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Electrical energy storage (EES) systems -
Part 5-2: Safety requirements for grid-integrated EES systems - Electrochemical-based systems

IEC 62933-5-2:2025-12(en)

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Electrical energy storage (EES) systems - Part 5-2: Safety requirements for grid-integrated EES systems - Electrochemical-based systems

FOREWORD

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IEC 62933-5-2 has been prepared by IEC technical committee 120: Electrical Energy Storage (EES) systems. It is an International Standard.

This second edition cancels and replaces the first edition published in 2020. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) New BESS categories: This document created new BESS energy categories “E-LI” (integrated within one enclosure), and “E-LS”(separated by two or more enclosures), because the safety measures are different for systems with one enclosure and systems with multiple enclosures.
b) Location risk: This document added information about differences in risk depending on location.

c) Reused or repurposed battery: Regarding ensuring the safety of BESS using reused or repurposed batteries, a reference to the new standard IEC 629933-5-3 was added.

d) Protection from fire hazards: Based on an analysis of BESS fires occurring around the world, the number of fire propagation measures have been significantly increased.

e) System validation and test: Test methods and criteria have been clarified. In addition, the validation of measures against gas generation and fire spread has been significantly revised.

This International Standard is to be used in conjunction with IEC 62933-5-1:2024.

The text of this International Standard is based on the following documents:

Draft	Report on voting
120/415/FDIS	120/436/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 62933 series, published under the general title *Electrical energy storage (EES) systems*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

– reconfirmed,
– withdrawn, or
– revised.

INTRODUCTION

All the electrical energy storage systems (EESS) follow the general safety requirements as described in IEC 62933-5-1, which is based on a system approach. This document follows the same structure as IEC 62933-5-1 and provides additional requirements for electrochemical-based EESS. The additional requirements are provided for the following reasons:

a) Electrochemical-based EESS can be integrated into a significant range of electrical grids.

b) The level of safety requirements awareness can vary between utilities, system integrators, operators and end-users.

c) Although the safety of individual subsystems is generally covered by international standards at ISO and IEC levels, the safety matters that arise due the combination of electrochemical accumulation subsystems and any electrical subsystems are not always considered. Electrochemical-based EESS are complex at the systems level due to the variety of potential battery options and configurations, including the combination of subsystems (e.g. control systems for electrochemical accumulation subsystems, electrochemical accumulation subsystems, power conversion subsystems and auxiliary subsystems). Compliance with standards and related material produced specifically for the safety of subsystems cannot be sufficient to reach an acceptable level of safety for the overall system.

d) Electrochemical-based EESS can have additional safety hazards, due, for example, to the presence of chemicals, the emission of toxic gases, chemicals spilt around the electrochemical accumulation subsystems and to events critical for safety from electrochemical accumulation subsystems that cause safety issues for the entire electrochemical-based EESS. They can cause loss of power at any part of the systems and buildings that can result in additional threats to safety. From a systems perspective, these individual hazards can have a system wide impact.

1 Scope

This part of IEC 62933 primarily describes safety aspects for people and, where appropriate, safety matters related to the surroundings and living beings for grid-connected energy storage systems where an electrochemical storage subsystem is used.

This document is applicable to the entire life cycle of BESS (from design to end of service life management).

This document provides further safety provisions that arise due to the use of an electrochemical storage subsystem (e.g. battery system) in EES systems that are beyond the general safety considerations described in IEC 62933-5-1.

This document specifies the safety requirements of an "electrochemical" energy storage system as a "system" to reduce the risk of harm or damage caused by the hazards of an electrochemical energy storage system due to interactions between the subsystems as presently understood.

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 60068-2-52, *Environmental testing - Part 2-52: Tests - Test Kb: Salt mist, cyclic (sodium chloride solution)*

IEC 60079-7:2015, *Explosive atmospheres - Part 7: Equipment protection by increased safety "e"*
IEC 60079-7:2015/AMD1:2017

IEC 60079-13, *Explosive atmospheres - Part 13: Equipment protection by pressurized room "p" and artificially ventilated room "v"*

IEC 60079-29 (all parts), *Explosive atmospheres - Gas detectors*

IEC 60364 (all parts), *Low-voltage electrical installations*

IEC 60364-4-44*, Low-voltage electrical installations - Part 4-44: Protection for safety - Protection against voltage disturbances and electromagnetic disturbances*

IEC 60364-6:2016, *Low voltage electrical installations - Part 6: Verification*

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

IEC 60664-1:2020, *Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests*

IEC 60812, *Failure modes and effects analysis (FMEA and FMECA)*

IEC 61000-1-2*, Electromagnetic compatibility (EMC) - Part 1-2: General - Methodology for the achievement of functional safety of electrical and electronic systems including equipment with regard to electromagnetic phenomena*

IEC 61000-6-7, *Electromagnetic compatibility (EMC) - Part 6-7: Generic standards - Immunity requirements for equipment intended to perform functions in a safety-related system (functional safety) in industrial locations*

IEC 61025, *Fault tree analysis (FTA)*

IEC 61660-1, *Short-circuit currents in d.c. auxiliary installations in power plants and substations - Part 1: Calculation of short-circuit currents*

IEC 61660-2, *Short-circuit currents in d.c. auxiliary installations in power plants and substations - Part 2: Calculation of effects*

IEC 61882, *Hazard and operability studies (HAZOP studies) - Application guide*

IEC 61936-1:2021, *Power installations exceeding 1 kV AC and 1,5 kV DC - Part 1: AC*

IEC 62305-2*, Protection against lightning - Part 2: Risk management*

IEC 62368-1, *Audio/video, information and communication technology equipment - Part 1: Safety requirements*

IEC 62477-1:2022, *Safety requirements for power electronic converter systems and equipment - Part 1: General*

IEC 62485-2, *Safety requirements for secondary batteries and battery installations - Part 2: Stationary batteries*

IEC 62619:2022, *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 62933-1, *Electrical energy storage (EES) systems - Part 1: Vocabulary*

IEC 62933-5-1:2024, *Electrical energy storage (EES) systems - Part 5-1: Safety considerations for grid integrated EES systems - General specification*

IEC 62933-5-3:2023, *Electrical energy storage (EES) systems - Part 5-3: Safety requirements for grid-integrated EES systems - Performing unplanned modification of electrochemical based system*

ISO/IEC 31010, *Risk management - Risk assessment techniques*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62933-1, IEC 62933-5-1, and the following apply.

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

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

NOTE Where differences in definitions appearing in IEC 62933-1 and IEC 62933-5-1 exist, the definition given in IEC 62933-1 prevail, unless otherwise specified here.

3.1
type test
conformity test made on one or more items representative of the production

[SOURCE: IEC 60050-151:2001, 151-16-16]

3.2
routine test
conformity test made on each individual item during or after manufacture

[SOURCE: IEC 60050-151:2001, 151-16-17]

3.3
battery management system
BMS
electronic system associated with a battery which has functions to controlling current in case of overcharge, overcurrent, over discharge, and overheating and which monitors and/or manages its state, calculates secondary data, reports that data and/or controls its environment to influence the battery's safety, performance and/or service life

[SOURCE: IEC 62619:2022, 3.12, modified – the notes have been removed.]

3.4
system integrator
manufacturer which integrates the individual subsystem and completes functions properly as a single system

4 Basic guidelines for safety of BESS

4.1 General

An assessment and reduction of risk associated with the BESS as manufactured and as intended to be installed shall be conducted in accordance with the procedure shown in Figure 1.

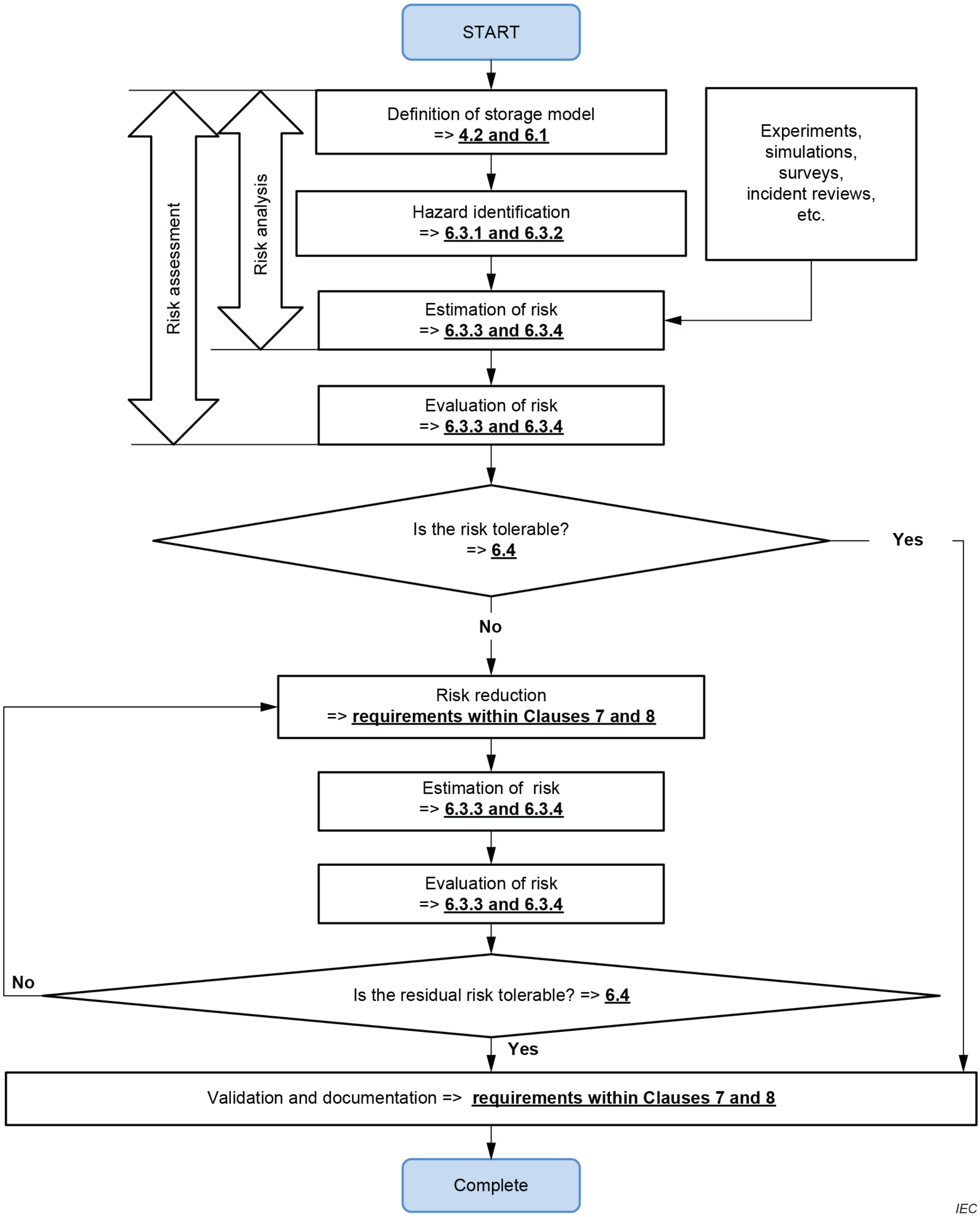


Figure 1 – General procedure for risk assessment and reduction of BESS

Risks can depend on many factors including location, chemistry and the size/scale (e.g. power) of the BESS and shall be assessed accordingly. The location of the BESS can range from single domestic situations, commercial and industrial applications to utility scale systems, and risks shall be assessed accordingly. Selection of chemistry for the electrochemical accumulation subsystem of the BESS can depend on the environment, performance characteristics and any associated costs and benefits.

As described in ISO/IEC Guide 51:2014, risk reduction measures taken during design are "inherently safe design", "guards and protective devices", and "information for end users". Additional measures at the use phase (life cycle safety management) are also described in ISO/IEC Guide 51.

4.2 Approach to BESS safety

The design of the BESS and its intended installation and integration within the built environment shall accommodate the specific risks that arise during each phase of the BESS life cycle. These life cycle phases typically include, but are not limited to:

- manufacturing/final assembly and factory acceptance testing (see 7.10, 7.11, and 8.2);
- transport (see 7.10, 7.11, and 8.2);
- installation, commissioning and site acceptance testing (see 7.10, 7.11, 7.12 and 8.2);
- operation (see 7.13);
- maintenance and repair (see 7.13);
- repurposing or decommissioning (see 7.13).

During the installation process, soundness of communication among subsystems, which are critical to minimizing risk and facilitating incident response shall be ensured to avoid any malfunctions of the protection subsystems. After the installation of the BESS, these subsystems shall be verified by inspection or other suitable means so that their proper functions are assured before the BESS is placed into service.

All health, safety and environment (HSE) requirements applicable to the BESS as installed shall be satisfied during system maintenance and repair.

The safety design considerations and risk analysis for each identified life cycle phase shall be documented and supplied in accordance with Clause 6 and 7.13.

A BESS that is designed and constructed to provide a specified level of reliability and durability shall include not only the levels of safety as a design feature of the overall system but also subsystem safety level which is necessary to achieve the specified level. At the subsystem level, all integrated electrochemical energy storage subsystems shall comply with appropriate safety standards (e.g. IEC 62477-1, IEC 62619).

Safety measures for interactions between subsystems shall be consistent with the result of the system level safety risk assessment.

Common BESS point of connection (POC) voltages, energy capacity, site occupancy and chemistry of electrochemical accumulation subsystem are distinguished as listed in Table 1.

Detailed implementation of safety measures required in Clause 7 and Clause 8 can be optimized in accordance with the result of the system risk assessment of BESS (see Clause 6) using the basic conditions in Table 1.

NOTE 1 Chemistries that are not in common widespread use for stationary applications are not considered in this document but can be considered in future editions.

NOTE 2 "Energy capacity" of BESS" means total energy capacity of electrochemical accumulation subsystems which are equipped behind one POC.

Table 1 – BESS categories

Features for categorization	Category denominations	Explanation
"POC voltage" where BESS is connected	V-L	Low: V ≤ 1 kV AC or 1.5 kV DC
	V-H	High: V > 1 kV AC or 1.5 kV DC
"Energy capacity" of BESS	E-S	Small: E ≤ 20 kWh
	E-LI	Large: E > 20 kWh / Integrated within one enclosure
	E-LS	Large: E > 20 kWh / Separated by two or more enclosures
"Site occupancy" in relation to electrochemical accumulation subsystem	S-O	Occupied site (see IEC 62933-1)
	S-U	Unoccupied site (see IEC 62933-1)
"Chemistry" of electrochemical accumulation subsystem	C-A	BESS using non-aqueous electrolyte battery (e.g. alkali ion based)
	C-B	BESS using aqueous electrolyte battery (e.g. Lead acid, Ni-based)
	C-C	BESS using high temperature battery (e.g. NaS, NaNiCl)
	C-D	BESS using flow battery
	C-Z	Others

NOTE 1 Denominations of BESS categorization are described as "V-X / E-X / S-X / C-X" in any requirements of this document (e.g. V-H / /E-LI / S-U / C-C). Some characteristics can be omitted if any limitation of category does not apply.

NOTE 2 To apply this document to both BESS and other electrochemical based EESS including chemical based super-capacitors, the latter EESS are included in category "C-Z".

NOTE 3 Combinations of two or more electrochemical accumulation chemistries are included in category "C-Z".

NOTE 4 Li-based batteries are categorized as C-A, no matter whether those electrolytes are non-aqueous liquids or solid electrolytes (typically referred to as solid state).

An example of BESS use can be described as shown in Table 2.

Table 2 – Examples of BESS application

Application environment	Site	Access restrictions/conditions during operation and maintenance
Residential	Installed in individual homes or shared by a small number of homes, apartments buildings or villas.	Can be placed in a location that is not accessible for regular maintenance without cooperation of the inhabitants of the home and is not part of a professional operating and maintenance regime.
	An example of using Table 1 in this BESS application environment can be as follows: "V-L / E-S or LI /S-O or U / C-A or B".	
Commercial	Installed in small businesses, shared by a large number of homes, etc., or a mixture of the above uses such as a street or a large apartment building.	Placed in a location that is accessible for regular maintenance during business hours and is usually part of a professional operating and maintenance regime.
	An example of using Table 1 in this BESS application environment can be as follows: "V-H or L / E-LI /S-O or U / C-A, B, C or D".	

Application environment	Site	Access restrictions/conditions during operation and maintenance
Industrial	Installed in large businesses like factories, data centres, warehouses etc., or shared by a large number of homes, such as a city quarter.	Placed in a location that is accessible for regular maintenance during business hours and is part of a professional operating and maintenance regime.
	An example of using Table 1 in this BESS application environment can be as follows: "V-H / E-LI or E-LS /S-O or U / C-A, B, C or D".	
Utility	Connected directly to the utility grid.	Placed in a location that is continuously accessible for regular maintenance and is part of a professional operating and maintenance regime. The system is typically placed inside a restricted access area, or access to the system itself is restricted to authorized people.
	An example of using Table 1 in this BESS application environment can be as follows: "V-H / E-LS / S-O or U / C-A, B, C or D".	

4.3 BESS changes in ownership, control or use

In all cases where a transfer of ownership or operational responsibility occurs, the monitoring log information should be transferred to the new owner as part of the system documentation, including measures for complying with the requirements in 7.13.2 and 7.13.3. When it is necessary to control identified BESS risks, there should be clarification on the roles and responsibilities for managing and controlling any existing or new safety risks arising out of the changes that are planned or have taken place.

Annex A provides further information regarding ownership of BESS.

5 Hazard considerations

The general hazard considerations for EESS in IEC 62933-5-1:2024, Clause 5, are applicable.

6 BESS system risk assessment

6.1 BESS structure

6.1.1 General characteristics

A storage model of the BESS with clarifying features as shown below shall be created for an appropriate safety risk assessment.

An example of a BESS including a primary POC, auxiliary POC and control subsystem is shown in Figure 2 and Table 2. In some cases, it is possible that one or more subsystems or components are not included. The communication arrangements between management, communication, protection and the other subsystems are shown as dotted arrow lines.

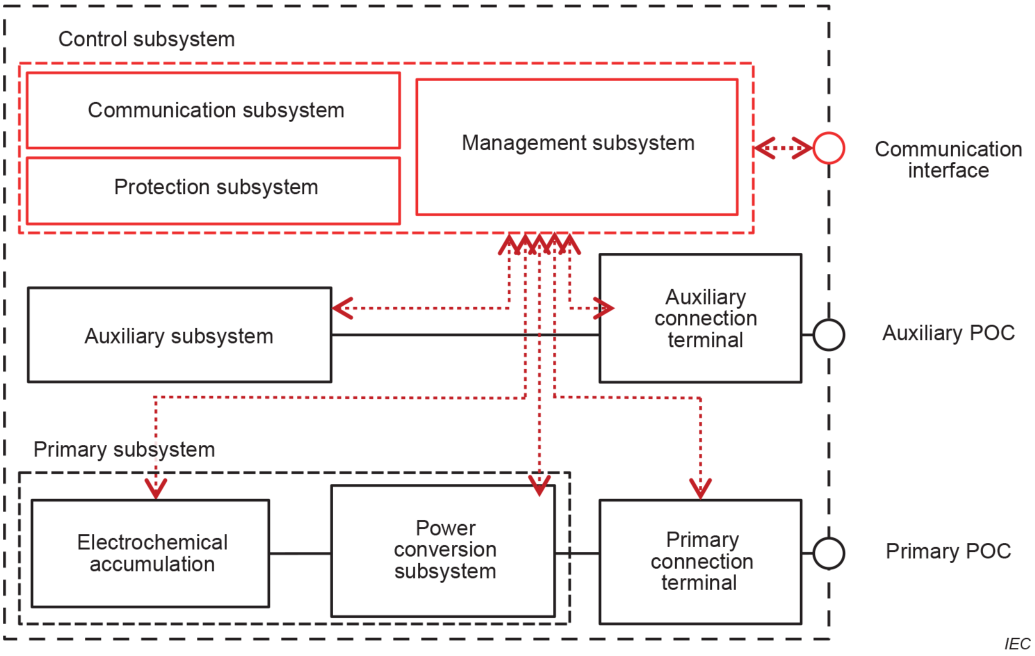


Figure 2 – An example of BESS architecture

NOTE Figure 2 is an example of a typical BESS architecture. There can be cases which do not fit in Figure 2.

Table 3 – Examples of components within subsystems of a BESS

Subsystems	Components
Management subsystem	System controller and/or energy management system
Communication subsystem	Operation panel (human interface), system communication and/or monitoring, meter communication
Protection subsystem	Relays (earth, overcurrent, over voltage, under voltage, over frequency, under frequency, etc.)
Auxiliary subsystem	Fire, heat, and/or smoke detection system(s), fire suppression system, HVAC (heating, ventilation and air conditioning), system anchors, auxiliary transformers, auxiliary power distribution switchgear, auxiliary power uninterruptible power supply (UPS)
Auxiliary connection terminal	Connection terminals, cable (type, fire rating, thermal rating, chemical rating, size and flexibility)
Electrochemical accumulation subsystem	Battery (incl. battery management system), communication devices, protective devices, mechanical fixing, cables, thermal management system NOTE There are many cases where BESS include multiple numbers or types of electrochemical accumulation subsystems
Power conversion subsystem	Transformer, AC/DC converter, inverter, power conditioning system (PCS) controller, switches
Primary connection terminal	Connection terminal, cable (type, thermal rating, chemical rating, size and flexibility)
Others	Room and/or building/enclosure, foundation, water supply, HVAC system of the building, fuses, safety markings

6.1.2 Specific characteristics

The main types of BESS that have been previously categorized according to 4.2 can differ not only in the chemistry of the electrochemical accumulation subsystem but also according to the type of auxiliary subsystems as given below:

- specific auxiliary subsystem of category "C-C" (BESS using high temperature battery)
  - electrochemical accumulation subsystem heating circuit;
- specific auxiliary subsystem of category "C-D" (BESS using flow battery)
  - heat exchanger;
  - fluid management system (pump, tank, piping, valve. etc).

6.1.3 Specific BESS implementation location

For reasons of difficulty of access and egress, rooftop BESS installations or BESS installations at elevated floor levels are not recommended. Should such an installation of a BESS still be envisaged, the risk analysis procedure (see 6.3) shall consider additional risk reduction measures that shall be taken to make sure that the residual risk is tolerable and acceptable by concerned emergency services.

6.2 Description of BESS conditions

The basic description of BESS conditions shall be categorized in accordance with Table 1 (see 4.2). The more detailed description in accordance with IEC 62933-5-1:2024, 6.2, is applicable to BESS.

6.3 Risk analysis

6.3.1 General

A risk analysis (hazard identification and risk estimation) of the BESS shall be carried out in accordance with 4.1, 4.2, 6.3.2, 6.3.3 and 6.3.4.

The general considerations for analysing any risk of EESS are described in IEC 62933-5-1.

An iterative approach shall be applied (because several successive applications can reduce the risk and make the best use with available technology). In carrying out this process, it is necessary to consider the safety of the BESS during all the phases of its life cycle.

Useful information about BESS hazards and risks is provided in Annex B.

An example of a method to perform a What-IF risk analysis is provided in Annex I.

6.3.2 Hazard identification specific to BESS

The scenario, as a result of BESS risk assessment, shall include specific subsystem failure modes (identified hazards specific to BESS) as starting points for the analysis.

6.3.3 Risk consideration

BESS risk scenarios shall include all interactions between subsystems. Examples of scenarios include but are not limited to:

- propagation from electrochemical accumulation subsystem(s) to others;
- propagation from non-accumulation subsystems;
- simultaneous failures/faults of multiple subsystems;
- loss of subsystem function related to safety.

6.3.4 System level risk analysis

The system level BESS risk shall be assessed at a component, module and final system level. A suitable analysis shall be performed to demonstrate that suitable risk analysis has been carried out at a component, module and final system level.

The general conditions of "system level risk analysis" are described in IEC 62933-5-1:2024, 6.3.3.

The system level BESS risk analysis shall be performed based on the risk (BESS size/severity) and complexity of the system using one of the following techniques or an equivalent one:

– bottom-up first principles risk analysis (e.g. FMEA (failure mode and effect analysis): see IEC 60812);
– top-down analysis (e.g. FTA (fault tree analysis): see IEC 61025);
– combined and/or integrated analysis (e.g. HAZOP (hazard and operability study): see IEC 61882, STAMP);
– structured What-IF technique (see ISO/IEC 31010).

6.4 System level risk assessment

All risks shall be assessed for their impact on operators, users and neighbours who can occupy the site of the BESS and be graded as tolerable or not.

If the systems are reliant upon electronics and software, an evaluation of the functionality of these controls shall be conducted. A suitable functional safety standard, for example, can be utilized for this purpose.

If some risks are not tolerable, appropriate measures shall be taken, in accordance with the requirements in Clause 7 and Clause 8.

Documentation attached to the assessment and reduction of risk of the BESS shall be available and shall comprise all requirements specified in Clause 6.

7 Requirements necessary to reduce risks

7.1 General measures to reduce risks

The general safety considerations for an EESS are described in IEC 62933-5-1:2024, 7.1.

The priority of risk reduction approaches (from ISO/IEC Guide 51:2014, 6.3.5) shall be:

- inherently safe design;
- guards and protective devices;
- information for end users.

Inherently safe design measures are the first and most important step in the risk reduction process. This is because protective measures inherent to the characteristics of the product or system are likely to remain effective, whereas experience has shown that even well-designed guards and protective devices can fail or be violated, and information for use might not be followed.

Guards and protective devices shall be used whenever an inherently safe design measure does not reasonably make it possible either to remove hazards or to sufficiently reduce risks. Complementary protective measures involving additional equipment (e.g. emergency stop equipment) might have to be implemented.

The end user has a role to play in the risk reduction procedure by complying with the information provided by the designer/supplier. However, information for use shall not be a substitute for the correct application of inherently safe design measures, guards or complementary protective measures.

All the safety design measures required in 7.2 to 7.12 shall be considered in accordance with BESS risk assessment processes specified in Clause 6.

Some of the specified measures can be waived provided that clear demonstration is made in the risk assessment that safety objectives supported by the waived measured are clearly achieved, even without the implementation of the concerned measure.

7.2 Preventive measures against damage to neighbouring inhabitants

The general safety considerations of EESS described in IEC 62933-5-1:2024, 7.2, are applicable.

7.3 Preventive measures against physical injury or damage to the health of workers and residents

The general safety considerations of EESS described in IEC 62933-5-1:2024, 7.3, are applicable.

7.4 Over current protection design

The general safety considerations of EESS described in IEC 62933-5-1:2024, 7.4, are applicable.

7.5 BESS disconnection and shutdown

The general safety considerations of EESS described in IEC 62933-5-1:2024, 7.5, are applicable. Additional safety requirements necessary to reduce risks of BESS during disconnection and shutdown are described in 7.11.2.

7.6 Operation and maintenance

The general safety considerations of EESS described in IEC 62933-5-1:2024, 7.6 are applicable.

7.7 Staff training

The general safety considerations of EESS described in IEC 62933-5-1:2024, 7.7, are applicable.

7.8 Safety design

The general safety considerations of EESS described in IEC 62933-5-1:2024, 7.3, are applicable. Additional safety requirements necessary to reduce risks of BESS through safety design are described in 7.10, 7.11.1, 7.11.3, and 7.12.

7.9 General requirements for BESS safety

Any failure or fault with a subsystem should not affect the safety of the other subsystem.

Any subsystem that develops a fault which could affect the safe operation of the BESS should be capable of being isolated from other subsystems. The safety functions of subsystems shall not be affected by such isolations and shall operate independently.

The BESS design should minimize noise, vibration and extreme temperatures generated from the BESS.

The architecture of subsystems within the BESS should not prevent operators from recognizing hazardous parts, sections and conditions.

Additionally, for category "V-H" BESS, measures shall be taken for preventing any remote dangerous operations if there is no evidence that can be obtained that workers are not at risk at the site.

Ergonomic principles specified in an appropriate standard (e.g. ISO 9241 (all parts)) should be taken into account in designing machinery so as to reduce the mental or physical stress of, and strain on, the operator. These principles should be considered when allocating functions to operator and machine (degree of automation) in the basic design.

