

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Railway applications – Rolling stock – Onboard lithium-ion traction batteries

Applications ferroviaires – Matériel roulant – Batteries d'accumulateurs de traction embarquées au lithium-ion



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IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
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INTERNATIONALE

ICS 45.060.01

ISBN 978-2-8322-5019-8

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**RAILWAY APPLICATIONS – ROLLING STOCK –
ONBOARD LITHIUM-ION TRACTION BATTERIES**

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International Standard IEC 62928 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

The text of this standard is based on the following documents:

FDIS	Report on voting
9/2317/FDIS	9/2329/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

In the 90s the market started developing mainly portable lithium technology batteries. Existing standards for lithium-ion batteries currently focus on small portable batteries:

- IEC 61960-3:2017, Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for portable applications – Part 3: Prismatic and cylindrical lithium secondary cells and batteries made from them
- IEC 62133 (all parts): Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications.

These above mentioned documents do not cover large cells and batteries for industrial and railway applications, which are non-portable and weigh hundreds of kilograms.

TC 21 and SC 21A decided to start work on large capacity lithium cells and batteries:

- IEC 62619:2017, Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries for use in industrial applications,
- IEC 62620:2014, Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for use in industrial applications.

The documents are often generic and mention railway applications only as an example.

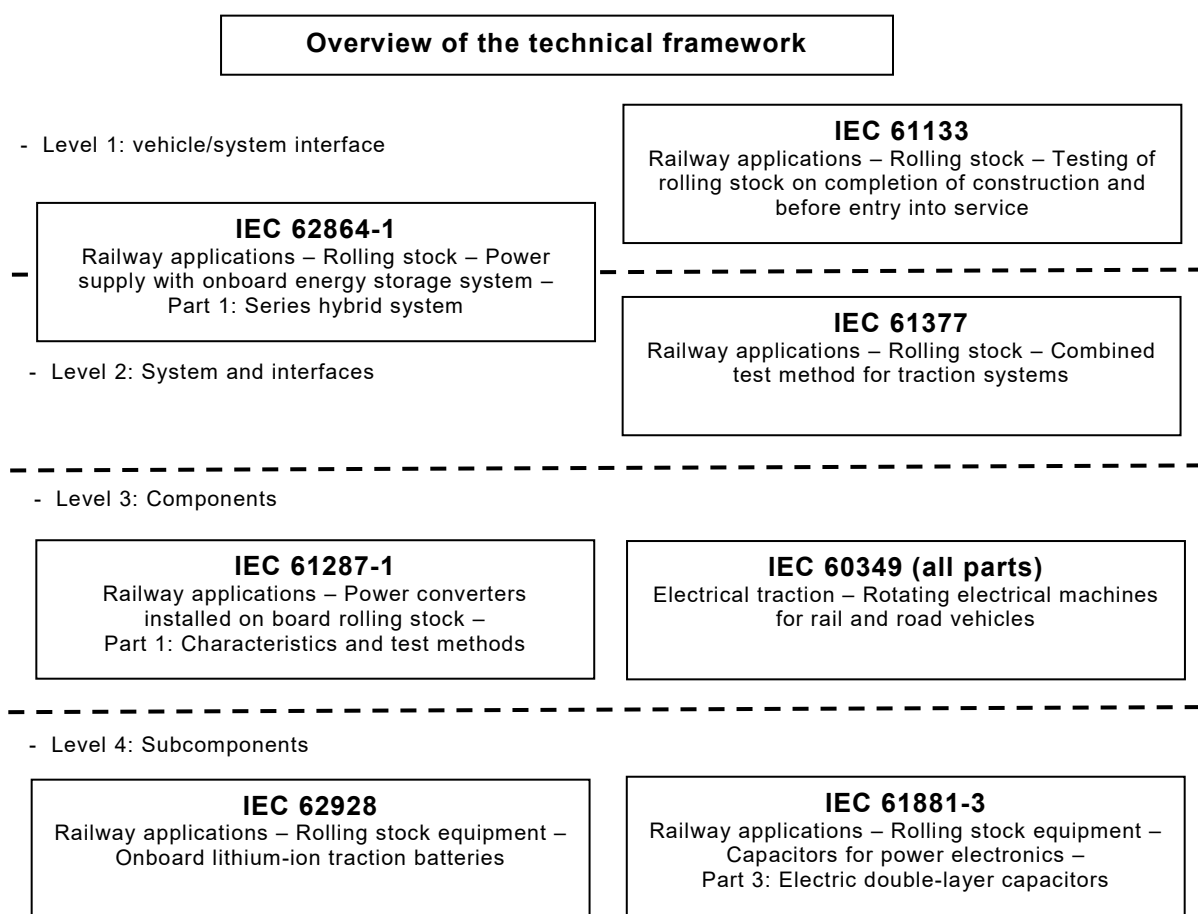
Therefore, this document is developed for specifying the requirements for railway traction applications.

In addition, TC 9 has developed the following document:

- IEC 62864-1:2016, Railway applications – Rolling stock – Power supply with onboard energy storage system – Part 1: Series hybrid system

IEC 62864-1:2016 specifies the general requirements for the onboard energy storage system as a system level. The hierarchy of standards is shown in Figure 1 of IEC 62864-1:2016.

It is part of a series of standards, referring to each other. The hierarchy of the standards used in the railway specific area related to IEC 62928 is as follows:



IEC

Figure 1 – Hierarchy of standards related to IEC 62928

The standards listed in Figure 1 are not exhaustive.

RAILWAY APPLICATIONS – ROLLING STOCK – ONBOARD LITHIUM-ION TRACTION BATTERIES

1 Scope

This document applies to onboard lithium-ion traction batteries for railway applications.

This document specifies the design, operation parameters, safety recommendations, data exchange, routine and type tests, as well as marking and designation.

Battery systems described in this document are used for the energy storage system (ESS) for the traction power of railway vehicles such as hybrid vehicles as defined in IEC 62864-1:2016. Auxiliary batteries to supply power only to the auxiliary equipment are excluded.

Subcomponents within the battery systems, e.g. battery management system (BMS) and battery thermal management system (BTMS), are also covered in this document.

Power conversion equipment (e.g. chopper, converter, etc.), inductors, capacitors and switchgear are excluded from the scope of this document.

General requirements for onboard ESS are described in IEC 62864-1:2016.

