AS 7486:2022

Railway energy storage: Rolling stock onboard electrical energy storage

RAIL INDUSTRY SAFETY AND STANDARDS BOARD

Rolling Stock Standard

Please note this is a RISSB Australian Standard® draft

Document content exists for RISSB product development purposes only and should not be relied upon or considered as final published content.

Any questions in relation to this document or RISSB's accredited development process should be referred to RISSB.

RISSB Office

Phone:
(07) 3724 0000
Overseas: +61 7 3724 0000

Email:
info@rissb.com.au

Web:
www.rissb.com.au

AS 7486 **Assigned Standard Development Manager**

Name: Ian Routcliffe

Phone: 0429 432095

Email: iroutcliffe@rissb.com.au

This Australian Standard® AS 7486 Railway energy storage: Rolling stock onboard electrical energy storage was prepared by a Rail Industry Safety and Standards Board (RISSB) Development Group consisting of representatives from the following organisations:

Frazer-Nash Consultancy	Metro Trains Melbourne	Keolis Downer
AECOM	ARUP	PTV(DoT)
TfNSW	PTA	Aurizon
BHP	Rail Project Victoria	

The Standard was approved by the Development Group and the Rolling Stock Standing Committee in Select SC approval date. On Select Board approval date the RISSB Board approved the Standard for release.

This standard was issued for public consultation and was independently validated before being approved.

Development of the Standard was undertaken in accordance with RISSB's accredited process. As part of the approval process, the Standing Committee verified that proper process was followed in developing the Standard

RISSB wishes to acknowledge the positive contribution of subject matter experts in the development of this Standard. Their efforts ranged from membership of the Development Group through to individuals providing comment on a draft of the Standard during the open review.

I commend this Standard to the Australasian rail industry as it represents industry good practice and has been developed through a rigorous process.

Deb Spring
Exec. Chair / CEO
Rail Industry Safety and Standards Board

Keeping Standards up-to-date

Australian Standards developed by RISSB are living documents that reflect progress in science, technology and systems. To maintain their currency, Australian Standards developed by RISSB are periodically reviewed, and new editions published when required. Between editions, amendments may be issued. Australian Standards developed by RISSB could also be withdrawn.

It is important that readers assure themselves they are using a current Australian Standard developed by RISSB, which should include any amendments that have been issued since the Standard was published. Information about Australian Standards developed by RISSB, including amendments, can be found by visiting www.rissb.com.au.

RISSB welcomes suggestions for improvements and asks readers to notify us immediately of any apparent inaccuracies or ambiguities. Members are encouraged to use the change request feature of the RISSB website at: http://www.rissb.com.au/products/. Otherwise, please contact us via email at info@rissb.com.au or write to Rail Industry Safety and Standards Board, PO Box 518 Spring Hill Qld 4004, Australia.

Notice to users

This RISSB product has been developed using input from rail experts from across the rail industry and represents good practice for the industry. The reliance upon or manner of use of this RISSB product is the sole responsibility of the user who is to assess whether it meets their organisation's operational environment and risk profile.

AS 7486:2022

Railway energy storage: Rolling stock onboard electrical energy storage

Document details

First published as: Enter first publication identifier (AS XXXX:yyyy)

ISBN Enter ISBN.

Document history

Publication Version	Effective Date	Reason for and Extent of Change(s)
2022	Select Board approval date	

Approval

Name	Date
Rail Industry Safety and Standards Board	Select Board approval date

Copyright

This Standard was prepared by the Rail Industry Safety and Standards Board (RISSB) Development Group AS 7486 Railway energy storage: Rolling stock onboard electrical energy storage. Membership of this Development Group consisted of representatives from the organisations listed on the inside cover of this document

This paragraph is used to indicate if this Standard supersedes other documents in whole or in part. … only change this paragraph if it is applicable

Compliance

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

1. Requirements.
2. Recommendations.
3. Permissions.
4. 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 recognise 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 / hazardous events within the railway industry. Where applicable to this Standard, these are listed in Appendix A: Australian Rail Risk Model (ARRM).

Contents

Introduction.. 6
1 Scope and general 7
1.1 Scope 7
1.2 Out of scope 7
1.3 Normative references.. 7
1.4 Terms, definitions, and abbreviated terms 8
2 Energy storage system (ESS) general context 12
2.1 Applications and purpose of the ESS within rolling stock 12
2.2 Description of the ESS within rolling stock 12
2.3 Systems interfacing with the ESS 15
3 ESS requirements and specification 17
3.1 General design principles.. 17
3.2 Assessment to inform ESS selection and implementation............................ 17
3.3 Operational requirements for energy and power performance 21
3.4 Interoperability 23
3.5 Environment.. 24
3.6 Rail vehicle certification and compliance... 26
3.7 Testing.. 26
3.8 Construction.. 26
3.9 Installation 26
3.10 Maintenance 27
3.11 Disposal.. 28
4 Safety... 30
4.1 General.. 30
4.2 Collision and crash worthiness.. 30
4.3 Electric shock and short circuit Protection.. 31
4.4 Thermal runaway, fire and explosion 33
4.5 Toxic and corrosive material 36
4.6 Component and release at velocity and fluid release at pressure................. 36
4.7 Handling and storage.. 37
4.8 Dynamic stability... 37
4.9 Out of gauge 38
4.10 Structural 38
4.11 Electromagnetic compatibility... 39
4.12 Acoustic noise.. 39
4.13 Functional failure 39
4.14 Human performance 40
4.15 Software and cyber security.. 41
4.16 Hazardous materials... 41

Appendix contents

Appendix A Hazard register (informative) ... 42
Appendix B Bibliography ... 45

Introduction

This standard supports Australian rolling stock operators (RSO) to specify and utilize onboard batteries and electric double-layer capacitors (EDLC) used mainly for traction purposes (propulsion and braking) so that they are used safely, effectively, and reliably in the Australian context and networks, throughout the life of the energy storage system (ESS). This document provides a basis for RSOs, vehicle manufacturers, and ESS manufacturers to understand and communicate the requirements on ESS.

This is done through guiding the understanding of:

(a) the ESS's contribution to rolling stock performance goals;

(b) the ESS's interface with onboard and offboard systems;

(c) the rolling stock operational context;

(d) international and national standards related to rolling stock with onboard ESS.

Adherence to this RISSB standard does not ensure compliance with the national law, national guidelines, standards, and codes of practice. However, this standard supports the duties under the Rail Safety National Law by articulating potential hazards arising from the ESS in the operational context.

Design principles are presented to support the elimination or mitigation of safety risk to be safe, so far as is reasonably practicable (SFAIRP). Where applicable, this standard also directs the reader to existing standards that can provide specific requirements and information.

This standard builds on existing national and international standards by providing additional guidance and requirements for ESS. The main existing international standards relevant to onboard ESS using batteries are IEC 62864-1, IEC 61881-3 and IEC 62928. Performance based requirements, recommendations, and guidance will not replicate existing published requirements and recommendations.

Note that IEC 62864-1 presents the relationship between the standards in terms of levels of systems and subsystems.

(a) Level 1 is the vehicle/system interface.

(b) Level 2 is system and interfaces.

(c) Level 3 is components.

(d) Level 4 is subcomponents.

The following provides a summary of the content of these standards and the additional guidance and recommendations that will be provided in this standard:

(a) IEC 62864-1 for power supply with onboard energy storage system covers basic system electrical configuration, tests to verify and some guidelines for manufacturing and evaluating. It is defined as Level 1/2, or across the vehicle/system interface and system levels. This standard will build on IEC 62864-1, by providing further guidance that considers the Australian rail operational context to inform:

  i. the performance requirements, design guidance throughout the ESS lifecycle; and

  ii. the identification and mitigation of relevant safety hazards.

(b) IEC 61881-3 for electric double-layer capacitors (EDLC) is at the component level (Level 4) within the IEC standard structure. It focusses on the quality requirements and testing of EDLCs. It provides guidance to support their design, selection and use, including their installation and operation. This standard will build on IEC 61881-3 by providing further guidance that considers the Australian rail operational context to inform:

   i. the performance requirements and design guidance throughout the ESS lifecycle;

   ii. the identification and mitigation of relevant safety hazards

(c) IEC 62928 for lithium-ion batteries is at the component level (Level 4) within the IEC standard structure and discusses the design, operation, parameters, safety recommendations, data exchange, routine and type tests as well as marking and designation. It includes broad coverage of operational conditions as well as some guidance in using the operational pattern for sizing. This standard will build on IEC 62928 by providing further safety guidance related to the Australian rail operational context.

1 Scope and general

1.1 Scope

The scope of this standard is the system functional and safety requirements for ESS which use batteries and EDLCs to be used on rolling stock in Australia. It focusses on hazards associated with lithium-ion batteries and EDLCs and their implementation, however safety and design guidance is equally relevant to other battery technologies including solid state and metal air batteries.

1.2 Out of scope

The following are out of scope:

(a) Wayside energy storage.

(b) Energy storage technologies other than batteries or EDLCs.

(c) Any requirements and recommendations on other systems that are not explicitly related to supporting the ESS function and safety. Systems that interface with the ESS are discussed in Section 2.4.

1.3 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 7501, *Rolling stock compliance certification*
- AS 7509, *Rolling stock – Dynamic Behaviour*
- AS 7519 (all parts), *Railway Rolling Stock – Bogie Structural Requirements*
- AS 7520 (all parts), *Australian Railway Rolling Stock – Body Structural Requirements*

- AS 7521, *Interior Crashworthiness*
- AS 7529 (all parts), *Australian Railway Rolling Stock – Fire Safety*
- AS 7530, *Electrical systems*
- AS 7540, *Rail Systems Interoperability*
- AS 7633, *Railway infrastructure: Clearances*
- AS 7770, *Rail Cyber Security*
- AS 7772, *EMC Management*
- IEC 61881-3, *Railway Applications – Rolling Stock Equipment – Capacitors for power electronics*
- IEC 62864-1, *Railway Applications – Rolling Stock – Power supply with onboard energy storage system – Part 1: Series Hybrid System:* Specifies general requirements for the onboard energy storage system at a system level.
- IEC 62928, *Railway Applications – Rolling Stock – Onboard lithium-ion traction batteries:* States the requirements for railway traction applications.

NOTE 1: Documents for informative purposes are listed in a Bibliography at the back of the Standard.

NOTE 2: The three IEC standards referenced in the Introduction are at different levels of the system hierarchy for a vehicle. This standard most directly aligns with the level of IEC 62864 and provides standards and recommendations at a system level, with an awareness of the influence of the subcomponents – i.e. batteries and EDLCs.