BESS using reused or repurposed batteries shall comply with IEC 62933-5-3:2023, Clause 9.

7.10 Inherently safe design of BESS

7.10.1 Protection from electrical hazards

The electrical installation of category "V-L" BESS shall be in accordance with appropriate parts of the IEC 60364 series.

The electrical installation of category "V-H" BESS shall be in accordance with IEC 61936-1 and IEC 60364 series.

The electrical protection for the subsystem connected to the DC side of the BESS shall be safe in accordance with, for example, IEC 61660-1 and IEC 61660-2.

The live parts of subsystems and the components of BESS that have hazardous voltage (above safety extra-low voltage (SELV)) circuits shall not be accessible to unauthorized people. The parts of BESS which are likely to cause electric shock shall be securely covered. The conductive parts of BESS which people are likely to touch shall be separated from any parts at hazardous voltage. The protection can be achieved by one of the following methods:

- preventing a current from passing through the body of any person or any livestock;
- limiting the current which can pass through a body to a non-hazardous value.

The electric wires and insulation shall each be rated for the maximum current, voltage and temperature.

All conductive parts of a BESS which can come in contact with a hazardous voltage through a single insulation fault shall be connected to earth in accordance with appropriate standards, manufacturer instructions and local regulations.

The physical spacing of circuits including securing leads and terminals, etc., shall be sufficient to prevent inadvertent short-circuits and/or the potential for arc flash.

Connection points of bare conductors shall be appropriately spaced and of suitable structure to prevent inadvertent short-circuits between electrochemical accumulation subsystems.

A risk assessment in accordance with the procedures contained in IEC 62305-2 shall be made to evaluate if lightning protection is necessary. If the assessment indicates that protection against lightning is required, then it shall be provided.

The voltage measurement systems associated with the BESS should be using a voltage reference.

Safety-related components (for example, certain sensors) of known reliability shall be used.

Protective devices, such as guards, shall be designed to be effective, as their failure can expose persons to hazards, and also because a reduction in their effectiveness could encourage attempts to defeat them.

The touch current and discharge energy shall be limited in accordance with IEC 62477-1:2022, 4.4.5.5.

The BESS shall be provided with an overcurrent protection function at the electrochemical accumulation subsystem connection.

NOTE The positions and the kind of overcurrent protection function are decided according to the risk analysis and type of electrochemical accumulation subsystem.

Duplication (or redundancy) of components can be used so that, if one component fails, another component or components continue to perform the respective function(s), thereby ensuring that the safety function remains available.

Testing shall be conducted, and compliance shall be assessed, in accordance with 8.2.1.3, 8.2.1.4, 8.2.1.5, and 8.2.1.6.

7.10.2 Protection from mechanical hazards

The components which people are likely to touch shall not have sharp edges.

Where edges or corners could be hazardous to personnel depending on the location or application in the equipment, they shall be rounded or smoothed.

Hazardous moving parts of the equipment (which means moving parts that have the potential to cause injury) shall be so arranged, enclosed or guarded as to reduce the risk of injury to persons.

The structure of the BESS shall have adequate protection and reduce the risk of subsystems and components dropping during operating conditions, transportation, assembly, installation and disassembly.

Especially in case of transportation, if it is difficult for the BESS enclosure itself to provide enough protection, it can be reinforced with additional jigs or fixtures. These are also considered as parts of the structure.

BESS shall be designed to keep operators and workers safe in normal operation.

The location and structure of the BESS shall be such as to not cause risks to workers in the event of a component malfunction.

Failure of interconnections between BESS subsystems shall not lead to a hazardous situation.

BESS shall be designed and installed to allow the installation and removal of battery modules using appropriate lifting equipment, unless the weight of the individual modules is low enough to be safely handled by at most two people.

Validation shall be conducted, and compliance shall be assessed in accordance with 8.2.2.1, 8.2.2.2 and 8.2.2.3.

The design of aisles and access areas is provided in Annex J.

7.10.3 Protection from explosion

Flammable materials shall not be placed in the path of gas or heat exhaust from electrochemical accumulation subsystems.

Category "E-S" BESS shall not have parts located in explosive atmospheres.

In category "E-LI or E-LS" BESS, control subsystems and those components placed in any explosive atmospheres shall be provided with a suitable gas purging system in accordance with appropriate standards, manufacturer instructions and local regulations.

A BESS enclosure or compartment shall not vent any flammable gases into any enclosed spaces where arc-producing elements are located.

Testing shall be conducted, and compliance shall be assessed in accordance with 8.2.3.1, 8.2.3.2 and 8.2.3.3.

A BESS enclosure or compartment shall consider projectile containment.

7.10.4 Protection from hazards arising from electric, magnetic, and electromagnetic fields

Safety functions of safety-related subsystems of BESS shall not be disturbed by electric, magnetic, and electromagnetic fields.

Where expected electric, magnetic, and electromagnetic noise levels could have an adverse impact on the operation of the BESS, the BESS shall be adequately protected to reduce those noise levels within the system manufacturer's instructions.

Testing shall be conducted, and compliance shall be assessed, in accordance with 8.2.4.

NOTE 1 The appropriate standards and local regulations can be applied to evaluate the clearance for safety. Another topic for evaluation is the free space necessary to perform the maintenance activities.

NOTE 2 Clearance distances between BESS containers are carefully determined to prevent fire propagation jumping from one container to a nearby container taking into consideration a number of other sizing criteria such as container accessibility, need for walking passes and access requirements from fire brigade vehicles.

7.10.5 Protection from fire hazards

Only non-combustible materials shall be used in the construction of the BESS enclosure or supporting structures and assemblies.

NOTE The non-combustibility test is described in ISO 1182.

Integration of electrochemical accumulation subsystems and their surroundings shall be designed to prevent chains of thermochemical reactions or fire propagation (e.g. separating into a battery section, charging equipment section and a section which includes a DC conductor, circuit breaker and discharge circuit). Where applicable, both fire and thermal risks that are adjacent to the BESS shall also be considered.

Compliance shall be reviewed by conducting safety design checks in accordance with the results of system level risk assessments (see Clause 6). Fire-load calculations on the BESS or experimental fire characteristics recommended in 8.2.5 with details in Annex C is applicable for the process of the system risk assessment.

The inside of the BESS shall be separated into a battery section, charging equipment section and a section which includes a circuit breaker and discharge circuit, using fire-proof partitions (e.g. metal plates, non-flammable boards etc.).

Testing shall be conducted, and compliance shall be assessed, in accordance with 8.2.5.

7.10.6 Protection from temperature hazards

The components that have the potential to be at high temperature shall not be accessible to operators or any other personnel. The parts which are likely to cause burns shall be securely covered.

NOTE The temperature limits for accessible parts specified in IEC 62477-1:2022, Table 15, can be referenced.

Thermal partitions such as a metal plate or appropriate physical spacing shall be provided between the electrochemical accumulation subsystems and the control subsystem.

7.10.7 Protection from chemical effects

The choice of materials used in enclosures and wires of the BESS shall consider degradation, corrosion, wear (due to long-term use) and toxicity in accordance with the system risk analysis performed and local regulations.

Consideration shall be given to adverse long-term changes in electrical and mechanical properties of certain insulating materials.

The effects of electrolyte spillage from the battery shall be prevented. This requirement does not apply to batteries with sealed structures.

The structure of the BESS shall be designed to prevent the scattering of hazardous fluid from electrodes or electrolytes in electrochemical accumulation subsystems in accordance with local regulations.

7.10.8 Protection from hazards arising from auxiliary, control and communication system malfunctions

Equipment shall be so designed that the risk of fire or electric shock due to mechanical or electrical overload or failure, or due to an abnormal operation or careless use, is limited as far as practicable. After an abnormal operation or a single fault, the equipment shall remain safe for an operator within the meaning of this document, but it is not required that the equipment still be in full working order. It is permitted to use fusible links, thermal cut-outs, overcurrent protection or similar devices as long as they are able to provide adequate protection.

BESS shall be designed to prevent a hazardous condition even if the energy supply (from both a primary POC and an auxiliary POC) is interrupted or has fluctuated.

When a safety critical component fails or operates abnormally, the system shall enter a safe state automatically.

Testing shall be conducted, and compliance shall be assessed in accordance with 8.2.8.

Guidance on conducting an abnormal operation and a single fault conditions can be found in IEC 62368-1 and IEC 62933-5-1.

Operator safety after an abnormal operation or a single fault should be checked by system testing with suitable simulated signals in consideration of IEC 62368-1.

7.10.9 Protection from hazards arising from environments

7.10.9.1 General

The BESS shall be designed to prevent a hazardous condition even if the BESS is exposed to conditions as given in 7.10.9.2 and 7.10.9.3.

7.10.9.2 Protection from exposure to moisture and pollution

BESS shall include in the risk assessment an evaluation of minimum IP ratings for moisture and foreign object ingress.

IP rate should be considered according to local environment, including indoor or outdoor.

Testing shall be conducted, and compliance shall be assessed, in accordance with 8.2.9.2.

For a BESS installation where there can be exposure to pollution in the form of dust, the minimum IP rating shall be IP5X.

For installations where there can be exposure to moisture, the minimum IP rating shall be IPX4.

NOTE IP rate for indoor/outdoor will be determined according to the result of risk assessment.

7.10.9.3 Exposure to marine environments

In case of installation in marine environments, the BESS shall be designed so as not to result in hazardous events during or after exposure to marine environments (e.g. salt mist).

Testing shall be conducted, and compliance shall be assessed, in accordance with 8.2.9.3.

7.11 Guards and protective measures

7.11.1 General

In addition to the inherently safe design of the BESS which is described in 7.10, guards and protective measures shall be used in a BESS. The minimum requirements of the guards and protective measures are given in 7.11.

Access control is integral to safe operation of a BESS, and appropriate locks and restriction to unauthorized personnel access shall be included in the system design. A safety interlock shall be provided where hazards within the context of this standard are normally present and operator access involves access to areas normally presenting hazards within the context of this document.

Protection provided by an enclosure can be regarded as restricted access.

In the case of a BESS with a control subsystem, the battery management system in any electrochemical accumulation subsystem shall monitor all relevant safety parameters of the battery as required in the applicable standards and report those parameters to the control subsystem.

For those BESS located where there is the potential for direct contact by untrained persons, a minimum IP rate of IP2X shall be determined in accordance with IEC 60529.

7.11.2 BESS disconnection and shutdown

7.11.2.1 General

In addition to the operational states that are defined in IEC 62933-5-1:2024, 7.5, a non-operational condition (the isolated condition for maintenance) is defined in this document. The isolated condition for maintenance is a system condition that allows for safe working on the DC power circuits, AC power circuits and DC auxiliary circuits of the electrochemical accumulation subsystem.

7.11.2.2 Grid disconnected state

The general requirements that are described in IEC 62933-5-1 shall apply. Additionally, isolating devices shall be used to allow local manual operation to override remote operation. The isolating devices shall be lockable in the disconnected state.

7.11.2.3 Stopped state

In the stopped state, the system has performed a shutdown sequence which includes the disconnection of the electrochemical accumulation subsystem from the power conversion subsystem, and the disconnection of the power conversion subsystem from the primary connection terminal. The stopped state can result from a regular command, or an emergency shutdown event command. This state is typically achieved using contactors or motorized circuit breakers. During their installation, the possibility of automatic re-energization or the state that cannot be completely electrically isolated shall be minimized for workers on the site.

Auxiliary power shall be allowed to be present to facilitate an automatic power-up sequence, or to power monitoring systems.

When the EES system is disconnected and the accumulation subsystem is not connected to the power conversion system, the EES system is in a stopped state. In this state, the accumulation system can be energized and there is a risk that the stored energy will be converted to thermal energy or other forms of energy by ageing or other effects. In the stopped state, part of the auxiliary subsystem should remain powered as it contains critical subsystems for safety and monitoring.

7.11.2.4 Isolated condition for maintenance

In the isolated condition for maintenance, it should be safe to work on at least the DC power circuit and storage component of the system. The whole isolation of the BESS (see Figure 3) or the partial isolation of the DC side of the BESS can be selected in accordance with the area that should be maintained. The BESS shall be capable of being locked in the isolated condition locally or via a removable disconnection tool so that it can only be connected by authorized personnel after the maintenance procedure. In order to bring the system to an isolated condition, the BESS shall first be brought to the stopped state as defined above. It shall then be capable of being brought and locked into a grid disconnected state, and then it shall be safely isolated (including keeping any power supply for safety-related subsystems of the BESS active). Consideration can be given to providing visible isolation with the lockable isolation device as is required in some jurisdictions.

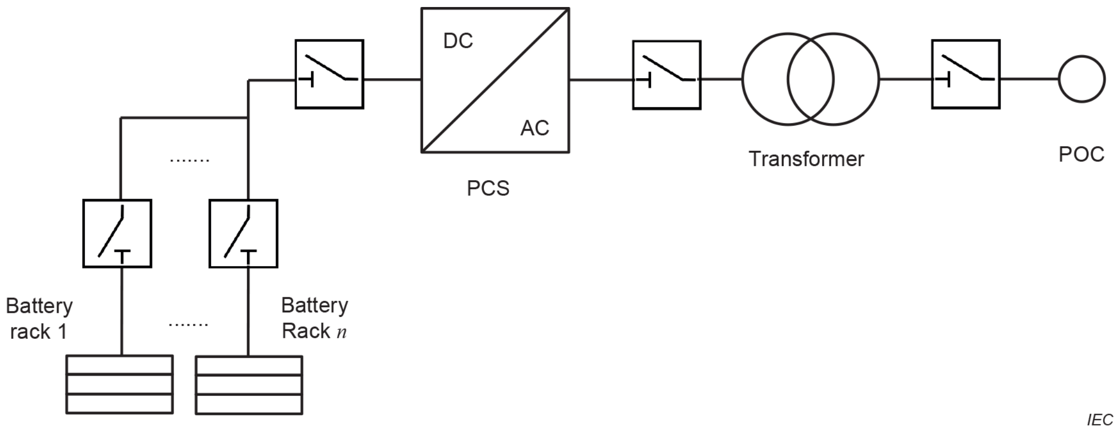


Figure 3 – Example of isolated condition (whole isolation of BESS)

The procedure to isolate the system shall:

- allow for disabling of the fire suppression system where a release of fire suppression agent can be harmful to people working in or near the system;
- allow the fire detection systems, HVAC, lighting and utility outlets to remain operational in the isolated state, to provide safe and comfortable working conditions.

The instructions to isolate the system shall:

– be available in a single location that is easily accessible to the person who carries out the system isolation, provide clear instructions and checks to achieve and confirm full isolation of the system, and

– provide clear instructions for restoring the system back to the operational (stopped) state.

The individual isolating devices referred to by the instructions shall be clearly marked.

7.11.3 Other guards and protective functions of BESS

7.11.3.1 Protection from electrical hazards

Protective devices and circuits shall be properly rated to protect electric circuits against short-circuits.

Electrochemical accumulation subsystems (within the energy storage system) shall be provided with a protective function to stop or limit short-circuit currents.

Earth fault protection shall be kept within both the AC and the DC sides of the power conversion subsystem. Detection of any earth fault in the BESS shall be reported to operators. This protection is mandatory if the AC and DC side are electrically isolated from a distribution grid. DC side protection is not necessary for safety extra-low voltage (SELV) battery voltage.

The BESS shall protect the batteries against overcharge and impulse voltages, including under a single fault condition within the charger. Protection can be accomplished by turning off the charger, or by interrupting the charging current or inrush current. If an overcharge happens, it shall be reported (to operators) by both audible alerts and visual signals.

The rating of a replaceable fuse in term of fuse voltage and current shall be marked on the fuse holder or adjacent to the fuse holder so that the rating of a fuse is obvious even if the fuse is removed. Other necessary information such as I^2t time delay or breaking capacity shall be indicated with the rating, or provided in the user or maintenance manual. The fuse replacement procedure shall be described in the BESS information described by the safety design and functions set out in 7.12.

Overcurrent conditions in electrochemical accumulation subsystems shall be reported to operators.

In the event of a single failure within the equipment, circuits shall be designed so that the current limits are not exceeded. If an over current condition occurs, it shall be reported to operators.

Unintentional islanding of the BESS shall be considered in accordance with IEC 62933-5-1:2024, 6.2.6.

Testing shall be conducted, and compliance shall be assessed in accordance with 8.2.1.1 and 8.2.1.2.

7.11.3.2 Protection from mechanical hazards

BESS enclosures that provide protection from access to hazardous parts shall be sufficiently robust to prevent mechanical damage due to possible mechanical abuse.

Testing shall be conducted, and compliance shall be assessed, in accordance with 8.2.2.1 and 8.2.2.2.

7.11.3.3 Protection from explosion

For categories "E-S / S-O / C-A, C-B, C-D and C-Z", detection systems for flammable gases generated by the electrochemical accumulation subsystems shall be provided at the site where the BESS is located. When a flammable gas is detected, it shall be reported (to operators) by both audible alerts and visual signals. It is a requirement of this document that the BESS cannot be installed in the site without any detection systems for flammable gases, and that this requirement shall be contained in the installation manuals.

Categories "E-S / S-U / C-A, C-B, C-D and C-Z" BESS shall have appropriate signage to identify restricted areas. The signage shall specify that flammable gases can be released from the BESS.

Categories "E-LI or E-LS / S-O / C-A, C-B, C-D and C-Z" BESS shall be provided with integral detection systems for flammable gases generated by electrochemical accumulation subsystems. An incident of flammable gas detection shall be reported (to operators) by both audible alerts and visual signals. The handling procedure of the detection systems shall be described in the system documentation as described in 7.12.

For categories "E-LI or E-LS / S-U / C-A, C-B, C-D and C-Z" BESS, the path of exhausted flammable gases shall be identified and documented in the installation manual. Appropriate signage to identify a restricted area shall be provided around any flammable gas outlet. Information of the path of the exhausted flammable gases shall be provided by the supplier to the owner.

For categories "C-A, C-B, C-D and C-Z" BESS, electrochemical accumulation subsystems can exhaust hydrogen. To prevent explosion or fire, the BESS and surrounding environment shall not have any spot or enclosure where the density of hydrogen can be over the explosive 4 % vol hydrogen LEL (lower explosion limit) threshold at the time of any incidents.

For categories "E-LI or E-LS / C-A, C-B, C-D and C-Z" BESS, appropriate reliable and/or redundant means to avoid flammable gas build-up inside the BESS shall be implemented.

Categories "E-S / S-O / C-A, C-B, C-D and C-Z" BESS shall be located in a site with appropriate ventilation systems.

NOTE 1 It can be considered equivalent to installation in a location of a ventilation system when it is installed in a place where proper ventilation is ensured.

NOTE 2 The ventilation systems for S-U BESS will be considered.

Category "E-LI or E-LS / S-O / C-A, C-B, C-D and C-Z" BESS shall be installed with appropriate ventilation systems as provided for in the following:

– the ventilation systems shall be able to keep an appropriate temperature within the enclosure,
– forced ventilation systems shall be provided where there is insufficient natural ventilation,
– the ventilation openings shall be designed and installed to prevent the spread of fires and water ingress.

Testing shall be conducted, and compliance shall be assessed, in accordance with 8.2.3.1, 8.2.3.2 and 8.2.3.3.

NOTE 3 For large-scale BESS with distributed installation of air conditioning subsystems, it is important that ventilation subsystems are functioning as intended to be able to take in air and discharge to the ambient atmosphere as intended.

7.11.3.4 Protection from fire hazards

A risk of fire can result from excessive temperatures either under normal operating conditions or due to overload, component failure, insulation breakdown or loose connections. Fires originating within the equipment should not spread beyond the immediate vicinity of the source of the fire, nor cause damage to the surroundings or the equipment. Cell firing is regarded as the most probable cause of component failure. However, the cause of ignition is not limited to cell ignition. All subsystems inside the entire storage equipment could become source of ignition and once one subsystem ignites and propagates to cells, subsequent propagation among cells takes place. In 7.11.3.4, the measures to suppress fire propagation are described, regardless of the cause of fires originating within the equipment.

The fire suppression system is an automatic operation subsystem installed in the BESS. Portable or semi-fixed fire extinguishers that are manually operated constitute additional firefighting equipment of this subsystem. Category "S-O" BESS shall have a fire detection system, fire alarms deploying both audible alerts and visual signals, and fire suppression system within the BESS location.

For category "E-LI or E-LS / S-O" BESS, if the electrochemical accumulation subsystems of the BESS have doors, the doors shall be fire protecting doors.

Category "S-U" BESS shall have a fire detection system, fire alarms deploying both audible alerts and visual signals, and fire suppression system within a safe and easily accessible location.

Fire detection signals shall be transmitted to the fire command centre with location data via a communication network, or secure relays and receivers where applicable.

If a fire incident is detected, the fire suppression system, if any, shall automatically operate and the fire alarms shall be automatically started.

Testing shall be conducted, and compliance shall be assessed, in accordance with 8.2.5.

Salt water should not be used on live electrical equipment.

NOTE 1 It is valid to use salt water of appropriate concentration to discharge the storage batteries after extinguishing the fire while preventing electric shock.

Physical separation and extinguishing agent are two key measures against fire propagation. The extinguishing agent includes, but is not limited to, agent such as cooling agent and fire propagation suppressing film. These two measures should be taken against both propagation among subsystems and propagation among battery subsystems (cells/modules). The two cases are separately described below.

1) Against subsystem-to-subsystem propagation

   The most critical propagation is the one from one subsystem to a battery subsystem which contains a number of cells in it. Physical separation is the way commonly taken and when regarded as necessary, a thick metal panel is placed between subsystems. The extinguishing agent should be properly distributed within the entire equipment. Cooling type or fire propagation suppressing film should be effectively placed depending on the type of the assumed ignition.

2) Against propagation among battery subsystems

   The measures to suppress fire propagation should be designed separately in each layer and be multi-layered as a whole. Measures should be designed separately for module-to-module propagation, rack-to-rack propagation, and container-to-container propagation.

   a) Module-to-module fire propagation

      In order to protect the modules from the heat and flames caused by the ignition of adjacent modules, protective measures such as inserting fire spread prevention plates between modules or arranging them via metal plates of appropriate thickness can be adopted.

      In addition, methods such as the use of local fire suppression system (extinguishing agents, fire propagation suppressing film, etc.), which make the entire module group hard to burn by forced water cooling, have begun to be adopted.

   b) Rack-to-rack and container to container fire propagation

      Regarding fires in adjacent racks and containers, it is necessary to consider not only heat propagation but also flame propagation and high-pressure, high-temperature gas propagation.

      The most popular countermeasure is to make the protective guard such as firewall and metal case/rack. In addition, it is important to suppress flames and high-temperature gas intrusion.

      When installing multiple containers or buildings outdoors, regulations in each country regarding the separated distance and separation methods can exist.

NOTE 2 Measures can be designed separately for cell-to-cell fire propagation inside of the module. Regardless of whether the cell is ignited internally or externally, once the cell is ignited it will be essential to prevent it from propagating to other cells. The most popular countermeasure is the direct heat transfer suppression. It used to be made by the battery manufacturer.

NOTE 3 In addition, stationary storage batteries systems are often used in environments where the cells are not enclosed, so there are some cases where local fire extinguishing systems for cells are used in racks and packages.

NOTE 4 To adopt such a local fire extinguishing system, it is useful to determine the structure of the module and the type and shape of the extinguishing agent. Calorie calculation is important for extinguishing agents that aim for a cooling effect, and how to create a sealed space is important for extinguishing agents and fire propagation supressing film that aim for a suffocating effect. A film-type fire extinguisher container that can effectively function over a wide area in the limited space within the module (easy to install fire propagation suppressing film) is effective as a module-side countermeasure.

NOTE 5 If installing a liquid cooling system or fire suppression system in the BESS, it is insulated and isolated to the battery and battery circuit, and leaking will be prevented. In addition, after the suppression system is activated, attention is paid to short circuits and ground faults.

NOTE 6 A fire suppression system using the suffocation effect that does not use water or liquids is used with caution.

NOTE 7 Also, it will be confirmed that the fire has been extinguished after suppression. Especially in the case of the fire suppression system using the suffocation effect, there is a risk of re-ignition if oxygen enters the space when the extinction is confirmed.

NOTE 8 When a fire propagation suppressing film is installed, the extinguishing performance is checked in advance.

7.11.3.5 Protection from temperature hazards

The BESS can have one or more critical temperatures which should be identified. According to the identified critical temperatures (e.g. touchable surface temperatures, power electronic component temperatures, and electrochemical accumulation subsystem temperatures), safety provisions shall be implemented to prevent these temperatures from being reached within the BESS.

Safety-related components (for example, certain sensors) of known reliability shall be used.

It shall be possible for operators to monitor the temperatures where the risk assessment concludes that any temperature monitoring is required in the internal atmosphere of the system enclosure.

If the operator does not have specialized knowledge, monitoring can be done by a simple display of the state of the temperature (icon to indicate whether the temperature is outside or inside charge/discharge, range, etc).

It shall be possible for operators to monitor the temperatures of subsystems in the BESS.

It shall be possible for operators to monitor operating conditions of ventilation subsystems, and detection of abnormal condition shall be reported to operators.

When monitored temperature(s) exceed those limit(s) provided by the manufacturer, it shall be reported to operators.

Testing shall be conducted, and compliance shall be assessed, in accordance with 8.2.6.1, 8.2.6.2 and 8.2.6.3.

7.11.3.6 Protection from chemical effects

Containment or neutralization, or both, of spilt hazardous fluids shall be provided. Methods utilized for containment shall be sufficient to hold the maximum quantity of fluids that could occur and if located outdoors designed to prevent inadvertent filling with rain. Instructions regarding the provision of suitable spill containment and neutralization shall be provided by the system manufacturer with the installation instructions.

For category "C-D" BESS, an automatic leak detection to indicate the release of hazardous fluids shall be provided.

For category "E-S/S-O" BESS, a detection system for toxic gases generated by electrochemical accumulation subsystems shall be provided in the BESS or the BESS installation. An incident of toxic gas detection shall be reported (to operators) by suitable alerts and signals (e.g. audible and visual). Also, evacuation during alerting from toxic gas shall be strongly recommended in any information for users.

For category "E-S/S-U" BESS, appropriate signage to indicate a restricted area shall be provided at the site where the BESS is located or on the BESS itself. The sign shall specify that toxic gases can be released from the BESS.

For category "E-LI or E-LS/S-O" BESS, a detection system for toxic gases generated by the electrochemical accumulation subsystems shall be provided in the BESS. An incident of toxic gas detection shall be reported (to operators) by suitable alerts and signals (e.g. audible and visual). Installation manuals shall include information on how to handle the detection system for toxic gases.

For category "E-LI or E-LS/S-U" BESS, the path of exhausted toxic gases shall be identified and documented in the installation manual. Appropriate signage to identify a restricted area shall be provided around a toxic gas outlet. Information of the path of exhausted toxic gases shall be provided by the supplier to the owner.

For category "S-O" BESS, gas concentration reduction measures shall be provided in order to protect the workspace from the high density of toxic gases from electrochemical accumulation subsystems in the BESS.

Category "E-S/S-O" BESS shall be located in sites that have protective measures against the hazards above such as, but not limited to:

– elimination of the generation of hazardous chemicals,
– dilution of hazardous chemicals,
– collection of hazardous chemicals (e.g. by a scrubber for hazardous gases),
– limitation of human access.

Category "E-LI or E-LS/ S-O" BESS shall be installed with the protective measures described above bullets. Testing shall be conducted, and compliance shall be assessed, in accordance with 8.2.7.1, 8.2.7.2, and 8.2.7.3.

7.12 Information for end users

Safety information as listed below should be available for end users:

- Warning signs and signals (including any limitation of available environments, confirmed by the validation and testing specified in 8.2.9).
- On-site signage and labelling which show any hazardous part of BESS clearly.
- Warning devices (audible alerts and visual signals), or others.
- A sequence diagram of safety designs shall be described via methods as specified in an appropriate international standard. (an example of reference document is IEC 60617 (all parts)).
- All the BESS information about the safety design and functions shall be kept accessible and available to all applicable BESS stakeholders.
- Expected usage.
- Operational period in the environment (lifecycle).
- How to respond after the end of service life.