This document specifies the lithium-ion battery technology but does not prevent the use of battery technologies other than lithium-ion technology for application as traction batteries.

A hybrid energy storage system, which uses two or more energy storage technologies combined, e.g. a traction battery and double layer capacitors, is not covered in this document. However, if different technologies of energy storage systems are used on the same railway vehicle and managed independently, each independent energy storage system is covered by its own document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-482:2004, *International Electrotechnical Vocabulary – Part 482: Primary and secondary cells and batteries*

IEC 60050-811:2017, *International Electrotechnical Vocabulary – Chapter 811: Electric traction*

IEC 60051 (all parts), *Direct acting indicating analogue electrical measuring instruments and their accessories*

IEC 60077-1, *Railway applications – Electric equipment for rolling stock – Part 1: General service conditions and general rules*

IEC 60077-5, *Railway applications – Electric equipment for rolling stock – Part 5: Electrotechnical components – Rules for HV fuses*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60571, *Railway applications – Electronic equipment used on rolling stock*

IEC 60850, *Railway applications – Supply voltages of traction systems*

IEC 61373, *Railway applications – Rolling stock equipment – Shock and vibration tests*

IEC 61991, *Railway applications – Rolling stock – Protective provisions against electrical hazards*

IEC 62236-3-2, *Railway applications – Electromagnetic compatibility – Part 3-2: Rolling stock – Apparatus*

IEC 62278:2002, *Railway applications – Specification and demonstration of reliability, availability, maintainability and safety (RAMS)*

IEC 62279, *Railway applications – Communications, signalling and processing systems – Software for railway control and protection systems*

IEC 62497-1, *Railway application – Insulation coordination – Part 1: Basic requirements – Clearances and creepage distances for all electrical and electronic equipment*

IEC 62498-1:2010, *Railway applications – Environmental conditions for equipment – Part 1: Equipment on board rolling stock*

IEC 62619:2017, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements secondary lithium cells and batteries for use in industrial applications*

IEC 62620:2014, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for use in industrial applications*

IEC 62864-1:2016, *Railway applications – Rolling stock – Power supply with onboard energy storage system – Part 1: Series hybrid system*

ISO/IEC Guide 51: 2014, *Safety aspects – Guidelines for their inclusion in standards*

ISO 7010, *Graphical symbols – Safety colours and safety signs – Registered safety signs*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-482, IEC 60050-811 and ISO/IEC Guide 51, as well as the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1.1**charge retention**

capacity retention

ability of battery system to retain capacity on open circuit under specified conditions

Note 1 to entry: See also self-discharge.

[SOURCE: IEC 60050-482:2004, 482-03-35, modified – “a cell or battery” has been changed to “battery system”]

3.1.2**self-discharge**

phenomenon by which a cell or battery system loses energy in other ways than by discharge into an external circuit

Note 1 to entry: See also charge retention.

[SOURCE: IEC 60050-482:2004, 482-03-27, modified – “battery” has been changed to “battery system”.]

3.1.3**final voltage**

end-of-discharge voltage

specified closed circuit voltage at which a discharge of a cell or battery system is terminated

[SOURCE: IEC 62620:2014, 3.3 modified – “battery” has been changed to “battery system”.]

3.1.4**nominal voltage**

suitable approximate value of voltage used to designate or identify the voltage of a cell or battery system

Note 1 to entry: The cell and/ or battery system manufacturer may provide the nominal voltage.

Note 2 to entry: The nominal voltage of a battery system of n series connected cells is equal to n times the nominal voltage of a single cell.

[SOURCE: IEC 62620:2014, 3.4, modified – “identify a cell” has been changed to “identify the voltage of a cell” and “battery” is changed to “battery system”.]

3.1.5**rated capacity**

capacity value of a cell or battery system determined under specified conditions and declared by the manufacturer

Note 1 to entry: The rated capacity is the quantity of electricity C_n Ah (ampere-hours) declared by the manufacturer which a single cell or battery can deliver during a n h period when charging, storing and discharging under the conditions specified in 6.3.1 of IEC 62620:2014. n is 5 for an E, M and H discharge rate type cell or battery.

[SOURCE: IEC 60050-482:2004, 482-03-15, modified – “battery” has been changed to “battery system” and Note 1 to entry has been added.]

3.1.6**state of charge****SOC**

remaining capacity to be discharged, normally expressed as a percentage of full capacity by selected expression as defined in Annex A of IEC 62864-1:2016

[SOURCE: IEC 62864-1:2016, 3.1.13, modified – “as expressed in relevant standards” has been changed to “by selected expression as defined in Annex A of IEC 62864-1:2016” and Note 1 to entry has been deleted.]

3.1.7

cell

secondary lithium cell

secondary cell where electrical energy is derived from the insertion/extraction reactions of lithium-ions or oxidation/reduction reaction of lithium between the negative electrode and the positive electrode

Note 1 to entry: The cell typically has an electrolyte that consists of a lithium salt and organic solvent compound in liquid, gel or solid form and has a metal or a laminate film casing. It is not ready for use in an application because it is not yet fitted with its final housing, terminal arrangement and electronic control device.

[SOURCE: IEC 62620:2014, 3.6]

3.1.8

cell block

group of cells connected together in parallel configuration with or without protective devices (e.g. fuse or PTC) and monitoring circuitry

Note 1 to entry: It is not ready for use in an application because it is not yet fitted with its final housing, terminal arrangement and electronic control device.

[SOURCE: IEC 62620:2014, 3.7]

3.1.9

battery pack/module

energy storage device, which is comprised of one or more cells electrically connected

Note 1 to entry: In this document a module is same as a battery pack.

Note 2 to entry: It incorporates a protective housing and be provided with terminals or other interconnection arrangement.

Note 3 to entry: It includes at least monitoring circuitry, which provides information (e.g. cell voltage, temperature) to a battery system.

Note 4 to entry: It may include a protective device and control circuitry.

[SOURCE: IEC 62620:2014, 3.9, modified – “/module” has been added in the term and “or module” has been deleted in the definition. Note 1 to entry has been divided into Note 2 to entry to Note 4 to entry and Note 1 to entry has been added.]

3.1.10

battery branch

group of battery packs/modules connected together either in a series and/or parallel configuration, which has the voltage equal to that of the battery system and is the smallest electrically isolatable subsystem

Note 1 to entry: Electrical isolation is done by means of disconnecting devices, e.g. contactors, switchgears, circuit breakers, etc.