1.4 Terms, definitions, and abbreviated terms

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

1.4.1

BMS

battery management system

[SOURCE: IEC 62928:2018, 3.1.29]

1.4.2

BTMS

battery thermal management system

[SOURCE: IEC 62928:2018, 3.1.30]

1.4.3

capacitor element

indivisible part of a capacitor consisting of two electrodes (typically made of carbon) separated by an electrolyte impregnated separator

[SOURCE: IEC 61881-3:2012, 3.1]

1.4.4

capacitor cell

one or more capacitor elements, packaged in the same enclosure with terminals brought out

[SOURCE: IEC 61881-3:2012, 3.2]

1.4.5

capacitor module

assembly of two or more capacitor cells, electrically connected to each other with or without additional electronics

[SOURCE: IEC 61881-3:2012, 3.3]

1.4.6

capacitor bank

assembly of two or more capacitor modules

[SOURCE: IEC 61881-3:2012, 3.4]

1.4.7

capacitor

general term used when it is not necessary to state whether a reference is made to capacitor cell, module or bank

[SOURCE: IEC 61881-3:2012, 3.5]

1.4.8

CSIRO

Commonwealth Scientific and Industrial Research Organisation

1.4.9

direct current

DC

electrical current that flows consistently in one direction

1.4.10

EDLC

electric double-layer capacitor

[SOURCE: IEC 62864-1:2016, 3.1.22]

1.4.11

environment

unless stated otherwise, refers to the natural, induced, and operational environment.

1.4.12

ESS

energy storage system

physical system which consists of one or more ESUs and the other equipment required to connect to the DC link such as converters, control and monitoring systems, inductors, protection devices, cooling systems, etc.

[SOURCE: IEC 62864-1:2016, 3.1.22]

1.4.13

energy storage unit

ESU

physical equipment which is comprised of energy storage technologies such as batteries or EDLC

[SOURCE: IEC 62864-1:2016, 3.1.20]

1.4.14

offboard

not installed on the rolling stock

1.4.15

OHW

overhead wiring

electrical cable providing traction power to electrified rolling stock

1.4.16

onboard

installed on the rolling stock

1.4.17

PPS

primary power source

1.4.18

regeneration

the function of capturing energy while braking so that the energy can be used for another purpose

1.4.19

through-life

the whole lifecycle of the ESS and its interaction with the vehicle and railway enterprise. This includes considering the ESS's installation, commissioning, operation, maintenance / support and final disposal

1.4.20

train control management system

TCMS

the combined control systems that sit at the top of the onboard consist control hierarchy, from which all signals to lower-level control systems flow

1.4.21

vehicle

single item of rolling stock

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

2 Energy storage system (ESS) general context

2.1 Applications and purpose of the ESS within rolling stock

ESS can be used for the following applications and purposes:

(a) As a primary or secondary power supply for the rolling stock.

(b) To reduce peak loads on the traction power supply network. For example, by supplementing the OHW traction power supply system during acceleration from stand still.

(c) To increase electric traction system efficiency and reduce emissions, either by:

i. capturing energy during regenerative braking and making it available during power. This energy would otherwise be directed to the braking resistors to be converted to heat and lost;

ii. allowing for zero emission coasting and idling with other power sources off, by providing an alternative power supply; or

iii. allowing other power sources, such as diesel engines, to operate at their peak thermal efficiency. For example, diesel engine efficiency varies with the loading on the engine. The ESS can allow the diesel generator to maximize operation at peak efficiency for a longer period by receiving and storing excess power for later use rather than being forced to operate at an operating condition with lower efficiency.

(d) To reduce noise, for example in noise sensitive areas when the ESS is used as the PPS instead of a diesel engine. This can allow for quiet shunting in yards and quiet acceleration from stations. The ESS can also reduce operating noise by allowing diesel-electric trains to minimize the use of maximum engine revolutions or power notch by providing the extra power demand of the traction system.

(e) To provide a back-up power supply to increase the availability of rail vehicle systems when other power and propulsion systems or energy sources are unavailable or have limited capacity.

(f) To reduce the amount of track-side electrical infrastructure required in some locations, such as OHW.

IEC 62864-1:2016 Section 4 provides a comprehensive description of various onboard ESS configurations and modes of operations for different types of rolling stock.

2.2 Description of the ESS within rolling stock

IEC 62864-1:2016 Section 4 provides an overview of some possible electrical system configurations including an ESS, where the ESS can comprise of the following electrical components:

(a) An energy storage unit (ESU).

(b) A chopper to convert the ESU output voltage to that required for the vehicle.

(c) An ESS bypass switch within the system boundary.

The component of key interest within the ESS is the ESU due to the novelty of large-scale batteries and EDLCs and the severity of the hazards they can cause. The ESU consists of one or multiple components that can repeatedly store and release electrical energy in a controlled manner. ESU component technologies other than batteries and EDLCs are out of the scope of this Standard as per section 1.2.

The ESU is likely to have a power level that is of the same order of magnitude as the power of the traction system. This can vary significantly from vehicle to vehicle depending on the purpose of the train, ranging from light rail through to freight. The ESU is likely to store energy so that it can provide the functions described in Section 2.1 for a useful period before recharging, which can range from seconds to hours based on the implementation and operation.

Figure 1 below shows possible rolling stock electrical system configurations including an ESS.

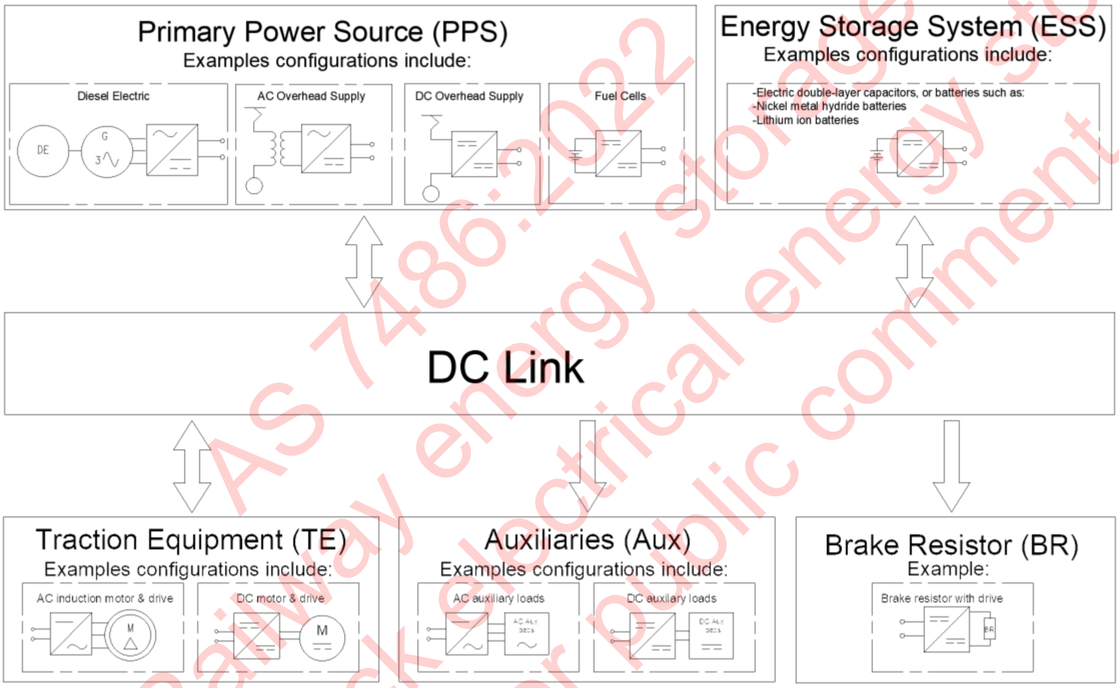

Figure 1: Block diagram of a series hybrid system.

A common arrangement of capacitor cells into capacitor modules, and of capacitor modules into capacitor banks, is shown in figure 2 below. IEC 61881-3:2012 Annex A provides additional detail for this type of arrangement .

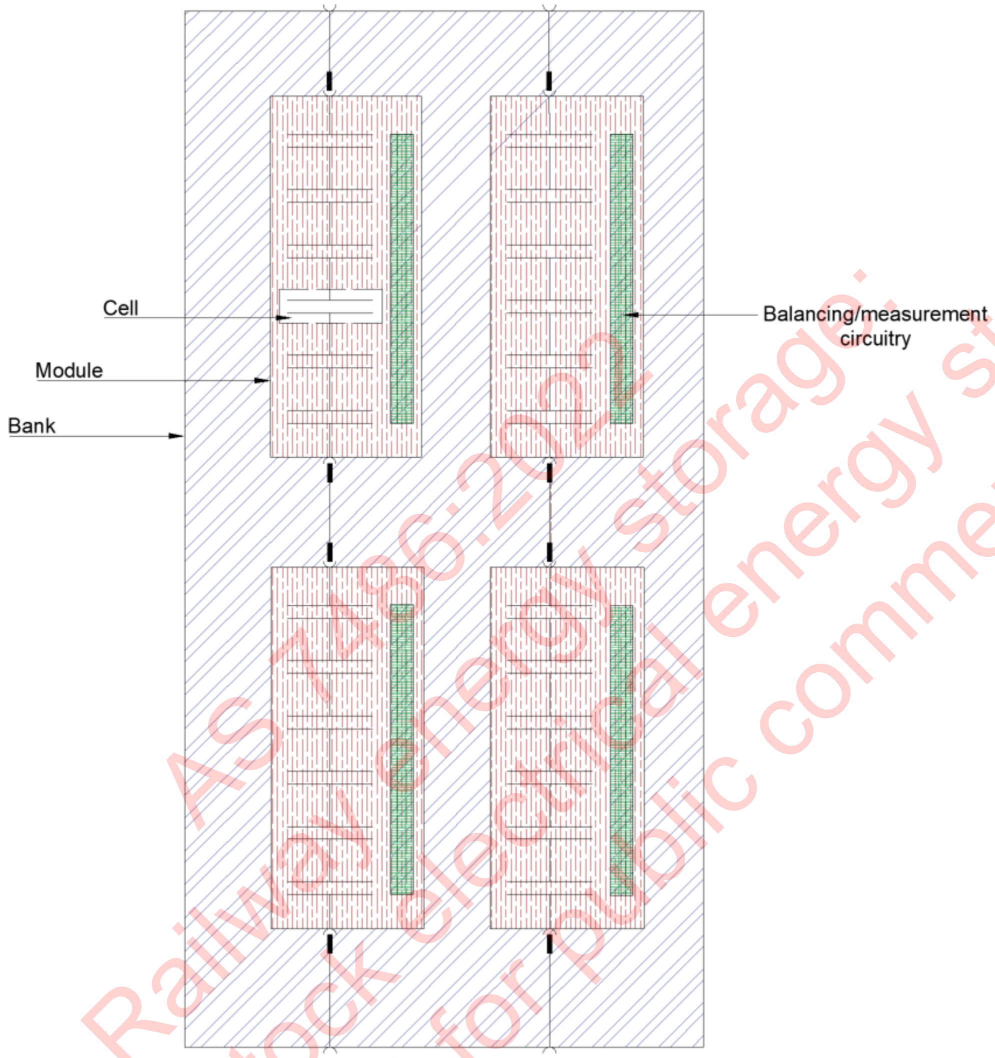

Figure 2: Block diagram of a series hybrid system.

Figure 3 below shows ESSs to include the battery system as the ESU, and can comprise of a battery converter, inductor, switchgear, and cooling system. Within the battery system there is a battery management system (BMS), which can include a battery thermal management system (BTMS). IEC 62928:2017 Section 4 provides further information on the configuration of battery systems.

