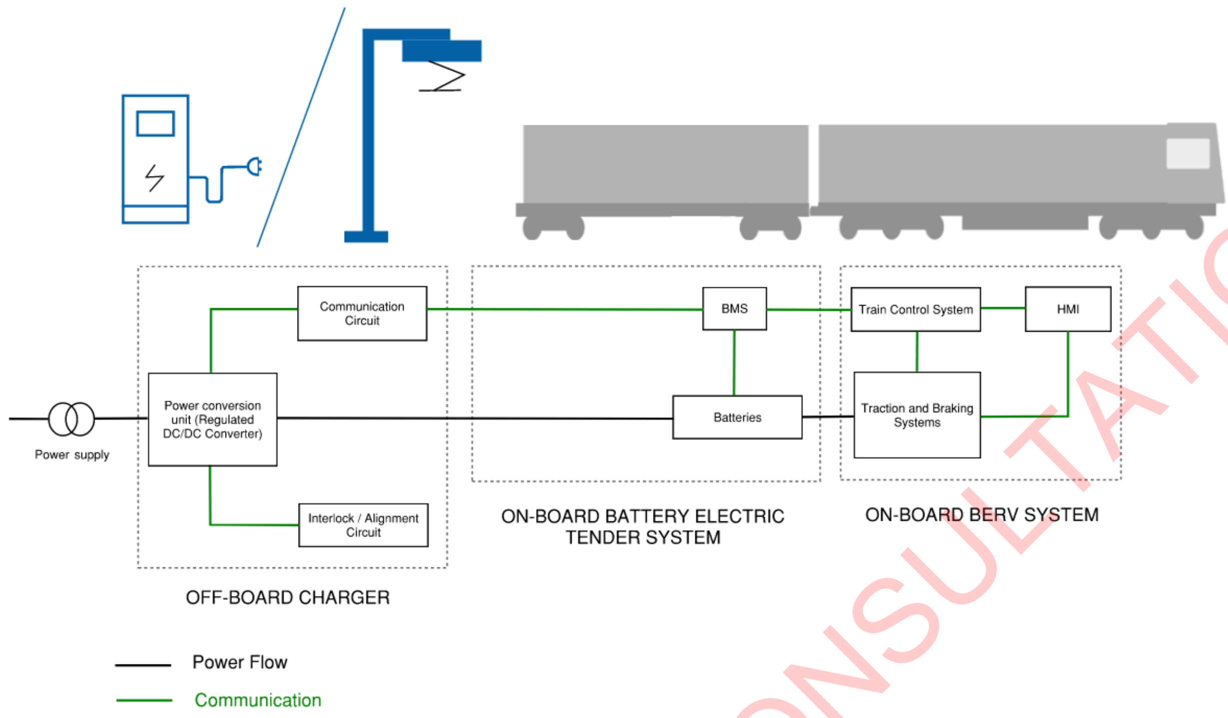

Figure 6 Typical interface between charging infrastructure, BET and a BERV

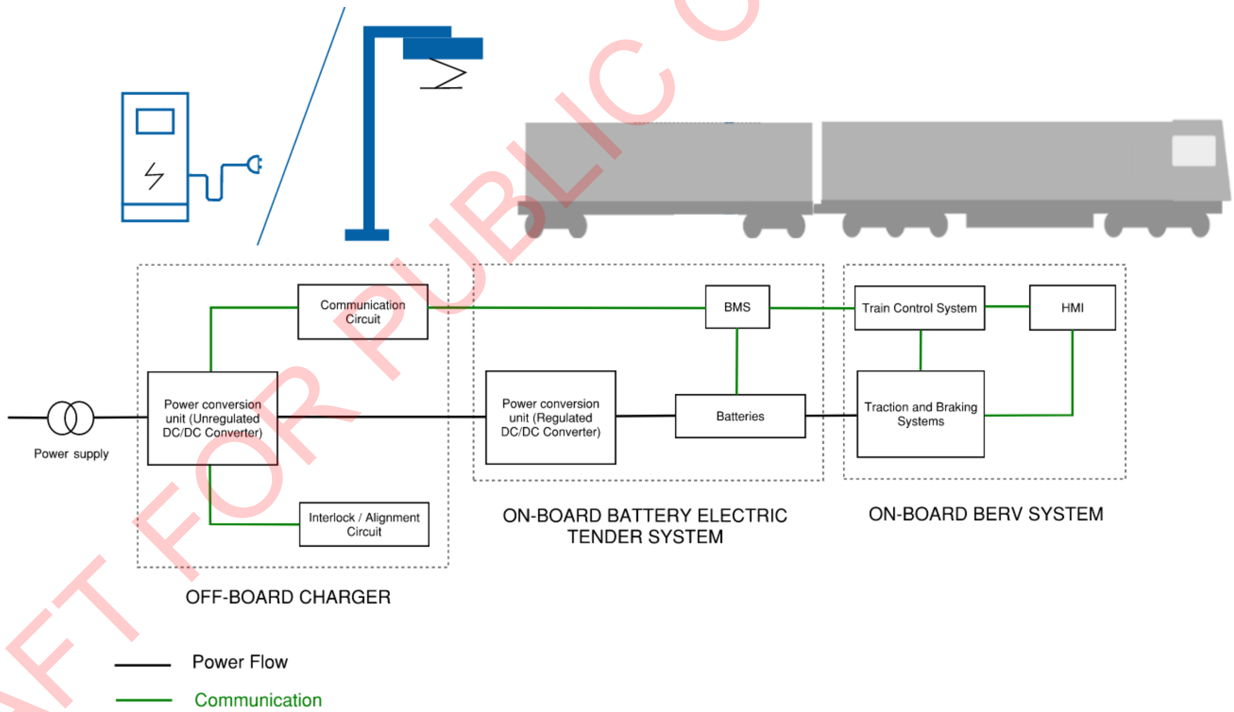

Figure 7 Typical interface between charging infrastructure, BET and a BERV (converter on-board)

6.8 Process of operation

The charging operation of a battery electric tender or batteries stored on wagons shall be similar to the charging methods as detailed in the Sections 3, 4, and 5.

Section 7 Mobile charging system

7.1 Requirements for mobile charging system

The mobile charging system shall provide high power DC static charging to the BERV via plug-in connector and adhere to the requirements outlined in Section 3 of this Standard.

Commentary *C7.1*

For the purpose of this Standard, a mobile charging system refers to an emergency power solution equipped with either a petrol/diesel-powered generator set, or a power bank module to be used at the maintenance facility or in case of trackside assistance for a stranded/discharged BERV.

7.2 Mobile charger design

In addition to requirements set out above, a mobile charging system shall also incorporate the in the design:

(a) vehicle type and suitability to safely transport the charging system and safety aspects of transporting stored energy products;

(b) access to enable connection from the mobile charging system (e.g., in cuttings or multiple track scenarios where hi-rail capability and/or a longer charging cable can be required or an emergency cable plug-in receptacle positioned at the front of the BERV(s) intended to be charged);

(c) power quality output of mobile charging system and compatibility with the battery system it is intended to charge;

(d) maintaining the same level of safety and protection as for a BERV utilizing charging methods and associated safety and protection functions as detailed in the sections above; and

(e) maintaining a communication system between the mobile charger system and the BERV as defined in the sections above plus the adequacy of power supply and reliability of that mobile based communication system.

Appendix A Additional relevant regulations, standards and guidelines for charging systems (Informative)

- AS 1319, Safety signs for the occupational environment