Note 2 to entry: A battery branch may be contained in a single enclosure or multiple enclosures.

3.1.11

battery system

system which incorporates one or more cells, modules or battery packs including battery management system and thermal management system as well as disconnecting and/ or isolating devices, e.g. contactors, disconnectors, fuses, etc.

Note 1 to entry: Refer to Figure 2, Figure 3 and Figure A.1 to Figure A.4.

[SOURCE: IEC 62620:2014, 3.10, modified – Definition after “battery packs” has been changed. Note 1 to entry has been replaced.]

3.1.12

hybrid vehicle

vehicle that can store energy in an onboard ESS and is driven by using the stored energy as well as electric power from a generator or overhead lines

[SOURCE: IEC 62864-1:2016, 3.1.14]

3.1.13

safety

freedom from risk which is not tolerable

[SOURCE: ISO/IEC Guide 51:2014, 3.14]

3.1.14

hazard

potential source of harm

[SOURCE: IEC 60050-903:2013, 903-01-02, modified – Note 1 to entry, Note 2 to entry and Note 3 to entry have been deleted.]

3.1.15

intended use

use in accordance with information provided with a product or system, or, in the absence of such information, by generally understood patterns of usage

Note 1 to entry: Intended use can include load profile agreed between the integrator and the battery system manufacturer.

[SOURCE: ISO/IEC Guide 51:2014, 3.6, modified – Note 1 to entry has been added.]

3.1.16

leakage

visible escape of liquid electrolyte

[SOURCE: IEC 62619:2017, 3.13]

3.1.17

venting

release of excessive internal pressure from a cell, module, battery pack, or battery system in a manner intended by design to preclude rupture or explosion

[SOURCE: IEC 62619:2017, 3.14]

3.1.18

rupture

mechanical failure of a cell container or battery case induced by an internal or external cause, resulting in exposure or spillage but not ejection of materials

[SOURCE: IEC 62619:2017, 3.15]

3.1.19

explosion

failure that occurs when a cell container or battery case opens violently and solid components are forcibly expelled

Note 1 to entry: Releasing liquid, gas, and/ or smoke is not explosion.

[SOURCE: IEC 62619:2017, 3.16, modified – Note 1 to entry has been modified.]

3.1.20

fire

emission of flames from a cell, battery pack/module or battery system

[SOURCE: IEC 62619:2017, 3.17, modified – “module, battery pack,” has been changed to “battery pack/module”.]

3.1.21

upper limit charging voltage of cell

highest charging voltage in the cell operating region from a safety stand point specified by the cell manufacturer

[SOURCE: IEC 62619:2017, 3.19, modified – “from a safety stand point” has been added before “by the cell”.]

3.1.22

maximum voltage of the battery system

highest voltage of the battery system in which the maximum voltage of any individual cell is below the upper limit charging voltage of cell as defined in 3.1.21 and any components operate in its specified/ permissible operating range under all operating conditions

3.1.23

lower limit discharging voltage of cell

lowest discharging voltage in the cell operating region from a safety stand point specified by the cell manufacturer

[SOURCE: IEC 62619:2017, 3.22, modified – “in the cell ... stand point” has been added.]

3.1.24

minimum voltage of battery system

lowest voltage of the battery system in which the minimum voltage of any individual cell is above the lower limit discharging voltage of cell as defined in 3.1.23 and any components operate in its specified/ permissible operating range under all operating conditions

3.1.25

maximum charging current

highest current for charging in the cell operating region from a safety stand point specified by the cell manufacturer

[SOURCE: IEC 62619:2017, 3.20, modified – “maximum” has been replaced with “highest”, “which is” has been changed to “from a safety stand point”.]

3.1.26

maximum discharging current

highest current for discharging in the cell operating region from a safety stand point specified by the cell manufacturer

3.1.27**energy storage system****ESS**

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]

3.1.28**energy storage unit****ESU**

physical equipment which is comprised of an energy storage technology, especially lithium-ion traction battery system in the context of this document

Note 1 to entry: Balancing the traction power among ESUs is a function of the upper system level.

[SOURCE: IEC 62864-1:2016, 3.1.20, modified – “technology” is specified to “lithium-ion traction battery system”, “standard” has been replaced with “document” and Note 1 to entry has been changed.]

3.1.29**battery management system****BMS**

system associated with a battery pack which monitors and/or manages its state, disconnects or isolates the battery pack, calculates secondary data, communicates data outside of the battery system and/or controls its environment to influence the battery’s safety, performance and/or service life

Note 1 to entry: The function of the BMS can be assigned to the battery pack or to equipment that uses the battery pack.

Note 2 to entry: Its functions include thermal control.

[SOURCE: IEC 62620:2014, 3.11, modified – “electronic” has been deleted, “disconnect or isolate the battery pack,” has been added, “reports that data” has been replaced with “communicates data outside of the battery system” and “and has the functions to cut ...” has been deleted. Note 2 to entry has been replaced.]

3.1.30**battery thermal management system****BTMS**

system associated with a battery pack which monitors and/or manages its thermal behaviour in order to maintain the temperature of the battery pack in the intended range for load profile agreed between the integrator and the battery system manufacturers

3.1.31**user**

organization which operates the traction system including ESS

Note 1 to entry: The user is normally an organization which operates the vehicle equipped with the traction system, unless the responsibility is delegated to a main contractor or consultant.

[SOURCE: IEC 61377:2016, 3.4, modified – “(see Figure 3)” has been deleted and “including ESS” has been added.]

3.1.32**integrator**

organization which has the technical responsibility of the complete traction system including ESS

Note 1 to entry: The integrator can be the user or the train builder or the manufacturer of a traction system, or none of them.

3.1.33

manufacturer

organization which has the technical responsibility for its scope of supply

Note 1 to entry: The manufacturer can be the train builder or the system integrator of a traction system, a cell manufacturer, etc. If necessary to explicitly distinguish, “traction system manufacturer”, “battery system manufacturer” or “cell manufacturer” is expressed.

3.1.34

operational pattern

definition by the user and/or the manufacturers in order to fulfil the needs of operations including auxiliaries, e.g. duty cycle, auxiliary loads, safety margin of energy content, degraded mode, etc.

Note 1 to entry: For the purposes of this document, operational pattern is considered at the vehicle level.