For rooms of electrochemical accumulation subsystems, appropriate information on the required flow of air shall be provided in the installation instructions where the electrochemical accumulation subsystem installation is supplied with the BESS. See Annex F for good practice for warning signs regarding BESS safety.

Local regulations can apply.

7.13 Life cycle safety management

7.13.1 Operation and maintenance

7.13.1.1 General

Any party which has responsibility for operations and maintenance should be mindful of their own safety when they work near the BESS. Incorrect operation and inadequate or neglected maintenance can cause harm by fire, gas poisoning and electric shock. It is necessary for all stakeholders to protect themselves from such risks.

Most BESS are expected to be operated automatically and remotely via information networks. The BESS is expected to be operational for decades. During such time, BESS parts will be replaced at regular scheduled preventive maintenance or as the result of unplanned events, such as the maintenance plan, preventive maintenance, system condition monitoring, partial subsystems or component replacement, or design change due to aging degradation.

NOTE The replacement will take into account the potential for any secondary use.

The availability of original parts for repair and replacement can be limited, or the parts can be unavailable, therefore compatible parts might be used. From a systems safety perspective, replacement parts shall be confirmed to be safe in the system before replacement because combinations of those parts or subsystems are important for monitoring of the system condition.

Any changes by on-site workers shall not be overwritten by any remote actions during the maintenance process by off-site workers, to keep on-site workers safe. Consideration shall be given to adverse long-term changes in the electrical and mechanical properties of certain insulating materials.

To ensure maintenance safety of the BESS, it is extremely important throughout the product life to comply with operating methods, to conduct daily maintenance and to respond to abnormal conditions. Therefore, the maintenance procedures during the BESS life cycle, and the modifications that should be made as appropriate will be agreed between the manufacturer and the owner in advance.

Personnel safety considerations for remote operation of the BESS shall be confirmed in case of emergency.

7.13.1.2 Operation and maintenance plan

An emergency response plan for safety shall be prepared, which shall include the requirements of 7.13.1.2.

A safety manual shall include at least descriptions of methods to communicate BESS problems, warnings to local firefighting agencies, workers and the surrounding residents, and the correct use of insulated tools.

When adjusting with a screwdriver or a similar tool while under applied voltage, protection against electric shock or energy hazard caused by inadvertent touch to the applied voltage sections shall be provided. Measures shall be taken to ensure that the possibility of inadvertent touch to incorrect parts with the tool is considered in the protection design.

An operation and maintenance manual shall be provided to the BESS owner or their designated agent and include but not be limited to:

a) how to maintain safety during maintenance (including safety instructions and specification of required personal protective equipment (PPE) for the various maintenance operations);
b) methods to detect, manage and control fire, explosion and toxic gas retention, etc including possibilities for venting gases outside in an emergency situation;
c) prohibited operating processes, for example,
   – prohibition of overcharge;
   – prohibition of over discharge (to avoid polarity inversion);
   – prohibition of charge or discharge in operating temperature exceeding the limit provided by the manufacturer;
d) emergency contact number(s);
e) safety issues to be disclosed in public (e.g. restricted area around BESS);
f) how to use safety subsystems;
g) how to use protection subsystems;
h) locking and unlocking procedures of all the protection subsystems;
i) the identification and specification of hazardous parts of the BESS.

NOTE These requirements do not prevent any other necessary safety issues from being described within any manuals and guidelines.

Information concerning the design and the installation processes shall always be accessible and checked during maintenance processes which might include following:

- The BESS components that are operated frequently under automatic and/or remote control.
- Failure and/or malfunctions that can be caused by the ingress of soil, overgrowth of plants, filter or clogging up of filters or pipes, etc.
- Cleaning and consumable replacement schedules should be included in the operation and maintenance plan.
- The nature and content of design or construction safety information that is to be provided to users by the supplier or manufacturer. This shall include but cannot be limited to:
  - all subsystem parameters related to safety;
  - combinations of subsystems and software that can have impact on the system safety for equivalent (replacement) devices;
  - past trouble instances, issues and quality problems associated with replacement of devices that can be deemed equivalent;
  - measurement accuracy and the condition of installation of sensors;
  - sensitivity and the condition of installation of gas sensors.

Information that is necessary to ensure that the equipment is unlikely to present a hazard within the meaning of this document during operation specified by the supplier, shall be provided to the user.

If it is necessary to take special precautions to avoid the introduction of hazards when operating, installing, servicing, transporting or storing equipment, the necessary instructions shall be made available.

7.13.1.3 Preventive maintenance

A periodic maintenance schedule shall be developed by the manufacturer or system integrator. The periodic maintenance schedule should include consideration of frequency of use, time elapsed, and ambient environment. Maintenance should include the overall system, each subsystem and subsystem devices.

NOTE The sensors that are critical for safety are calibrated following the supplier's criteria.

Regular preventive maintenance such as cleaning and consumables replacement with system monitoring is a key component of safety from a systems perspective. Reactive maintenance is also required for occurrences that a scheduled maintenance would not pick up on and that impact system integrity, such as the ingress of water or soil due to unexpected weather conditions, or when animals such as birds or rodents impact the integrity of the system enclosure.

The malfunction and performance degradation of components or parts of the system or the subsystems due to long term use should be considered. They can be present without obvious signs. It is possible that there is no obvious indications of the malfunction of the circuit breakers, lights, and ventilation fans. For example, the circuit breaker cannot function correctly when the switching mechanism in the circuit breaker becomes welded as a type of failure. The malfunction of lights and ventilating fans can only be noticeable after their activation. The measuring and monitoring of system soundness described in 7.13.1.4 shall be considered to increase safety of the BESS.

Safety manuals for operation and maintenance of the BESS required in 7.13.1.2 shall be utilized by workers under the supervision of trained operators or maintenance staff, or both.

7.13.1.4 Measuring and monitoring of system condition

Measuring and monitoring of system soundness are essential for preventive and reactive maintenance. Items that form part of the measuring and monitoring of the system soundness test should be based on knowledge gained from past incidents and risk analysis utilizing FTA, FMEA, etc. The detection of malfunctions and performance degradations should be considered. In most cases the BESS systems are likely to be operated remotely without trained operators on site. In such cases, the BESS system's soundness should be remotely monitored.

At least all the parameters that have been found important for system conditions during the risk analysis, shall be measured and monitored, and the logged information shall be made available to the operators (e.g. voltage, current, temperature, state of charge (SOC), etc.)

During operation and after shutdown, it is important to monitor the parameters to understand the condition of the battery from the point of view of safety. For example, there is a possibility of thermal runaway inside batteries even after disconnection from the grid. Remote monitoring of system soundness shall be continued after disconnection.

Monitoring and controlling functions shall be continually maintained to detect the abnormal status of the BESS under automatic or remote control, or both.

7.13.1.5 Staff training

For category "E-S" BESS, any requirement of 7.13.1.5 shall apply to the staff training for service staff of BESS suppliers.

For category "E-LI or E-LS" BESS, any requirement of 7.13.1.5 shall apply to staff training for the staff of both the BESS suppliers and operators in accordance with the results of the risk assessment process (see Clause 6).

Staff training shall include safety skills and information. At the installation phase, the BESS provider and subsystem manufacturer shall provide the operating and safety manuals to the owner, installer and operator. These manuals shall include a description on permitted operations and a description of prohibited operations.

Training guidelines and manuals should be prepared using information identified in 7.12. This information should be provided by the supplier and should include, but not be limited to:

– evacuation procedures,
– evacuation guidance,
– use of fire suppression system or, if any, the fire suppression system in the early stages,
– information communications,
– directions for the use of essential protection tools (e.g. protection instruments, protection equipment including personal protective equipment and the safety data sheets (SDS) of key chemicals of the BESS subsystems),
– how to retain and record knowledge for the prevention of burns and electric shocks,
– protection measures and control logic of the BESS,
– operating methods for safety measures, and
– locking and unlocking procedures of all of the protection subsystems.

The manufacturer shall provide guidance on the competence and authorization level requirements for personnel who operate devices or safety systems. The guidance shall be taken into account for the required operator training or authorization to enter restricted areas.

7.13.2 Partial system change

When the system is partially changed within the original plan, it is essential that the compatibility and conformity of the parts be checked. Validation of compatibility and conformity of the parts to the system should be considered. Any changes that can degrade the safety level of the BESS should be considered.

BESS safety shall be reassessed in the following situations:

– Changes in the system itself (for example deterioration due to ageing), caused by changes to the BESS throughout its service life (i.e. parts and materials for repair); it shall be confirmed that there is no change in BESS safety condition after the changes.
– Changes in the ambient environment that include, but are not limited to, temperature, humidity, building foundations, rainstorm environment, ventilation, anti-fire provision, and the surrounding environment.

Attention shall be paid to:

- a list of user exchangeable parts,
- changes in output and efficiency,
- when a BESS is located where collateral damage can have a big impact (large building, shopping centre, etc.) and located where there are severe environmental conditions (significant changes in temperature),
- maintenance records should be referred to at each relocation.

In case the BESS is undergoing unplanned modifications, it shall comply with the appropriate clause or subclause of IEC 62933-5-3:2023.

7.13.3 Design revision

See IEC 62933-5-3.

7.13.4 End of service life management

BESS should be designed to be dismantled into separate subsystems or into separate components safely at the end of its life. Dismantled subsystems or components should be handled according to appropriate standards, manufacturer instructions. Local regulations can apply.

7.13.5 Measures for validating life cycle safety management

Compliance with 7.13.1 to 7.13.4 shall be confirmed by appropriate validations. Annex E shows information of good practice for these validations.

8 System validation and testing

8.1 General

The BESS testing is conducted to verify the safety and effectiveness of the inherently safe design of the BESS as noted in 7.10 and the guards and protective measures as noted in 7.11. The test program will be impacted by the size (i.e. voltage and amount of energy contained), location of installation (e.g. outdoor remote, indoor), technology (e.g. lead acid), and exposure (e.g. residential). For example, a residential, indoor installation, lithium ion, 240 V, 1 kWh appliance type BESS test program is addressed in a different manner than a large complex utility system consisting of multiple parts that are not a complete BESS until they are installed in the field.

Residential BESS and smaller commercial/industrial BESS are typically contained in a single mass-produced enclosure and evaluated in the same way as an appliance in that it would be subjected to a type test program, with factory acceptance testing upon production before leaving the factory, and perhaps some minor site acceptance testing upon installation. The complex, uniquely designed, utility system would have its major components or subsystems type tested as part of those subsystem standard criteria, and the components would be subjected to factory acceptance testing according to the component standard. For these complex uniquely designed systems, the site acceptance testing (SAT) should be more comprehensive to include FAT testing on the complete system, since the BESS is not a complete system until it is assembled and commissioned in the field.

A system type test program should encompass all safety relevant aspects. If system components have already been evaluated according to type test standards by an accredited test house, a re-test of these components as part of a type test is not required. In addition to the type tests, each individual storage system (or system's major components or subsystems) shall be subjected to routine tests, the factory acceptance test (FAT) and the site acceptance tests (SAT) for the complete system after its installation and before being placed into normal operation.

The factory acceptance test (FAT) shall cover at least the following points:

- presence and correct ratings of fuses and breakers;
- presence and correct operation of residual current devices, insulation monitors and earth fault detectors;
- presence and correct operation of automatic and manual disconnectors;
- the system FAT can be performed with a partially installed battery pack or a dummy pack, in the case where the battery pack components have undergone a separate FAT;
- the system can only be installed on site if one of the following conditions is met:
  - the system passes all tests during the FAT; or
  - the system passes most of the tests from the FAT, and the remaining points can be corrected during installation on-site and re-tested during the SAT without negatively affecting the safety situation.

After installation, the system is subjected to the site acceptance test (SAT), which shall cover at least the following points:

a) correct installation;
b) inspection and resistance measurement of earthing;
c) correct operation of residual current devices, insulation monitors, earth fault detectors and automatic and manual disconnectors;
d) testing of any electrical, mechanical and liquid connections made on site;
e) complete commissioning as per manual, risk analysis. Local regulations can apply.
f) during the SAT, local inspectors, fire brigade officials and government agency representatives can be involved for education and final approval of the system.

The general requirements that are described in IEC 62933-5-1:2024, Clause 8, shall apply.

The setting of all interactions between key subsystems of the BESS shall be tested.

Some of the specified system validation and testing can be waived provided that clear demonstration is made in the risk assessment that safety objectives supported by the waived measures are clearly achieved, even without the implementation of the concerned measure.

Table 4 shows the list of validation and testing for the BESS.

Table 4 – Overview of validation and testing for BESS

Validation list	Subclause	Reference document	Required tests at subsystem level		Alternative acceptable method required to the tests at product level (if is not possible to set the test)		Required tests/checks at system level	
			Type test	Routine test	Technical assessment	Simulation / Calculation	FAT	SAT
Electrical hazards								
Short-circuit (high current discharge) protection	8.2.1.1	-	S	-	-	-	R	-
Overcharge protection	8.2.1.2	-	S	-	-	-	R	R
High current protection	8.2.1.3	-	S	-	-	-	R	R
Earth fault protection	8.2.1.4	-	S	-	-	-	R	R
Impulse withstand voltage protection	8.2.1.5	IEC 60664-1	T	-	-	-	-	-
Dielectric test								
Dielectric voltage on the subsystems	8.2.1.6	IEC 60664-1	T	T	-	-	R*	R*
Dielectric voltage on power cable between the subsystems	8.2.1.6	IEC 60664-1	-	-	-	-	-	T*
Insulation resistance								
Insulation resistance on the subsystems	8.2.1.7	IEC 60364-6	T	T	-	-	R*	R*
Insulation resistance on power cable between the subsystems	8.2.1.7	IEC 60364-6	-	-	-	-	-	T*
Protective bonding on the subsystems	8.2.1.8	IEC 60364-4-41 IEC 60364-6 IEC 61936-1	T	T	-	-	R	C
Earthing system check	8.2.1.8	IEC 60364-4-41 IEC 60364-6 IEC 61936-1	T*	-	-	-	-	T*
Anti-islanding	8.2.1.9	-	T*	-	-	-	R*	R*
Mechanical hazards								
Enclosure strength against impact	8.2.2.1	IEC 62477-1	T	-	-	-	-	-
Enclosure strength against static force	8.2.2.2	IEC 62477-1	T	-	-	-	-	-
Impact and vibration during transportation and seismic events (e.g. earthquakes)	8.2.2.3	-	T	-	X	X	-	C

Validation list	Subclause	Reference document	Required tests at subsystem level		Alternative acceptable method required to the tests at product level (if is not possible to set the test)		Required tests/checks at system level	
			Type test	Routine test	Technical assessment	Simulation / Calculation	FAT	SAT
Explosion hazards								
Specification of flammable gas	8.2.3.1	-	T	T	-	-	R	R
Gas detection/ off-gas detection	8.2.3.2	IEC 60079-29 (all parts)	T	T	-	-	R*	R*
Anti deflagration equipment	8.2.3.2	IEC 60079-29 (all parts)	T	-	X	X	R	C
Ventilation	8.2.3.3	IEC 60079-7 IEC 60079-13	T	T	-	-	R*	R*
Hazards arising from electric, magnetic, and electromagnetic fields	8.2.4	IEC 61000-1-2 IEC 61000-6-1 IEC 61000-6-2 IEC 61000-6-5 IEC 61000-6-7 IEC 60364-4-44	T	-	-	-	-	-
Fire hazards								
Propagations	8.2.5	IEC 62619	T	-	X	X	-	-
Smoke & thermal detection, audible alerts and visual signals	8.2.5	-	T	T	-	-	R*	R*
Fire suppression system	8.2.5	-	T	T	-	-	R*	R*
Temperature hazards								
Verification of thermal control operation	8.2.6.1	-	T*	T	-	-	R	R
Abnormal operation of subsystems for ventilation	8.2.6.2	-	T	-	-	-	R	-
Temperature under normal operation tests	8.2.6.3	-	T	-	-	-	-	R
Chemical hazards								
Fluids detection	8.2.7.2	-	T	T	-	-	R*	C*
Protective measures against hazardous fluids	8.2.7.3	-	T	T	-	-	R*	C*

Validation list	Subclause	Reference document	Required tests at subsystem level		Alternative acceptable method required to the tests at product level (if is not possible to set the test)		Required tests/checks at system level	
			Type test	Routine test	Technical assessment	Simulation / Calculation	FAT	SAT
Hazards arising from auxiliary, control and communication system malfunctions								
Hazards arising from auxiliary, control and communication system malfunctions on the subsystems	8.2.8	IEC 62933-5-1–	T	-	-	-	R*	R*
Hazards arising from auxiliary, control and communication system malfunctions on the BESS	8.2.8	IEC 62933-5-1–	T	-	-	-	R*	R*
Hazards arising from environments								
Exposure to moisture ingress	8.2.9.2	IEC 60529	T	-	X	-	-	-
Humidity detection	8.2.9.3	-	T	-	-	-	-	R
Exposure to marine environments (e.g. salt mist)	8.2.9.4	IEC 60086-5-52	T	-	X	-	-	-
IP rating of BESS enclosure and protective guards	8.2.10	IEC 60529	T	-	-	-	-	C

Key

T: Test using real Lab instrumentations

S: Simulated test using real signals or simulated signals

R: Repeated test (about the agreement between customer and manufacturer/supplier).

This kind of test can be:

S: Simulated test; or T: Test

C: Check by visual inspection

X: it is possible an alternative method to verify it (e.g. with technical assessment, simulation or calculation)

NOTE 1 Detailed applicable conditions of "*" testing items can be found in individual subclauses.

NOTE 2 Detailed testing items and procedures of SAT can be decided by considering the individual BESS system design.

NOTE 3 In any case R Repeated test will be S or T but as routine test.

8.2 Validation and testing of BESS

8.2.1 Electrical hazards

8.2.1.1 Short-circuit (High current discharge) protection

The DC circuits of the BESS shall be protected from short-circuits (or be short-circuit proof) on both the AC and DC sides. Each electrochemical accumulation subsystem (battery subsystem) shall be protected from short-circuit. Each power conversion subsystem shall be protected from short-circuit. Upon application of the real signal or suitable simulated signals, the short-circuit protection shall operate to prevent damage to the BESS that can result in a hazardous condition. The short-circuit protection mechanisms shall operate as designed.

A safety of short-circuit check or validation shall be performed for each subsystem to perform a short-circuit test for the entire BESS.

Before performing the short-circuit test, protective devices (e.g. fuses, circuit breakers, etc.) shall be installed in the system to protect the BESS, testing facilities and the electric grid.

– The protective devices shall use the appropriate or higher capacity of the PCS overcurrent protection rating and shall be representative of the type of protective devices that would be located in a suitable location. The protective devices size, location in the circuit and type shall be documented.

NOTE 1 The fuses can use 120 % or more capacity of the power conversion subsystem overcurrent protection rating.

– The resistance of the short circuit test shall use the appropriate value which will be measured and recorded before the short circuit test.

NOTE 2 Generally, lower resistance (in ohm) is better. But it is important to take into consider the maximum short circuit current in the BESS and test facilities. Therefore, This test will be done coordinatation between short circuit resistance and short circuit current, and short circuit test time.

– The short circuit test shall be performed when the electrochemical accumulation system's energy level is sufficient.

NOTE 3 The state of system energy can be over 90 %.

– The temperature change and the short circuit current of BESS (battery subsystem, PCS subsystem etc.) shall be measured and recorded in the short circuit test.

NOTE 4 The temperature measurements can be performed every 1 s. The current measurements can be performed each 100 μs.

When performing a short-circuit test in which a large current is applied to actual BESS instead of simulated test, refer to Annex H for test methods and procedures.

The criteria of this test/check are as follows:

– the protection functions shall work as designed;
– all system (including connection and cables) insulation and functionality shall be maintained;
– a fire shall not start.

8.2.1.2 Overcharge protection

The electrochemical accumulation subsystems (battery subsystem) of the BESS shall be protected from overcharge. The BESS shall be tested with real signal or suitable simulated signals to determine whether the charging circuit shall be disconnected as designed when a state of overcharging in the electrochemical accumulation subsystems (battery subsystem) is detected.

If the overcharge protection of the battery subsystem is built directly into the battery system protection such as the BMS and this protection has been evaluated as part of the battery system evaluation to the battery safety standard, this test shall not be repeated at the battery subsystem level.

Either as a type test check of the protection controls (for category "V-L" BESS) or upon installation as a SAT (for category "V-H" BESS), any subsystem functions providing protection during charging shall be tested during a normal charging operation with real signals or suitable simulated signals for the fault events listed below:

– Capacity upper limit of the electrochemical accumulation subsystems will be indicated as overcharging.
– Voltage upper limit of the electrochemical accumulation subsystems will be indicated as overcharging.
– Temperature upper limit of the electrochemical accumulation subsystems will be indicated as overcharging.
– The overcharge test shall be started when the electrochemical accumulation system's energy level is sufficient.

NOTE 1 The state of system energy can be started over 90 %.

– Regarding the overcharge test current and voltage, the nominal value of battery shall be taken into consideration.

NOTE 2 The PCS can be controlled W [watt] and Wh [Watt-hour] detention. Attention is paid to the battery voltage and input Ah.

– The voltage, current and temperature of the battery subsystem shall be measured and recorded in an overcharging test.

NOTE 3 The measurements of resolution can be performed every 1 s.

Refer to Annex H for test methods and procedures when performing an overcharge protection test in which an overcharge is applied to actual BESS instead of simulated test.

The criteria of this test/check are as bellow.

– The protection functions shall work as designed.
– All System insulation and functionality shall be maintained.
– A fire shall not start.

8.2.1.3 High current protection

The BESS shall be protected from high current charge and discharge. The BESS shall be tested with real signals or suitable simulated signals to determine whether the charging/discharging circuit shall be disconnected as designed when a state of high current charge in each subsystem (electrochemical accumulation subsystems, PCS subsystem, etc.) is detected.

If the high current charge/discharge protection of the battery subsystem is built directly into the battery system protection such as the BMS and this protection has been evaluated as part of the battery system evaluation to the battery safety standard, this test shall not be repeated at the battery subsystem level. Also, the PCS subsystem is the same.

Either as a type test check of the protection controls (for category "V-L" BESS) or upon installation as a SAT (for category "V-H" BESS), any subsystem functions providing protection during charging/discharging shall be tested during a normal charging/discharging operation with real signals or suitable simulated signals for the fault events listed below:

– Current upper limit of the electrochemical accumulation subsystems will be indicated as high current.
– Current upper limit of the PCS subsystems will be indicated as high current.
– Current upper limit of the electric grid will be indicated as high current.
– Before performing the high current test, protective devices (e.g. fuses, circuit breakers etc.) shall be installed in the system to protect the BESS, testing facilities and the electric grid.

The protective devices shall use the appropriate or higher capacity of the PCS overcurrent protection rating and shall be representative of the type of protective devices that would be located in a suitable location. The protective devices size, location in the circuit and type shall be documented.

NOTE 1 The fuses can use 120 % or more capacity of the power conversion subsystem overcurrent protection rating.

– The high current test shall be performed when the electrochemical accumulation system's energy level is suitable.

NOTE 2 Generally, the state of system energy can be half level (50 %).

– The voltage, current and temperature of battery-subsystem and PCS subsystem shall be measured and recorded in high current test.

NOTE 3 The measurements of resolution can be performed every 1 s.

When performing a high current test in which a large current is applied to the actual BESS instead of simulated test, refer to Annex H for test methods and procedures

The criteria of this test/check are as follows.

– The protection functions shall work as designed.
– All system insulation and functionality shall be maintained.
– A fire shall not start.

8.2.1.4 Earth fault protection

The BESS shall be protected from earth fault. The BESS shall be tested with real signals or suitable simulated signals to determine whether the main electric power circuit shall be disconnected as designed when a state of earth fault in the whole BESS is detected.

Either as a type test FAT check of the protection controls (for category "V-L" BESS) or upon installation as a SAT (for category "V-H" BESS), any subsystem functions providing protection during charging shall be tested during earth fault with real signal or suitable simulated signals.

Before the earth fault testing, protective fuses in the system shall be installed.

– The capacity of the protective devices (fuses) being additionally installed for testing shall be operable using the power conversion subsystem rated load.

NOTE 1 the fuses can use 120 % or more capacity of the power conversion subsystem overcurrent protection rating. The earth fault test will be performed when the electrochemical accumulation system's energy level is sufficient (e.g. 80 %).

– It takes into consider that test charging current should be nominal current.

NOTE 2 The state of the system energy can be 80 %.

– The voltage and earth current change of the BESS (battery subsystem, PCS etc.) shall be measured and recorded in the earth fault test.

NOTE 3 The measurements of resolution can be performed each 100 μs.

When performing the earth fault test in which a large earth current is applied to actual BESS instead of simulated test, refer to Annex H for test methods and procedures to keep safety.

The criteria of this test/check are as follows.

- The protection functions shall be worked as designed.
- All System insulation and functionality shall be maintained.
- A fire shall not start.

8.2.1.5 Impulse withstand voltage protection

This test is a type test as it can result in damage to the BESS under test. The impulse voltage test is to verify the capability of the solid insulation to withstand the rated impulse voltage. The voltage waveforms used for this test should simulate the overvoltage of atmospheric origin and cover overvoltage due to switching of low-voltage equipment.

An impulse voltage test in accordance with IEC 60664-1:2020, 6.4.4, shall be conducted on the solid insulation of the BESS.

This test covers both categories V-L and V-H. However, the test shall be done for safety-related subsystems in case of category V-H BESS.

In case of a test for PCS as safety-related subsystems in BESS of category V-H, the test may be applied to the "overvoltage" category and the pollution degree reduced according to IEC 62477-1.

This test covers both categories V-L and V-H. However, the test shall be done for safety-related subsystems in case of category V-H BESS.

At least overvoltage category III (for category "V-L" BESS itself) or IV (for safety-related subsystems of category "V-H" BESS) in IEC 60664-1:2020, Table F.1, shall apply for the determination of rated impulse voltages criteria.

For the determination of clearances criteria, the highest value of the following that is specified in IEC 60664-1:2020 shall apply.

- Pollution degree 2 or 3 in Table F.2, or
- Table F.8.

As an alternative to apply IEC 60664-1:2020, Table F.2, IEC 60664-1:2020, 6.2.2.1, can apply if a clearance as specified in Case A of Table F.2 is maintained. In this case, the clearances specified in IEC 60664-1:2020, Table F.8, shall at least be maintained.

The criteria of this test/check are as follows.

- The protection functions shall work as designed.
- No puncture or partial breakdown of solid insulation shall occur during the test, but partial discharges are allowed.
- Partial breakdown will be indicated by a step in the resulting wave shape which will occur earlier in successive impulses.
- Breakdown on the first impulse can either indicate a complete failure of the insulation system or the operation of overvoltage limiting devices in the equipment.
- A fire shall not start.

An impulse test may be waived if the BESS employs surge protection that has already been evaluated for anticipated surges.

8.2.1.6 Dielectric test

See the scheme for dielectric test in Figure 4.

Figure 4 shows an example for the scheme of dielectric voltage test and insulation resistance test.