- AS/NZS 3008.1.1, Electrical Installations – Selection of Cables – Part 1.1: Cables for alternating voltages up to and including 0.6/1 kV – Typical Australian installation conditions
- AS/NZS 3013, Electrical Installations – Classification of the fire and mechanical performance of wiring system
- AS 4086.2, Secondary batteries for use with stand-alone power systems - Installation and maintenance
- AS/NZS 4509, Stand Alone Power Systems
- AS 7486, Railway energy storage: Rolling stock onboard electrical energy storage
- AS/CA S009, Installation requirements for customer cabling (Wiring rules)
- Australian Design Rules 109/00 – Electric Power Train Safety Requirements
- Australian Building Codes Board. National Construction Code 2019, Volume One, 'Building Code of Australia Class 2 to Class 9 Buildings'
- Australasian Fire Authorities Council. Fire Brigade Intervention Model
- Automotive Industry Standard, AIS-138 (Part 1) – Electric Vehicle Conductive AC Charging System
- Automotive Industry Standard, AIS-138 (Part 2) – Electric Vehicle Conductive DC Charging System
- BS EN IEC 63407, Conductive charging of electric vehicles – Contact interface for automated connection device (ACD)
- CharIN Design Guide for Combined Charging System
- CharIN Implementation Guide CCS Basic
- CharIN Position Paper of Charging Interface Initiative e.V. – DC CCS Power Classes
- Contact Lines for Electrified Railways – Planning, Design, Implementation, Maintenance
- EN 50119, Railway applications – Fixed installations – Electric traction overhead contact lines
- EN 50122-1, Railway applications – Fixed installations – Electrical safety, earthing and the return circuit – Part 1: Protective provisions against electric shock
- EN 50124-1, Railway applications – Insulation coordination – Part 1: Basic requirements – Clearances and creepage distances for all electrical and electronic equipment
- EN 50124-2, Railway applications – Insulation coordination – Part 2: Overvoltages and related protection
- ENA NENS 09-2014, National Guideline for the Selection, Use and Maintenance of Personal Protection Equipment for Electrical Arc Hazards
- Global Mining Guideline Group (GMG), Recommended Practices for Battery Electric Vehicles in Underground Mining
- IEC 61140, Protection against electric shock – Common aspects for installation and equipment