[SOURCE: IEC 62864-1:2016, 3.1.19 modified – Note 1 to entry has been added.]

3.1.35

load profile

electric power against time of occurrence to illustrate the variance in a load during a given time interval

Note 1 to entry: For the purposes of this document, the load profile is defined at the terminals of the battery system.

[SOURCE: IEC 60050-617:2009, 617-04-05 modified – “curve representing supplied” has been deleted. Note 1 to entry has been added.]

3.1.36

end of life

EOL

point at which the battery system cannot fulfil the required functionality or operational pattern as initially agreed among the user/ the integrator and the manufacturers

Note 1 to entry: The internal resistance or capacity may be used as a parameter of the end of life.

[SOURCE: IEC 62864-1:2016, 3.1.15, modified – “the user” has been replaced with “the user/ the integrator”. Note 1 to entry has been added.]

3.1.37

beginning of life

BOL

point at which the battery system has the rated capacity or energy fully available as minimum performance at manufacturer’s delivery

[SOURCE: IEC 62864-1:2016, 3.1.16, modified– “the ESU” has been replaced with “the battery system”.]

3.1.38

down time of battery system

time interval for which the battery system is not in traction operation

Note 1 to entry: Down time includes times for standstill, maintenance, storage in depot, transport, etc., under switched off or switched on condition.

3.2 Abbreviated terms

AC	Alternating current
BMS	Battery management system
BOL	Beginning of life
BTMS	Battery thermal management system
DC	Direct current
EOL	End of life
ESS	Energy storage system
ESU	Energy storage unit
IP	International protection
PPS	Primary power source
PTC	Positive temperature coefficient
SOC	State of charge
SOE	State of energy
SOH	State of health

4 Configuration of battery system

4.1 Battery system

The battery system is composed of battery cells, cell blocks, battery packs and subsystems, e.g. BMS, BTMS, etc. There are many possibilities for the configuration of a battery system. Such subsystems can be located outside the battery box, e.g. in a traction converter.

The battery box is the unit in the battery system directly accessible by the user. The battery system can be separated in several battery boxes (several mechanical enclosures).

In some battery boxes cells need not to be included (e.g., separated BMS).

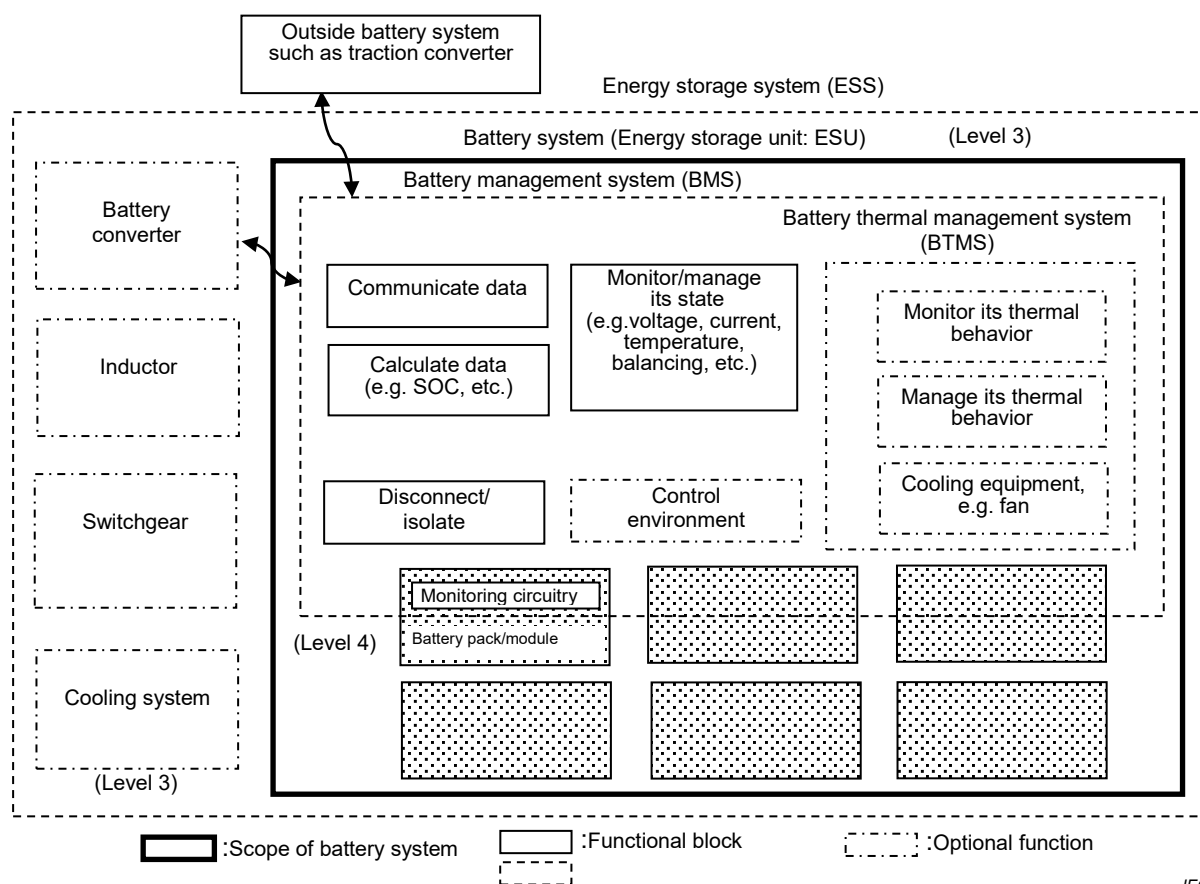
Refer to Figure 4 of IEC 62864-1:2016 as an example for ESU as a constituent of an ESS within a series hybrid system on rolling stock.

Functional configuration of the battery system is shown in Figure 2.

Applying a battery management system (BMS) is mandatory. Whereas, the application of a battery thermal management system (BTMS) is optional.

The level is defined according to IEC 62864-1:2016.

- a) level 1: vehicle/system interface;
- b) level 2: systems and interfaces;
- c) level 3: components; and
- d) level 4: subcomponents.