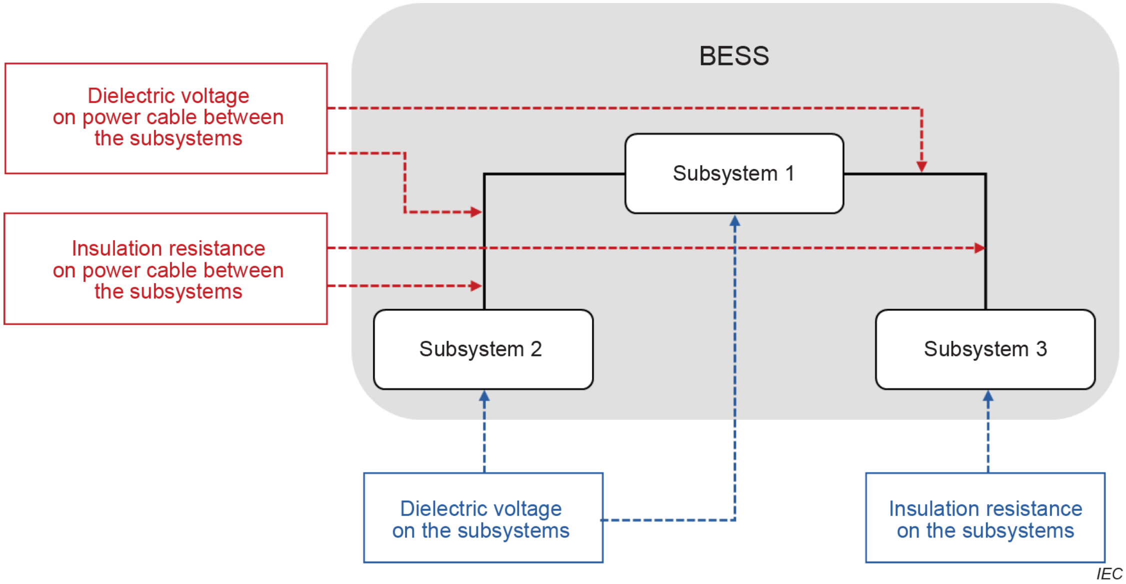


Figure 4 – Example for the scheme of dielectric voltage test and insulation resistance test

The AC dielectric test should verify the capability of the solid insulation to withstand:

– the short-term temporary overvoltage;
– the highest steady-state voltage;
– the recurring peak voltage.

If the peak value of the AC dielectric test voltage is equal to or higher than the rated impulse voltage, the impulse voltage test in 8.2.1.3 is covered by the AC dielectric test.

An AC dielectric test in accordance with IEC 60664-1:2020, 6.4.5, shall be conducted. At least overvoltage category III (for category "V-L" BESS itself) or IV (for safety-related subsystems of category "V-H" BESS) in IEC 60664-1:2020, Table F.1, shall apply for the determination of rated impulse voltages criteria.

NOTE 1 See 8.2.1.5 for determination of clearances criteria.

As an alternative to the AC dielectric test, a DC dielectric test according to IEC 60664-1:2020, 6.4.7, may be conducted.

The criteria of this test/check are as follows.

– There shall be no trace of dielectric breakdown of the tested circuits.
– All system insulation and functionalities shall be maintained.

A dielectric test shall also be conducted on the whole BESS or, at least, the electrochemical accumulation subsystems with working voltages exceeding SELV as a FAT.

NOTE 2 This test can cause arcing inside battery cells or electrochemical accumulation subsystems with associated ignition and explosion of gases and electrolytes. A safe testing process will therefore be ensured.

NOTE 3 Repeating the dielectric voltage test is avoided because it would cause insulation ageing. The test is conducted for the whole system only once.

8.2.1.7 Insulation resistance

See the scheme for insulation resistance in Figure 4.

An insulation resistance test should be conducted in accordance with IEC 60364-6:2016, 6.4.3.3 and 6.4.3.4.

The resistance of insulation used on hazardous voltage circuits within a BESS shall comply with the values in IEC 60346-6:2016, Table 6.1.

8.2.1.8 Earthing system check

The earthing system of a BESS shall be confirmed in accordance with the methods noted below. The measurements shall be made between any two locations of the earthing system.

For category "V-L", the earthing system of the BESS shall be validated by measurement of the resistance of the earth electrode in accordance with IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, 411.4 (TN systems), 411.5 (TT systems), or 411.6 (IT systems) and IEC 60364-6:2016, 6.4.3.7.2, or the measurement of the earth fault loop impedance in accordance with IEC 60364-6:2016, 6.4.3.7.3.

For category "V-H", the earthing system of the BESS shall be validated in accordance with IEC 61936-1:2021, Clause 10.

8.2.1.9 Anti-islanding

Any anti-islanding function of the BESS shall be validated or tested in an appropriate way to confirm the requirements in 7.11.3.1.

NOTE The presence or not of the anti-islanding function depends on local grid code requirements.

8.2.2 Mechanical hazards

8.2.2.1 Enclosure strength against impact

For category "E-S" BESS, enclosures shall be subjected to an impact test in accordance with IEC 62477-1:2022, 5.2.2.4.3. As a result of this impact test, there shall be no damage that would result in access to hazardous parts in accordance with 8.2.10. After this test the BESS shall not show any electrical shock hazard as determined in accordance with the dielectric test in 8.2.1.4.

For category "E-LI or E-LS", the enclosures of subsystems of BESS shall be subjected to impact tests as above.

8.2.2.2 Enclosure strength against static force

For category "E-S" BESS, enclosures shall be subjected to the test in IEC 62477-1:2022, 5.2.2.4.2.3. As a result of the force tests, there shall be no damage that would result in access to hazardous parts in accordance with 8.2.10. After this test the BESS shall not show any electrical shock hazard as determined in accordance with the dielectric test in 8.2.1.4.

For category "E-LI or E-LS", the enclosures of subsystems of BESS shall be subjected to the static force test as above.

8.2.2.3 Impact and vibration during transportation and seismic events (e.g. earthquakes)

The safety design level against impact and vibration during transportation and seismic events (e.g. earthquakes) generally depends on local regulations and the installation environment. However, the safety level itself should be confirmed on site in accordance with the result of a system risk assessment (see Clause 6). At least the states in the list below shall be verified as SAT in accordance with the standards and manufacturer instructions. Local regulations can apply as well:

– Each subsystem and whole system should be securely fixed and connected to each structure, foundation or earth. The connection bolt torque on the site shall be checked.
– The power circuits and connection points between subsystems should remain functional after seismic events; It should be checked connection for visual confirmation.
– The control, monitoring and earthing circuits should remain functional after seismic events.

NOTE If it is not possible to perform the earthquake impact and vibration type test (for example for large scale BESS), it is possible to use an alternative method to verify it (e.g. with technical assessment, simulation or calculation).

8.2.3 Explosion

8.2.3.1 Specification of flammable gas

If flammable gases can be generated during normal or abuse conditions as part of the failure analysis in Clause 6, the flammable gases which shall be detected shall be specified during the appropriate system design process.

This requirement depends on the electrochemical accumulation subsystem chemistry. As noted in Annex B, some BESS shall discharge flammable gas under normal operating conditions and other BESS shall vent explosive or flammable gas during abuse conditions that result in overheating of the BESS and possible fire or explosion. The term of off-gas exhaust with venting the rapture.

It is also necessary to pay attention to the gas that is generated later, for example fire propagation with battery packing material can generate flammable gas.

Therefore, the information on all gas components that will occur during the entire period from one battery venting to the whole BESS fire should be researched and analysed.

The general chemical properties of flammable gases which are specified for the above process should be confirmed.

In addition, the following off-gas data is beneficial to evaluating the suitability of protection mechanisms in the BESS and installation to prevent explosions:

1) the type of gas per cell/battery off gassed during venting;
2) the volume of gas per cell/battery off gassed during venting;
3) the LFL of the gas vented from the cell/battery (ASTM E918);
4) the burning velocity of the gas (ISO 817);
5) the maximum deflagration pressure of the gas (BS EN 15967).

Parameters 1), 2), and 3) above are important for understanding the volume of gas and its flammability that are coming from an individual unit of the BESS such as a cell, along with the large-scale fire testing, which provides the level of cell venting that can occur from the system. Parameters 4) and 5) above are used for determining suitability of deflagration venting within a system or installation.

These off-gas data should be requested from the battery manufacturer. Alternatively, a battery gassing test can be performed to collect gas data..

8.2.3.2 Gas detection/off-gas detection

The flammable gas/off-gas which is specified in 8.2.3.1 should be detected accurately.

The discharge gas under normal operating conditions shall be detected with gas concentration.

It shall be arranged with the sensor sensitivity class depending on the risk limit of the flammable/toxic gas. For example, the hydrogen gas concentration outside the BESS or inside shall be maintained under the explosive 4 % vol hydrogen LEL threshold. Therefore, the gas detection system shall detect under 4 % vol.

The off-gas detection time which is from the venting gas to the starting gas alarm shall be determined appropriately considering the most stringent conditions.

The off-gas detection time which is from the venting gas to the starting gas alarm should be validated by using the information below:

– The amount of gas and speed of gas generation should be checked as specified in 8.2.3.1.
– The sensitivity class/level of the gas sensor.
– The sensor location, number and room capacity (W:D:H) information.

The gas/off-gas detection time should be sufficiently faster than the battery propagation time or fire spread time.

When checking the detection time in the test, the following should be noted:

– Although it is possible to use a simulated gas, using the actual venting gas is preferred.
– It should be checked that all sensors work at the set sensitivity level.
– The simulated gas generation is carried out under the most severe conditions from the gas sensor installation position.
– All the air conditioner and ventilation system are working at a normal level.

The criteria of this test/check are as follows.

– The detection time shall be within 10 % of designed time.
– The audible alerts and visual signals shall be operated.

NOTE 1 Generally, the detection time can be within 10 s.

The location and number of sensors installed for the test shall be described on the BESS diagram and specified in the test report.

NOTE 2 In addition, for BESS that can experience potential for thermal runaway according to Annex B, a large-scale fire test that includes monitoring for flammable gas emissions can be conducted. Data on the type and quantity of flammable gas emissions obtained during testing can assist in determining suitable deflagration venting to prevent explosion hazards in the event of a fire from the BESS. See Annex C for details regarding large scale fire testing.

Upon installation, any functions of the detection systems, audible alerts and visual signals for reporting an incident of flammable gas shall be tested in accordance with the appropriate standards and manufacturer instructions to confirm that their functions automatically operate when the concentrations of flammable gas exceed the limit which is indicated by the manufacturer. Local regulations can apply. Their functions shall operate as designed. The type test for the individual components of detection systems, audible alerts and visual signals shall be done. Evaluation to the appropriate component standard is considered as compliance to this criteria.

The FAT or SAT for the BESS with the combination of detection systems, audible alerts and visual signals shall also be done with suitable simulated signals for events to be detected.

Refer to the IEC 60079-29 series for standards for flammable gas detectors and guidance on installation of flammable gas detectors.

8.2.3.3 Ventilation

The ventilation systems provided at the site where the BESS has been located or provided within the BESS itself shall be tested. The type test for individual components shall be done. The SAT for the BESS with ventilation systems shall also be done. As a result of tests conducted, the ventilation systems shall automatically operate as designed.

If the general (24 h) ventilation system is provided, the SAT shall confirm the whole ventilation capacity and local exhaust capacity. Especially, the local exhaust capacity around battery subsystem should be tested.

For category "E-LI or E-LS / S-O/ C-A, C-B, C-D and C-Z" BESS, if a forced ventilation system is provided, the SAT for the forced ventilation system shall also be performed with suitable simulated signals which would be sent upon detection of flammable gases. As a result of that, the ventilation systems shall automatically operate as designed.

Ventilation systems shall be designed to activate prior to combustible concentrations accumulating, as in the case of the detection of trace amounts of gas from initial cell venting.

If a forced ventilation system is provided, the SAT shall confirm the time of activation and the ventilation capacity.

The ventilation system shall keep the hydrogen concentration under 25% of the hydrogen LEL threshold.

NOTE 1 The activation time can be calculated with the opening and closing time of the damper and the start-up time of the ventilation fan.

NOTE 2 The ventilation capacity can be determined by the rate of gas generation and the allowable limit of flammable or toxic gas.

Refer to IEC 60079-7:2015, 6.6.4, for a method to evaluate battery compartment ventilation or IEC 60079-13.

When checking the active time and capacity in the test, the following should be noted.

- The trigger of this test is each sensor or BESS trouble signal.
- End of test time is reached to nominal power of ventilation. In addition, capacity can be measured by the nominal power of the ventilation system.
- As a test condition, BESS is implemented in 3 modes: active mode (charge/discharge), idle/wait mode, and rest/stop mode.
- All the air conditioner and safety subsystems are working in normal level.

The criteria of this test/check are as follows.

- The active time shall be within 10 % of designed time.
- The capacity of ventilation shall be within 10 % of designed capacity.
- The audible alerts and visual signals shall work.

If the fire suppression system is activated, the ventilation system shall be stopped. The SAT shall be tested for this safety sequence.

8.2.4 Hazards arising from electric, magnetic, and electromagnetic fields

The safety functions of the safety-related subsystems of BESS shall comply with IEC 61000-6-7, or functional safety shall be considered with regard to electromagnetic phenomena in accordance with IEC 61000-1-2 if applicable.

Protective measures from disturbance-induced malfunctions of subsystems of BESS shall be validated with the method given in IEC 60364-4-44.

For category "E-S" compliance with the requirements above shall be confirmed by a type test with a representative BESS.

For category "E-LI or E-LS" compliance with the requirements above shall be confirmed by type tests with individual safety-related BESS subsystems and on-site validation of BESS control subsystems.

NOTE It is beneficial that suitable documents are referred to depending on the BESS application. (e.g. IEC 61000-6-1, IEC 61000-6-2, and IEC 6100-6-5 etc.).

8.2.5 Fire hazards (propagation)

Category "C-A" electrochemical accumulation subsystems (battery subsystem) shall be tested and validated in accordance with the requirements of IEC 62619:2022, 7.3.3. This IEC 62619:2022, 7.3.3, propagation test shall be observed for 8 h to see if there are any abnormalities such as fire. Therefore, each temperature shall be measured on the target cell, adjacent cells and enclosure inside/outside. This temperature data shall be used for the thermal simulation of the whole BESS.

If the temperature data for fire propagation test is not specified in IEC 62619, the thermal simulation of the BESS cannot be done. In this case, the fire propagation test shall be done on a small-scale BESS or battery subsystem as type test.

Fire characteristics of a BESS which has the potential to exhibit thermal runaway according to Annex B, should be determined through a large-scale fire test of the BESS that evaluates fire propagation and heat generation for an anticipated BESS installation with and without the fire suppression system. Test data generated as a result of large-scale fire testing can validate a BESS installation with the intended fire suppression system.

Before installation of category "C-A" BESS, at least a test or simulation shall be done as follows:

– For category "E-S" BESS, heat/flame/high-temperature gas propagation should be tested/simulated for the completed BESS size under actual installation conditions (such as indoor/outdoor, self-standing/wall-connected). Fire propagation from PCS (inverter/converter) fire should be considered.
– For category "E-LI" BESS, at least heat propagation simulation, based on the data obtained in accordance with IEC 62619:2022, 7.3.3, “propagation test” shall be done for the completed BESS size under actual installation conditions.
– For category "E-LS" BESS, at least heat propagation simulation, based on the data obtained in accordance with IEC 62619:2022, 7.3.3,” propagation test” shall be done for an electrochemical accumulation subsystem under actual installation conditions.
– It is recommended to conduct a cell propagation test at the module battery level as a preliminary test in advance when performing the BESS propagation test.
– Measure the voltage and temperature of the target cell, adjacent cells and modules when performing the propagation test.
– Measure the temperature of the BESS inside/outside, the exhaust port of vent gas, and enclosures when performing the BESS propagation test.

The criteria of this test/check are as follows:

- No fire outside of BESS/enclosure for 8 h.
- No propagation of another subsystem and the adjacent battery subsystem.
- The vent gas from the exhaust port of BESS should be discharged in a direction that does not directly contact the human body.
- When the BESS door is opened and an explosion occurs due to off-gas mixing with outside air, the BESS door shall not be blown away and equipment inside the BESS shall not be forced out though the door.

See Annex C for details regarding large scale fire testing. Upon installation, the following measures shall be taken:

- for category "S-O" BESS, that fire alarms and fire suppression subsystems are installed and commissioned at the BESS location;
- for category "S-U" BESS, that any fire alarms and fire suppression subsystems should be provided. The fire alarming signal should notify the people who are monitoring the BESS;
- in the case of both, if a fire alarm detects a fire hazard, that fire suppression subsystems automatically operate.

In the case that the results of the system level risk assessment show that fire suppression system is not necessary, it would not be necessary to install a fire suppression system.

On the other hand, generally single cell or other cell fires are easier to extinguish in battery fires, therefore the installation of local fire suppression system in BESS shall be effective.

The effectiveness of the communication function shall be confirmed by inputting suitable simulated signals. The signals shall be transmitted to the communication networks, relays, receivers and fire suppression subsystem securely as designed.

Upon installation, any functions of the fire detection systems, audible alerts and visual signals for reporting an incident of fire, and fire suppression system, shall be tested in accordance with appropriate standards, and manufacturer instructions to confirm that their functions automatically operate when the fire incident occurs. Local regulations can apply. Their functions shall operate as designed. The operation check test for individual components of detection systems, audible alerts and visual signals shall be done. The FAT or SAT for the whole of the BESS installation with a combination of detection systems, audible alerts and visual signals and fire suppression system shall also be done.

8.2.6 Temperature hazards

8.2.6.1 Verification of thermal control operation

BESS shall be subjected to the following validation or testing:

- Electrochemical accumulation subsystems with battery temperature measurements shall be checked by subjecting them to a suitable simulated signal indicating an over-temperature condition to verify the system response.
- When the temperature of the BESS is above specified values, the thermal controls shall stop or otherwise control the charging and discharging to keep the specified operation conditions.
- If not previously conducted as part of the type testing, upon installation, the BESS shall be checked to ascertain if the charging and discharging are stopped when the temperature of electrochemical accumulation subsystems exceeds the temperature limit which is indicated by the manufacturer.
- In the case that a current limiting device is equipped outside the electrochemical accumulation subsystems, the function of the current limiting device shall be checked by system validation or by testing with suitable simulated signals of overcharging or temperature rise.

Upon installation, any functions of overheating detection systems, audible alerts and visual signals for reporting an incident of overheating shall be validated or tested in accordance with appropriate standards and manufacturer instructions to confirm that their functions automatically operate when monitored temperature limits exceed those provided by the manufacturer. Local regulations can apply. The type test for individual components of detection systems, audible alerts and visual signals shall be conducted.

For category "E-LI or E-LS" BESS, the SAT for the whole BESS installation with a combination of detection systems, audible alerts and visual signals shall be conducted.

All the functions above shall operate as designed.

Annex G provides further information regarding thermal control operation.

8.2.6.2 Abnormal operation of subsystems for ventilation

This test is conducted on BESS with ventilation systems or ventilation openings in the BESS enclosure. The ventilation system of the BESS is to be blocked or disconnected. The BESS is then to be subjected to any internal heat sources (i.e. discharge/charge cycle of electrochemical accumulation subsystems) to see if the controls detect the faulted ventilation system and if they end the charging and discharging before the BESS overheats. The test may be conducted with the ventilation system operating and any ventilation openings or ducts blocked.

Upon installation, the BESS that is monitored by an operator station, shall be checked to ascertain if the detection of abnormal conditions of the ventilation subsystems is reported to operators.

Upon installation, the BESS shall be checked to ascertain if the function of report to the operator automatically operates when the temperature of the electrochemical accumulation subsystems exceeds the temperature limit which is indicated by the manufacturer.

Any warning device functions shall be checked by system testing with suitable simulated signals.

All the functions to prevent a hazardous condition if there is a fault in the ventilation system as noted above shall operate as designed.

8.2.6.3 Temperature under normal operation tests

When operated at maximum operating loads and parameters, temperatures on temperature sensitive components of the BESS shall be within their ratings which are indicated by the manufacturer. The operating parameters for electrochemical accumulation subsystems shall be within their operating parameters for voltage, current and temperatures which are indicated by the manufacturer.

The BESS shall be operated normally at the maximum load conditions for charging and discharging. During this operation, temperatures on temperature critical components including electrochemical accumulation subsystems and the voltage and current of the electrochemical accumulation subsystems shall be monitored to determine whether or not they are operating within their specified temperature, current and voltage range.

All the functions above shall operate as designed and temperatures measured shall not exceed the component limits. The voltage and current of the electrochemical accumulation subsystem shall be within the specified limits.

8.2.7 Chemical effects

8.2.7.1 Specification of hazardous fluids

The hazardous fluids which shall be detected shall be first identified and specified during the appropriate system design process.

NOTE The outcome of this requirement will depend on the chemistry of the electrochemical accumulation subsystem. See Annex B.

8.2.7.2 Fluids detection

Upon installation, any functions of the detection systems, audible alerts and visual signals for reporting an incident of hazardous fluids shall be tested in accordance with appropriate standards and manufacturer instructions to confirm that their functions automatically operate when the concentration or leakage of hazardous fluids occurs. Local regulations can apply. Their functions shall operate as designed. The SAT for individual components of detection systems, audible alerts and visual signals shall be conducted with suitable simulated signals for the events to be detected.

These tests can be conducted as a type test if hazardous chemical sensors and alarm systems are provided as part of the BESS rather than as a protection system installed as part of the installation site.

8.2.7.3 Protective measures against hazardous fluid

Any functions of protective measures against hazardous fluid required in 7.11.3.1 shall be validated or tested in accordance with appropriate standards and manufacturer instructions. Local regulations can apply. Their functions shall operate as designed.

8.2.8 Hazards arising from auxiliary, control and communication system malfunctions

The tests to determine if hazards result from an auxiliary system malfunction, control system malfunction, internal communications system malfunction and external communication system malfunction of the BESS are to be conducted in accordance with IEC 62933-5-1. Analysis of the system shall provide guidance on possible faults to these subsystems of the BESS.

The correct operation of safety interlock function shall be validated in accordance with the processes specified in 8.2.8.

Parameters for monitoring the current state and abnormal conditions of the BESS shall be available over a communication network even when the system is shut down correctly.

NOTE When checking BESS parameters, they can be monitored with an external device which is connected to BESS temporarily to get parameters (via communication interface, etc).

All the functions above shall operate as designed.

8.2.9 Hazards arising from environments

8.2.9.1 General

The tests noted below apply to those BESS that have environmental ratings or intend to be installed where environmental conditions can affect their safety.

8.2.9.2 Exposure to moisture ingress

The BESS shall include in the risk assessment the minimum IP ratings for moisture and foreign object ingress. The risk assessment shall include results of any ingress protection testing in accordance with IEC 60529.

If the BESS are to be tested for the ingress of moisture, the BESS shall not exhibit signs of fire or explosion, and there shall be no damage to the enclosure that would result in access to hazardous parts in accordance with 8.2.10. The protective subsystems shall remain functional. The BESS shall not pose an electrical shock hazard as determined by compliance to the dielectric voltage withstand test of 8.2.1.4.

BESS shall be subject to a water immersion exposure test using salt water that has a weight of 5 % NaCl in H_2O considering that they are intended to be installed in a location that can be subjected to flooding. The BESS shall be completely immersed or portions of the BESS that would be impacted by water immersion are to be immersed for 2 h or until reactions appear to have stopped. As a result of the immersion, there shall be no fire or explosion.

In case the submersion test (salt mist cycle test) is impossible for entire BESS or part of BESS, it can be replaced by a system level risk assessment by a review of related documents such as drawing or specifications for the validation of countermeasures toward marine environmental risks on the design.

In case of toxic gas or fluid release in the presence of water, gas or fluids shall be detected. They shall be identified (nature) and specified (released volume) during the appropriate system design process. Protection from chemical effects shall be provided as described in 7.11.3.6.

The process that is required to comply with the above is included in the testing example that is given in Annex D.

8.2.9.3 Humidity detection

If the BESS is equipped with humidity detection, the following shall be performed:

a) the humidity sensor's documentation shall be checked;
b) the verification of the correct measurement between a portable sample sensor and the sensors installed within EESS enclosure shall be done;
c) the verification of the correct humidity control with the HVAC's regulation thresholds shall be done.

8.2.9.4 Exposure to marine environnements (salt mist)

BESS intended for installation in or around a marine environment (e.g. near seashores, on docks, etc.) shall be confirmed by system design check in accordance with the results of the system risk assessment (see Clause 6) or wholly subjected to the exposure test method 1 or 2 specified in IEC 60068-2-52.

NOTE IEC 60068-2-52 defines test method 1 or 2 for equipment which are continuously used in or around a marine environment.

As a result of the salt mist exposure, the BESS shall not exhibit signs of fire or explosion. There shall be no damage of the enclosure that would result in access to hazardous parts. BESS shall not pose an electric shock hazard as determined by compliance to the dielectric voltage withstand test of 8.2.1.4.

In case the submersion test (salt mist cycle test) is impossible for entire BESS or part of the BESS, it can be by a system level risk assessment by a review of related documents such as drawings or specifications for the validation of countermeasures toward marine environmental risks on the design.

In case of toxic gas or fluid release in the presence of salt water, gas or fluids shall be detected. They shall be identified (nature) and specified (released volume) during the appropriate system design process. Protection from chemical effects shall be provided as described in 7.11.3.6.

The possible process that is to be done for complying with the above is included in the testing example shown in Annex D.

8.2.10 IP rating of BESS enclosure and protective guards

The BESS enclosure and protective guards shall comply with their IP rating for access to hazardous parts (e.g. hazardous moving parts, uninsulated electrical parts at hazardous voltage) in accordance with IEC 60529.

9 Guidelines and manuals

In addition to the requirements in 7.12, and 7.13.1.1 to 7.13.1.4, the considerations in IEC 62933-5-1, Clause 9, are applicable.

Annex A
(informative)

Ownership models of BESS

This document deals with safety and does not decide the ownership of the BESS, but the decision and clarification of ownership are important for BESS safety and responsibility. Therefore, the description of ownership models is also important because that is helpful for the decision of ownership.

Ownership models are a critical consideration for the BESS, particularly in smaller domestic and commercial installations. Where larger installations would generally form part of a larger utility system having specific procedures and tasks assigned, smaller installations would likely be regarded in the same manner as household appliances such as a refrigerator. In this instance it should be assumed that the system user has neither technical expertise nor a satisfactory level of consciousness as to the safety aspects of BESS.

For ownership models, the following should be considered:

- should the system be sold outright with no ongoing engagement between the system owner and/or supplier?
- would the safety and performance goals of the system be better achieved through a managed lease model?
- is the option of a managed lease or contracted service regime practical or cost effective?
- should this aspect be subject to regulation?
- does the ownership model necessarily restrict the type of chemistries that can be installed in these smaller installations?
- what are the impacts of transfer of ownership where an incoming owner cannot even be aware the BESS exists?
- what level of engagement is required with the electrical supply utility where the BESS is on the consumer's side of the electrical meter; what are the rights of the utility in this circumstance?
- at what point does the system become a significant risk to require regulatory measures, when the most basic BESS could have the size and simplicity of a basic UPS system where the only difference is bi-directional flow?
- what end-of-life outcomes can be relied upon under different ownership models?

Annex B
(informative)

BESS hazards and risks

B.1 General introduction

Battery energy storage systems (BESS) that are designed with sufficient safety protections and are installed, operated, and maintained in a manner that maintains the system safety can be operated without incident as evidenced by the systems currently operating safely in the field. It is important that the safety controls and hazard mitigation approach consider the inherent hazards associated with these systems, which can vary depending on the battery technology.

All electrochemical energy storage systems have several risks in common. These include:

- the inability to always be able to isolate the energy or reduce it to safe levels, giving rise to a potential risk of electrical shock or other electrical energy hazards,
- batteries can provide a large DC short-circuit current,
- chemical hazards due to electrolyte release,
- battery constituents can be flammable,
- batteries can generate gases as part of normal operation (hydrogen) or because of abnormal operation (e.g. chlorine, bromine, H_2S, SO_2),
- battery modules can be heavy,
- failure of the communication link (internal or external) affecting the system's ability to enter a safe state.

The main conditions leading to hazards commonly pertaining to all BESS listed in Table 1 include but are not limited to:

- error of earth fault detection of the "BESS" itself,
- loss of control of the electrochemical accumulation subsystem(s) while in a charged condition (especially malfunction caused by the other subsystems, e.g. oscillation and/or noise of power conversion subsystem),
- collapse, drop and physical oscillation (vibration) of the electrochemical accumulation subsystem and housing,
- malfunction of subsystems caused by electric noise and electromagnetic (or electrostatic) induced stress,
- foreseeable misuse conditions of the batteries and the final installed system,
- compatibility of chosen batteries and the final system as designed, and
- conditions not anticipated with the batteries and final installed system.

The principal hazards of BESS in category "C-A: using non-aqueous electrolyte battery" include but are not limited to:

- thermal propagation originating from an uncontrolled failure in the electrochemical accumulation subsystem(s),
- combustible release of gas from the electrochemical accumulation subsystem(s),
- fire induced chemical/toxic threats originating from the electrochemical accumulation subsystem(s).