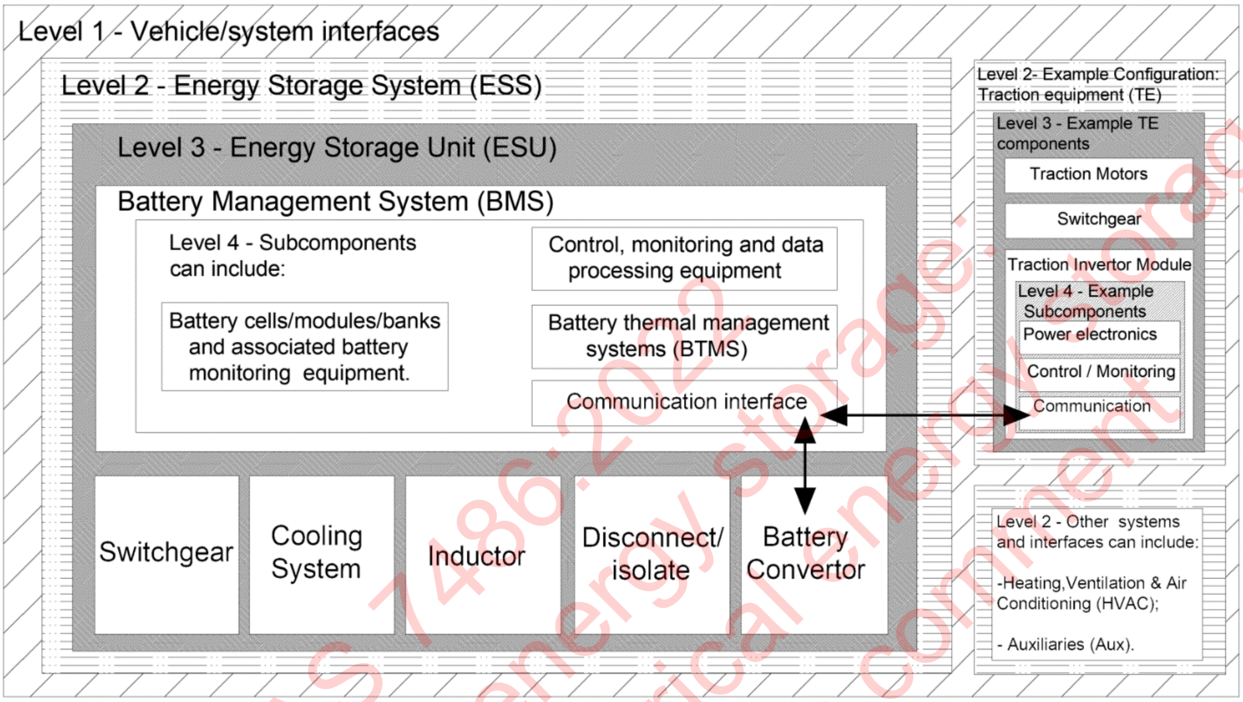

Figure 3: Block diagram of a battery ESS.

2.3 Systems interfacing with the ESS

The ESS can interface with the following systems, through the interfaces described below:

(a) Train control & management system (TCMS): The overall protection and control system, or systems, for the vehicle. The interface with the TMS takes the form of connectors and cables carrying electrical control signals comprising of either analogue voltages from sensors, or logical signals to communicate data.

(b) Vehicle electrical systems: The ESS can be connected to the DC link as illustrated in IEC 62684-1:2016 Section 4 and illustrated in Figure 1. The DC link is the main traction power connection between the PPS (onboard power generation or external traction electrical supply through a current collection device) and the traction equipment including the dynamic brake choppers. Other loads powered by the PPS such as the auxiliary power supply system can also be connected to the DC link. The ESS can provide power to the DC link for the traction equipment and can be recharged using power from the DC link from the PPS and or from the traction equipment during electrodynamic braking. As power flow is often controlled by power electronics an isolating switch can be included at the interface between the ESS and the DC link for safety.

(c) Offboard electrical systems: The ESS can directly connect to offboard electrical systems without connection to the vehicle DC link. An offboard DC connection can distribute power between the ESS to offboard the vehicle. This is most likely to be present as an independent charging connection while stationary.

(d) Cooling system: The ESS can include an internal cooling system to take heat away from the internal subsystems and components to the boundary of the ESS. An additional cooling system, through an active fluid interface, can then be used to remove waste heat from the ESS boundary, such as a heat exchanger, if the environment for the ESS does not provide sufficient passive cooling.

(e) Vehicle structure: The system which reacts to loads to hold vehicle components in position. The interfaces are the mechanical fixings such as bolts, rivets, spigots and anti-vibration mounts to hold the ESS to the structure in position, withstand loads, balance loads across the vehicle and manage shock and vibration.

(f) Safety systems: The ESS can be supported by external safety systems which can include isolators, extinguishers, smoke extraction and venting. The ESS can be connected to these systems, or it can be independent from them. For example the ESS can provide temperature signals to the TCMS to operate an external extinguishing system, or alternatively an independent sensor connected solely to the TCMS can detect high temperatures and operate the extinguishing system. A fluid interface can be used to enable venting from the ESS. Gas from the ESS can need to be vented in operation or in response to high temperature.

(g) Installation systems: Systems that are used to install and commission the ESS onto the vehicle.

(h) Maintenance systems: Systems that are used to maintain the ESS.

(i) Disposal systems: Systems that are used to dispose of the ESS.

3 ESS requirements and specification

3.1 General design principles

These principles are to support the aim that ESS are used safely, effectively and reliably in the Australian context, throughout the life of the ESS. They shall be applicable to new or retrofitted vehicles:

(a) The ESS and the vehicle it is integrated with shall be safe, so far as is reasonably practicable (SFAIRP), throughout its lifecycle for its intended application and environment.

(b) The ESS shall be specified to deliver its purpose in its environment and to effectively enable all stages of its lifecycle.

(c) The ESS shall be specified to address the through-life factors and hazards in Section 3 and 4 of this document.

(d) The ESS shall perform as defined in the system requirements.

(e) The ESS implementation shall have requirements on it to allow the vehicle to meet its requirements, including the interfaces from the vehicle to offboard systems.

3.2 Assessment to inform ESS selection and implementation

3.2.1 Assessment approach

Assessments should be conducted to evaluate a candidate ESS specification and implementation approach. Section 3 and Section 4 of this document provide prompts for aspects to be considered.

Assessments can provide:

(a) confidence that the candidate ESS and implementation complies with the general design principles; and

(b) confidence as to which candidate ESS and implementation is the preferred option when alternatives are considered.

The overall assessment process should consist the following:

(a) Determining the level of confidence needed in the overall assessment, for example high, medium, and low. This is guided by the level of risk, both technical and commercial, that can be associated with the use of the ESS. For example, if the ESS is to be critical to the operation of the vehicle, if the operating environment for the vehicle is particularly hazardous or if the scale of the investment into the ESS is significant relative to the budget of the operating organization then this would suggest that a high level of confidence is needed.

(b) Determining the factors of interest and how important they are in the overall assessment.

(c) Assess the factors of interest. The results can take the format of pass/fail, a ranking, or a score.

(d) Combine the results of individual factors assessments, with their respective importance, to reach a final decision on the overall assessment.

The process for combining the assessments of individual factors is shown in Figure 4.

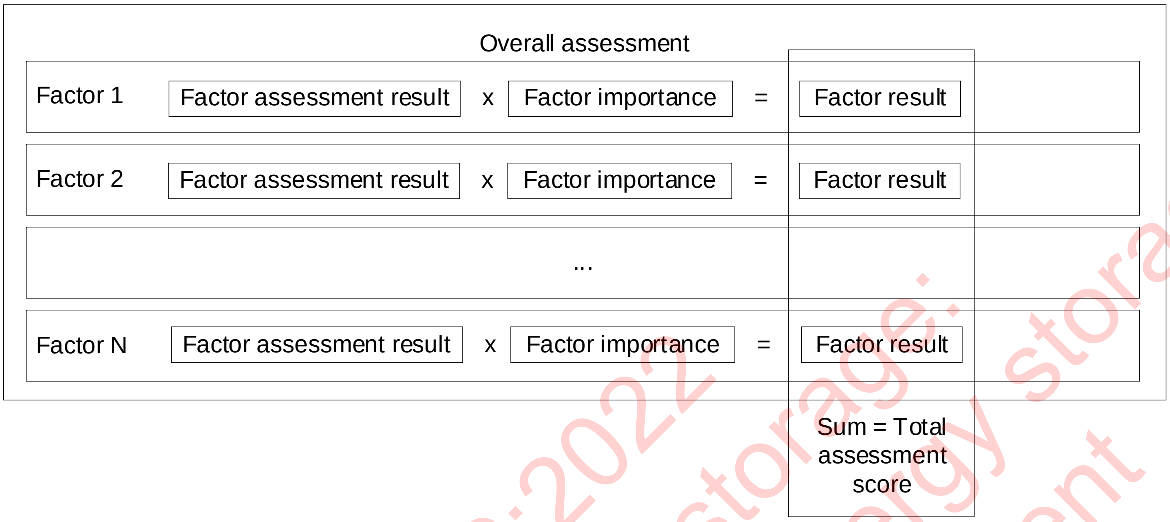

Figure 4: Combining multiple factor assessments into an overall score

Factors that can be assessed through-life include the following:

(a) Safety (see Section 4 and Appendix A for prompts).

(b) Energy and power characteristics of the ESS against the operational requirements.

(c) Availability, reliability and maintainability, including local technical support from manufacturers.

(d) Influence on vehicle or railway availability, efficiency, and performance.

(e) Suitability for the operational context such as the natural and induced environment.

(f) Ease of installation, commissioning, operation, maintenance and disposal.

(g) Certification and compliance.

(h) Service life.

(i) Training requirements.

(j) Total cost through-life.

The level of certainty required in the assessment determines the rigour applied to the assessment approach. For higher levels of certainty assessment approaches should include increased levels of rigour considering the repeatability, accuracy, and uncertainty in the body of evidence underpinning the assessment.

Approaches to assess factors can include:

(a) review of documentation by expert panel;
(b) inspection;
(c) modelling; and
(d) tests and trials.

These are described below.

3.2.2 Assess factors

3.2.2.1 Review of documentation by expert panel

Factors of interest may be assessed through a review of the available documentation. This type of review should be performed by:

(a) defining the factors to be assessed;
(b) gathering a person, or a panel, who is/are sufficiently qualified and experienced to make judgements on the factors of interest;
(c) defining the criteria for the assessment, for example what attracts a given score, rank, or a pass/fail result;
(d) gathering documented evidence from stakeholders, such as manufacturers or testing institutions; and
(e) reviewing the evidence and allocating a result, referencing key evidence that justifies that finding.

3.2.2.2 Inspection

Factors of interest may be assessed by inspecting physical equipment or software. This is similar to the review of documentation, except that it is the resulting engineered products that are considered, as opposed to documentation. This type of review should be performed by:

(a) defining the factors to be assessed;
(b) gathering a person, or a panel, who is/are sufficiently qualified and experienced to make judgements on the factors of interest;
(c) defining the criteria for the assessment, for example what attracts a given score, or a pass/fail result;
(d) inspecting the physical equipment or software, gathering evidence for justification, for example, consisting of notes, inspection data, photos and videos; and
(e) reviewing the evidence and allocating a result, referencing key evidence that justifies that finding.