- IEC TS 63379, Plugs, socket-outlets, vehicle connectors and vehicle inlets – conductive charging of electric vehicles - Vehicle connector, vehicle inlet and cable assembly for Megawatt DC charging
- IEC 60309, Plugs, fixed or portable socket-outlets and appliance inlets for industrial purposes
- IEC 60364-5-54, Low voltage electrical installations: Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors
- IEC 60364-7-722, Low voltage electrical installations: Part 7-722: Requirements for special installations or locations – Supply of Electric vehicle
- ISO/IEC 15118-1, Road vehicles – Vehicle to grid communication interface – Part 1: General information and use-case definition
- ISO 6469-3, Electric road vehicles – Safety specifications – Part 3: Electrical safety
- ISO 17409, Electrically propelled road vehicle – Conductive power transfer – Safety requirements
- IEC PAS 62840-3, Electric vehicle battery swap system – Part 3: Particular safety and interoperability requirements for battery swap systems operating with removable RESS/battery systems
- NFPA 70E, Standards for Electrical Safety in the Workplace
- SAE J1772, Electric vehicle and plug in hybrid electric vehicle conductive charge coupler

Appendix B Hazard register (Informative)

Hazard Number	Hazard
5.2.1	Rolling Stock - Harm to infrastructure by rolling stock - Derailment or Collision, Human Error, Design Failure, Security Breach, Loads not Secure, and or Vandalism
5.3.1	Rolling Stock - Harm to persons - Derailment or Collision, Human Error, Track Failure, Design Failure, Health, Organisational SMS Failure, Security Breaches, Loads not Secure and or Vandalism
5.5.1	Rolling Stock - Harm to Rolling Stock Related Processes - Derailment or Collision, Human Error, Track Failure, Track Obstruction, Design Failure, Health Failure, Organisational SMS Failure, Security Breach, Load not Secure and or Vandalism
5.14.1.12	Rolling Stock - Alerting system failure - Design Failure, Security Breach and Vandalism - Inadequate performance of vehicle equipment (Failure with interface to wayside systems - Hardware faulty - System faulty)
5.16.1.5	Rolling Stock - Train protection system failure - Derailment or Collision, Human Error, Track Failure, Track Obstruction, Design Failure, Health Failure, Organisational SMS Failure and or Vandalism - Wayside systems (System faulty)
5.32.1	Rolling Stock – Fire - Derailment or Collision, Human Error, Track Failure, Track Obstructions, Design Failure, Health Failure, Organisational SMS Failure, Security Breach, Load not Secure and or Vandalism
5.40.1.21	Rolling Stock - Person/s being crushed - Derailment or Collision, Human Error, Track Failure, Track Obstructions, Design Failure, Health Failure, Organisational SMS Failure, Security Breach, Load not Secure and or Vandalism - Electrical/electronic equipment not being adequately shielded.
5.41.1.1	Rolling Stock – Radiation - Derailment or Collision, Human Error, Track Failure, Design Failure, Health Failure, Organisational SMS Failure, Security Breach, Load not Secure and or Vandalism - Affecting persons with pacemakers, defibrillators, hearing aids etc. (Unsafe exposure to non-ionising radiation)
5.41.1.17	Rolling Stock – Radiation - Derailment or Collision, Human Error, Track Failure, Design Failure, Health Failure, Organisational SMS Failure, Security Breach, Load not Secure and or Vandalism - High voltage cabling not adequately shielded (Electrical equipment - Magnetic and electromagnetic fields - Unsafe exposure to non-ionising radiation)
5.42.1	Rolling Stock - Electric shock - Failure of protection - Derailment or Collision, Human Error, Track Failure, Track Obstructions, Design Failure, Health Failure, Organisational SMS Failure, Environmental Impact, Security Breach, Load not Secure, and or Vandalism

6.5.1	Infrastructure – Harm to Persons - Derailment or Collision, Human Error, Track Failure, Design Failure, Organisational SMS Failure and or Environmental Impact
6.17.1	Infrastructure - Fire - Derailment or Collision, Human Error, Health Failure, Design Failure, Security Breaches and or Vandalism
6.24.1	Infrastructure - Electric shock - Derailment and or Collision, Human Error, Track Failure, Threat, Design Failure, Organisational SMS Failure, Security Breach, Loads not Secure and or Vandalism
7.2.1.6	Human Factors – Harm to Persons - Lack of training and or competence
7.2.1.15	Human Factors - Harm to Persons - Poor equipment layout
7.3.1.6	Human Factors - Damage to Rolling Stock and or Infrastructure - Lack of training and or competence
7.3.1.15	Human Factors - Damage to Rolling Stock and or Infrastructure - Poor equipment layout
8.2.1.11	Operations - Damage to Rolling Stock and or Infrastructure - Human Error, Design Failure, Health Failure, Organisational SMS Failure, Environmental Impact, Security Breach, Vandalism and or Threat

Appendix C Bibliography (Informative)

The following referenced documents are used by this Standard for information only:

- AS 7524, Couplers and drawgear
- AS 7529.1, Australian Railway Rolling Stock- Fire Safety - Locomotive
- EN 50121, Railway applications - Electromagnetic compatibility
- EN 50155, Railway applications - Rolling stock - Electronic equipment
- ISO 14001, Environmental Management Systems
- IEEE Standard 519 'Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems'
- RISSB Guideline, Condition Monitoring of Rolling Stock
- RISSB Guideline – Requirements for the Procurement of Rolling Stock
- Australasian Railway Association – On Track to a Sustainable Future