The principal hazards of BESS in category "C-B: using aqueous electrolyte battery" include but are not limited to:

- combustible chemical (e.g. hydrogen gas) propagation from the electrochemical accumulation subsystem(s),
- toxic chemical (e.g. electrolyte) propagation from the electrochemical accumulation subsystem(s).

The principal hazards of BESS in category "C-C: using high temperature battery" include but are not limited to:

- thermal propagation originating from uncontrolled failure in the electrochemical accumulation subsystem(s),
- abnormal heat from the electrochemical accumulation subsystem(s).

The principal hazards of BESS in category "C-D: using flow battery" include but are not limited to:

- combustible chemical (e.g. hydrogen gas) propagation from the electrochemical accumulation subsystem(s)
- toxic chemical (gas, liquid) propagation from the electrochemical accumulation subsystem(s)

Table B.1 to Table B.5 show the lists of hazards of BESS. These tables are just for clarification of the hazards to be considered for the risk assessment process of the BESS, and not those of the individual batteries themselves.

The performed risk analysis can consider the relevant categorizations within 4.2 and the overall risk of the BESS including but not limited to:

- risks associated with aggregation of multiple components and/or battery units,
- complexity of final system and failure modes,
- any considerations to take account of the safety across the life cycle usage of the BESS,
- inadequate earthing, insulation and connection among BESS subsystems,
- hazardous (restrictive, confined, limited) workspace,
- water and dust ingress (unsuitable IP grade),
- transient electrical input in the connected grid.

Table B.1 – Hazards of BESS in common

<table>
<tr><td colspan="5">"System hazard" – combination with each subsystem</td></tr>
<tr><td rowspan="9"></td><td colspan="2">Kind</td><td colspan="2">Hazards as "subsystem incidents" (yes or no / details)</td></tr>
<tr><td colspan="2" rowspan="5">Electrical</td><td rowspan="5">Y</td><td>Inadequate earthing essential for safety in combination with electrochemical accumulation subsystem, power conversion subsystem, management/communication subsystem, protection subsystem, and housing</td></tr>
<tr><td>Error of earth fault detection in combination with electrochemical accumulation subsystem, power conversion subsystem, management/communication subsystem, protection subsystem, housing and connection terminal to grid</td></tr>
<tr><td>Losing control of electrochemical accumulation subsystem with energy in combination with power conversion subsystem, management/communication subsystem, protection subsystem, housing, connection terminal to grid and interfaces</td></tr>
<tr><td>Inadequate insulation essential for safety in combination with electrochemical accumulation subsystem, power conversion subsystem, housing, and connection terminal to grid</td></tr>
<tr><td>Inadequate connection essential for safety in combination with electrochemical accumulation subsystem, power conversion subsystem, management/communication subsystem and protection subsystem</td></tr>
<tr><td colspan="2">Mechanical</td><td>Y</td><td>Collapse, drop and physical oscillation of electrochemical accumulation subsystem and housing</td></tr>
<tr><td colspan="2">Electric, magnetic, and electromagnetic fields</td><td>Y</td><td>Malfunction of subsystems caused by electric noise and physical oscillation of subsystems caused by magnetic noise in combination with electrochemical accumulation subsystem, power conversion subsystem, management/communication subsystem, protection subsystem, housing and connection terminal to grid</td></tr>
<tr><td colspan="5">"Hazard concerning location, environment, and application"</td></tr>
<tr><td rowspan="12"></td><td colspan="4">Location</td></tr>
<tr><td rowspan="3"></td><td>Category</td><td colspan="2">Hazards (yes or no / details)</td></tr>
<tr><td>Mechanical</td><td>Y</td><td>Vibration, impact</td></tr>
<tr><td>Dangerous working conditions</td><td>Y</td><td>Hazardous (restrictive, confined, limited) workspace</td></tr>
<tr><td colspan="4">Environment</td></tr>
<tr><td rowspan="2"></td><td>Category</td><td colspan="2">Hazards (yes or no / details)</td></tr>
<tr><td>Waterfront</td><td>Y</td><td>Water ingress</td></tr>
<tr><td colspan="4">Application</td></tr>
<tr><td rowspan="2"></td><td>Category</td><td colspan="2">Hazards (yes or no / details)</td></tr>
<tr><td>Any case</td><td>Y</td><td>High voltage, excess current</td></tr>
</table>

Table B.2 – Hazards of BESS using non-aqueous electrolyte battery (category "C-A")

<table>
<tr><th colspan="4">"System hazard" – combination with each subsystem</th></tr>
<tr><td rowspan="6"></td><th>Kind</th><th colspan="2">Hazards as "subsystem incidents" (yes or no / details)</th></tr>
<tr><td>Electrical</td><td>Y</td><td>In addition to Table B.1:
Internal short-circuit of battery cell in combination with electrochemical accumulation subsystem, management/communication subsystem and housing
Internal short-circuit of electrochemical accumulation subsystem in combination with electrochemical accumulation subsystem, management/communication subsystem and housing</td></tr>
<tr><td>Explosion</td><td>Y</td><td>Retention of combustible gas in combination with electrochemical accumulation subsystem and HVAC subsystem
Sparking in combination with electrochemical accumulation subsystem, power conversion subsystem, protection subsystem, housing and connection terminal to grid
Insulation breakdown in electrochemical accumulation subsystem in combination with management/communication subsystem and protection subsystem
Fusing of conductor in combination with electrochemical accumulation subsystem, power conversion subsystem, management/communication subsystem, protection subsystem, housing and connection terminal to grid
Increase of inner pressure in electrochemical accumulation subsystem in combination with management/communication subsystem and HVAC subsystem</td></tr>
<tr><td>Fire</td><td>Y</td><td>Fire from electrochemical accumulation subsystem in combination with electrochemical accumulation subsystem, power conversion subsystem, management/communication subsystem, protection subsystem, HVAC subsystem, housing and connection terminal to grid
Propagation of thermal runaway from electrochemical accumulation subsystem in combination with electrochemical accumulation subsystem, management/communication subsystem, protection subsystem, housing and connection terminal to grid
Fire from the other subsystem in combination with management/communication subsystem, protection subsystem, housing and interfaces</td></tr>
<tr><td>Temperature</td><td>Y</td><td>Exposure of heated surface in combination with electrochemical accumulation subsystem, power conversion subsystem, management/communication subsystem, HVAC subsystem, housing and interface</td></tr>
<tr><td>Chemical</td><td>Y</td><td>Liquid spill, gas release, and solid emission from electrochemical accumulation subsystem (electrolytes, active materials, and reaction products) in combination with electrochemical accumulation subsystem, power conversion subsystem, management/communication subsystem, protection subsystem and HVAC subsystem</td></tr>
</table>

Table B.3 – Hazards of BESS using aqueous electrolyte battery (category "C-B")

<table>
<tr><th colspan="4">"System hazard" – combination with each subsystem</th></tr>
<tr><td rowspan="7"></td><th>Kind</th><th colspan="2">Hazards as "subsystem incidents" (yes or no / details)</th></tr>
<tr><td>Electrical</td><td>Y</td><td>Same as Table B.1</td></tr>
<tr><td>Explosion</td><td>Y</td><td>Retention of combustible gas in combination with electrochemical accumulation subsystem and HVAC subsystem

Sparking in combination with electrochemical accumulation subsystem, power conversion subsystem, protection subsystem, housing and connection terminal to grid

Fusing of conductors in combination with electrochemical accumulation subsystem, power conversion subsystem, management/communication subsystem, protection subsystem, housing and connection terminal to grid

Increase of inner pressure in electrochemical accumulation subsystem in combination with management/communication subsystem and HVAC subsystem</td></tr>
<tr><td>Fire</td><td>N</td><td>Insulating oil fire with transformer.

Heat generation due to deterioration or overcharging, etc.</td></tr>
<tr><td>Temperature</td><td>N</td><td>N/A</td></tr>
<tr><td>Chemical</td><td>Y</td><td>Liquid spill and gas release from electrochemical accumulation subsystem (electrolytes, active materials, and reaction products) in combination with electrochemical accumulation subsystem, power conversion subsystem, management/communication subsystem, protection subsystem and HVAC subsystem</td></tr>
</table>

Table B.4 – Hazards of BESS using high temperature battery (category "C-C")

"System hazard" – combination with each subsystem			
	Kind	**Hazards as "subsystem incidents" (yes or no / details)**	
	Electrical	Y	In addition to Table B.1: Internal short-circuit of electrochemical accumulation subsystem in combination with management/communication subsystem and housing Battery heating circuit failure in combination with electrochemical accumulation subsystem, management/communication subsystem and protection subsystem
	Explosion	Y	Dissolution of battery and conductive parts by negative electrode material (sodium) in combination with electrochemical accumulation subsystem, management/communication subsystem, protection subsystem and battery heating circuit Sparking in combination with electrochemical accumulation subsystem, power conversion subsystem, protection subsystem, housing and connection terminal to grid Insulation breakdown in electrochemical accumulation subsystem in combination with management/communication subsystem and protection subsystem Fusing of conductor in combination with electrochemical accumulation subsystem, power conversion subsystem, management/communication subsystem, protection subsystem, housing and connection terminal to grid Increase of inner pressure in electrochemical accumulation subsystem in combination with management/communication subsystem and HVAC subsystem
	Fire	Y	Fire from electrochemical accumulation subsystem in combination with management/communication subsystem, protection subsystem, HVAC subsystem, battery heating circuit, housing and connection terminal to grid
	Temperature	Y	Exposure of heated surface in combination with electrochemical accumulation subsystem, power conversion subsystem, management/communication subsystem, HVAC subsystem, battery heating circuit, housing and interface Battery heating circuit failure in combination with electrochemical accumulation subsystem, management/communication subsystem and protection subsystem
	Chemical	Y	Liquid spill, gas release, and solid emission from electrochemical accumulation subsystem (electrolytes, active materials, and reaction products) in combination with management/communication subsystem, protection subsystem, HVAC subsystem and battery heating circuit Chemical reaction of sodium with water in combination with electrochemical accumulation subsystem, management/communication subsystem and protection subsystem

Table B.5 – Hazards of BESS using flow battery (category "C-D")

"System hazard" – combination with each subsystem			
	Kind	**Hazards as "subsystem incidents" (yes or no / details)**	
	Electrical	Y	Same as Table B.1
	Explosion	Y	Retention of combustible gas in combination with electrochemical accumulation subsystem and fluid system Sparking in combination with electrochemical accumulation subsystem, power conversion subsystem, protection subsystem, housing and connection terminal to grid Fusing of conductor in combination with electrochemical accumulation subsystem, power conversion subsystem, management/communication subsystem, protection subsystem, housing and connection terminal to grid
	Fire	N	N/A
	Temperature	Y	Exposure of heated surface in combination with electrochemical accumulation subsystem, power conversion subsystem, management/communication subsystem, heat exchanger, fluid system, housing and interface Temperature control error in combination with management/communication subsystem and heat exchanger
	Chemical	Y	Liquid spill and gas release from electrochemical accumulation subsystem (electrolytes, active materials, and reaction products) in combination with electrochemical accumulation subsystem, heat exchanger and fluid system Gas generation by electrolysis of water in combination with electrochemical accumulation subsystem and management/communication subsystem

B.2 Hazards to be addressed

B.2.1 General

The hazards to be addressed for BESS are caused by: fire and explosion, chemical, electrical, stored energy, and physical. The nature and impact of these hazards can vary depending on technology and on operating conditions which can change from normal to abnormal or emergency. The hazards identified below apply to all people interacting with BESS including first responders.

B.2.2 Fire hazards

The fire hazard potential can be evaluated through assessment of the elements of the fire triangle. These elements are the fuel for fire, the oxidant, and the ignition source heat. There is no potential for fire unless there is an appropriate concentration of fuel, oxidant, and a heat source sufficient to cause ignition.

B.2.3 Chemical hazards

Chemical hazards are categorized in accordance with the hazardous material limits for normal operation of the BESS.

B.2.4 Electrical hazards

Electrical hazards are electrical shock and arc flash due to contact with energized parts greater than 50 V and exposed to arcing of electric energy with an incident energy level of 5 J/cm^2 (1,2 cal/cm^2) (sufficient to cause second-degree burns on skin). Electrical hazards to emergency responders that result from BESS that have been exposed to fire or other emergency incidents should be addressed, including the potential for electrical shock and arc flash hazards due to shorting from damaged parts of the BESS and water around them. Since first responders are not trained electrical workers and might not have appropriate PPE for direct contact with live parts or arc flash incidents, acceptable levels of voltage and incident energy should be reduced from that allowed for trained workers with suitable PPE.

B.2.5 Stored electrical energy hazards

Stored electrical energy hazards to people include not knowing the SOC (state of charge) or voltage, and being unaware of the hazard that stored energy. This hazard represents a potential unknown electrical risk. For example, it is low risk as pertains to normal conditions BESS for repair and replacement by trained workers, but it is high risk to emergency responders dealing with damaged BESS that can still contain hazardous energy.

B.2.6 Physical hazards

Physical hazards are due to contact with parts having sufficient kinetic energy to cause harm, parts that have hazardous thermal characteristics that can cause burns, or parts that contain fluids at hazardous pressure levels with either insufficient structural integrity to safely contain the fluids or the ability to safely relieve the pressure. For electrochemical BESS, the potential exists for burn hazards to workers in contact with some technologies during normal operation and repair, if not properly thermally insulated.

B.2.7 High-pressure hazards

There are no known high-pressure hazards with these systems under normal operations, but under abnormal conditions, there can be over-pressurization when the safety relief system fails. This could present a hazard to first responders dealing with damaged BESS.

B.3 Hazard considerations under normal operating conditions

B.3.1 Fire and explosive hazards

Fire and explosive hazards can exist under normal operating conditions or during maintenance or service. Heat sources such as live parts, and so forth, which are in contact with combustible materials during service or maintenance can cause the ignition of combustible concentrations of flammable fluids and solids. Such circumstances can arise as part of the normal operation of BESS, such as hydrogen release from batteries with aqueous electrolytes.

B.3.2 Chemical hazards

Under normal operating conditions, people can be exposed to hazardous chemicals.

Examples of chemical hazards are as follows:

1) Liquid hazards:
   a) Corrosive electrolytes: batteries with electrolytes in the range of pH ≤ 2 or ≥ 11,5 are corrosive (acid or caustic). Systems with these electrolytes pose a hazard due to leaks or spills during maintenance or normal operation. There should be measures for spill containment, and people should have appropriate safe work procedures and protective clothing to work around systems with these corrosive liquids. This does not apply to lead acid batteries of the VRLA type. Batteries containing these hazardous materials should be marked with suitable symbols conforming to the results of risk analysis. Local regulations can apply.
   b) Toxic liquids: People can be exposed to toxic liquids during normal operating, servicing, and maintenance of some systems. Guidance for exposure to toxic liquids can be found in GHSs (globally harmonized systems). People in contact with these systems should be made aware of potential hazards and have appropriate procedures and equipment/PPE to avoid these hazards and know how to use them. Batteries containing these hazardous materials should be marked with suitable symbols conforming to the results of risk analysis. Local regulations can apply.
2) Oxidizers: Oxidizers, if present within a BESS, will increase the flammability potential of other materials. Batteries containing these hazardous materials should be marked with suitable symbols conforming to the results of risk analysis. Local regulations can apply.

3) Toxic gases: The potential exists for exposure to toxic gases under normal conditions of maintenance and service of some BESS systems. Batteries containing these hazardous materials should be marked with suitable symbols conforming to the results of risk analysis. Local regulations can apply.

NOTE 1 The concentrations of these gases will be limited in accordance with applicable code and local regulations.

NOTE 2 For example, OSHA and NIOSH provide guidance for exposures, including permissible exposure limits (PEL), recommended exposure limits (REL) for exposure during an 8 h or 10 h workday, ceiling limits, which are the upper limit of a safe exposure, and IDLH, which represents concentrations that are immediately dangerous to life and health.

4) Solids: Water-reactive and toxic metals that might be contained in some battery technologies typically are not exposed during routine maintenance and servicing of these systems but can present issues under abnormal conditions. Batteries containing these hazardous materials should be marked with suitable symbols conforming to the results of risk analysis and local regulations.

B.3.3 Electrical hazards

Under normal operating conditions some battery systems might have electrical hazards to be addressed as part of operation and maintenance. Electrical hazards that can occur during normal operating conditions include:

1) Electrical shock: BESS with voltages above 50 V can pose hazards to trained people who might come in contact with live parts during operation and servicing of the systems. It is necessary that appropriate labeling and procedures and protective equipment are utilized by workers when servicing these systems.
2) Arc flash: BESS that have an incident energy level greater than 5 J/cm^2 (1,2 cal/cm^2) should have the arc flash boundaries calculated, identified through markings, and proper procedures and equipment in place to prevent worker injury from arc flash during normal operation and servicing.
3) Stored energy hazards: A BESS can have sufficient stored energy to be hazardous to people. The stored energy hazards arise from not being discharged sufficiently or from BESS that are damaged and where the potential exists for electric shock and arc flash. For normal operating conditions, locations that house commercial and industrial BESS should maintain readily available on site instructions for isolation of hazardous voltage and energy for maintenance, and for discharging batteries for safe replacement and disposal. Residential and smaller commercial systems should have readily available information provided and ensure access for trained people to perform their duties to ensure that stranded and stored energy does not represent a hazard under normal operating conditions.

B.3.4 Physical hazards

Physical hazards include the following:

1) Burn hazards: Potential contact with hot surfaces during maintenance that could result in burns if not wearing PPE.
2) Parts containing pressurized fluids and gases.
3) Parts with kinetic energy: Parts of the BESS balance of plant components that might contain moving parts that could cause injury if not guarded properly. This might also be an issue for a hybrid system of batteries and flywheels.

B.4 Hazard considerations under emergency/abnormal conditions

B.4.1 Fire hazards

Fire hazards include the following:

1) Combustible/flammable concentrations due to overheating and venting of flammable gases near sources of ignition can occur during emergency/abnormal conditions. Vented gases, such as hydrogen, in sufficient concentration to create combustible/flammable in the presence of parts that are hot enough to initiate ignition can result in either a fire or an explosion. All batteries, with the exception of hermetically sealed types such as NaNiCl and NaS, have means to relieve internal pressure when overheated to prevent explosions of the battery cell from over-pressurization.
2) Fires due to overheating of electrical parts under abnormal conditions such as short-circuits.
3) Suffocation due to inert non toxic gases designed for fire suppression. Inadvertent leakage of such gases should be prevented.

B.4.2 Chemical hazards

Examples of chemical hazards are as follows:

1) Examples of liquid hazards are as follows:
   a) Corrosive spills: A liquid with a pH ≤ 2 or ≥ 11,5 is corrosive and a hazard level 3 and can cause serious or permanent eye injury for someone who comes in direct contact with it according to NFPA 704:2017, Table B.1. With some systems that contain corrosive liquids, there can be the possibility of leaks or spills from the system under emergency/abnormal conditions. Batteries containing corrosive liquids are to be marked health hazard level 3 in the NFPA 704 hazard diamond.
   b) Toxic liquid vapour exposure: There are different levels of toxicity from liquid vapours that can occur under emergency conditions such as fires and hazardous leaks and spills. There are a range of hazard levels outlined in NFPA 704 as follows:
      i) Level 4: Can be lethal. Any liquid whose saturated vapour concentration at 20 °C is equal to or greater than 10 times its LC50 for acute inhalation toxicity, if its LC50 is less than or equal to 1 000 mg/L
      ii) Level 3: Can cause serious or permanent injury. Any liquid whose saturated vapour concentration at 20 °C is equal to or greater than its LC50 for acute inhalation toxicity, if its LC50 is less than or equal to 3 000 mg/L, and that does not meet the criteria for degree of hazard level 4.
      iii) Level 2: Can cause temporary incapacitation or residual injury under emergency conditions. Any liquid whose saturated vapour concentration at 20 °C is equal to or greater than one-fifth its LC50 for acute inhalation toxicity, if its LC50 is less than or equal to 5 000 mg/L, and that does not meet the criteria for either degree of hazard level 3 or degree of hazard level 4.
      iv) Level 1: Can cause significant irritation under emergency conditions. Mists whose LC50 for acute inhalation toxicity is greater than 10 mg/L but less than or equal to 200 mg/L.
2) Oxidizers: The potential exists for oxidizers to be present within the BESS. An oxidizer will increase the intensity of a fire of other materials. NFPA 400:2019, Annex G, provides information on tests to classify an oxidizer material and identifies known oxidizing materials under their classifications. NFPA 400:2019, Annex G, also provides guidance on safety measures to be used when there are significant exposed quantities of known oxidizers, that can occur during abnormal conditions of certain BESS technologies that contain them. Batteries containing oxidizers are to be marked in the special hazard section of the NFPA 704 hazard diamond.

3) Water reactive solids: Some battery technologies contain water-reactive materials that can react violently when in contact with moisture, including moisture in the air. Although not exposed under normal operating conditions, these materials could be exposed under abnormal conditions. Batteries containing water-reactive substances should be marked as such in the NFPA 704 hazard diamond.

4) Toxic gases: While similar to toxic vapours emanating from liquids (see above), there are different requirements for each toxic gas hazard level:

   a) Level 4: Gases that can be lethal; gases whose LC50 for acute inhalation toxicity is less than or equal to 1 000 mg/L.

   b) Level 3: Gases that can cause serious or permanent injury under emergency conditions; gases whose LC50 for acute inhalation toxicity is greater than 1 000 mg/L but less than or equal to 3 000 mg/L.

   c) Level 2: Gases that can cause temporary incapacitation or residual injury under emergency conditions; gases whose LC50 for acute inhalation toxicity is greater than 3 000 mg/L but less than or equal to 5 000 mg/L.

   d) Level 1: Gases that can cause significant irritation under emergency conditions; gases and vapours whose LC50 for acute inhalation toxicity is greater than 5 000 mg/L but less than or equal to 10 000 mg/L.

   NOTE As outlined in NFPA 704, LC50 for acute toxicity on inhalation is that concentration of vapour, mist, or dust, which, when administered by continuous inhalation to both male and female young adult albino rats for 1 h, is most likely to cause death within 14 days in one half of the animals tested. The criteria for inhalation toxicity of vapours are based on LC50 data relating to 1 h exposures.

B.4.3 Electrical hazards

Examples of electrical hazards are as follows:

1) Electrical shock: Circuits voltages above 50 V can present an electrical shock hazard, because first responders under emergency conditions would not have the training and protective equipment that trained electrical workers would have under normal servicing and maintenance conditions. Information should be available for maintenance staff and first responders on how to address electrical shock hazards.

   In addition, under emergency conditions emergency responders can be exposed to live parts due to contact with conductive fluids such as water and live parts exposed as a result of abnormal conditions. Manufacturers/installers of BESS should define standoff distances and the type and angle of water spray for first responders. Emergency response guidelines should address the issue of isolation of hazardous voltages.

   NOTE UL research (Firefighter Safety and Photovoltaic Installations Research Project, November 29, 2011) into the issue of potential shock to fire fighters from water spray on PV fires indicated that the electric shock hazard due to application of water is dependent on voltage, water conductivity, distance, and spray pattern. For example: (1) A slight adjustment from a solid stream toward a fog pattern (a 10° cone angle) reduced measured current below perception level. (2) Salt water must not be used on live electrical equipment. (3) A distance of 6,1 m (20 ft) had been determined to reduce potential shock hazard from a 1 000 V DC source to a level below 2 mA and is considered as safe.

2) Shock, arc flash, and arc blast hazards: First responders are generally not provided with training and proper protection from arc flash, arc blast, and shock hazards, including clothing, gloves, and so forth, so the potential for sufficient energy that will result in a hazardous electrical event occurring during an emergency response exists. BESS integrator should provide emergency response guidance on how to reduce arc flash and blast hazards.

3) Stored energy hazards: BESS damaged during an emergency incident can present potential shock, arc flash, arc blast, and re-ignition hazards. Sites should have access to on-call trained staff to assist in emergency situations to isolate potential hazard energy and, if necessary, to reduce energy to prevent potential re-ignition of some technologies. For commercial and industrial installations, there should be trained personnel available for emergency response on site. For residential and smaller scale commercial systems, on-call trained personnel should be made available to assist first responders and address discharging of stored energy in batteries for disposal.

B.4.4 Physical hazards

Examples of physical hazards are as follows:

1) Hazardous pressures can develop due to overheating of equipment and devices that do not have pressure relief means (e.g. some chemistries such as flow batteries, etc.).
2) There can be extremely hot parts that pose a contact hazard. It is recommended that appropriate protection be worn, in particular suitable gloves.
3) Exposed parts with hazardous kinetic energy sufficient to cause bodily harm for persons coming in contact with them, such as exposed fan blades, and so forth, under abnormal conditions.

B.5 Commercially available battery technologies

B.5.1 Lithium ion (Li-ion) batteries (C-A)

The term lithium-ion battery refers to a battery where the negative electrode (anode) and positive electrode (cathode) materials serve as a host for the lithium ion (Li+). Lithium ions move from the anode to the cathode during discharge and are intercalated into (inserted into voids in the crystallographic structure of the cathode). The direction of the ions is reversed during charging. Since lithium ions are intercalated into host materials during charge or discharge, there is no free lithium metal within a lithium-ion cell and thus, even if a cell does ignite due to external flame impingement or an internal fault, metal fire suppression techniques are not appropriate for controlling the lithium-ion fire.

Hazards in Li-ion batteries under normal operating conditions are as follows:

1) Fire hazards: A fire hazard can exist if there are latent defects within the cells or design issues with the controls that prevent thermal runaway of the cells. Systems should be evaluated for their ability to prevent propagation due to these defects.
2) Chemical hazards: Not applicable.
3) Electrical hazards: Electrical hazards due to hazardous voltage and energy levels can exist during routine procedures such as maintenance.
4) Stored energy hazards: A stored energy hazard can exist during maintenance if the batteries cannot be isolated for maintenance or during replacement of batteries.
5) Physical hazards: Not applicable.

Hazards in Li-ion batteries under emergency/abnormal conditions are as follows:

- Fire hazards: A thermal runaway hazard can exist if the batteries are not maintained at appropriate operating parameters as a result of abnormal conditions. There can also be fire hazards due to short-circuiting abnormal conditions.
- Chemical hazards: The off-gassing of hazardous vapours can occur under abnormal conditions depending on the size of the cells and the level of failure.
- Electrical hazards: Under abnormal conditions there can be hazardous voltage and energy levels.
- Stored energy hazards: A stranded energy hazard can exist when batteries are exposed to abnormal conditions. Damaged batteries might contain stored energy that can be a hazard during disposal if care is not taken.
- Physical hazards: Depending on the design of the system, the potential exists for physical hazards under abnormal conditions if accessible parts are overheating or if there is exposure to moving hazardous parts such as fans where guards might be missing.

B.5.2 Lead-acid batteries (C-B)

B.5.2.1 General description

Lead acid batteries have lead dioxide as the active material of their positive electrode and metallic lead as the negative electrode with a 1,28 specific gravity (at 28 °C) sulfuric acid solution electrolyte. During discharge, both positive and negative electrodes are converted to lead sulfate. There are two basic categories of lead-acid batteries:

1) Vented lead-acid batteries, also called wet cell or flooded lead-acid batteries.
2) Valve-regulated lead-acid (VRLA) batteries, sometimes referred to as starved electrolyte or maintenance-free batteries.

Vented lead-acid batteries require ongoing maintenance of the electrolyte, and the contents of the battery are open to the atmosphere through a vent/flame arrester assembly. VRLA batteries are generally sealed to the atmosphere and contain a valve that can open when pressure builds up in the battery and then close again. The electrolyte in VRLA batteries is immobilized either through use of a gel electrolyte or through absorption of the electrolyte in a porous absorptive glass matt separator.