3.2.2.3 Modelling

Analysis should be undertaken to understand the requirements and performance assessment criteria of ESS. The following levels of analyses may be undertaken

(a) Simple analysis: this analysis is limited to a quasi-static case and does not fully represent the actual ESS performance for train operational scenarios.

However, it allows the estimation of the minimum energy required for a trip by assuming an average main speed and computing the sum of the resistances to motion, and the potential energy effects resulting from changes in altitude.

The energy usage is also subject to signalling conditions; braking, stop-starts, and the design of grades, this shall also be addressed within the simple analysis. For reference see ‘Design and simulation of rail vehicles’ (2014, CRC Press, Boca Raton, FL, USA) and ‘Longitudinal heavy haul train simulations and energy analysis for typical Australian track routes’ (Proceedings of the Institution of Mechanical Engineers Part F: Journal of Rail and Rapid Transit, 2014, 228(4), 355-366).

(b) Full analysis: this analysis considers the longitudinal behaviour of the train as a function of many issues including train control inputs from the locomotive, train brake inputs, track design characteristics and vehicle connection characteristics. Vehicle mass, passenger load, HVAC load and regenerative braking are also included.

In this analysis, the battery behaviour and performance can be described with simplistic equations and algorithms that represent the outcomes of ESS management strategies for actual train configurations running on the specific track section. For reference see ‘Conceptual designs of hybrid locomotives for application as heavy haul trains on typical track lines’. (Proceedings of the Institution of Mechanical Engineers Part F: Journal of Rail and Rapid Transit, 2013, 227(5), 439-452).

(c) Advanced analysis: this type of analysis presents additional extensions to the full analysis that focus on the interaction of longitudinal train dynamics and rail vehicle full mechatronic models, and it can be performed in a sequential or co-simulation mode in/between longitudinal train dynamics simulators, multibody software packages and a graphical programming environment or similar software products for simulating and analysing a full multidisciplinary system using system engineering approaches.

The multidisciplinary (multidomain) co-simulation approaches provide significant benefits in the representation of the system close to the actual system operating in the real world and such approaches shall be combined to precisely reproduce the full mechatronic system behaviour in the train and to deliver comprehensive simulation results. This analysis should be performed for the following tasks:

i. Development and analysis of battery or capacitor element behaviour at the individual or package levels.

ii. Detailed analysis of the ESS power system and its management algorithms (e.g. detailed element characteristics, power integration strategies, heat transfer and cooling processes etc.).

iii. ESS management strategies considering rail vehicle or train operational scenarios.

For reference see ‘Rail vehicle mechatronics’ (2021, CRC Press, Boca Raton, FL, USA).

Simulation software used for full and advanced analysis shall be an industry-recognized dynamics tool and shall include the validated modelling of the behaviour of the longitudinal train dynamics (as evidenced by peer review in technical publications). The supplier of the longitudinal train dynamics simulation software should be able to provide evidence of its validation and suitability for its application to train dynamics studies. For reference see 'International benchmarking of longitudinal train dynamics simulators: benchmarking questions', Vehicle System Dynamics, 2017, 55(4), Taylor & Francis, London, UK.

In a case when, due to the level of rigour, advanced analysis is required to use individual vehicle dynamics simulations in addition to overall train simulations, it shall follow a validation process for vehicle dynamics models as per Section 2.4 in AS 7509.

3.2.2.4 Bench tests and trials

One method of assessing the factors of interest can be to perform bench tests and trials on equipment. Note that testing to support type acceptance and routine testing is covered in Section 3.7.

Note that this is likely to be the most expensive method for obtaining information, however it is likely to provide the highest rigour in the results as it includes real-world systems, operation, and environment. Developing tests and trials is a significant undertaking and the below is just an initial list for consideration.

This should be performed by the following:

(a) Defining the factors to be assessed.

(b) Defining the criteria for the assessment, for example what attracts a given score, rank, or a pass/fail result.

(c) Developing a test or trial that will provide evidence on the factors of interest. This covers a vast range of areas, but should consider:

  i. the location and environment of where the bench test or trial is being performed;

  ii. the equipment that is to be tested.

  iii. The equipment to support the tests, such as jigs or measuring and logging equipment;

  iv. the commissioning and decommissioning plan for the tests;

  v. a test plan including what is to be tested, in what conditions and how many times tests are repeated;

  vi. a health and safety assessment, leading to implemented mitigations so that the bench tests or trials are safe SFAIRP.

(d) Performing the test or trial.

(e) Gathering information and evidence from the tests.

(f) Reviewing the evidence and allocating a result, referencing key evidence that justifies that finding.

3.3 Operational requirements for energy and power performance

Two key parameters of interest for the ESS are the rated power it can produce, and the useful energy stored. The general design principles in Section 3.1 should be considered. Battery requirements are provided in IEC 62928 and EDLC requirements in IEC 61881.

The energy and power requirements for the ESS should be developed with consideration of the following:

(a) The type of train the ESS-fitted vehicle will be part of, for example light passenger rail or freight. Heavier vehicles are likely to need larger energy storage capacity and higher powers.

(b) The potential applications in Section 2.1 as well as the performance requirements on the vehicle for factors such as gradient, range, speed and acceleration through-life. These could be described in terms of operating profiles for how the vehicle will be used showing power variation in time. These should then be used with other traction system parameters to define the ESS power output and energy storage requirement. For example, some Australian railways have sections of significant length and the feasibility of the application of the ESU in the absence of other power sources should be considered.

(c) The intended design life of the ESS.

(d) The variability or uncertainty in performance requirements, and the variability in the delivered ESS performed. For example, if the ESS power requirements were to be 5 % above the nominal power target, and the manufactured ESU could have a 5 % shortfall from the specification, then consider specifying an ESS with 10 % higher power than the nominal power target.

(e) The efficiencies of the traction system, such as any converter and transformer efficiencies, the motor efficiency, and the rolling losses. This should include variation within the operational environment, such as increased temperatures while operational. Operation using the lowest efficiency foreseen through-life should be considered.

(f) The method by which the ESS will be charged and discharged and the operating cycle for these events. If the ESU is charged infrequently, then a larger energy store could be required to sustain its function to the next charging event.

(g) The potential rate of charge of the ESS, such as from OHW via the DC link or from regenerative braking.

(h) The safe limits on the rate of charge and discharge of the ESU, and the limits which prevent harm to the ESS or connected electrical equipment.

(i) The power transients that the traction system can place on the ESS, both for demand and supply of power. Accelerating a vehicle from a standing start on a hill while overcoming stiction can provide the highest peak power demand on the traction motors, and therefore the supply from the ESS.

(j) The demand from auxiliary systems such as heating, ventilation and air-conditions, include variation within the operational environment, such as increased temperatures while operational.

(k) ESSs can degrade in power and energy performance through-life. This should be considered in setting the minimum capability acceptable towards the end of the ESS design life. Degradation can be influenced by the number of cycles performed, the ambient temperature and the depth of discharge.

(l) The energy demand from vehicle systems and their priority. In the instance that a fault occurs in the PPS or the ESS, the graceful performance degradation profile should allow priority systems to operate for a set amount of time and capability.

Should the ESS go below the minimum energy and power performance thresholds during life, then it should be removed from service. The removal approach criteria shall be identified and shall render the vehicle safe SFAIRP through-life. Approaches can include removing the ESS immediately or waiting until the end of the operating period.

3.4 Interoperability

3.4.1 Interoperability within a vehicle

As highlighted in Section 3.1 the implementation of the ESS should allow the vehicle to meet the requirements placed on it. Requirements on the vehicle shall be identified decomposed and attributed to systems across the vehicle, including the ESS. The ESS implementations shall be able to interface with the systems of the vehicle, as described Section 2.3, as necessary for the vehicle to meet its requirements. In turn the ESS can place requirements on other systems.

An example: a requirement for "Vehicle to be interoperable with other vehicles on variable train consist, for example, on locomotive hauled passenger and freight train consist." An influence of this vehicle-level requirement on the requirements for the ESS arise because any vehicle should be assessed in accordance with the RISSB Code of Practice for Distributed Power Freight Trains. If the vehicle is predicted to produce unacceptable in-train forces, then the specification of the tractive power curve for the vehicle's traction system, including the response of the ESS, is likely to be influenced. For ESS fitted vehicles this can arise because:

(a) ESS fitted vehicles can have a different tractive power curve that can have an impact when inserted in a train consist using distributed power;

(b) ESS fitted vehicles can be configured to increase the efficiency of a passenger or freight train consist that also uses power cars or locomotives not fitted with ESS. In this operating mode, an efficiency strategy can require the braking effort to be mostly undertaken by the ESS fitted vehicle to maximize regenerative braking energy capture and storage.

Another example of a requirement placed on the vehicle is the definition of how it is required to interface with the electrical network, if at all. The system requirements placed on the ESS address the decomposition of vehicle requirements across electrical requirements. The vehicle requirements could require engagement with rail infrastructure managers (RIM) and network operators.

3.4.2 Interoperability of vehicle across rail networks

Where the vehicle is expected to be operated across multiple states in Australia, those requirements which the ESS implementation could impact should be considered. Principles of interoperability at the vehicle level for the Australian railway industry are in AS 7540.

Difference characteristics between railway networks that could influence ESS implementation can include the following factors:

(a) Gauge: Consider the kinematic envelope of the vehicle and the position of the ESS across gauges.

(b) Voltage and power quality: Consider whether the operation of the DC link changes between networks and therefore whether the ESS operation is also required to change.

(c) Supply chain: Are the components to enable the ESS through-life available in all regions of interest.

(d) Support and maintenance capability: Are the systems to support the ESS available in all regions of interest.

(e) Network operations philosophy: How the ESS is used or limited in its use under network policy.

(f) Software: How ESS software is compatible with the local interfacing control systems.

3.5 Environment

3.5.1 Naturally occurring environment

The naturally occurring environment refers to aspects such as temperature, humidity, altitude, rain, ice, snow and hail, ice, lightning, air movement, solar radiation.

The ESS shall be suitable for the range of environmental conditions that shall be reasonably be expected to be experienced through-life, as identified in the chosen approach to inform ESS selection. Depending on the intended locations of the ESS, it can be appropriate for an implemented ESS to be able to operate in a range of environmental conditions. This approach can also enable some of the ESS components such as the battery to be resold at a more competitive price to a broader market. However, it can prove more cost effective to procure an ESS that covers a smaller subset of Australian environmental conditions if operating conditions allow for this.