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Figure 2 – Functional block of battery system

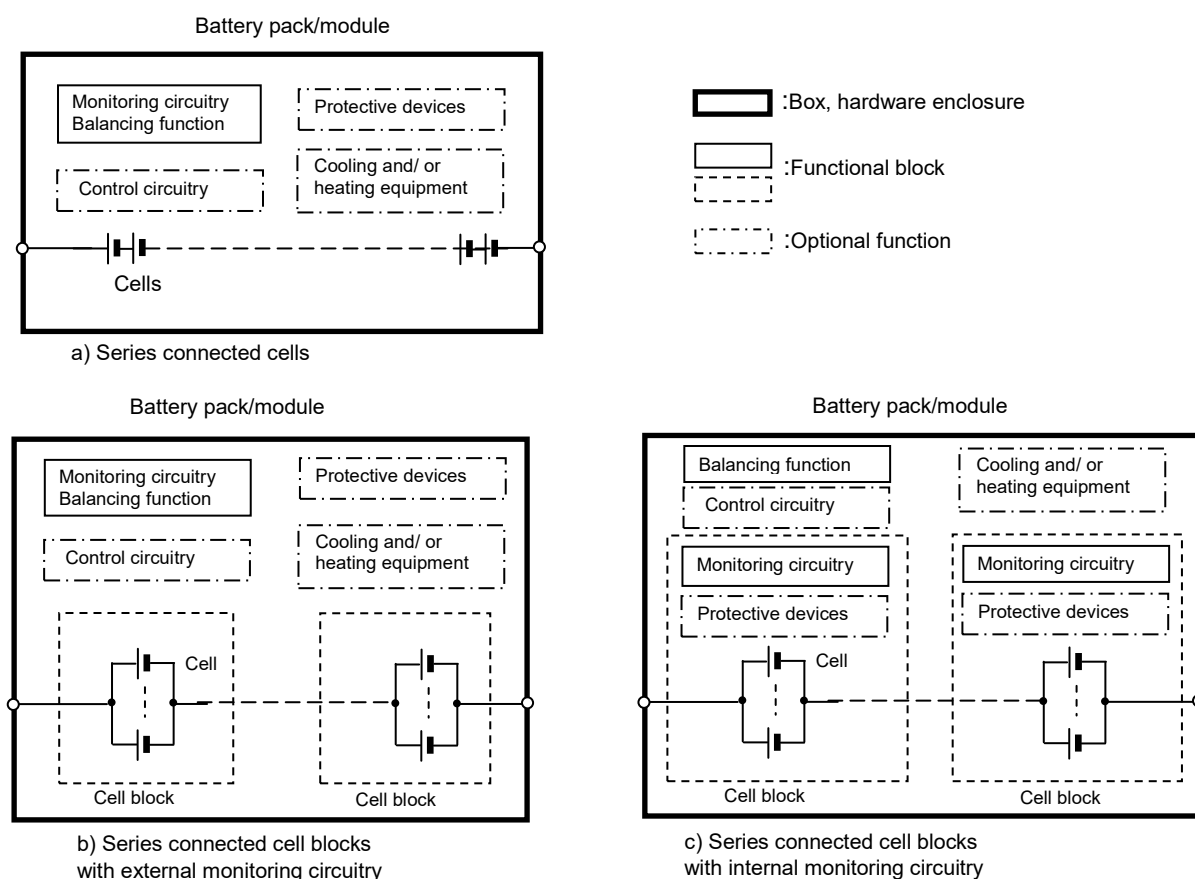
The examples of the battery system configuration are described in Annex A.

4.2 Battery pack/module

Functional configuration of the cell, cell block and battery pack/module is shown in Figure 3. Some functions incorporate cells.

The monitoring circuit, which monitors the state of cells such as voltage, current, temperature, etc., and provides the information to BMS, is mandatory for battery pack.

The control circuitry and protective devices may be included as optional functions.



IEC

Figure 3 – Illustration of definitions for cell, cell block and battery pack/module

4.3 Battery management system (BMS)

The battery management system (BMS) is a subsystem to provide safe operation and optimized performance of the battery system.

The BMS has several functions:

- to monitor voltage of every cell or every cell block;
- to monitor current of every cell block or every battery branch;
- to monitor temperature of representative cells;
- to disconnect or isolate battery packs, battery branches if abnormal operating parameters are detected;
- to calculate state of charge (SOC), etc., from the data obtained by the monitoring function;
- to communicate the data obtained to the outside of the battery system;

NOTE 1 In case of systems with some autonomous safety functions, a short temporary loss of communication for the intended intervals is accepted, as agreed between the user/ the integrator and the battery system manufacturer, and documented,

- to manage the cells or battery packs/ modules in order to establish the balance of voltage or SOC;

NOTE 2 Balancing the traction power among ESUs is a function of the upper system level.

- optionally to control ambient conditions inside the battery system, e.g. air conditioning (temperature, humidity) etc., which may include BTMS.

In some cases, parts of BMS functions can be integrated in other systems such as a traction converter, vehicle control unit, passive balancing battery module, etc.

4.4 Battery thermal management system (BTMS)

The battery thermal management system (BTMS) is an optional subsystem to maintain the temperature of battery pack/module in order to achieve the defined performance and life time according to the specified operational pattern.

If required, the temperature range may be agreed between the user/ the integrator and the battery system manufacturer.

The BTMS may include the following functions:

- to monitor temperature of cells, cooling medium, ambient, etc.;
- to control cooling fans and/ or heaters;
- to communicate BTMS data to outside.

Cooling equipment such as cooling fans, etc., may be installed inside the battery box or outside the battery box or as part of the traction cooling system, etc.

5 Parameter measurement tolerances

The overall accuracy of specific measuring instrument for the tests for the battery system in this document, relative to the specified or actual values, shall be within these tolerances as specified in IEC 62620:2014, Clause 4:

- a) $\pm 0,5 \%$ for voltage;
- b) $\pm 1 \%$ for current;
- c) $\pm 2 \text{ K}$ for temperature;
- d) $\pm 0,1 \%$ for time;
- e) $\pm 1 \%$ for dimensions.

These tolerances comprise the combined overall accuracy of the measuring instruments, the measurement techniques used, and all other sources of error in the test procedure.

For assistance in selecting instrumentation see IEC 60051 for analogue instruments. The details of the instrumentation used shall be provided in any report of results.

Unless other levels of overall accuracies are defined in the subclauses of the individual test items in this document, above accuracies shall apply.

6 Operational conditions

6.1 General

Service conditions for the electrical equipment on rolling stock are defined in IEC 60077-1. Special conditions, which are different from those conditions in IEC 60077-1, are defined in the relevant product standards.