B.5.2.2 Vented lead-acid batteries

Hazards in vented lead-acid batteries under normal operating conditions are as follows:

1) Fire hazards: Hydrogen generation due to electrolysis is related to the flow of the charging current and if charging continues once the battery is fully charged, the rate of hydrogen production increases. This current increases with increasing battery temperature and is caused by excessive charge voltages ($V > 2{,}45\ V_{pc}$). IEC 62485-2 gives appropriate guidance in this matter. During discharge no hydrogen is produced but a small temporary release from the cell can occur nevertheless in the form of hydrogen that was trapped in the negative active mass and subsequently liberated during the discharge.
2) Chemical hazards: Contact with sulfuric acid electrolyte can occur during maintenance and leakage through the vent. Workers require suitable PPE to prevent direct exposure to acid when working with and around the batteries. Systems should be provided with spill control and neutralization per codes.
3) Electrical hazards: There are electrical hazards associated with the routine maintenance of these batteries if they are at hazardous voltage and energy levels.
4) Stored energy hazards: A stored energy hazard can exist during maintenance if the batteries cannot be isolated for maintenance or during replacement of batteries.

Hazards in vented lead-acid batteries under emergency/abnormal conditions are as follows:

- Fire hazards: There is the potential for concentrations of hydrogen from vented lead-acid batteries due to overheating from abnormal conditions if the area where the batteries are located is not properly ventilated. Another hazard during abnormal conditions is electrical shorting creating dangerous high current circuits.
- Chemical hazards: Contact with the corrosive sulfuric acid electrolyte during abnormal conditions can present a hazard. Contact can occur with acid leaks or bubbling out through openings. The acid can be held in a spill containment system or not. First responders, in emergency situations, should be aware of potential acid spills that can occur and take appropriate precautions around these batteries.
- Electrical hazards: Electrical hazards might be present under abnormal conditions if the system is at hazardous voltage and energy levels.
- Stored energy hazards: There can be the potential for stored or stranded energy hazards if batteries are subject to abnormal conditions.

B.5.2.3 Valve-regulated lead-acid batteries (VRLA)

Hazards in VRLA batteries under normal operating conditions are as follows:

1) Fire hazards: VRLA cells and mono-blocks emit hydrogen under all operating conditions. The ventilation requirements are specified in IEC 62485-2 for normal and boost charge conditions together with the appropriate safety distances to be implemented between the vent opening and a nearby spark or heat source. Under abnormal operating, i.e. overcharge, conditions the amount of hydrogen emitted can increase by a factor of 50.
2) Chemical hazards: These batteries are starved electrolyte types, so there should be no issue with exposure to corrosive electrolytes under normal operating conditions.
3) Electrical hazards: There are electrical hazards associated with routine maintenance of these batteries if they have been at hazardous voltage and energy levels.
4) Stored energy hazards: A stored energy hazard can exist during maintenance if the batteries cannot be isolated for maintenance or during replacement of batteries.

Hazards in VRLA batteries under emergency/abnormal conditions are as follows:

- Fire hazards: Off-gassing of hydrogen under abnormal conditions can occur when batteries overheat. At combustible concentrations hydrogen can present a fire hazard. Thermal runaway can occur if the batteries are not maintained at appropriate operating parameters. Short-circuiting of electrical current abnormal conditions can also be a hazard.
- Chemical hazards: Although these batteries contain a corrosive electrolyte, when compared to similar vented types, they have much less free electrolyte that could result in a hazardous spill. If battery cases crack or leak, there might be some minor release of electrolyte traces or potential for some leakage under abnormal conditions.
- Electrical hazards: Electrical hazards might be present under abnormal conditions if the system is at hazardous voltage and energy levels.
- Stored energy hazards: There can be the potential for stored energy hazards if the batteries are exposed to abnormal conditions. Damaged batteries might contain stored energy that can be a hazard during dismantling or disposal if care is not taken.

B.5.3 Nickel batteries (C-B)

B.5.3.1 General description

Nickel batteries for stationary applications are divided into two main technologies: nickel-cadmium (Ni-Cd) and nickel-metal hydride (NiMH). Nickel-cadmium batteries have nickel hydroxide as the active material for the positive electrode and cadmium for the negative electrode with potassium hydroxide solution for the electrolyte. The nickel-cadmium batteries for stationary applications can be vented pocket-plate or vented sintered-plate batteries that have multiple cells in a mono-block battery similar to a vented lead-acid battery. They also have vents for maintenance of the electrolyte. Nickel-cadmium batteries can also be sealed types, such as a fiber nickel-cadmium battery that is sealed and provided with a pressure relief valve similar to a VRLA battery. Nickel-metal hydride batteries have nickel hydroxide as the active material for the positive electrode, a metal hydride alloy for the negative electrode, and a solution of potassium hydroxide as the electrolyte. Nickel-metal hydride batteries are sealed in either a single cell design or a mono-block design with multiple internal cells and are provided with an enclosable valve for relieving pressure similar to a VRLA battery.

B.5.3.2 Nickel-cadmium (Ni-Cd) batteries

Hazards in Ni-Cd batteries under normal operating conditions are as follows:

1) Fire hazards: There is the potential for concentrations of hydrogen from vented Ni-Cd batteries if the area where the batteries are located is not properly ventilated. However, this is unlikely for systems that are compliant with installation codes.
2) Chemical hazards: There is the potential for contact with the corrosive/caustic potassium hydroxide electrolyte because these batteries require maintenance and are open to the atmosphere. Workers near these batteries should use appropriate level PPE and take care to prevent exposure to caustic electrolyte when working around the batteries. These systems should be provided with spill control and neutralization as per applicable code and local regulations.
3) Electrical hazards: Electrical hazards associated with routine maintenance of these batteries can arise if they are at hazardous voltage and energy levels.
4) Stored energy hazards: A stored energy hazard can exist during maintenance if the batteries cannot be isolated for maintenance or during replacement of batteries.
5) Physical hazards: Not applicable.

Hazards in Ni-Cd batteries under emergency/abnormal conditions are as follows:

- Fire hazards: There is the potential for concentrations of hydrogen from vented Ni-Cd batteries due to overheating from abnormal conditions if the area where the batteries are located is not properly ventilated. Another area that might create problems during abnormal conditions would be the potential for shorting of high-current circuits.
- Chemical hazards: There is the potential for contact with the corrosive/caustic potassium hydroxide electrolyte during abnormal conditions, should electrolyte leak or bubble through openings that might be created if spill containment is not present or sufficient to contain large quantities of leaked electrolyte. First responders, in an emergency situation, should be aware of potential caustic spills that can occur and take appropriate caution around these batteries. Ni-Cd batteries contain cadmium, which is toxic and a hazardous waste. Although not exposed under normal conditions, there might be potential for cadmium in vapours of burning batteries during abnormal conditions.
- Electrical hazards: Electrical hazards might be present under abnormal conditions if the system is at hazardous voltage and energy levels.
- Stored electrical energy hazards: A stored energy hazard can exist if the batteries are exposed to abnormal conditions where they could still contain hazardous levels of energy. Damaged batteries might contain stored energy that can be a hazard during disposal if care is not taken.
- Physical hazards: Depending on the design of the system, the potential exists for physical hazards under abnormal conditions if accessible parts are overheating or if there is exposure to moving hazardous parts such as fans where guards might be missing.

B.5.3.3 Nickel-metal hydride (NiMH) batteries

Hazards in NiMH batteries under normal operating conditions are as follows:

1) Fire hazards: There should be no combustible gas generation under normal operating conditions, if batteries are operated as designed to prevent overheating and thermal runaway conditions.
2) Chemical hazards: These batteries are starved electrolyte types and so there should be no exposure to corrosive electrolyte under normal operating conditions.
3) Electrical hazards: There are electrical hazards associated with routine maintenance of these batteries if they are at hazardous voltage and energy levels.
4) Stored energy hazards: A stored energy hazard can exist during maintenance if the batteries cannot be isolated for maintenance or during replacement of batteries.
5) Physical hazards: Not applicable.

Hazards in NiMH batteries under emergency/abnormal conditions are as follows:

- Fire hazards: A hydrogen off-gassing hazard exists under abnormal conditions when batteries overheat. This can present a potential fire hazard when in combustible concentrations. There can be the potential for thermal runaway if the batteries are not maintained at appropriate operating parameters. Also, there could be fire hazards due to short-circuiting.
- Chemical hazards: Although these batteries contain a corrosive electrolyte, they have less free electrolyte that could result in spill hazards when compared to vented types. There might be some bubbling of electrolyte or potential for some leakage under abnormal conditions if battery cases crack or leak. Burning NiMH batteries can release toxic vapours, including cobalt oxide fumes, nickel oxide fumes, and so forth.
- Electrical hazards: Electrical hazards can be present under abnormal conditions if the system is at hazardous voltage and energy levels.
- Stored energy hazards: There can be the potential for stored energy hazards if the batteries are exposed to abnormal conditions where they might still contain hazardous levels of energy. Damaged batteries might contain stored energy that can be a hazard during disposal if care is not taken.
- Physical hazards: Depending on the design of the system, the potential exists for physical hazards under abnormal conditions if accessible parts are overheating or if there is exposure to moving hazardous parts such as fans where guards might be missing.

B.5.4 High-temperature sodium batteries (C-C)

B.5.4.1 General description

High-temperature sodium batteries, sometimes referred to as sodium beta batteries or molten salt batteries, are hermetically sealed batteries with metallic sodium as the negative electrode and a ceramic beta-alumina as the electrolyte. These batteries operate at very high temperatures of 270 °C to 350 °C so that the active materials are in a molten state and to ensure ionic conductivity. There are two types of commercially available high-temperature sodium batteries: sodium sulfur and sodium nickel chloride. Sodium sulfur batteries consist of a sodium negative electrode, a beta-alumina electrolyte, and a sulfur positive electrode with an operating temperature within a temperature range of 310 °C to 370 °C. Sodium nickel chloride batteries consist of a sodium negative electrode, a beta-alumina as the electrolyte, and a positive electrode that can consist of nickel, nickel chloride, or sodium chloride with an operating temperature range of 270 °C to 350 °C.

B.5.4.2 Sodium sulfur (NaS) batteries

Hazards in NaS batteries under normal operating conditions are as follows:

1) Fire hazards: The potential exists for fire hazards if there are latent defects within the cells or design issues with the controls that prevent thermal runaway of the cells. Systems should be evaluated for their ability to prevent propagation due to these defects.
2) Chemical hazards: Not applicable. The batteries contain water-reactive sodium, but the systems are hermetically sealed.
3) Electrical hazards: There are electrical hazards associated with routine maintenance of these batteries if they are at hazardous voltage and energy levels.
4) Stored energy hazards: Not applicable.
5) Physical hazards: There should be no hazards associated with these batteries if the designs have sufficient insulation to prevent exposure to hot surfaces, because these batteries run at very hot temperatures under normal operating conditions.

Hazards in NaS batteries under emergency/abnormal conditions are as follows:

- Fire hazards: These systems might be subject to thermal runaway due to defects within the cells and protection scheme. Large energy systems can result in fires if there are abnormal conditions such as short-circuiting within the cell.
- Chemical hazards: The potential exists for exposure to hazardous water-reactive materials if the hermetic seals are broken and sodium is exposed to the atmosphere. PPE is required to address exposure during abnormal conditions.
- Electrical hazards: Electrical hazards might be present under abnormal conditions if the system is at hazardous voltage and energy levels.
- Stored energy hazards: The potential exists for stored energy hazards if the batteries are exposed to abnormal conditions where they might still contain hazardous levels of energy.
- Physical hazards: Depending on the design of the system, the potential exists for physical hazards under abnormal conditions if accessible parts are overheating.

B.5.4.3 Sodium nickel chloride batteries

Hazards in sodium nickel chloride batteries under normal operating conditions are as follows:

1) Fire hazards: The potential exists for fire hazards if there are latent defects within the cells or design issues with the controls that prevent thermal runaway of the cells. Systems should be evaluated for their ability to prevent propagation due to these defects.
2) Chemical hazards: Not applicable. Although sodium is water reactive, the systems are hermetically sealed.
3) Electrical hazards: There are electrical hazards associated with routine maintenance of these batteries if they are at hazardous voltage and energy levels.
4) Stored energy hazards: Not applicable.
5) Physical hazards: There should be no hazards associated with these batteries if the designs have sufficient insulation to prevent exposure to hot surfaces, because these batteries run at very hot temperatures under normal operating conditions.

Hazards in sodium nickel chloride batteries under emergency/abnormal conditions are as follows:

- Fire hazards: These systems might be subject to thermal runaway due to defects within the cells and protection scheme. Fires can occur in large energy systems if there are abnormal conditions such as short-circuiting.
- Chemical hazards: The potential exists for exposure to hazardous water-reactive materials if the hermetic seals are broken and sodium is exposed to the atmosphere. PPE is required to address exposure during abnormal conditions.
- Electrical hazards: Electrical hazards might be present under abnormal conditions if the system is at hazardous voltage and energy levels.
- Stored energy hazards: The potential exists for stored energy hazards if the batteries are exposed to abnormal conditions where they could still contain hazardous levels of energy.
- Physical hazards: Depending on the design of the system, the potential exists for physical hazards under abnormal conditions if accessible parts are overheating.

B.5.5 Flow batteries (C-D)

B.5.5.1 General description

A flow battery is an energy storage component like a fuel cell that stores its active materials in the form of two electrolytes external to the reactor interface. When in use, the electrolytes are transferred between the reactor and storage tanks. Two commercially available flow battery technologies are zinc bromine and vanadium redox. Zinc bromine flow batteries have zinc at the negative electrode and bromide at the positive electrode with an aqueous solution containing zinc bromide and other compounds contained in two separate reservoirs. During charging, energy is stored as zinc metal within the cell and poly-bromide in the cathode reservoir. During discharge, the zinc is oxidized to zinc oxide and the bromine is reduced to bromide. Vanadium redox flow batteries contain vanadium salts in various stages of oxidation in a sulfuric acid electrolyte. Charging and discharging the battery changes the oxidation state of the vanadium in the electrolyte solutions.

B.5.5.2 Vanadium redox flow batteries

Hazards in vanadium redox flow batteries under normal operating conditions are as follows:

1) Fire hazards: There can be the potential for fire hazards in common electrical components such as the power conversion subsystem, fan or pump.
2) Chemical hazards: They contain corrosive liquid that might present a safety concern under normal conditions if the electrolyte is handled/replenished as part of maintenance.
3) Electrical hazards: There are electrical hazards associated with routine maintenance of these batteries when there are hazardous voltage and energy levels.
4) Stored energy hazards: Not applicable.
5) Physical hazards: There can be the potential for stored energy hazards during maintenance if the batteries cannot be isolated for maintenance or replacement of batteries.

Hazards in vanadium redox flow batteries under emergency/abnormal conditions are as follows:

- Fire hazards: Liquids can boil off to create flammable gases (e.g., hydrogen). There can also be risks associated with the balance of plant components overheating and creating the potential for fire hazards under abnormal conditions.
- Chemical hazards: There are large amounts of corrosive liquids.
- Electrical hazards: Electrical hazards might be present under abnormal conditions if the system is at hazardous voltage and energy levels.
- Stored energy hazards: Not applicable.
- Physical hazards: Depending on the design of the system, the potential exists for physical hazards under abnormal conditions if accessible parts are overheating, if there is insufficient pressure relief when the system is overheating and gas is generated, or if there is exposure to moving hazardous parts such as fans or exposed pump parts where guards might be missing.

B.5.5.3 Zinc bromine (ZnBr) flow batteries

Hazards in ZnBr flow batteries under normal operating conditions are as follows:

1) Fire hazards: Not applicable.
2) Chemical hazards: These batteries contain zinc bromide electrolyte, which is corrosive (acid) and toxic with a hazardous classification level of 3 according to NFPA 704. The electrolyte should be reliably sealed in the system, so this should only be an issue for normal operating conditions if electrolyte as part of maintenance or installation is added.
3) Electrical hazards: There are electrical hazards associated with routine maintenance of these batteries if they have been at hazardous voltage and energy levels.
4) Stored energy hazards: Not applicable.

5) Physical hazards: Not applicable.

Hazards in ZnBr flow batteries under emergency/abnormal conditions are as follows:

- Fire hazards: There can be problems with the balance of plant components overheating and creating potential for fire hazards under abnormal conditions.
- Chemical hazards: These batteries contain zinc bromide electrolyte, which is corrosive (acid) and toxic with a hazardous classification level of 3 per NFPA 704. Under abnormal conditions, care should be taken where there might be spills of the electrolyte.
- Electrical hazards: Electrical hazards might be present under abnormal conditions if the system is at hazardous voltage and energy levels.
- Stored energy hazards: Not applicable.
- Physical hazards: Depending on the design of the system, the potential exists for physical hazards under abnormal conditions if accessible parts are overheating, if there is insufficient pressure relief when the system is overheating and gas is generated, or if there is exposure to moving hazard parts such as fans or exposed pump parts where guards can be missing.

B.5.6 Lithium metal solid state batteries (C-Z)

Lithium metal batteries employing liquid electrolytes have been developed for commercial use but have had safety and performance problems in the field. These batteries have not been developed at this time for stationary battery energy storage. Commercially available lithium metal batteries utilized for BESS do not employ liquid electrolytes. The current lithium metal technologies use solid polymer electrolytes, a lithium metal negative electrode and a metal oxide cathode such as vanadium oxide combined with lithium salt and polymer to form a plastic composite. The SPE-type lithium metal batteries have to be heated to about 60 °C to 80 °C in order to be activated.

Hazards in lithium metal batteries under normal operating conditions are as follows:

1) (Fire hazards: There can be the potential for fire hazards if there are defects within the cells or design issues with the controls that prevent thermal runaway of the cells. Systems should be evaluated for their ability to prevent propagation due to these defects.
2) Chemical hazards: Not applicable.
3) Electrical hazards: There are electrical hazards associated with routine maintenance of these batteries if they are at hazardous voltage and energy levels.
4) Stored energy hazards: A stored energy hazard can exist during maintenance if the batteries cannot be isolated for maintenance or during replacement of batteries.
5) Physical hazards: No known significant direct hazards.

Hazards in lithium metal batteries under emergency/abnormal conditions are as follows:

- Fire hazards: There can be the potential for thermal runaway if the batteries are not maintained at appropriate operating parameters as a result of abnormal conditions and if not evaluated for their ability to prevent propagation due to latent defects. Also, there might be fire hazards due to short-circuiting abnormal conditions.
- Chemical hazards: The potential exists for exposure of water-reactive lithium metal.
- Electrical hazards: Electrical hazards might be present under abnormal conditions if the system is at hazardous voltage and energy levels.
- Stored energy hazards: There can be the potential for stored energy hazards if the batteries are exposed to abnormal conditions where they might still contain hazardous levels of energy. Damaged batteries might contain stored energy that can be a hazard during disposal if care is not taken.
- Physical hazards: Depending on the design of the system, the potential exists for physical hazards under abnormal conditions if accessible parts are overheating or if there is exposure to moving hazardous parts such as fans where guards might be missing.

B.6 Other technologies

To be described in the next edition, if any.

Annex C
(informative)

Large scale fire testing on BESS

A large-scale fire BESS test is intended to evaluate the fire characteristics of a BESS system that undergoes thermal runaway. The data generated can be used to determine the fire and explosion protection required for installation of a BESS. An example of this type of test method can be found in UL 9540A.

The test method is initiated through the establishment of a thermal runaway condition that leads to combustion within the BESS. The test method outlined in UL 9540A consists of several steps: cell level testing, module level testing, unit level testing and installation level testing. The cell and module level testing steps are information gathering steps to inform the unit and installation level testing. The following outlines the information that is gathered as part of this testing:

- Cell level – An individual cell fails in a manner that leads to thermal runaway and fire through a suitable method such as external heating. Data such as off-gassing contents, temperatures at venting and temperatures at thermal runaway are recorded.
- Module level – One or more cells within a BESS module fail in the manner determined during the cell level testing. Data such as fire propagation in the module, temperatures on the failed cells and surrounding cells, off-gassing contents and heat release data are gathered.
- Unit level – A complete BESS is installed surrounded by target (e.g. dummy) BESS and walls separated at a distance as intended in its installation. The module level test is repeated on a module located in the BESS in the most unfavorable location. Data such as temperature within the BESS, on surrounding walls and target BESS; incident heat flux on walls and target BESS; observation of fire propagation from BESS to target units and walls as well as observance of explosions or evidence of re-ignition within the BESS; and heat release and off-gassing contents are gathered.
- Installation level – This test is a repeat of the unit level test with the test conducted within a test room and with the intended fire suppression system installed as well as any overhead cables (that can lead to fire propagation) installed. This test is intended to validate the fire suppression system for the BESS installation. Data such as temperatures within the BESS, on surrounding walls and target BESSs; incident heat flux on walls and target BESS; fire propagation from the BESS to target units, walls or overhead cables and any observable explosion incidents or re-ignition within the BESS; and off-gassing contents (if necessary) and heat release are gathered.

The data and other information gathered as a result of the testing steps noted above can be used to determine the suitability of the protection measures utilized in the BESS installation. These include the following:

1) Control of the size, separation distances and maximum quantity of BESS for an installation based upon data gathered during testing.
2) Suitability of installation construction based upon temperatures measured and observable fire propagation.
3) Suitability of the fire suppression means for a BESS installation based upon temperatures and observable fire propagation.
4) Design of ventilation, exhaust and deflagration protection necessary within an installation per local codes and regulations based upon off-gassing information.
5) Location and type of gas detection within a BESS installation based upon off-gassing information.
6) The fire protecting door of BESS should be selected to allow firefighters to react.

Annex D
(informative)

Test methods for protection from hazards arising from environments

D.1 General

Annex D includes the test methods for confirming compliance with 8.2.9.1, 8.2.9.2 and 8.2.9.3. They are based on the test methods that can be found in ANSI/CAN/UL-9540.

D.2 Outdoor installations subject to moisture exposure

The BESS intended for installation outdoors, where they will be subject to rated levels of moisture exposure should be tested in accordance with their environmental ratings outlined in their nameplate labels and installation instructions.

Based upon the ratings of the system, moisture resistance testing should be done in accordance with either IEC 60529 or another appropriate standard, if any.

At the conclusion of the test, the sample is to be subjected to the electric insulation resistance tests in 8.2.1.5 (or in another appropriate standard, if any) and examined for signs of water in the system that could result in a hazardous condition.

As a result of the water exposure, there should be no evidence of water on parts that could result in a hazard and no reduction of spacing or breakdown/deterioration in insulation levels.

D.3 Outdoor installation near marine environments

The BESS intended for installation outdoors near marine environments in accordance with the installation instructions, where they will be subject to salt mist exposure, should be tested as outlined below.

The BESS should be tested in accordance with IEC 60068-2-52 for severities 1 or 2.

At the conclusion of the testing, the systems should be subjected to the electric insulation resistance tests in 8.2.1.5 (or in another appropriate standard, if any) to determine that insulation has not been damaged in a manner that would result in an electric shock hazard.

The BESS should be examined for signs of damage because of salt exposure that would indicate a potential for a safety hazard (e.g. corrosion of parts that could result in weakening of a security or an enclosure, damage to insulation). If operational, the BESS is to be operated to determine that it can do so without hazard.

As a result of the test, the BESS should not show evidence of damage from salt mist exposure that could result in a hazard such as electrical, shock, overheating or damage that could result in a physical hazard.

Annex E
(informative)

Information required for BESS life cycle safety management

E.1 Overview

Annex E provides minimum requirements for safety related information that is required by BESS operation and maintenance stakeholders throughout its lifetime. To keep the BESS in a safe condition, stakeholders with responsibility for operation and maintenance, and manufacturers and integrators should develop together the information set out in Annex E.

E.2 General introduction

During the lifetime of BESS, the chemical state of electrochemical accumulation subsystems constantly changes because of charge, discharge, and deterioration due to ageing. The operation and maintenance workers of BESS can also be rotated from time to time.

Therefore, it is important to reduce the occurrence of incidents by using a proactive approach to safety. A combination of continuous data monitoring of the BESS state over a communication network (e.g. Internet of things) and constant observation by workers (e.g. surveillance image viewing, on-site patrol) is highly expected. It is also necessary to keep any manuals, frameworks and facilities for safety of untrained staff and neighbouring inhabitant.

E.3 Operation and maintenance process

The operation and maintenance process should be managed within guidelines, manuals, risk assessment and application of national and local rules according to 7.13.1.2 and Clause 9. This process should be assured by a third party to confirm that the BESS has been maintained and operated in a safe condition.

E.4 Preventive maintenance

Preventive maintenance should be conducted according to 7.13.1.3. Additional recommended practices for preventive maintenance are described below.

The identification data (ID) of operation and of maintenance staff will be registered together with their qualifications and training records. All the IDs of operation and maintenance staff in charge will be recorded every time that they interact with the BESS.

All the replacements of consumables and all engineering tasks that are performed will be recorded in maintenance information.

During on-site maintenance the following operations will be undertaken:

- confirmation of the correct operation of subsystems and fixtures of subsystems;
- confirmation of the physical and data communications between subsystems;
- a check of the cleanliness of filters within air conditioning subsystems;
- an operational check of measurement devices, circuit breakers, and air conditioning subsystems;
- a visual and operational check and checking whether a cleaning around electrochemical accumulation subsystems is necessary (e.g. removing incrustations such as electrolyte liquid spilt, dirt around terminals, migration and corrosion products);

– a soundness check of the cable according to any appropriate international standards;
– a soundness check of the HVAC subsystem according to any appropriate international standards;
– a soundness check of monitoring systems in general;
– a soundness check of the fire detection, suppression and alarm subsystem according to any appropriate international standards.

E.5 Measuring and monitoring of system soundness

The measuring and monitoring of system soundness should be done according to 7.13.1.4.

E.6 Staff training

Staff training should be done for appropriate staff periodically according to the safety training guidelines created according to 7.13.1.5. In addition to safety training for normal operation of the BESS, there should be training to prepare for potential emergencies. For example, in the case of a subsystem failure where the automatic fire suppression system does not work, training can include the operation and use of manual fire suppression system process. Emergency training should be led by the facility manager or operation manager.

E.7 Partial system change

Partial subsystem or device change should be noted according to 7.13.2. The confirmation tests after a partial system change should pay attention to safety. Consideration should be given to the interference and mutual effect risk between subsystems, the propagation risk of heat and EMC. Because these can be difficult to check before the confirmation test, the facility manager or operations manager should pay attention to safety conditions not only through a confirmation test but also by inspections after a confirmation test for several hours or several weeks.

E.8 Design revision

Safety design revisions should be done according to 7.13.3. During this process, attention should be paid to the scope of the BESS application and to whether changes are made to the whole systems or with a given subsystem. Whole subsystems replacements require a safety design revision. Where replacements of the internal devices of subsystems have to be done the safety design revision is still required in spite of its difficulty because of the potential to cause BESS incidents.

The facility manager or operation manager should prioritise their attention first to the total BESS safety. They should request the system integrator or manufacturer to do the risk BESS safety analyses (e.g. FMEA etc.). An analysis should be requested when the protection, control and monitoring system and safety equipment are replaced.

Annex F
(informative)

BESS safety signage

Safety signs should be provided in accordance with the result of the risk assessment process (see Clause 6). Local regulations can apply. The following, among others, should be included:

- emergency exit;
- manufacturer name;
- phone number for emergency;
- prohibition of access to unauthorized persons;
- mandatory use of PPE;
- AC voltage [VAC] warning;
- DC voltage [VDC] warning;
- first aid measures;
- arc flash and shock hazard – appropriate PPE required;
- battery types;
- gas hazard.

Annex G
(informative)

Example of testing for verification of thermal control operation

BESS that fit within a temperature testing chamber should undergo this type test.

As part of type testing, the BESS should be checked to ascertain if charging and discharging are stopped when the temperature of electrochemical accumulation subsystems exceeds the temperature limit which is indicated by the manufacturer.

The BESS is to be placed in a chamber that is heated to the maximum ambient temperature for charging specified for the BESS plus an additional 10 °C. The BESS should remain in the chamber for sufficient time for temperatures to stabilize before attempting to charge.

An attempt to charge the BESS, while it is in the heated condition, should be conducted to confirm that charging is not possible when the BESS is heated above the specified ambient temperature for charging.

A similar method is used for discharging, by first heating the BESS to the maximum discharge condition temperature plus 10 °C, until it is stabilized at that temperature. An attempt is then made to discharge the BESS to confirm that it cannot be discharged above the maximum specified discharge temperature.