Australia's climate is predicted to change over time, with anticipated higher average temperatures and subsequent extreme weather conditions such as heatwaves and rainfall to occur at higher frequencies. These changes in the naturally occurring environment should be considered when determining an appropriate ESS specification to meet both current and future operational needs. Refer to the Australian Bureau of Meteorology and CSIRO climate projections website for more information. Available at: https://www.climatechangeinaustralia.gov.au/en/overview/

Figure 5 divides the Australian continent into eight Australian climate zones defined by the National Construction Code of Australia and published by the Australian Building Codes Board. Climate zone categorisation of specific locations within these eight zones can be found at: https://www.abcb.gov.au/sites/default/files/resources/2020/ClimateZoneMapAUST.pdf

Characteristics of these regions are presented in Table 1 which has been sourced from the National Construction Code Guide to Volume 1, available at https://ncc.abcb.gov.au/editions-national-construction-code

Note these are guidelines only and additional local region characteristics such as wind patterns and specific seasonal temperatures and rainfalls should also be considered when developing an ESS, further information can be found on the Australian Bureau of Meteorology website. Changes due to altitude should also be considered, such as variations in ambient pressure and temperature.

The ESS shall be protected from physical damage caused by weather events such as hail.

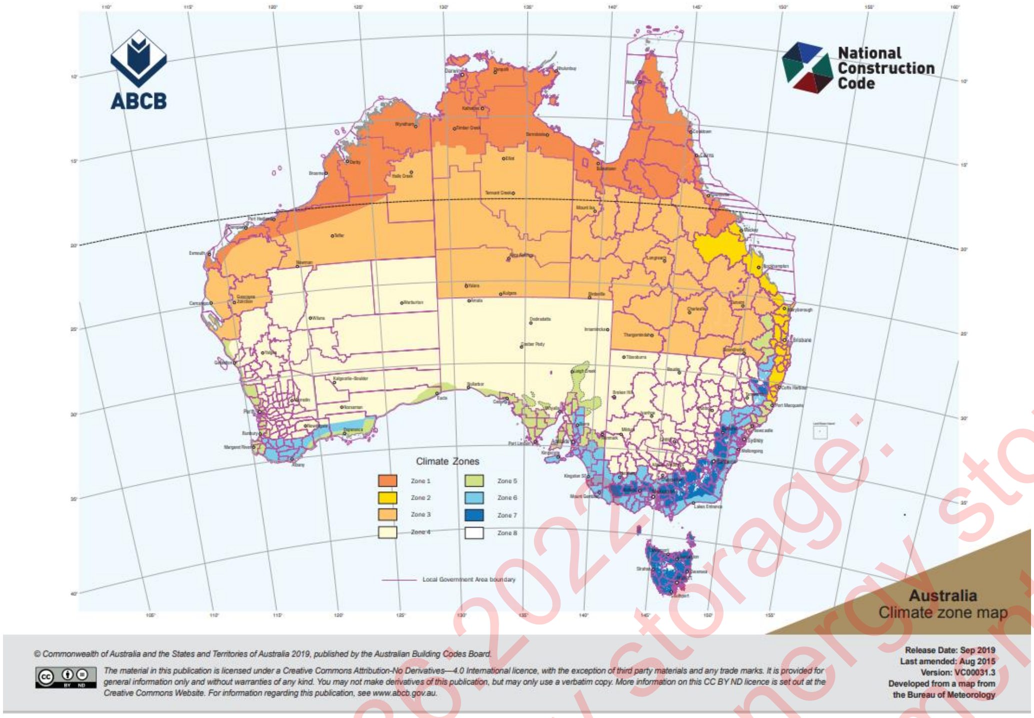

Figure 5: Eight Australian Climate Zones

Climate zones	Description	Average 3 pm January water vapour pressure (kPa)	Average January maximum temperature (°C)	Average July mean temperature (°C)	Average annual heating degree days
1	High humidity summer, warm winter	≥ 2.1kPa	≥ 30°C	N/A	N/A
2	Warm humid summer, mild winter	≥ 2.1kPa	≥ 30°C	N/A	N/A
3	Hot dry summer, warm winter	< 2.1kPa	< 30°C	≥ 14 °C	N/A
4	Hot dry summer, cool winter	< 2.1kPa	≥ 30°C	< 14 °C	N/A
5	Warm temperate	< 2.1kPa	< 30°C	N/A	≤ 1,000
6	Mild temperate	< 2.1kPa	< 30°C	N/A	1,000 to 1,999
7	Cool temperate	< 2.1kPa	< 30°C	N/A	≥ 2,000 other than alpine areas

Table 1: Characteristics of the eight Australian Climate Zones

3.5.2 Induced environment

The induced environment refers to the ESS environment other than that which occurs naturally. This includes the chemical environment, biological environment, pollution, vibration, shocks, electromagnetic environment, acoustic noise environment and the supply system.

The installed ESS should be compliant with IEC 62864-1:2016 Clause 5.1 which refers to classes of service conditions.

3.5.3 Unusual service conditions

Unusual service conditions include those outside the descriptions in Sections 3.5.1 and 3.5.2

Criteria shall be defined that establishes the unusual service conditions for the installed ESS through life. These are defined in IEC 61881-3:2012 Clause 4.2 which provides prompts to consider during specification.

3.6 Rail vehicle certification and compliance

The ESS and its implementation should be designed, installed, and commissioned to support certification of the rolling stock compliance in accordance with AS 7501.

3.7 Testing

Testing provides confidence in the performance, safety, reliability and suitability of an implemented ESS. The results of testing can be required to support rail vehicle certification and compliance. Note that there is potential cross-over with the testing performed in relation to Section 3.2.2.4.

Testing can be performed as type tests, optional tests or routine tests. Testing for all ESS should be performed in accordance with IEC 62864-1 which provides guidance on the categories of tests, the items to be tested, the system level and locations for tests. Testing for ESS using batteries should consider similar guidance in IEC 62928 and testing for ESS using EDLCs should consider IEC 61881-3 for similar relevant guidance as these documents consider specific tests for those technologies.

As an example, retrofitting of ESS onto existing vehicles can alter the dynamic behaviour of the rolling stock, due to factors such as shifting the centre of gravity of the vehicle. Therefore, testing in accordance with AS 7509 should be performed.

3.8 Construction

During construction the ESS is assembled into a complete unit that can be transported, stored, and installed onto a vehicle.

The general design principles in Section 3.1 shall be applied during design for construction.

Additional design principles for construction are:

(a) the ESS shall be safe throughout construction for its intended environment. The hazards at each step during construction shall be identified and mitigated SFAIRP in design;

(b) the ESS design shall provide detail in regard to the ease of construction, including how the ESS interfaces are managed through-life. Standardization of parts, design for access of components, design for easy and safe movement of the ESS and its components should be considered.

3.9 Installation

During installation the ESS is transported to the installation location, stored, moved to the vehicle, and assembled into the vehicle.

The general design principles in Section 3.1 shall be applied during installation.

Additional design principles for installation are:

(a) the ESS and vehicle shall be safe throughout installation for the intended environment. The hazards at each step during installation shall be considered and mitigated SFAIRP in design;

(b) the ESS design shall consider ease of installation into the vehicle, including how it the ESS is handled and moved into position and ease of access to the required interfaces.

Installation shall be done in accordance with the ESS manufacturer's instructions, so long as such instructions are in accordance with the design principles. The use of special tooling should be identified and considered.

Criteria shall be identified for the transport and storage of ESS prior to installation.

IEC 61881-3 provides more in-depth installation guidance for EDLCs mentioning aspects such as overstressing, cooling of connectors and parallel/series connection. IEC 62928 provides guidance on storage and transport conditions for batteries.

3.10 Maintenance

Maintenance includes aspects such as inspection, testing, removal, repair and replacement.

The general design principles in Section 3.1 shall be applied during maintenance. Additional design principles for maintenance are as follows:

(a) The ESS and vehicle shall be safe throughout maintenance for the intended environment. The hazards at each step during maintenance shall be considered and mitigated SFAIRP in design.

(b) The ESS design shall consider ease of maintenance, including how the ESS and its subsystems are handled and moved into position as well as ease of access to the required interfaces.

(c) The ESS design for maintenance should consider the reduction of waste.

(d) The maintenance and support approach for the ESS shall detail the cost of the maintenance approach against the reliability, availability, and maintainability of the ESS through-life.

(e) Replacement components to maintain the performance and safety of the ESS shall be available throughout its design life, without introducing a requirement for functional modification.

Maintenance shall be done in accordance with the ESS manufacturer's instructions, so long as such instructions are in accordance with the design principles. The use of special tooling should be identified and considered.

Each of the ESS components should be able to be serviced and maintained separately and independently. The transport and storage of ESS components occurring through maintenance shall be considered.

Maintenance procedures for testing, removal, replacement and servicing need to take the characteristics of the ESU technology into account. Before maintenance activities can be allowed, the following shall apply:

(a) The ESS is discharged to an energy level so that its associated electrical risk to maintainers is minimized SFAIRP. Note that it is likely that a battery will have a potential across its terminals and therefore insulated tools and PPE must be used. EDLCs can be fully discharged if a safe mechanism for discharging is provided. Once the EDLC is fully and safely discharged a short-circuit device can be applied.

(b) The ESS is mechanically isolated from all external electrical connections (on both polarities).

Access to the ESU shall be limited and controlled. It shall be mechanically interlocked with its chopper.

Refer to the normative references in Section 4.1 for additional guidance, as well as requirements to perform reviews and drills, maintain equipment and calibrate equipment.

The ESS condition can be monitored through sensors. This information can be communicated to the TCMS for presentation to the driver, or to be communicated off of the vehicle to maintainers.

The design of the ESS to allow for the replacement of consumables, such as fuses, should consider the accessibility of fuses and the likelihood of their current limits being exceeded. For example, if an ESU comprises of multiple sub-units which are more difficult to access for maintenance then:

(a) at the outer-most, most accessible level of the ESU, one level of fusing can be used;

(b) within the ESU assembly, which is less accessible, fuses with higher current ratings can be used.

The design approach for consumable components (such as fuses) shall include the following:

(a) The safety requirements on the consumable components.

(b) The ease of access.

(c) The frequency of replacement.

(d) The target availability of the system.

(e) Human factors such as the potential for inadvertent or accidental incorrect component selection and misuse.

3.11 Disposal

Disposal refers to the activities performed at the end of the ESS's operational life. This can occur when the ESS reaches its design life, becomes unsafe or when it fails to meet acceptable performance thresholds. Causes can arise from damage or from repeated use.

During disposal the ESS is removed from the vehicle, moved to storage, and then transported to a disposal location.

Options for disposal include:

(a) disassembly and recycling of the material where possible; and

(b) repurposing of the ESS for other functions, such as wayside energy storage.

The general design principles in Section 3.1 shall be applied during disposal.

Additional design principles for installation are as follows:

(a) The ESS and vehicle shall be safe throughout disposal for the intended environment. The hazards at each step during disposal shall be considered and mitigated SFAIRP in design.

(b) Minimising the amount of hazardous material in the ESS SFAIRP.

(c) The ESS design shall consider ease of disposal, including how the ESS is handled and moved out of position, ease of access to the required interfaces and ease of repurposing or disassembly to recover materials.

(d) Opportunities to minimize waste and gain value from the disposal approach of the ESS should be explored. Circular economy principles and strategies can be applied to maximize resource efficiency, and to minimize embodied impacts associated within the supply chain and waste disposal. Repurposed ESS can be useful for offboard energy storage.