The major conditions extracted from IEC 60077-1 and the specific conditions for the battery system are described in 6.2 to 6.6.

Other standards relevant to rolling stock are listed in the bibliography.

6.2 Mechanical conditions

The battery system shall withstand vibration and shock as stated in IEC 61373.

NOTE Welding conditions and strength are well performed according to the relevant standards.

6.3 Environmental conditions

6.3.1 General

Environmental conditions are given in IEC 62864-1:2016, IEC 60077-1 and IEC 62498-1:2010, unless otherwise specified.

6.3.2 Ambient temperature

T1: from – 25 °C to + 40 °C in IEC 62498-1:2010 shall apply unless otherwise specified.

Ambient temperature is the air temperature outside rolling stock.

Higher and lower operational temperature outside the above range, if any, shall be specified by the user/the integrator.

6.3.3 Temperature in battery enclosure

Components inside the battery enclosure shall be designed to operate within inside temperature ranges according to column (2) or column (3) of Table 2 in IEC 62498-1:2010, unless otherwise specified.

6.3.4 Temperature for life time calculation

TR1 in IEC 62498-1:2010, Table 3 shall apply for life time calculation, unless otherwise specified. The temperature is an open air temperature. For the battery system installed in the enclosure, the temperature rise of the air inside the enclosure shall be considered taking into consideration the cooling conditions (BTMS in operation, etc.).

An ambient temperature histogram provided by the user or the integrator shall be used, if available. This temperature histogram may be discussed and agreed between the user/the integrator and the battery system manufacturer.

6.4 Electrical conditions

6.4.1 Traction circuits

The voltage ranges of the battery system connected to traction circuits, directly or indirectly shall be in accordance with IEC 60850. Other voltages than those listed in IEC 60850 may be used by agreement between the user/the integrator and the battery system manufacturer.

The voltages of the traction circuits connected to the onboard PPS shall be based on specifications of PPS.

6.4.2 Control circuits

The control voltage shall be in accordance with IEC 60077-1 in case the power for the control circuits of the battery system is supplied from the outside of the battery system.

In case electronic circuits are used in the battery system for BMS the requirements specified in IEC 60571 shall apply.

6.4.3 Insulation coordination

Clearances, creepage distances and dielectric test voltages are given in IEC 62497-1. Dielectric test for equipment is given in IEC 60077-1.

6.5 Electromagnetic compatibility (EMC)

The common EMC standard for rolling stock apparatus: IEC 62236-3-2 shall apply to the battery system.

6.6 Software

BMS software architecture and validation shall fulfil the common railway standards: IEC 62279 and IEC 62278:2002.

7 Designation and marking

7.1 Nameplate

Nameplates of the battery system or each separable battery box shall be placed on the surface, where easily visible and accessible. Nameplate shall not be easily detached nor disappear.

NOTE As for a battery box see 4.1.

Mandatory information for the nameplates is as follows:

- lithium-ion or li-ion (considered part, if applicable);
- name or identification of the manufacturer;
- month and year of manufacturing (date may be indicated if possible);
- unique serial number for a complete battery system (separable boxes shall have individual unique serial numbers);
- designations (see 7.2);
- nominal voltage (considered part, if applicable);
- rated capacity or calculated rated capacity (see the last paragraph) (considered part, if applicable);
- weight;
- type of cooling;
- revision level (if applicable);
- part number for a complete battery system or any separable parts.

If evaluated by testing the split unit of a battery system, it shall be indicated as the rated capacity and shall be the amount calculated by a reasonable method.

7.2 Designations for cells and battery system

The cells shall be designated with the following form:

A1A2A3/N2/N3/N4/ A4/TLTH/ NC

Refer to IEC 62620:2014, 5.2.

The battery pack/module and the battery system shall be designated with the following form:

A1A2A3/N2/N3/N4/[S1]A4/TLTH/Nc

Refer to IEC 62620:2014, 5.3.

7.3 Marking

7.3.1 General

Durable markings shall be carried on a visible and non removable surface (considering railways harsh environment) of the relevant products.

7.3.2 Battery pack/module and cells

Information for the battery pack/module and cells shall meet the requirement specified in IEC 62620:2014, 5.1.

7.3.3 Other components

Nameplates or markings of other components, e.g. BMS, contactor, cooling fan, etc., shall meet the relevant product standards.

7.3.4 Additional information

The following information should be indicated, if applicable:

- polarity (terminal) (may be omitted if alternative arrangement is provided to ensure correct connection.);
- wiring number, etc.

The following information shall be included in the manual or instruction documents, if not marked on the battery system or battery boxes:

- method for calculating the rated capacity;
- appropriate caution statement (including disposal instructions);
- recommended charging instructions.

For safety markings, see 8.2.

8 Safety requirements

8.1 General safety consideration

The battery system manufacturer shall provide recommendations for the safe handling of the battery pack/module as high voltages always remain at the terminals of batteries.

Safety requirements for the cell, battery pack/module and battery system are given in IEC 62619:2017.

The specification and verification of the safety requirements shall be in accordance with IEC 62278.

Protection for electrical shock shall comply with IEC 61991.

At least the following potential hazards should be considered:

- a) fire;
- b) burst/ explosion;
- c) leakage of cell electrolyte;
- d) continuous venting of flammable and/or toxic gases;
- e) rupture of the battery case with exposure of internal components.

8.2 Safety signs

8.2.1 Outside the battery box

As a minimum the following safety signs according to ISO 7010 should be placed on the outside of the battery box. Details are subject to agreement between the user/the integrator and the battery system manufacturer:

Warning signs:

- W012 – Warning; electricity
- W026 – Warning; battery charging

Prohibition sign:

- P003 – No open flame; fire, open ignition source and smoking prohibited.

Additional signs should be agreed between the user/ the integrator and the battery system manufacturer. E.g. “No step”, if the battery system is installed on the roof.

8.2.2 Inside the battery box

Following safety signs according to ISO 7010 should be considered to be placed inside the battery box. Details are subject to agreement between the user/the integrator and the battery system manufacturer:

Warning signs:

- W012 – Warning; electricity
- W026 – Warning; battery charging
- W002 – Warning; explosive material

Prohibition sign:

- P003 – No open flame; fire, open ignition source and smoking prohibited

Mandatory action signs:

- M002 – Refer to instruction manual/booklet
- M004 – Wear eye protection
- M009 – Wear protective gloves
- M010 – Wear protective clothing

If the safety signs are fixed on the tray or crate, the signs may be in black and white or colour.