Annex H
(informative)

Examples of test procedures and methods that can be applicable to BESS

H.1 Overview

Annex H provides examples of test procedures and methods that can be applicable to BESS.

NOTE If the subsystems (e.g. PCS) are in compliance with product safety standards (i.e. IEC 62477-1) it is not useful repeat the same tests that are performed at PCS type test level.

H.2 Examples of testing procedures

H.2.1 Electrical hazards test procedure and test method in 8.2.1

H.2.1.1 High current discharge (short-circuit) protection

a) In Figure H.1 to Figure H.4, connect the short-circuit testing equipment for the short-circuit test.

NOTE The resistance value of the short-circuit testing equipment is configured so that the short-circuit current that occurs during testing will be 10 or more times the rated current.

b) Operate the power conversion subsystem in charge mode and charge the electrochemical accumulation subsystem to rated capacity.

c) While charging, perform the short-circuit test by using the short-circuit test equipment installed in a).

d) Restore the SUT to the state prior to the test and repeat a) to c) in discharge mode.

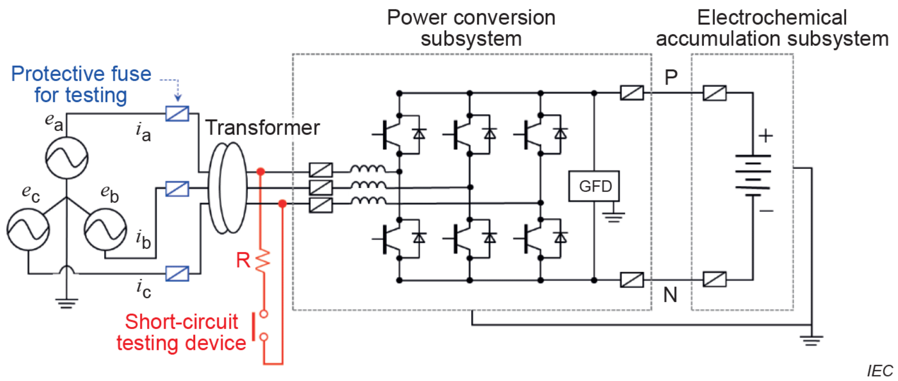


Figure H.1 – Composition of circuits for short-circuit test – AC short circuit

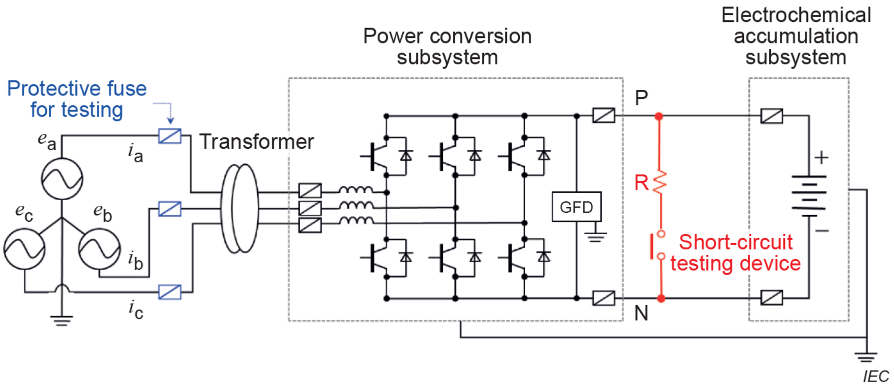


Figure H.2 – Composition of circuits for short-circuit test – DC short circuit

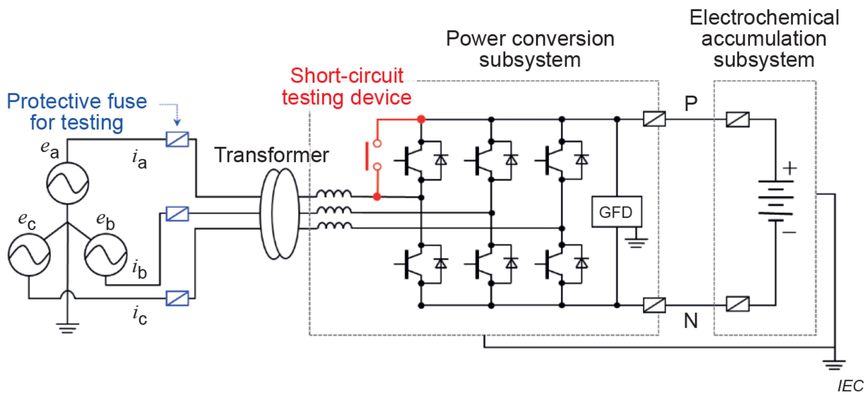


Figure H.3 – Composition of circuits for short-circuit test – Switching element short-circuit

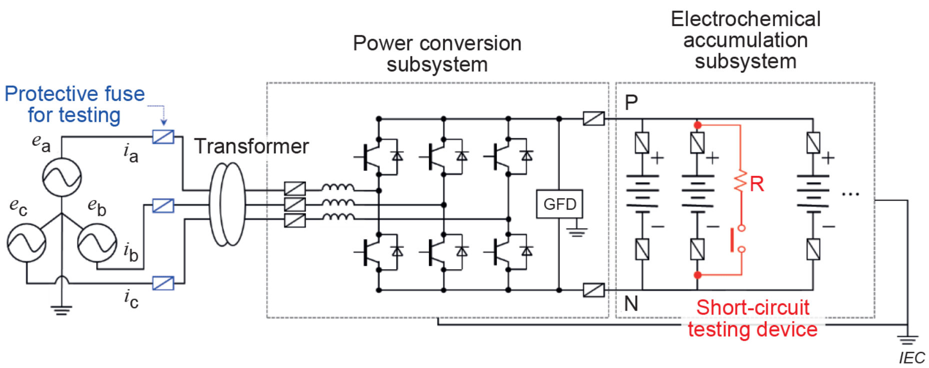


Figure H.4 – Composition of circuits for short-circuit test – Short-circuit in rack exterior

The acceptance criteria are as follows:

– During the short-circuit test, the protection system should operate appropriately, not leading to any explosion or fire or an explosion/fire occur in the DC contactor, affecting the other adjacent components.

– If fuses are installed in the AC circuits of the power conversion subsystem, the protection systems should be open (primary side protection).

– For systems without protection systems installed in the AC circuits of the power conversion system, this condition (primary protection) does not have to be met.

– In accordance with Table H.1, confirm that the secondary protective measures are operated properly.

Table H.1 – Criteria for judgment of short-circuit test (secondary)

Location of short-circuit	Criteria for judgment of secondary protection
AC short-circuit	The power conversion system's switching element gate block function and the AC low voltage stop function should operate and the charge (or discharge) of the BESS system should be stopped safely.
DC short-circuit	The power conversion system's switching element gate block function and the DC overcurrent or low voltage stop function should operate and the charge (or discharge) of the BESS system should be stopped safely.
Switching element short-circuit	The power conversion system should be stopped safely and separated from both the AC and DC ends.
Short-circuit in rack exterior	The rack protection systems of the lithium-ion secondary battery system should be open.

H.2.1.2 Overcharge, high current charge and earth fault protection

H.2.1.2.1 Overcharge

The test method for the physical protection system should consider the following:

The specimen should be configured as 90 % of the charging upper limit for EMS.

To protect BESS from overcharging:

a) Deactivate the value set on EMS and charge the BESS at the rated power suggested by the manufacturer.

The acceptance criteria are as follows:

– At the time when BESS reaches a SOC of 100 % charging and enters into over-charging, the BMS should recognize over-charging and operate a protective element (e.g. circuit breaker) to stop charging.

– At the time when the SOC exceeds the charging upper limit set on BMS, the BMS should recognize over-charging and operate a protective element (e.g. circuit breaker) to stop charging.

For the software protection system, the test method follows:

1) Set the BMS charging upper limit for EMS at 90 %.

2) Charge the BESS at the rated power suggested by manufacturer.

The acceptance criteria are as follows:

– At the time when it exceeds the charging upper limit set on the BMS, over-charging is recognized by the EMS and the signal for finishing charging is sent to the power conversion subsystem to stop the charging in the software.

– Operation availability of both physical protection system and software protection system should be confirmed.

H.2.1.2.2 High current charge

For category BESS, the test method is as follows:

a) Check BMS and power management system’s (PMS) specification of the battery that prevents over-charging current and set it 10 % lower.

b) Start the power conversion subsystem charging with the value that triggers over-charging protection system.

c) The protection system is operated to confirm that the power conversion subsystem is turned off safely.

d) Disable the protection system and charging on the power conversion subsystem so that the over-charging protection system is operated.

e) The protection system is operated to check if the power conversion subsystem is turned off safely.

The acceptance criteria are as follows:

– The BMS and PMS protection system should operate to turn the power conversion subsystem off safely.

H.2.1.2.3 Earth faults

For category "E-LI or E-LS" BESS, the test method is as follows:

a) Following Figure H.5 and Figure H.6, connect the earth fault testing devices to each identified location.

NOTE The specifications and setting conditions for the GFD (or IMD) installed in the power conversion system are checked and a fitting resistance (e.g. 90 kΩ) in the earth fault testing device is installed.

b) Operate the power conversion subsystem in charge mode and charge the electrochemical accumulation subsystem to its rated capacity.

c) While charging, use the earth fault testing device installed in a) to cause an earth fault.

d) Restore the system to its pe-test state and repeat a) to c) in discharge mode.

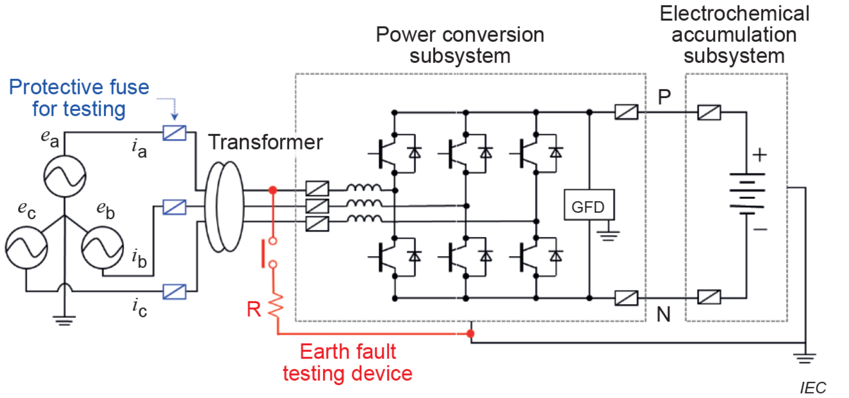


Figure H.5 – Composition of circuits for earth fault test – AC earth fault

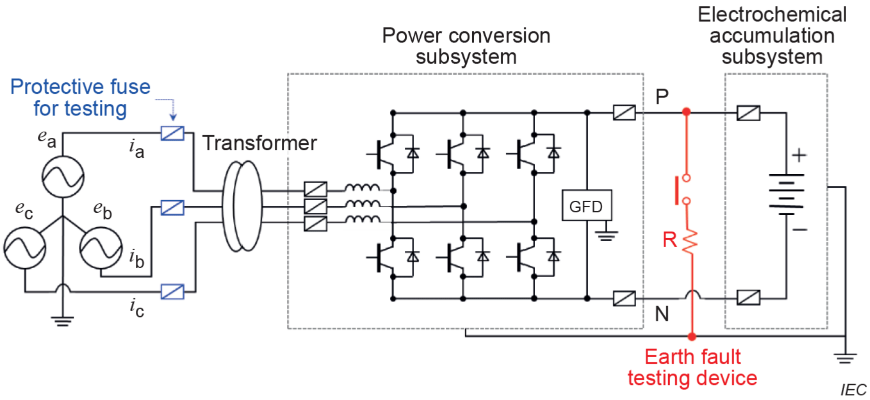


Figure H.6 – Composition of circuits for earth fault test – DC earth fault

The acceptance criteria are as follows:

– During testing the protective device should operate normally so that the lithium-ion based BESS system's safety is not affected.
– The power conversion system should stop operating safely after the operational latency time (the time it takes for the GFD/IMD to open after an earth fault is detected) set for the GFD/IMD by the manufacturer, without any damage to internal parts.
– During the test, the switching elements of the power conversion system should not have been damaged (short-circuited) and earth fault currents should not flow in the lithium ion secondary battery system.

H.2.1.3 Impulse withstand voltage protection

For category E-S BESS, the test method is as follows:

a) Apply the over-voltage classification system on the BESS following Table H.2 to carry out an impulse test.

Table H.2 – Rated impulse withstand voltage for equipment energized directly from mains supply

Nominal voltage of the mains supply based on IEC 60038[a]		Voltage line-to-neutral derived from nominal voltage AC or DC up to and including	Rated impulse withstand voltage			
			Overvoltage category			
Three-phase V	Single phase V	V	I V	II V	III V	IV V
		50	330	500	800	1 500
		100	500	800	1 500	2 500
	120 to 240	150[b]	800	1 500	2 500	4 000
230/400 277/480		300	1 500	2 500	4 000	6 000
400/600		600	2 500	4 000	6 000	8 000
1 000		1 000	4 000	6 000	8 000	12 000
	> 1 000 ≤ 1 250[c]	1 250	4 000	6 000	8 000	12 000
	> 1 250 ≤ 1 500[c]	1 500	6 000	8 000	10 000	15 000

[a] The / mark indicates a four-wire three-phase distribution system. The lower value is the voltage line-to-neutral, while the higher value is the voltage line-to-line. Where only one value is indicated, it refers to three-wire, three-phase systems and specifies the value line-to-line.

[b] Nominal voltages for single-phase systems in Japan are 100 V or 100 V to 200 V. However, the value of the rated impulse withstand voltage for the voltages is determined from columns applicable to the voltage line-to-neutral of 150 V.

[c] For DC values only.

Table H.2's over-voltage classification III (category V-L BESS system) or IV (category V-H BESS sub-system related to system safety) based on IEC 60664-1 is applied for determining rated impulse voltage criteria.

For category E-LI or E-LS BESS, the test method is as follows:

a) The over-voltage classification system on BESS following the table in IEC 60664-1 should be applied to carry out the impulse test.

b) As indicated in Figure H.7 below, this test is carried out at 3 points (A, B, C) and the test voltage fitting to the rated voltage of the corresponding point has been used.

The power conversion subsystem of the BESS is connected to the POC and over-voltage is applied at point B to the AC input terminal of the power conversion subsystem. In relation to point B, the insulation between the high voltage part of the battery rack and SELV of the BMS, which is the connection point that monitors the voltage of the battery rack, should also be considered.

Point A: The power conversion subsystem and battery are connected. If backup power exists, over-voltage is applied to the DC terminal of the backup power.

Point C is the part where the auxiliary connection terminal and auxiliary POC are connected. While the BMS of BESS and control power input terminal of PMS are commonly connected, over-voltage is applied to auxiliary connection input terminal.

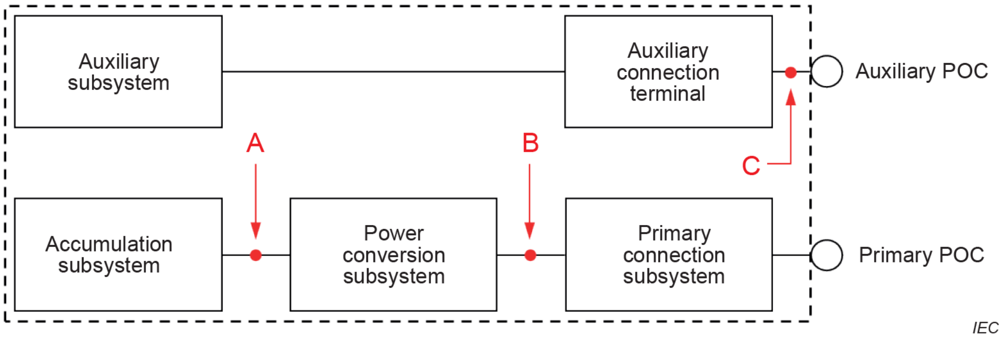


Figure H.7 – Impulse withstand voltage test points

The acceptance criteria are as follows:

– As a result of the impulse voltage applications, no puncture or partial breakdown of solid insulation should occur during the test, but partial discharges are allowed. Partial breakdown will be indicated by a step in the resulting wave shape which will occur earlier in successive impulses. Breakdown on the first impulse can either indicate a complete failure of the insulation system or the operation of overvoltage limiting devices in the equipment.
– An impulse test can be waived if the BESS employs surge protection that has already been evaluated for anticipated surges.

H.2.1.4 Dielectric test

For category E-S BESS, the following test method applies:

a) BESS dielectric over-voltage testing should be in accordance with the IEC 60664-1 classification system.

NOTE See Table H.2 for rated impulse withstand voltage for equipment energized directly from mains supply.

Table H.2 over-voltage classification III (category V-L BESS system) or IV (category V-H BESS sub-system related to system safety) based on IEC 60664-1 is applied for determining the rated dielectric voltage criteria.

For category E-LI or E-LS BESS, the test method is as follows:

a) The BESS over-voltage dielectric test should follow the classification system table in IEC 60664-1.

As indicated in Figure H.8, this test is carried out at 3 points (A, B, C).

Point B is the part where the power conversion subsystem of the BESS is connected to the POC and over-voltage is applied to the AC input terminal of the power conversion subsystem. In relation to point B, the insulation between the high voltage part of the battery rack and the SELV of the BMS, which is the connection point that monitors the voltage of the battery rack, should also be considered.

Point A is the part where the power conversion subsystem and battery are connected. If backup power exists, over-voltage is applied to the DC terminal of the backup power.

Point C is the part where the auxiliary connection terminal and auxiliary POC are connected. While the BMS of the BESS and the control power input terminal of PMS are commonly connected, over-voltage is applied to auxiliary connection input terminal.

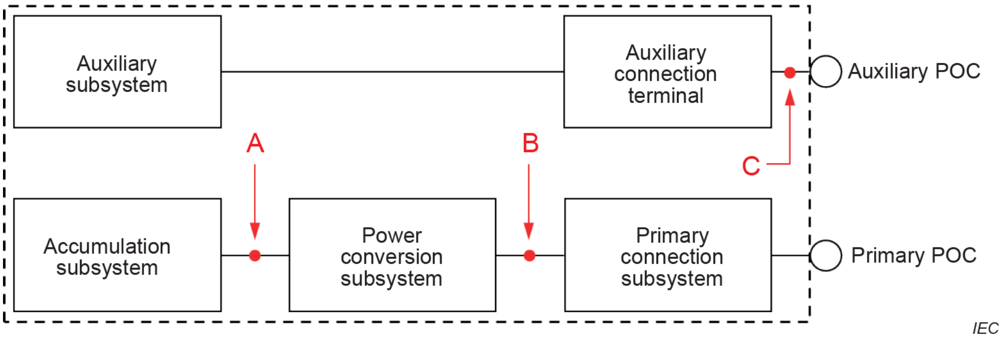


Figure H.8 – Dielectric test points

The acceptance criteria are as follows:

– Penetration or partial damage should not occur on solid insulation because of the application of the test voltage for the required duration.

H.2.1.5 Insulation resistance

Insulation resistance should be checked on the part where the BESS component's electrical insulation can be compromised. Insulation resistance should be measured in the same place where the impulse test is carried out.

As indicated in Figure H.9, this test is carried out at 3 points (A, B, C) and the test voltage fitting to the rated voltage of the corresponding point has been used.

Point B is the part where the power conversion subsystem of the BESS is connected to the POC and over-voltage is applied to the AC input terminal of the power conversion subsystem. In relation to point B, the insulation between the high voltage part of the battery rack and the SELV of the BMS, which is the connection point that monitors the voltage of the battery rack, should also be considered.

Point A is the part where the power conversion subsystem and battery are connected. If a BCP is present, the over-voltage is applied to DC terminal of BCP.

Point C is the part where the auxiliary connection terminal and auxiliary POC are connected. While the BMS of the BESS and control power input terminal of PMS are commonly connected, over-voltage is applied to auxiliary connection input terminal.

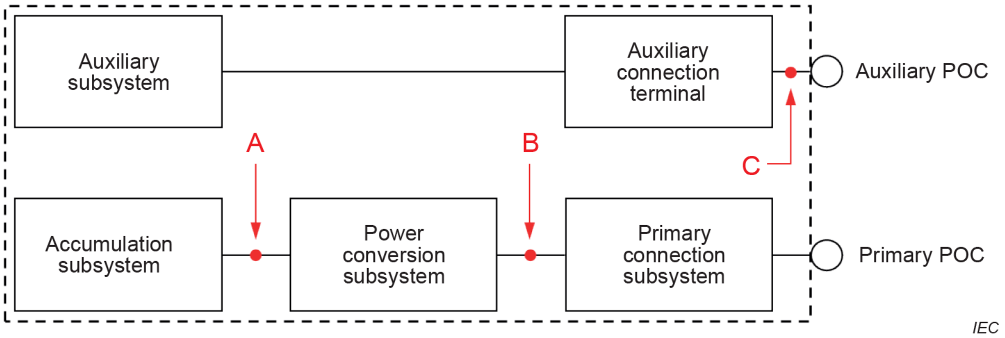


Figure H.9 – Insulation resistance test points

Before the device is connected, measurement can be carried out during installation. Parts that can be damaged due to SPD and test should be detached before conducting the test.

Table H.3 – Example of minimum values of insulation resistance

Nominal circuit voltage V	**Test voltage DC** V	**Minimum insulation resistance** MΩ
SELV	250	0,5
Up to and including 500 V	500	1
Above 500 V	Equal to or quarter of the rated voltage	1

Other than the type test, insulation resistance measurement requires a SAT test in the workplace where BESS is installed. Insulation resistance is measured while power conversion subsystem, battery, and other control power are connected.

The acceptance are as criteria follows:

– Penetration or partial damage should not occur on solid insulator as a result of applying voltage during the test.

H.2.1.6 Earthing system check

Refer to 8.2.1.8.

H.2.1.7 Anti-islanding

Unintentional islanding has the potential of having considerable impact on the safety of human bodies and facilities. The public as well as technical staff might be at risk of electric shock during incident investigation or during equipment removal operations.

There is a requirement that unless designed for intentional islanding, measures are to be taken to prevent the islanding operation by detecting it directly or indirectly using the protection relay or other methods and swiftly disconnecting the BESS system from the distributing network.

For category "E-LI or E-LS" BESS, the test method is as follows:

a) Test in accordance with IEC 62116:2014, 6.1.

The acceptance criteria are as follows:

– Follow IEC 62116:2014, 6.2.

H.2.2 Mechanical hazards test procedures and test methods in 8.2.2

H.2.2.1 Enclosure strength against impact

For category "E-S" BESS, the test method is as follows:

a) Test 1: A sample consisting of the complete enclosure, or a portion thereof representing the largest unreinforced area, is supported in its normal position. A solid smooth steel ball, approximately 50 mm in diameter and with a mass of 500 g ± 25 g, is permitted to fall freely from rest through a vertical distance (H) of 1,3 m (see Figure H.10) onto the sample. Vertical surfaces are exempt from this test.

b) Test 2. The steel ball is suspended by a cord and swung as a pendulum in order to apply a horizontal impact, dropping through a vertical distance (H) of 1,3 m (see Figure H.10) onto the sample. Horizontal surfaces are exempt from this test. Alternatively, the sample is rotated 90° about each of its horizontal axes and the ball dropped as in the vertical impact test.

Tests are not applied to flat panel displays or to the platen glass of equipment.

Dimensions in metres

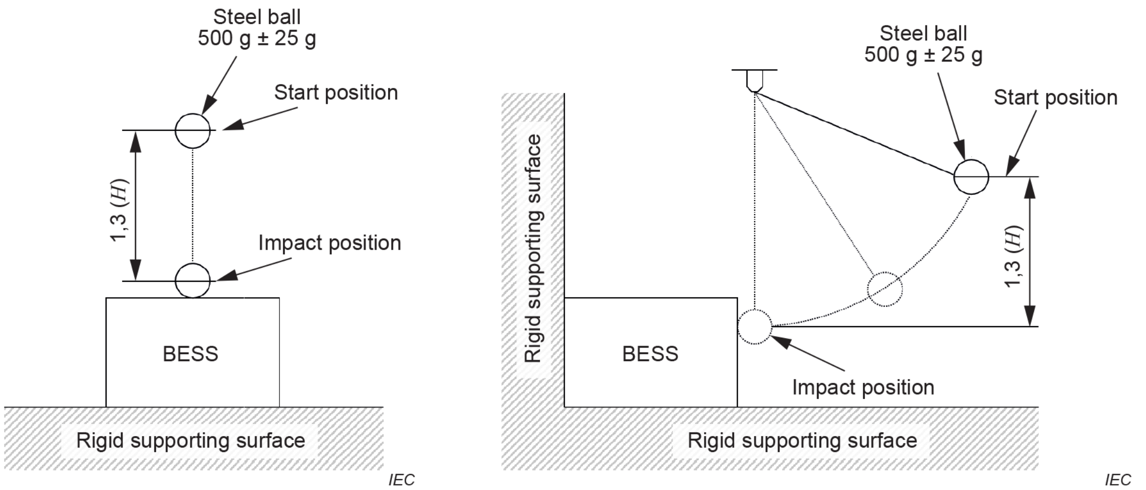


Figure H.10 – Impact test using a steel ball

For category "E-LI or E-LS" BESS, the test method is as follows:

a) The power conversion sub-system should be tested using the same method as E-S BESS.

Electrochemical accumulation system should be tested at different impact points depending on the type of battery rack enclosure.

a) For the open frame racks, the steel ball used on the impact test is identical with the conditions specified above. The position where the steel ball should strike is indicated as below.

   It should be carried out while the communication line and electrical wire in every module are connected:

   1) front and rear side of the module and centre in both sides (excluding upper and bottom side);
   2) communication terminal in the module;
   3) wire connection in the module (+/- terminal);
   4) centre part of the fan;

5) other weak structure on the module;
6) vertical/horizontal centre in the rack frame.

b) For a cabinet rack with a door, the test should be carried out using the same method as used for the E-S BESS.
c) For a cabinet rack without door, the upper part and side part of the rack should be tested with the same method as E-S BESS and the front side of the rack (open part) should be tested with the same method as used in the open frame rack test.

The acceptance criteria are as follows:

– After carrying out the impact test, the BESS or sub-system of the BESS should not be damaged. Any damaged part on the BESS (or power conversion sub-system, rack frame, module frame) enclosure should not provide access to any type of risk element due to impact.
– If should be confirmed that the BESS operates normally after carrying out the impact test.

H.2.2.2 Enclosure strength against static force

During the tests, earthed or unearthed conductive enclosures should not reduce clearance and creepage distances required for basic insulation or withstand the impulse voltage test.

For category "E-S" BESS, the test method is as follows:

a) External enclosures are subjected to a steady force of 250 N ± 10 N for a period of 5 s, applied in turn to the top, bottom and sides of the enclosure fitted to the equipment, by means of a suitable test tool providing contact over a circular plane surface 30 mm in diameter. This test is not applied to the bottom of an enclosure of equipment having a mass of more than 18 kg or to surfaces that are mounted to a wall.

For surfaces that are neither horizontal nor vertical, the test should be performed by tilting the equipment in a suitable way so that the surface is either horizontal or vertical.

Dimensions in millimetres

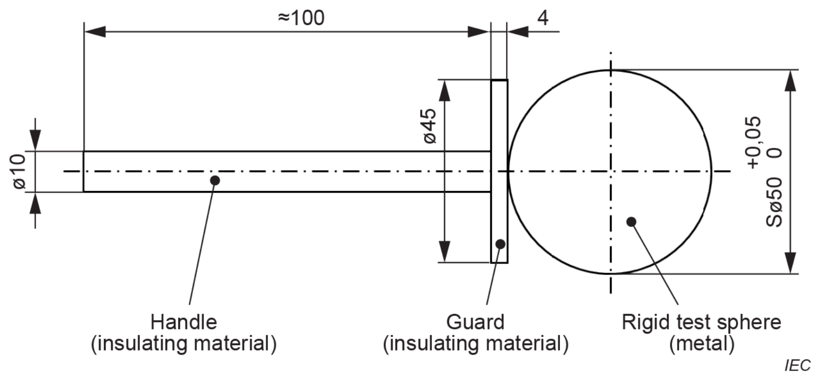


Figure H.11 – Test probe A

The probe illustrated in Figure H.11 is intended to verify the protection of persons against access to hazardous parts. It is also used to verify the protection against access with the back of the hand.