(e) The disposal should be performed in accordance with an ISO 14001:2015 compliant environmental management system so that it follows best practice.

Disposal shall be done in accordance with the ESS manufacturer's instructions, so long as such instructions are in accordance with the design principles. The use of special tooling should be identified and considered.

4 Safety

4.1 General

The ESS implementation shall allow the vehicle it is integrated with to be safe, SFAIRP, throughout the ESS's lifecycle for its intended application and environment.

All hazards identified in this Section shall be assessed and mitigated so that they are safe SFAIRP. The assessments and mitigations shall be documented to allow for audits and reviews.

This Section provides potential mitigations to hazards. Mitigations to hazards can arise through ESS design, ESS implementation, design of other systems, vehicle design and vehicle operation approaches. Therefore, communication of the hazards between ESS manufacturers, vehicle manufacturers, RSOs and RIMs is encouraged. The use of ESS can place requirements on to other systems and the vehicle.

A comprehensive list of hazards can be identified by considering the following:

(a) The stages of life of the ESS and its integration with the vehicle.

(b) The types of operational environment that the ESS and vehicle will experience, whether that is in terms of the natural and induced environment, or the location, such as urban through to outback Australia.

(c) Across types of intended rolling stock , for example light rail or freight.

(d) The people who might be exposed to hazards.

(e) The types of energy or material that might cause harm, for example mechanical energy, electrical energy, gravitational potential energy, or toxic and flammable chemicals.

(f) The systems interfacing with the ESS.

(g) The amount of energy present.

Throughout this Section:

(a) ESS safety requirements are provided by IEC 62864-1, including electrical hazards, fire behaviour and protection, protection against impact and short circuit protection.

(b) Safety requirements for EDLCs are provided in IEC 61881-3, including discharge devices, case connections, environmental protection and other. Requirements.

(c) Safety requirements for batteries provided by IEC 62928 including markings, isolation for maintenance/service and fire protection.

4.2 Collision and crash worthiness

Impact or puncture to the ESS can lead to damage, which in turn can lead to explosion, gas venting/release and other effects. The collision hazard shall be made safe SFAIRP.

The collision hazard should be mitigated by:

(a) installing the ESS away from potential crumple zones;

(b) designing the structure of the ESS to be strong enough to protect the ESU components from impact;

(c) designing the structure of the ESS, and the interfaces with the vehicle structure which manage loads and deflections to be strong and flexible enough to withstand the loads and control the deflections during a collision;

(d) where there is a potential for fire, explosion and venting / release of gases in a collision, derailment or rollover, locating the ESS away from doors, windows and other emergency egress locations such as designated cut-out locations on vehicle roofs;

(e) containing harmful materials and energized components SFAIRP.

AS 7520 should be considered for structural requirements as it provides design guidance across many aspects including types of rolling stock structure, rolling stock types, fatigue and verification. AS 7521 should be considered for ESS installed in spaces where passengers can be located to minimize the risk of injury during derailments, collisions and accidents.

4.3 Electric shock and short circuit Protection

Electric shock can arise from a damaged ESS, a faulty ESS or from contact with live terminals or cabling. Requirements for mitigating electric shock are covered in the normative references in Section 4.1.

The ESS and its implementation shall comply with AS 7530 as this is the standard for electric systems on Australian rolling stock. The electric shock hazard shall be made safe SFAIRP.

Electric shock should be mitigated through the following:

(a) Preventing damage to the ESS.

(b) Earthing the ESS casing.

(c) Providing surge protection and fusing to the ESS, protecting the ESS, personnel and the vehicle systems.

(d) Implementing the ESS with lockable isolators where it is connected to the DC link, with clear visible indicators as to the isolators state, as well as control signals to operation/maintenance systems.

(e) Providing indicators as to the state of charge or fault status of the ESS.

(f) Using cables and connectors that comply with AS 7530.

(g) Remove the possibility of mechanical wear on cables and connectors, where it might cause other components to become live from damage.

(h) Maintaining the ESS in accordance with manufacturer instructions.

(i) Maintaining electrical cables and connections so they continue to comply with AS 7530.

(j) Implement discharge devices to allow for the safe discharge of the ESS to a low energy state SFAIRP. Consider using the brake choppers and resistors for discharge. Note that EDLCs can be fully discharged but batteries have a maximum depth of discharge before their through-life capacity is reduced. Therefore, for batteries the hazard of the energy stored in the battery during maintenance has to be considered against the capacity for the remaining life of the battery.

(k) Design the ESS with appropriate internal component creepage clearances so that elevated dirt/dust/moisture ingress due to cooling/air filtration failure or neglect does not result in risk of an electric shock or a thermal event. The required ingress protection shall consider the natural and induced environmental conditions, such as ambient pressure or flooding.

(l) Physical security measures such as locks, so that only those permitted to access the ESS can do so. This can prevent sabotage.

(m) Markings to indicate the location of the ESS and the electrical shock hazard it presents to personnel.

(n) Isolating/separating high voltage components from other components and clearly marking them.

(o) Segregating and isolating energy storage components within the ESU to minimize the amount of electrical energy that can be released SFAIRP.

(p) Minimising the contact between ESS and other electrically live systems.

(q) Implementing an ESS isolator or bypass switch prior to connection with the DC Link.

(r) The ESS should also utilize surge protection to protect against lightning strikes.

Test requirements to test internal short-circuits protections at the component or cell level are specified in IEC 62619 for lithium batteries. Internal short-circuit protection can use internal fuses to permanently isolate shorted individual or groups of battery cells from the rest of the battery. Internal short-circuits can result from intrinsic causes such as cell failure or extrinsic causes such as physical damage to battery cell including penetration with a sharp conductive object. By isolating the shorted cell or groups of cells, thermal runaway can be prevented and function can be preserved at the cost of a small voltage drop.

Test requirements to test external short circuits protections at a system level are specified in IEC 62928 for lithium-ion traction batteries. System level external short-circuit protection can use ancillary external fuses and contactors to disconnect the energy storage system. This short-circuit protection protects against short-circuiting of the battery box output.

IEC 62928-2018 Annex A shows examples of ESS configurations including the location of the contactors and battery management system in relation to battery box that contain the individual ESU battery packs or modules. The contactors or circuit breakers and battery management system can be internal to and part of the battery box or can be external to the battery box.

The configuration with the internally located contactors should be used to prevent the exposed battery box terminals from being live during storage and handling. The internal contactors/ circuit breaker can only be cut-in by the control system or safety systems once the battery box has been installed and all safety systems activated. If this configuration is used, the isolation system shall be interlocked with the internal contactors.

The ancillary contactors or circuit breakers shall comply with IEC 60077-3.

The ancillary fuses shall comply with IEC 60077-5.

The length of the unprotected cable or connection between the fuse or contactors and the batteries shall be kept to a minimum.

4.4 Thermal runaway, fire and explosion

4.4.1 General

ESS shall be designed and implemented to:

(a) reduce the likelihood and severity of ESS overheating, catching fire, and exploding SFAIRP;

(b) remain safe SFAIRP should they be exposed to overheating and fire;

(c) prevent external surfaces of the ESS that could be touched from causing burns, where heat might arise during normal operation or from thermal runaway events, SFAIRP;

(d) prevent the compartment temperature from becoming too hot to safely work in as intended during normal operation, SFAIRP.

Requirements and guidance for mitigating thermal runaway, fire and explosion are presented in the normative references in Section 4.1. The ESS and its implementation should allow the vehicle to comply with AS 7529 (all parts) which relates to fire safety on Australian rolling stock and how to mitigate the hazard.

ESS are likely to contain materials that are flammable and therefore require mitigations to be safe SFAIRP.

ESS using batteries are susceptible to thermal runaway, leading to high temperatures, fire and potentially explosions. Thermal runaway describes the process where the battery components are heated leading to a reaction which in turn creates more heat. Eventually excessive amounts of heat are generated leading either to fire, or to excessive amounts of gas being produced which can't be sufficiently vented, leading to explosion. Thermal runaway can be caused by electrical damage, mechanical damage, overheating, sabotage or arson.

ESUs are energy dense and in failure modes or damaged conditions can rapidly release large amounts of energy that result in thermal runaway, fires and or explosions.

ESS that use lithium-ion batteries present enhanced fire risk due to the largely flammable components of the battery that releases oxygen during a fire making extinguishing by smothering with water or other fire retardant difficult. Water is normally used to extinguish lithium-ion battery fires with the aim of taking away the heat energy and cooling the battery to prevent re-ignition.

The location of onboard ESS that use lithium-ion batteries shall ensure that ESS fires can be rendered safe SFAIRP by water directed from fire-brigade hoses. For example, roof mounted lithium-ion ESS can be easier to access than undercarriage. Internally mounted ESS can be enclosed in metallic fire barriers that have openings to allow venting of fires, gases and explosion as well as provide access by fire-brigade water hoses.

The performance of ESS fire barriers designed to protect crew and passengers and the rest of the vehicle during an ESS fire will be informed primarily by life preservation requirements but also the tolerance to the risk of total vehicle loss during an ESS fire.

The chosen fire barrier time rating should consider the requirement of the national practice for fire protection on rolling stock to preserve life as well as consideration to provide protection to the rest of the vehicle, taking into account the risk of ESS fire and the tolerance to the risk of total vehicle asset loss due to an ESS fire.

The hazard should be mitigated by the following:

(a) Preventing the ESS from being damaged either through electrical or mechanical means. See Section 4.2 and 4.3. This can also prevent sabotage.

(b) Installing the ESS such that the temperature of its environment, both natural and induced, are within the acceptable limits of the manufacture. Consider the influence of solar radiation, wind speed influence as well as radiators for other systems.

(c) Use fire resistant casing materials and coatings for the ESS, such as using intumescent paint. This can also reduce the hazard caused by arson.

(d) Having temperature sensors or fire/smoke detectors in the ESS, or close to the ESS.

(e) Designing the ESS and its mounting to be able to expand and contract under heating, cooling and pressurisation.

(f) Maintaining the ESS in accordance with manufacturer instructions.

(g) Designing the ESS so that any surfaces that could be touched by people are at a safe temperature during normal operation and minimized SFAIRP during thermal runaway.

(h) Performing routine inspections and maintenance to verify the integrity and operation of the ESS as instructed by the manufacturer.

(i) Using management systems (such as BMS) to control and monitor the ESS.

(j) Allowing for any gas within the ESS to safely vent and disperse away from the vehicle, reducing pressure in the ESS and dispersing flammable gas away from sources of ignition.

(k) Protecting the ESS components and any thermal management systems from harmful ingress by dust, dirt or liquid which could lead to build ups of flammable material or that can prevent cooling/air filtration systems from working as intended. The required ingress protection shall consider the natural and induced environmental conditions, such as ambient pressure or flooding.

(l) Designing the ESS with appropriate internal component creepage clearances so that elevated dirt/dust/moisture ingress due to cooling/air filtration failure or neglect does not result in risk of an electric shock or a thermal event.

(m) Containing the ESS in a structure strong enough to withstand or mitigate explosions.

(n) Using smoke exhausting systems.

(o) Providing sufficient cooling to the ESS to cover expected environmental extremes and faults in the cooling system SFAIRP. This includes variations in environmental pressure.