8.3 Isolation for maintenance or service

Isolation of the battery system for maintenance or service shall be agreed between the user/ the integrator and the battery system manufacturer.

8.4 Fire protection

Lithium-ion battery has high energy content in a relatively small volume. In many cases the electrolyte is flammable and therefore special consideration for fire safety shall be taken.

Non-exhaustive examples of possible mitigation measures are listed below:

- enclosing battery system in a metallic frame;
- employing smoke detector and/ or fire detector;
- employing smoke exhausting equipment, etc.

Fire retardant measures shall be considered according to national practices. National laws for fire protection are listed in IEC 62864-1:2016, Annex C for information.

9 Dimensions

Outline dimensions of components of the battery system, such as a battery pack/module, battery box shall be within the tolerances agreed between the user/ the integrator and the battery system manufacturers.

Dimensions of terminals and fixing points shall be within the tolerances specified in the drawings.

10 Electrical requirements

10.1 Operating voltage range of the battery system

The battery system voltage range shall be specified based on the application requirements and the traction system architecture.

The maximum and minimum of operating voltages shall be specified by the integrator considering the maximum voltage and the minimum voltage of the battery system. The maximum voltage and the minimum voltage of the battery system shall be provided by the battery system manufacturer.

10.2 Ripple current

The ripple current level and range of fundamental frequencies shall be specified and agreed between the integrator and the battery system manufacturer.

10.3 Charge and discharge control of the battery system

Control of the battery system shall be in accordance with IEC 62619:2017 and IEC 62620:2014 to ensure every cell remains within the cell operating region (voltage, current and temperature).

NOTE For the cell operating region, see Annex A in IEC 62619:2017.

10.4 Communication

There are different means for communication between the battery system and the external system (e.g. traction system, vehicle control system, etc.); the choice of the communication method should be the subject of agreement between the user/ the integrator and the battery system manufacturer. The internal communication between subsystems of the battery system may be different from the type of the communication network used in the train.

10.5 Starting of disabled battery system

The battery system shall be considered as disabled in the following cases:

- no voltage at the terminals of the battery system after the defined delay time; or
- no communication with BMS; or
- BMS sending the battery system disabled status signals.

NOTE No voltage at the terminals of the battery system can occur due to internal start up procedures, environmental conditions, etc. Reconnection of the battery system can occur after a defined delay time by the integrator and the battery system manufacturer.

The detailed conditions of these cases shall be agreed between the integrator and the battery system manufacturer. In case the battery system is disabled, it is not recommended to use the battery system any further, e.g. occurrence of over discharge, etc.

However, in case of an emergency the possibility to ignore the disable status received from BMS may be considered. Such an operation should be agreed between the user/ the integrator and the battery system manufacturer and documented.

The user should contact the integrator or the battery system manufacturer in case there is no documentation regarding usage of the battery system, which is disabled.

10.6 Insulation status

Insulation status of the battery system between the terminals and the battery box (under the battery system manufacturer responsibility) or vehicle's body (under the integrator responsibility) is an important safety measure. The insulation status, e.g. insulation resistance should be checked or monitored.

These may be performed periodically by manual inspection or automatically within the battery system.

Automatic monitoring may be an option for a DC traction power supply system.

Automatic monitoring should be used for an AC traction power supply system and vehicles used with the isolated body from earth, e.g. rubber tired vehicles.

10.7 Battery management system (BMS)

The BMS shall have the functions and selected option as described in 4.3.

The permissible range of unbalance, which is measured as difference of voltage and/ or SOC of all cells within an ESU, shall be agreed between the integrator and the battery system manufacturer. The BMS shall keep the cells within an ESU (see Figure 3) balanced during operation, e.g. during operating hours, after or during down times of battery system.

11 Mechanical requirement

11.1 Mechanical integration

Integration of the cell, battery pack and battery system shall be considered so that electrolyte, coolant or gasses shall not be dropped out or exhausted in an uncontrollable manner.

11.2 Shock and vibration

Shock and vibration shall comply with the mechanical conditions in 6.2.

NOTE Welding conditions and strength are well performed according to the relevant standards. E.g, for European countries, refer to EN 15085 series.

11.3 Degree of protection

The degree of protection shall be selected from those defined in IEC 60529.

IP requirement shall be fulfilled at least at the highest mechanical integration level, e.g. battery box, traction converter box including a part of battery system (see Annex A), etc.

12 Performance requirement

12.1 Design energy and power calculation methodology

12.1.1 General

Application of rolling stock requires the following performances:

- high power design;
 - at accelerating the train, a high power discharge is required;
 - at regenerative braking, a high power charge is required;
 - at charging station, a high power charge is required;
- high energy design;

In case the battery systems are used as the only power source for systems consuming energy for a long time, e.g. traction and/or auxiliaries, a high energy capability is required.

There are also different sizing requirements:

- special or seldom happening conditions, e.g. overload conditions, that are not regularly repeated;
- normal conditions, when the rolling stock is operated on a regular route profile.

These requirements for the onboard energy storage system are described in the system specifications or system level standard of IEC 62864-1:2016.

12.1.2 Sizing

The battery systems shall be sized in accordance with the required operational pattern (e.g. normal operation, overload conditions, long-time discharge, low or high temperature performance), including the end of life (EOL). It is therefore necessary to have a clear definition of the different operational patterns, as well as of their expected repetition over daily operation (with possible insertion of special conditions). It should be noted that the operational patterns are dependent on application and/ or seasons (e.g. winter / summer / mid-season variations, especially when comfort auxiliaries take a significant part of the operational pattern).

Sizing is of key importance in that the battery system can fulfil its function without operating beyond its intended use (meaning a loss of operational availability with safety protection features activation if necessary).

The user specifies the operational patterns of rolling stock based on time, speed, loads, stops, gradients, environmental conditions, etc.

The integrator shall then define the specifications, e.g. load profile, energy reserve, etc., requested along the operational pattern. These specifications shall be used for verification for the battery system test.

The battery system manufacturer shall propose the sizing of the battery system, e.g. including manufacturing tolerances, permissible range of unbalance, ageing behaviour, etc. The operating current calculated according to the load profile specified by the integrator shall be provided by the battery system manufacturer. The battery system manufacturer shall consider the cell operating region, e.g. the maximum charging current and maximum discharging current of the cell.