(p) Providing extinguishing systems using the correct extinguishing medium for the ESS and its installed location.

(q) Using ESS with internal extinguishing capability.

(r) Using an ESS management system that monitors voltage, potential faults, state of charge and temperature.

(s) Preventing overcharging of the ESS by managing the connection to the DC link and severing it when necessary.

(t) Cleaning the ESS surfaces to remove the build-up of flammable dust and material.

(u) Insulating the external components of the ESS with fire-retardant material.

4.4.2 External flammable and explosive materials

The ESS can be implemented in vehicles where it is in proximity to external flammable or explosive materials. This can be from other fuels or substances used on the vehicle, on adjacent vehicles, or from freight being carried in the consist. Diesel is the most popular fuel used across the railway however alternative fuels, such as hydrogen, can also be present.

The presence of such material increases the likelihood and severity of thermal runaway, fire and explosion as it provides both an additional potential source of heat if ignited, and an additional store of chemical energy to be released in a thermal runaway, fire or explosion event.

This should be mitigated by the following:

(a) Containing the heat, fire and explosion completely within the ESU enclosure.

(b) Placing the ESU a safe distance away from such materials SFAIRP.

(c) Limiting the use of the ESS fitted vehicle to haulage operations that will not expose the ESS to such materials.

(d) Considering the design of the vessels of such materials to contain heat, fire and explosion.

4.4.3 Emergency response

Throughout the locations where the vehicle equipped with the ESS is present through-life, the emergency response to fire and explosion shall be considered in the design of the ESS implementation and the planning of emergency responses. Emergency planning and the roles and responsibilities to be considered are contained in The Guideline Rail Emergency Management Planning.

The ESS implementation should consider the following:

(a) Onboard systems to extinguish fires.

(b) Markings to indicate the location of the ESS and the hazard it prevents to response personnel (for example danger of explosion, danger of electric shock).

(c) The type of extinguisher to be used on the ESS.

(d) Minimising the amount of hazardous material in the ESS SFAIRP.

(e) How the extinguishing substance (for example, water) can reach the ESS if pumped from outside of the vehicle. This includes when the vehicle is rolled over, such as from collision or derailment scenarios.

Where the implications of a potential fire and explosion incident and planned responses to manage it safely SFAIRP are different to standard practice, this shall be developed and shared across the rail and emergency response organizations and roles as described in The Guideline Rail Emergency Management Planning.

4.5 Toxic and corrosive material

ESS shall be designed and implemented to minimize the hazard of toxic and corrosive material SFAIRP.

ESS can include toxic and corrosive materials in their construction to achieve high energy and power density. Alternatively, materials can become toxic once they are spilled or burned during fire.

The hazard should be mitigated by the following:

(a) Limiting the amount of toxic and corrosive material within the ESS.

(b) Limiting the amount of material in the ESS that becomes toxic and corrosive on exposure to heat or fire.

(c) Reducing the likelihood of excessive heating or fire considering Section 4.4.

(d) Providing controlled routes for gaseous and liquid material to either be contained or diverted away from the ESS to a safe location. This can include controlled venting of gases / particulates or having a container underneath the ESS to catch and hold liquid safely. Note that this can also mitigate the risk of personnel slipping due to wet surface from liquids spilt from the ESS.

(e) Considering the ingress protection that renders this hazard safe SFAIRP by containing harmful dust, dirt, or liquid within the ESS.

4.6 Component and release at velocity and fluid release at pressure

Components of the ESS can be released at high speed if they are not restrained against the loading acting on them. Tension, compression, pressure and torsional loading can all cause solid components to become detached from their mountings and any remaining elastic energy can be converted to kinetic energy.

The most likely cause of high-pressure fluid is the release of gasses during a thermal event. Other causes can be pressurisation in cooling systems.

The integrated ESS shall minimize the hazard from components released at velocity, and high-pressure fluid release SFAIRP.

This hazard should be mitigated by the following:

(a) Designing components of the ESS to be strong enough to withstand all loads foreseen through life (i.e. dynamic loads, gravitational, thermally induced structural loads, any transmitted structural loads).

(b) Allowing the structure of the ESS to deform in response to loads and isolate internal components, reducing load transmission through ESS components.

(c) Containing the ESS components within a casing strong enough to contain components should they become detached during loading.

(d) Designing components of the ESS to be strong enough to withstand the pressure foreseen through life.

(e) Maintaining the ESS, its mountings, venting and pipework through-life.

(f) Installing the ESS in accordance with manufacturer’s instructions.

4.7 Handling and storage

ESS can be heavy so there is a risk of serious harm occurring should they be dropped or physically damaged. Physical damage has to the potential to lead to thermal runaway, fire and explosion and should therefore be prevented.

When installed, transported, stored and operated around other heavy machinery, such as on rolling stock, there is also a risk that heavy objects will be dropped onto the ESS leading to damage which can cause further hazards (such as thermal runaway).

The ESS and its implementation shall mitigate the hazard of dropping the ESS or of dropping other objects onto the ESS SFAIRP.

This hazard should be mitigated by the following:

(a) Considering the location of the ESS through-life, including the multiple positions it can be in during the installation, maintenance, and disposal processes. This includes when the ESS is not onboard a vehicle.

(b) Using handling approaches and equipment that protect the ESS and can withstand the weight of the ESS to hold it securely during the installation, storage, transportation, maintenance, and disposal processes.

(c) Considering the location of other equipment and personnel relative to the ESS through-life and minimising the possibility of dropping the ESS to harm people or dropping objects on the ESS.

(d) Securing the ESS to the vehicle structure using mountings that can withstand the static and dynamic loads that are expected to be experienced through life, including collision.

(e) Providing secure and adequately rated lifting points to interface with lifting equipment.

(f) Providing a visual indication of the equipment's centre of gravity.

(g) Providing protection against damage caused by weather events such as hail, falling tree branches or the ingress of dust/dirt/liquid, such as from flooding.

4.8 Dynamic stability

ESS can be heavy and therefore they can influence the dynamic stability of rolling stock. By installing the ESS above the centre of gravity for the rolling stock it will reduce the dynamic stability, increasing the likelihood of overturning when cornering or experiencing other lateral loads.

The ESS shall be implemented so that it allows the vehicle's dynamic stability to be compliant with AS 7509, the standard for dynamic behaviour of Australian rolling stock, to mitigate the hazard.

The hazard can be mitigated by the following:

(a) Installing the ESS at, or below, the centre of gravity of the rest of the vehicle.

(b) Installing the ESS so that its centre of gravity is on the lateral centreline of the vehicle, so that no one side of the vehicle is more likely to overturn that another.

(c) Performing dynamic numerical modelling of the vehicle with the ESS, within the operational context, to demonstrate that the hazard is safe SFAIRP.

(d) Reduction of permitted vehicle speed when negotiating sharp track curves.

(e) Considering the impact of sloshing loads if the ESS contains liquid.

4.9 Out of gauge

The positioning of the ESS shall be such that the kinematic envelope of the vehicle is compliant to AS 7633. This is to mitigate the risk of an infrastructure or vehicle strike.

4.10 Structural

ESS can be heavy and therefore they can place additional weight and dynamic loads onto rolling stock structures and bogies. This increases the hazard of structural failure due to overloading. The structure also protects the ESS from damage from objects falling onto it.

The hazard of structural failure due to the implementation of the ESS shall be mitigated SFAIRP.

This hazard should be mitigated by the following:

(a) Using a structure and mountings that can withstand the predicted dynamic and static loads for the ESS implementation, when applying load reserve factors to those loads. AS 7520 suggests load factors between 1.15 and 1.5 depending on the calculation. This can be verified with modelling of through-life loading scenarios.

(b) Using bogies that are strong enough for the ESS implementation. This can be verified with numerical modelling or testing of through-life loading scenarios.

(c) The structure of the vehicle can be strong enough reduce the force of heavy objects from falling onto the ESS.

(d) Performing dynamic structural modelling of the interaction between the ESS structure and the rail vehicle to verify structural performance.

(e) Considering the impact of sloshing loads if the ESS contains liquid.

The loading from the ESS implementation shall be included in the consideration against requirements on the structure to comply with AS 7520 and AS 7519.

Physical damage has to the potential to lead to thermal runaway, fire and explosion and should therefore be prevented SFAIRP. The ESS shall be designed to safely withstand the shock and vibration environment through-life with the environmental conditions listed in Section 3.5.2 SFAIRP. This should be done through:

(a) designing the shock and vibration response of the structural interface between the ESS;

(b) designing the shock and vibration response of the ESS internal components;

(c) considering the change in the shock and vibration response through time due to degradation of components.

Physical damage can also occur because of weather events, for example wind blowing tree branches onto the ESS and hail. The ESS shall be protected during these events SFAIRP.

4.11 Electromagnetic compatibility

Electromagnetic interference can prevent equipment from operating properly or can damage it.

The ESS implementation shall allow the ESS to operate as intended in the through-life electromagnetic environment. It shall also not adversely affect the electromagnetic environment so that other vehicle equipment can operate as intended.

Requirements for managing electromagnetic compatibility are covered in the normative references in Section 4.1. The ESS implementation shall be in accordance with AS 7772 which provides guidance to mitigate the hazard. Electromagnetic interference can be mitigated by using electromagnetic shielding around sources of interference.

4.12 Acoustic noise

The noise produced by the ESS shall be acceptable against the through-life requirements of its installation environment. Requirements for managing noise are covered in the normative references in Section 4.1.

4.13 Functional failure

Should the ESS fail to function as intended it will impact how other systems operate. This can cause a hazard depending on how critical the system is to safety. Such hazards include risks to personal safety due to the failure of security systems.

The ESS can fail functionally in the following ways:

(a) Not functioning at all.

(b) Functioning outside of specification, i.e. outputting the wrong amount of energy or power compared to what is required by the system. This could arise through putting out the right amount of energy, but at the wrong time due to delays being caused. It could also arise due to degraded ESS function such as loss of capacity due to wear, atypical environmental conditions or the failure of a cell or capacitor within the ESS.

(c) Consuming power during recharging in the wrong way, drawing too much power from the DC link.

The implementation of the ESS shall mitigate the hazards from functional failure to be safe SFAIRP.

The hazards arising from ESS functional failure can be identified by considering the list of prompts in Section 4.1 for each of the systems that are influenced by the ESS functioning. These hazards should be mitigated by the following:

(a) Maintaining and operating the ESS in accordance with manufacturer instructions to maximize its availability.

(b) Systems “failing safe” in the case of power loss or drop-off.

(c) Through having redundancy in the power supply to the system, in the case of power loss or drop-off.

(d) Through surge protection in the case of excessive power or energy being provided compared to what is required.

(e) Preventing damage to the ESS.

(f) Identifying, assessing and eliminating single point failures where practicable by design.

(g) Allowing for remote isolation from the driver's cabin.

4.14 Human performance

Human interaction with the ESS can lead to a wide variety of hazards, some of which are described in previous sections. The ESS implementation shall be designed with an awareness of human factors to mitigate these hazards SFAIRP.