According to the sign defined in IEC 62864-1:2016, the positive power at the battery system level is defined as corresponding to the train acceleration (taking energy from the battery system to accelerate or power the auxiliaries for an example), when the negative power at battery system level corresponds to a deceleration (and recuperation of the energy into the battery system). The sign is used for a drawing load profile.

12.1.3 Documentation

The results of the calculations and simulations for sizing shall be documented in a report. The minimum reporting contents are:

- key data for the battery system: type, capacity and quantity of cells, electrical architecture as initially defined by the integrator,
- description of the battery system behaviour over an intended operational pattern, with indication of compliance versus requested conditions (e.g. minimum voltage) for each load profile segment in their occurrence order,
- environmental conditions (e.g. temperatures for charge and discharge) and derating factors.

12.2 Cooling / heating requirement

The ambient temperature required for the railway vehicle stated in 6.3.2 may differ from the permissible temperature of cells. Also non-uniform cell temperatures may occur. In such a case adequate methods, e.g. cooling or heating, etc., to control temperature of cells shall be equipped in the battery system. The heating-cooling requirement shall be proposed by the battery system manufacturer.

Energy consumption of the BTMS shall be calculated by the BTMS manufacturer based on the temperature of lifetime calculation in 6.3.4.

12.3 End of life performance

The ESU shall perform the operational pattern until the point where it reaches the end of life as defined in the battery system sizing as agreed between the user/the integrator and the battery system manufacturer. Refer to IEC 62864-1:2016, 6.7.

NOTE State of health (SOH) is one of the figures to evaluate the conditions of the ESU. There are various approaches for definitions of SOH (parameters and/ or evaluating methods, etc.). Several influencing parameters (capacity, internal resistance, mechanical durability, etc.) and operational conditions (temperature, SOE reserve, etc.) exist. Such parameters and operational conditions will be defined by the battery manufacturer, the integrator and the user using percentage scaling based on agreed parameters.

For example,

- at EOL, SOH is defined as 0 % and is related to the load profile. When the operational pattern cannot be fulfilled, the value of 0 % is reached. The battery system might still have a useful capacity for other application.
- at BOL, SOH is defined as 100 % and is related to the rated capacity as indicated on the name plate and/ or the initial internal DC or AC resistance (refer to 14.2.1).

13 Storage and transportation conditions

13.1 Transportation

According to the valid standards of the respective country, the battery system manual should accompany the battery systems.

NOTE 1 For European countries EN 50272-2 applies.

NOTE 2 For United Nations Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, 5th revised edition, part III, section 38.3 – Ref. ST/SG/AC.10/11/rev.5,amd.1 (UN 38.3) applies.

13.2 Storage of battery systems

The battery system manufacturer shall specify the method of storage in the manual.

13.3 Self-discharge

Especially for the railway application, a long time storage or transportation can occur before and/ or after commissioning of rolling stock. The battery system shall be operable for commissioning and operation.

Charge retention of cells, which is reduced by self-discharge, is specified in IEC 62620:2014, 6.4.

Additional components, e.g. balancing function of the BMS, increase the self-discharge rate of the battery system. Guidance for the battery system shall be stated by the battery system manufacturer to ensure a safe transport as well as an appropriate operation after a long time transportation and/ or storage before installation on rolling stock and commissioning.

NOTE Detailed guidance can be found in UN 38.3.

The time period after commissioning and delivery of the built rolling stock to the user's site until revenue operation starts should be defined by the user, and considered in the battery system design.

The battery system manufacturer shall define an additional maintenance equipment, software, procedure, etc., for a long time storage.

14 Tests

14.1 Kind of tests

14.1.1 General

The type test conditions shall be agreed between the cell manufacturer and the battery system manufacturer, to validate the design and performance of the battery system. It shall be done according to 14.1.2.

Routine tests are carried out to verify that each system is correctly assembled and that all components and system operate properly and safely. It shall be done according to 14.1.2.

If a routine test of all cells or all battery pack/modules is done, it is not necessary to repeat the same test at a different level except upon agreement between the cell manufacturer and the battery system manufacturer and/ or the integrator.

The test items listed in Table 1 are not exhaustive. Other test items may be carried out under agreement between the cell manufacturer and the battery system manufacturer and/ or the integrator, if necessary.

14.1.2 Test categories

The test items are listed in Table 1.

Table 1 – List of tests

Test item	Test object		Clause number
	Type test	Routine test	
Electrical tests			
Electrical characteristics tests			14.2.1
a) discharge performance at 25 °C	C and B	C or B ^a	14.2.1
b) discharge performance at low temperature	C	-	14.2.1
c) high rate permissible current	C	-	14.2.1
d) charge retention and recovery	C	-	14.2.1
e) internal AC resistance	C	-	14.2.1
f) internal DC resistance	C and B	B	14.2.1
g) endurance in cycles	C	-	14.2.1
Battery management system (BMS) tests	B	-	14.2.2
Performance test	B	-	14.2.3
Endurance in cycles	C	-	14.2.4
Endurance in cycles test (General)	C		14.2.4.2
Endurance in cycles test (High power)	C ^b		14.2.4.3
Dielectric test	B	B	14.2.5
Self-discharge test	B	-	14.2.6
Operational balancing test	B	-	14.2.7
Mechanical tests			
Physical appearance	B ^c	B ^c	14.3.1
Mass measurement	B	-	14.3.2
Shock and vibration test	B	-	14.3.3
Test of the degree of protection	B	-	14.3.4
Safety tests			
Safety test according to IEC 62619			14.4.1
Product safety tests			14.4.1.2
a) external short circuit test	C	-	14.4.1.2
b) impact test	C	-	14.4.1.2
c) drop test	C and B	-	14.4.1.2
d) thermal abuse test	C	-	14.4.1.2
e) overcharge test	C	-	14.4.1.2
f) forced discharge test	C	-	14.4.1.2
g) consideration for internal short circuit	Either:	-	
– internal short circuit test	C	-	14.4.1.2
– propagation test	B	-	14.4.1.2
Functional safety tests			14.4.1.3
a) overcharge control of voltage	B	-	14.4.1.3
b) overcharge control of current	B	-	14.4.1.3
c) overheating control	B	-	14.4.1.3