Human performance hazards should be mitigated by the following:

(a) Enabling the train operator to drive the train safely by reducing the cognitive effort required to operate the ESS SFAIRP.

(b) Automatically managing the ESS through the ESS controlling systems, whether the TCMS or control systems internal to the ESS, so that the operator has sufficient cognitive function to manage train safety.

(c) Training provided to train operators, ESS installers, ESS maintainers and accident responders so that the ESS and the vehicle it is installed in is safe through-life.

(d) Minimising the information provided by the ESS to the train operator so that only information that is critical to the safe and effective operation of the train is provided.

(e) Locating the ESS so that the position of personnel interacting with it through life (installation, operation, maintenance and disposal) are not required to have an awkward or harmful posture or be placed in potentially dangerous locations (such as between wheel and rail).

(f) Having no sharp edges or burrs on the edges of the ESS.

(g) Installing the ESS such that it does not block intended evacuation routes.

(h) Installing the ESS so that it does not create a slip/trip hazard or impede access routes for inspection or accessing serviceable components.

(i) Providing a data interface for diagnostic work that can be undertaken either onboard, through the vehicle's diagnostic interface, or offboard by a service port. The diagnostic equipment can be designed to enable the ESS to be effectively managed, maintained and repaired through its operational life.

(j) Allowing sub-units of the ESS to be locked out and tagged for ease and safety of operation and maintenance.

(k) Cleaning the external surfaces and markings of ESS to keep them hygienic and to keep markings clear.

(l) Use markings in well-lit machinery spaces.

(m) Locating the ESS so it does not obstruct the view of the operator.

(n) Locating the ESS so it does not obstruct any horns or alarms.

4.15 Software and cyber security

The ESS is likely to use software which is critical to the ESS operating safely. Furthermore, the ESS is also likely to interface with the TCMS, to allow the overall vehicle to operate safely. This means that:

(a) configuration control, management and maintenance of software is critical to the safety of the vehicle; and

(b) the ESS is a potential vector for a cyber-attack that would have safety implications.

The ESS shall comply with AS 7770 to mitigate the cyber security hazard. This applies to both the software in the ESS and the potential data connections to the ESS , both internal and external. The Code of Practice for Rail Cyber Security for Rolling Stock & Train Control Systems, as well as the Guideline for Firmware, Software, and Configuration Management of Operational Rail Assets provide addition information.

4.16 Hazardous materials

Hazardous materials in the ESS can cause harm to personnel who interact with it. This can occur during transport, maintenance, installation, operation, maintenance, emergencies and disposal. The hazard shall be mitigated SFAIRP.

Hazardous materials are documented in the Hazardous Chemical Information System (HCIS) at http://hcis.safeworkaustralia.gov.au/

This risk should be mitigated by:

(a) minimising the use of hazardous materials in the construction and implementation of the ESS SFAIRP;

(b) producing safe handling procedures for interacting with the ESS through-life;

(c) providing robust containment for hazardous materials for potential release events though-life.

Appendix A Hazard register (informative)

The lifecycle of the ESS has been considered alongside the operational environment and the types of energy/harmful materials that exist to identify hazards. The hazards below have been identified as the most succinct set relevant to the scope of this standard that are contained in the RISSB Hazard Register. These hazards should be assessed for their likelihood and severity for the operations and environment of interest.

Hazard number and hazard	Section addressing
2.1.10 The failure to identify and document major hazards across operations	4.1
2.1.27 The failure to maintain and service equipment, infrastructure and rolling stock	4.3, 4.4, 4.6, 4.13, 4.14
3.2 A breach of Security	4.13
3.2.1.30 Arson	4.4
3.2.1.34 Cyber attack	4.15
3.2.1.35 Sabotage	4.3, 4.4
5.32 Fire	4.4
5.3.1.39 Harmful exposure to noise	4.12
5.38 Hazardous substances contact	4.5, 4.17,
5.4.1.38 EMI	4.11
5.42 Electric shock - Failure of protection	4.3
5.3.1.9 Large mass, shape or size of objects when manual handling	4.7
5.3.1.15 Sharp edges, burrs or cuts	4.14
5.3.1.46 Poor posture	4.14
5.14 Alerting system failure	4.13
5.20.1.3 Complicated, continuous cognitive functioning being required to operate trains	4.14
5.20.1.4 Continual interruptions / messages from onboard systems	4.14
5.17.1.9 The view from seating positions being affected by cab structures and / or equipment (Seating position affecting vision)	4.14
5.36.1.12 Spilt or leaking fluids (e.g. fuel, oil) causing wet surfaces (Slippery access path surface)	4.5, 4.17
5.43 Explosion	4.4
5.2.1.8 Objects dropping down / falling off trains causing collision with wayside structures	4.10
5.29.1.14 Mounts or components failing due to fatigue (Rolling stock equipment - Object drops down / falls off a train)	4.10
5.29.1.16 Mount fasteners not being tightened properly (Rolling stock equipment - Object drops down / falls off a train)	4.10

Hazard number and hazard	Section addressing
5.3.1.13 The environment being too cold causing thermal stress	4.6
5.3.1.14 The environment being too hot causing thermal stress	4.6
5.3.1.31 Hot equipment causing burns by conduction	4.4
5.20.1.10 Uncomfortable temperature	4.4
5.3.1.43 Harmful exposure to released pressured gas or fluid	4.6
5.4.1.62 Inadequate rolling stock modification	4
5.6.1.6 Brakes being applied somewhere on train and traction not cutting out resulting in uncommanded traction	4.13
5.8 Collision	4.2
5.19.1.44 Vehicles overturning	4.2
5.19.1.45 Vehicles overturning because they are loaded to one side resulting in vehicle unbalance causing wheel unloading or overturning	4.8
5.28.1.2 High centres of gravity	4.8
5.28.1.7 Liquid load moving to one side (Load off to one side)	4.10
5.28.1.8 Loads being inadequately restrained (Load off to one side)	4.10
5.28.1.9 Poor loading (Load off to one side)	4.8
5.28.1.6 Overspeed (Overturning at higher speeds to outside of curve)	4.8
5.29.1.14 Mounts or components failing due to fatigue (Rolling stock equipment - Object drops down / falls off a train)	4.10
5.31 Out of gauge trains	4.9
5.34.1.7 Devices being obscured by rolling stock fixtures resulting in train horns or reversing beepers not being loud enough	4.14
5.36.1.12 Spilt or leaking fluids (e.g. fuel, oil) causing wet surfaces (Slippery access path surface)	4.5, 4.17
5.37.1.14 Poor quality water - Contaminated source - Contaminated water	4.5, 4.17
5.37.1.9 Surfaces being inadequately cleaned creating contaminated surfaces	4.14
5.39.1.6 No (effective) monitoring systems (Lack of deterrents on the train - Threatened / assaulted on a train)	4.13
5.39.1.8 No or inadequate lighting (Lack of deterrents on the train - Threatened / assaulted on a train)	4.13
5.40.1.9 Being crushed between wheel and rail during rolling stock inspection or maintenance activities	4.14
5.25.1.14 Overloaded rolling stock (Frame cracking or bending - Frame failure)	4.10
5.25.1.15 Overloaded rolling stock (Spring failure - Suspension failure)	4.10
5.44 Bodily impact	4.10

Hazard number and hazard	Section addressing
5.45 Evacuation hazards	4.14
5.46.1.10 Traction system faults (Excessive longitudinal acceleration)	4.13
5.53 Inadequate vehicle assessments	4.2, 4.3
6.7 Inadequate Rail Safety Worker Competencies	4.14
- Thermal runaway caused by overvoltage or overpowering ESS components, leading to fire.	4.4
Thermal runaway caused by mechanical damage to the ESS from impact or stressing of the ESS, leading to fire.	4.4
- Thermal runaway caused by excessive temperature in operating environment, and the ESS not being cooled, leading to fire.	4.4
- Thermal runaway caused by overvoltage or overpowering ESS components, leading to explosion.	4.4
- Thermal runaway caused by mechanical damage to the ESS from impact or stressing of the ESS, leading to explosion.	4.4
- Thermal runaway caused by excessive temperature in operating environment, and the ESS not being cooled, leading to explosion.	4.4

Appendix B Bibliography

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

(a) Design and simulation of rail vehicles, 2014, CRC Press, Boca Raton, FL, USA

(b) Longitudinal heavy haul train simulations and energy analysis for typical Australian track routes, 2014, Proceedings of the Institution of Mechanical Engineers Part F: Journal of Rail and Rapid Transit, 228(4), 355-366

(c) Conceptual designs of hybrid locomotives for application as heavy haul trains on typical track lines, 2013, Proceedings of the Institution of Mechanical Engineers Part F: Journal of Rail and Rapid Transit, 227(5), 439-452

(d) Rail vehicle mechatronics, 2021, CRC Press, Boca Raton, FL, USA

(e) International benchmarking of longitudinal train dynamics simulators: benchmarking questions, 2017, Vehicle System Dynamics, 55(4), Taylor & Francis, London, UK

(f) Climate Change in Australia, 2022, Australian Bureau of Meteorology and CSIRO. Available at: https://www.climatechangeinaustralia.gov.au/en/overview/

(g) Australia climate zone map, 2019, Australian Building Codes Board. Available at: https://www.abcb.gov.au/sites/default/files/resources/2020/ClimateZoneMapAUST.pdf

(h) National Construction Code Guide to Volume 1, 2019, Australian Building Codes Board. Available at: https://ncc.abcb.gov.au/editions-national-construction-code

(i) ISO 14001:2015, Environmental management systems – Requirements with guidance for use

(j) Rail Safety National Law (Cth)

Hazardous Chemical Information System (HCIS), Available at: http://hcis.safeworkaustralia.gov.au/

About Rail Industry Safety and Standards Board

The Rail Industry Safety and Standards Board is a not for profit company limited by guarantee. Wholly owned by its funding members, RISSB is required to apply the whole of its income and assets to achieving the objects listed in its constitution.

RISSB is responsible for the development and management of Standards, Rules, Codes of Practice and Guidelines for the Australian rail industry.

For further information, visit www.rissb.com.au

RISSB Australian Standards Development Process

The Standards development process is rigorous and transparent.

Authors work with RISSB's Standards Development Managers and Development Groups to ensure that products are acceptable to industry. Standing Committees oversee this work and ensure that proper governance and process is followed. The products are exposed to the public and industry for comment and validated by an independent validator.

Once agreed by the Development Groups, Standing Committees and Validator, the drafts are passed to the RISSB Board for approval.

The same process is used in developing other RISSB products, although Guidelines are not exposed to the public for comment or validated, given their non-binding nature.

Standards Development and Accreditation Committee

RISSB is accredited by the Standards Development and Accreditation Committee (SDAC), and all Standards produced by RISSB since 31 July 2007 are published as Australian Standards.

The Standards Development and Accreditation Committee audits RISSB annually to ensure that RISSB’s processes are in accordance with SDAC accreditation requirements.

ABN 58 105 001 465

For information regarding the development of Australian Standards developed by RISSB contact:

Rail Industry Safety and Standards Board

PO Box 518
Spring Hill, QLD, 4004

T +61 7 3724 000
E Info@rissb.com.au

:

ISBN: Enter ISBN.