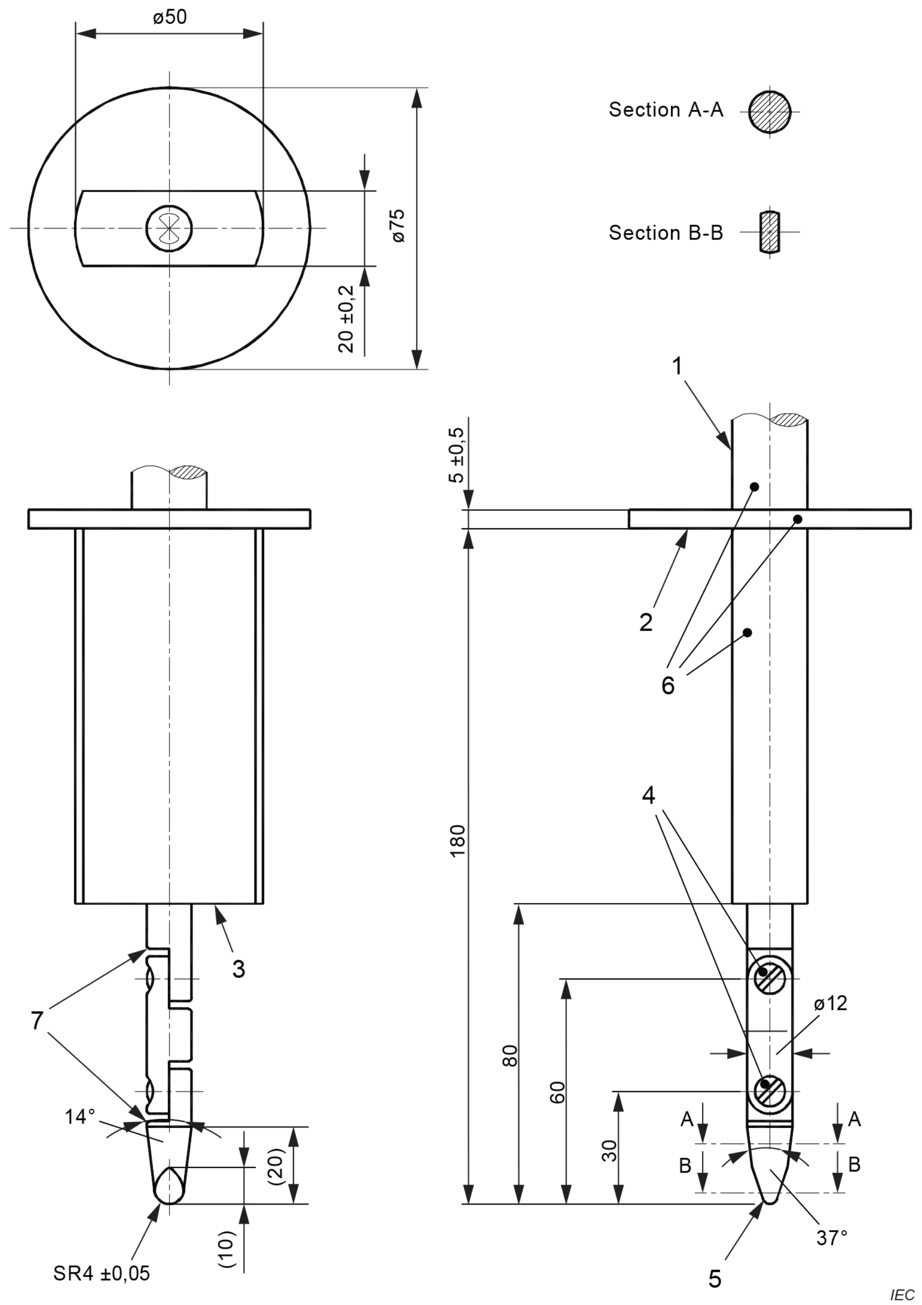
For category "E-LI or E-LS" BESS, the test method is as follows:

a) The power conversion sub-system should be tested using the same method as was applied to the E-S BESS.

Electrochemical accumulation system should be tested with the same method as was applied to the E-S BESS regardless of the type of rack enclosure.

In case of an open frame rack or cabinet rack without door, a test finger (IEC 61032:1997, Figure 2, probe B) should be used on the exposed part in the module to apply 30 N ± 3 N force for 5 s (see Figure H.12).

Dimensions in millimetres



Material: metal, except where otherwise specified.

Tolerance on dimensions when no specific tolerance is given:

– on angles: $^{0}_{-10}$ '

– on linear dimensions: up to 25 mm $^{0}_{-0,05}$ mm; over 25 mm: ±0,2 mm.

Both joints should permit movement in the same plane and the same direction through an angle of 90° with a 0° to +10° tolerance.

Figure H.12 – Test probe B

The acceptance criteria are as follows:

- After carrying out the impact test, the BESS or sub-system of the BESS should not be damaged. Any damaged part on the BESS (or power conversion sub-system, rack frame, module frame) enclosure should not provide access to any type of risk element due to impact.
- BESS should be operated normally after carrying out the impact test.

H.2.2.3 Impact and vibration during transportation and seismic events (e.g. earthquakes)

For category "E-S" BESS, the test method is as follows:

a) Vibration, impact, and seismic test should be tested in class 1 in accordance with the IEC 60255-21 series and IEC 60068-2-6.

Seismic test should be tested in method A (the single axis sine sweep seismic test).

For category "E-LI or E-LS" BESS, the test method is as follows:

- In case of E-LI or E-LS BESS, the test should be carried out for each subsystem.
- The electrochemical accumulation subsystem should be composed of one rack.
- For the safety of the test, one normal module should be installed on the upper-most rack. A dummy of the same size and weight should be installed on the remaining areas.
- Vibration, impact, and seismic test should be tested in class 1 in accordance with the IEC 60255-21 series and IEC 60068-2-6.
- The seismic test should be tested in method B (the biaxial multi-frequency random seismic test).
- If the seismic test device is not large enough to install every subsystem of BESS, the test should be conducted on each subsystem. However, wiring should be applied in every subsystem.
- BESS should be in standby status during the test.

The acceptance criteria are as follows:

- After the test is finished, the BESS should maintain its function.
- In case of E-LI or E-LS BESS, connection should be maintained between subsystems.

H.2.3 Explosion hazards test procedure and test method in 8.2.3

H.2.3.1 Specification of flammable gas

The information on all gas components that can occur during the entire period from venting to fire for one battery cell should be extracted. The information to be extracted at this time is as follows:

- type,
- amount,
- time of occurrence.

The test is carried out in an 82 L (21,7 gal) pressure vessel and is carried out under an oxygen condition of less than 1 % atmospheric pressure.

At the top of the pressure vessel, a Fourier transformable infrared spectrometer or gas analyser that can analyse gas components should be installed. Figure H.14 is the image of an abuse chamber.

The gas data should be extracted every 5 s from the gas release, and the test report should include the table and graph (see Figure H.13) that specify the gas composition information.

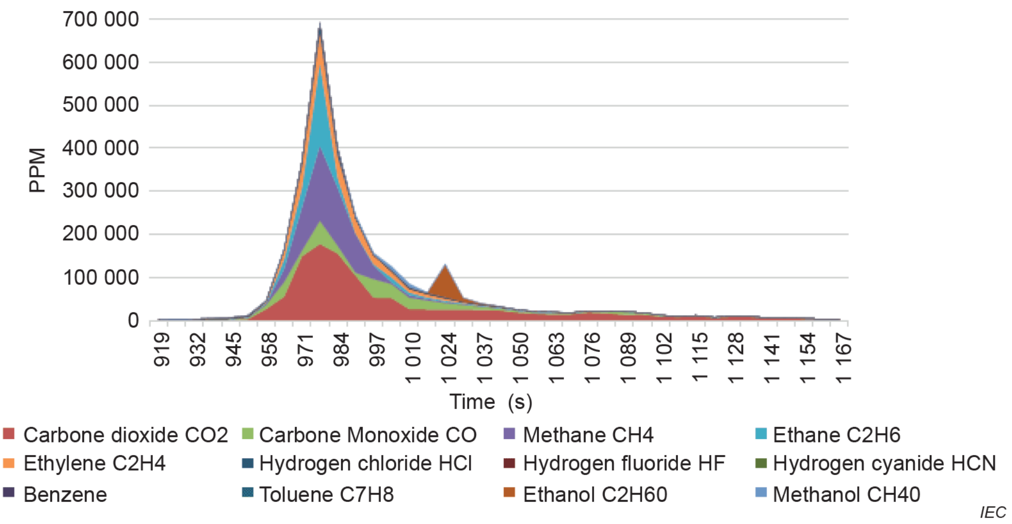


Figure H.13 – Gas release profile of an overheated NMC pouch cell of 100 % SOC

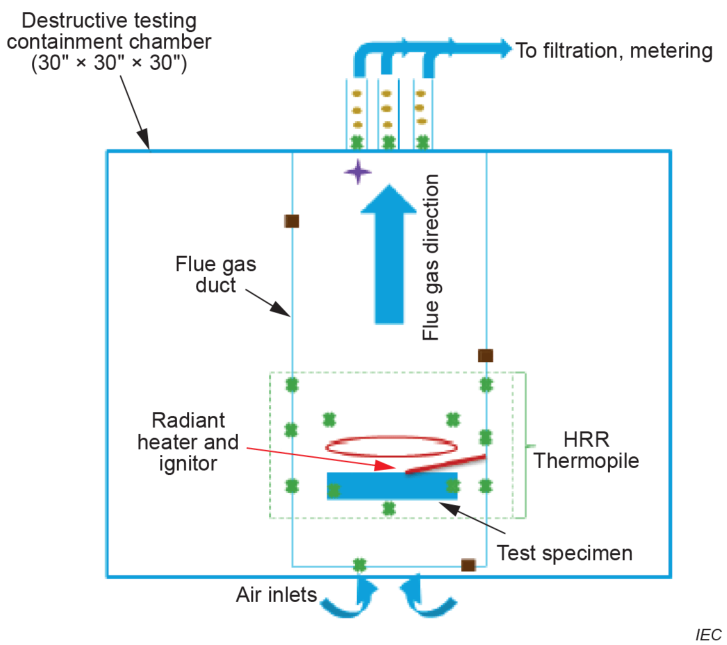


Figure H.14 – Diagram of the abuse chamber used for signal cell testing

NOTE 1 The temperature of the test environment is 25 °C ± 5 °C and the humidity is maintained at 50% RH ± 25 % RH.

NOTE 2 Battery cells are tested in the fully charged state suggested by the manufacturer.

One of the following methods can be selected as a method of causing a fire in a battery cell:

a) mechanical (e.g. nail penetration);

b) electrical stresses in the form of overcharging, over discharging or external short-circuiting;

c) use of alternative heating source (e.g. oven).

NOTE 3 When testing using a heating source, the cell surface temperature will be set to rise between 4 °C to 7 °C/min .

NOTE 4 In case of testing with a thermal pad, the limit of the maximum temperature that can be raised by the thermal pad is decided by the tester in consultation with the manufacturer.

NOTE 5 If a fire does not occur with the initially selected test method, another test method will be used.

NOTE 6 If the manufacturer provides a test report according to UL 9540A, the test can be replaced by reviewing the corresponding test report.

H.2.3.2 Gas detection / off-gas detection

The installation location and number of gas (or off-gas) sensors are to be selected by the applicant. Figure H.15 is an example on the gas sample emission position. The location and number of sensors installed for the test should be described on the BESS diagram and specified in the test report.

NOTE The optimal design for the location and number of sensors can be decided according to Annex B.

The test report should be provided with the specification information (detectable gas type, amount) of the sensor installed in the BESS.

Gas detection:

For all-category BESS, the test method is as follows:

a) It should be checked whether the gas detection system as specified in the IEC 60079-29 series is installed on the BESS.
b) While the test is being carried out, operation of the subsystem generating wind in the BESS (e.g. ventilation system, air-conditioning system) should be stopped. The inside of the BESS should maintain room temperature during the test.

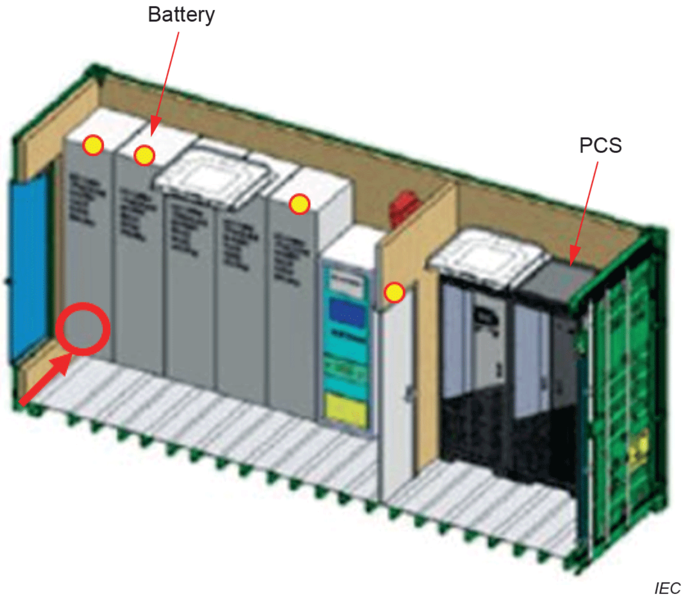


Figure H.15 – Example of gas sensor placement accuracy verification test

Based on the location of the sensor installed in the BESS, the point where gas detection is expected to be most vulnerable (e.g. blind spot) should be identified and injected with combustible gas at that point.

The type and amount of combustible gas used in the test should be selected based on the information provided in H.2.3.1.

Annex B for the method of selecting the type and amount of combustible gas to be used in the test from the data in H.2.3.1 should be referred to.

The acceptance criteria are as follows:

– The gas detection system should identify the flammable gas within design time after the test gas is released and notify the PMS (or PCS) of the gas generation.
– Upon receiving the signal from the gas detection system, the PMS should immediately stop the operation of the PCS and turn off the main breaker of the battery rack.
– In addition, it is necessary to operate the ventilation system so that the combustible gas inside the BESS does not condense. Figure H.15 is an example on the gas sample emission position.
– The PMS should immediately generate audible alerts and visual signals after shutting down the BESS. It should be possible only to stop the termination of the triggered alarm and sign by the user's operation.

In case of BESS with off-gas detector installed, the following tests should be performed.

Based on the location of the off-gas sensor installed in the BESS, the point where the gas detection is expected to be most vulnerable (e.g. blind spot) should be identified and injected with off-gas at that point.

The type and amount of off-gas used in the test should be selected based on the information provided in H.2.3.1.

The acceptance criteria are as follows:

– The off-gas detection system should identify the off-gas within design time after the test gas is released and notify the PMS (or PCS) of the gas generation.
– Upon receiving the signal from the gas detection system, the PMS should immediately stop the operation of the PCS and turn off the main breaker of the battery rack. Ventilation systems should also be operational.
– After the PMS recognizes off-gassing, it should generate audible alerts and visual signals. Alarms and signs should be started within 20 s and be maintained for more than 60 s.

H.2.3.3 Ventilation

For category "E-S" BESS, the test method is as follows:

a) For the ventilation system (e.g. fan) installed on E-S BESS, the test should be carried out as specified in IEC 60079-7:2015, 6.6.4.

The acceptance criteria are as follows:

– The test is satisfactory if the hydrogen concentration thus determined does not exceed 2 %.

For category "E-LI or E-LS" BESS, the test method is as follows:

a) A simulated signal should be used to operate the ventilation system. It should be checked whether the ventilation system exhausts 18 m^3/h per 1 m^2.

If there is more than one ventilation in the BESS, it should be checked whether the sum of the exhausting capacity of all ventilation complies with 18 m^3/h or more per 1 m^2.

If a BESS enclosure does not exist, a SAT should be used for checking the performance of the ventilation system in the place where the BESS is installed.

If this test is performed with the ventilation system using the test in H.2.3.2, it is not necessary to use the simulated signal.

The acceptance criteria are as follows:

– The ventilation system should be operated normally and the emission volume should be 18 m^3/h per 1 m^2.

H.2.4 Hazards arising from electric, magnetic, and electromagnetic fields test procedure and test method in 8.2.4

H.2.4.1 Conductive disturbance emission

Electromagnetic wave testing regarding hazards arising from electric and magnetic fields should be performed at the input/output terminal of the battery and battery management system, as electromagnetic waves can directly affect the battery management system and battery connected through the secondary DC output from the power conversion system.

For all category BESS, the test method is as specified in CISPR 11:

a) Using a 150 Ω DC four-circuit network (DC-AN) or a current probe on the DC I/O section of the power conversion system, measure the conductive disturbance emission of the DC power port. Confirm the suitability of the conductive disturbance emission measured by comparing it with the limit values.

The acceptance criteria are as follows:

– The conductive disturbance in Table H.4 should be satisfied.

Table H.4 – Limits for electromagnetic conductive disturbance from DC voltage ports

Frequency range MHz	Rated input power ≤ 20 kVA		Rated input power > 20 kVA, ≤ 75 kVA				Rated input power > 75 kVA			
	Voltage value		Voltage value		Current value		Voltage value		Current value	
	Quasi-peak dB(μV)	Average value dB(μV)	Quasi-peak dB(μV)	Average value dB(μV)	Quasi-peak dB(μA)	Average value dB(μA)	Quasi-peak dB(μA)	Average value dB(μV)	Quasi-peak dB(μA)	Average value dB(μA)
0.15 ~ 5	97 ~ 89	84 ~ 76	116~106	106~96	72~62	62~52	132~122	122~112	88~78	78~68
5 ~ 30	89	76	106~89	96~76	62~45	52~32	122~105	112~92	78~61	68~48

H.2.4.2 Conduction tolerance

When carrying out an electromagnetic wave conduction tolerance test, the maximum output is not always required. However, the output value should be such that specimen performance evaluation criteria can be confirmed in operation, and all functions can be checked for normal operation. Electromagnetic wave tolerance performance evaluation is shown as Table H.5.

Subject to the judgment of the tester, if function checking is impossible during normal operation a performance confirmation procedure can be undertaken after the electromagnetic wave conduction tolerance test.

For all category BESS, the test method is as follows:

a) Test in accordance with IEC 61000-6-2.

The acceptance criteria are as follows:

– During the test no sort of communication error should occur in the BESS system, and the below performance evaluation standards should be met.

NOTE Performance errors refer to unintended stoppages of the subsystem that provide communication functions such as the BMS or PMS, or loss/distortion of communicated messages.

Table H.5 – Electromagnetic wave tolerance performance evaluation criteria

Category	Performance evaluation criteria
Performance evaluation criteria A	The device should continue to operate as intended during and after the test. If the device is used as intended, performance drops or loss of function below the performance levels stipulated by the manufacturer are not allowed. If the performance levels were not stipulated by the manufacturer, the reasonable level of performance a user can expect from the device when it is used according to the user manual and product documentation should be considered.
Performance evaluation criteria B	The device should continue to operate as intended after the test. If the device is used as intended, performance drops or loss of function below the performance levels stipulated by the manufacturer are not allowed. Performance levels can be replaced with allowable performance loss. Performance loss during testing is allowed, but changes in the actual operation status or accumulation data are not allowed. If the minimum performance levels or allowable performance loss was not stipulated by the manufacturer, the reasonable level of performance a user can expect from the device when it is used according to the user manual and product documentation should be considered
Performance evaluation criteria C	If the function can be self-recovered or recovered through control operation, momentary function loss during testing is allowed.

H.2.5 Fire hazards test procedure and test method in 8.2.5

For category "E-LI or E-LS" BESS, the test method is as follows (SAT):

a) In case of BESS having lithium-ion secondary battery, it should be checked whether the lithium-ion secondary battery has been verified of fire risk in accordance with IEC 62619.
b) S-O verifies that the fire alarm and fire suppression system are installed and operated in the BESS location.
c) S-U verifies that the fire alarm and fire suppression system are provided within the area.
d) Both cases verify that the fire suppression system automatically activates when the fire alarm detects the fire hazard.
e) It should be verified that fire detection sensor with performance verification is installed in E-LI or E-LS BESS.
f) While the test is being carried out, operation of the subsystem generating wind in the BESS (e.g. ventilation system, air-conditioning system) should be stopped. The inside of the BESS should maintain room temperature during the test.

Based on the location of the fire detection sensor installed in the BESS, the point where fire detection is expected to be most vulnerable (e.g. blind spot) should be identified and injected with the test reference gas (CO) at that point.

The acceptance criteria are as follows:

– The fire detection system should identify the fire within design time and generate audible alerts and visual signals. Alarm and signal should be activated for more than 20 s.
– The fire detection system identifies the gas and notifies the PMS of the outbreak of the fire within 5 s.
– After receiving the signal from the fire detection system, the PMS should immediately terminate the charge and discharge of the BESS and terminate the power supply. The power conversion subsystem should be deactivated, and the main breaker of battery rack should be turned off.
– The fire suppression system should be activated.

H.2.6 Temperature hazards test procedure and test method in 8.2.6

H.2.6.1 Verification of temperature control operation

H.2.6.1.1 Battery temperature test

Unintentional islanding is in danger of having considerable impact on the safety of human bodies and facilities. The public as well as technical staff might be at risk of electric shock during incident investigation or during equipment removal operations.

H.2.6.1.2 BESS temperature test

The BESS should be operated at its rated value.

In order for the BESS to detect the abnormal temperature of the BESS, the allowable temperature of the BESS should be set in the BMS to be lower than the current temperature.

The allowable high temperature setting value of the device (e.g. air conditioner, thermo-hygrometer) that monitors the internal temperature of the BESS which is lower than the current temperature should be set.

The allowable low temperature setting value of the device that monitors the internal temperature of the BESS which is higher than the current temperature should be set.

NOTE In case of an E-S BESS whose temperature setting value cannot be changed, a test will be conducted by increasing it to the allowable high temperature setting value inside the BESS suggested by the manufacturer in the temperature chamber.

The acceptance criteria are as follows:

– As soon as the device that monitors the internal temperature of the BESS detects an abnormal temperature, it should notify the PMS. The PMS should stop the operation of the PCS and turn off the main breaker of the battery rack.
– It should be checked whether the BESS operator is notified of the abnormal condition of the internal temperature of the BESS.
– It should be checked whether the abnormal history of the internal temperature of the BESS is recorded.

H.2.6.1.3 BESS current limiting device test

If there is a current limiting device external to the battery, its function should be verified through system verification or with a simulated signal of overcharge/temperature rise.

To create an overcharged state, the BESS should be charged at a value 10 % lower than the voltage declared by the manufacturer.

At this time, if the current limiting device detects overcharging or high temperature, the PMS should immediately terminate the charging and discharging of the BESS and power off. The main circuit breaker of the battery rack should be turned OFF.

H.2.6.2 Abnormal operations of subsystems for ventilation

The abnormal vent condition by removing or blocking the vent connector should be prepared.

In order for the BESS to detect the abnormal temperature of the BESS, the allowable temperature of the BESS should be set in the PMS to be lower than the current temperature.

During this procedure, the air conditioning facility is deactivated. A situation in which the internal heat is increasing due to the BESS's charge and discharge cycle is set and it will be verified that the BESS terminates the charge and discharge when the temperature exceeds the limit specified by the manufacturer.

The charging/discharging does not have to be terminated if the temperature is appropriately controlled by the air conditioning facilities, even when the vent is not operating.

The vent abnormal condition test is conducted in repetition, with the vent system operating normally, and with the vent hole or duct blocked.

To verify that the abnormal condition of the vent system is reported to the BESS operator, when the temperature rises with the vent system blocked, verify that the charging/discharging is terminated, and an alarm is sounded from the PMS system or a signal is sent to the BESS operator.

Deactivate the vent and air conditioning facilities, and verify that when the temperature declines, the charging/discharging is terminated, and an alarm is sounded from the PMS system or signal is sent to the BESS operator.

H.2.6.3 Temperature under normal operation tests

For temperature-sensitive components used in the BESS, verify whether they exceed the temperature limits during normal operation.

With the BESS load connected normally, operate until the temperature of the main components is saturated. If saturation does not take place within 4 h, temperature is measured after 4 h. Verify whether the measured temperature exceeds the temperature limit specified by the manufacturer.

Based on the location of the temperature sensor installed in the BESS, the point where temperature detection is expected to be most vulnerable (e.g. blind spot) should be identified.

At this time, the difference between the temperature measured by the tester and the temperature inside the BESS detected by the PMS should be within 2°.

Verify if the temperature value measuring the BESS environment during the 4 h of normal operation exceeds the value specified by the manufacturer.

H.2.7 Explosion hazards test procedure and test method in 8.2.7

H.2.7.1 Specification of hazardous fluids

For gas:

The information on all toxic gas components that can occur during the entire period from venting to fire for one battery cell should be extracted. The information to be extracted at this time is as follows:

- type;
- amount;
- time of occurrence.

Test conditions and methods are the same as in H.2.3.1.

It should be checked whether the generated gas contains components harmful to the human body.

For liquid:

The manufacturer should provide information on the composition, amount, and characteristics (chemical reaction under specific conditions) of the electrolyte of the battery used in the BESS.

It should be checked whether any of the components of the electrolyte are harmful to the human body.

H.2.7.2 Fluids detection

If there is a possibility that toxic fluid can be generated from the BESS based on risk assessment of Clause 7, a toxic gas detector and a leak detection sensor that satisfy the following conditions should be installed.

For toxic gas detector:

The installation location and number of toxic gas detectors is to be selected by the client. The location and number of sensors installed for the test on the BESS diagram should be indicated and specified in the test report.

NOTE 1 The client can design optimally the location and number of sensors according to Annex B.

The customer should provide specification information (detectable gas type, amount) of the sensor installed in the BESS.

Test conditions and methods are the same as in 8.2.3.2.

The type and amount of toxic gas used in the test are selected by the testing lab based on the information investigated by 8.2.7.2. For the safety of the tester, an appropriate PPE to protect against toxic gas should be provided, and a device for inhaling toxic gas during and after the test should be provided.

Annex B for the method of selecting the type and amount of combustible gas to be used in the test from the data in 8.2.7.2 should be referred to.

The acceptance criteria are as follows:

- The toxic gas detector should identify the toxic gas within X s after the test gas is sprayed and notify the PMS (or PCS) of the gas generation.
- Upon receiving the signal from the toxic gas detector, the PMS should immediately stop the operation of the PCS and turn off the main circuit breaker of the battery rack.
- In addition, the ventilation system should be operated to prevent the toxic gas from condensing inside the BESS.
- The PMS should immediately generate audible alerts and visual signals after shutting down the BESS. The termination of the triggered alarm and sign should be able to be stopped only by the user's operation.

For leak detection sensor:

A certain amount of water is injected at the point where leakage detection is expected to be most vulnerable (e.g. blind spot) among the battery installation locations in the BESS.

NOTE 2 The water capacity is determined by referring to the information provided by the manufacturer in 8.2.7.2(e.g. the quantity of the electrolyte that can be discharged from a single cell).

For category "E-LI or E-LS" BESS, a stack of modules should be installed in every compartment of the rack.

For the safety of the tester, adequate PPE to protect against toxic liquids should be provided, and a device for inhaling toxic liquids during and after the test should be provided.

The acceptance criteria are as follows:

– The leak detection sensor should identify the water within X s after the water is injected and notify the PMS (or PCS) of the liquid leak.
– Upon receiving the signal from the leak detection sensor, the PMS should immediately stop the operation of the PCS and turn off the main breaker of the battery rack.
– In addition, the ventilation system should be operated to prevent the toxic gas from condensing inside the BESS.
– The PMS should immediately generate audible alerts and visual signals after shutting down the BESS. The termination of the triggered alarm and sign should be able to be stopped only by the user's operation.

H.2.7.3 Protective measures against hazardous fluid

For liquid:

Let the 80 ml of water from the battery location in the BESS drain.

For category "E-S" BESS, the acceptance criteria are as follows:

– Water should not spill out of the product.

For category "E-LI or E-LS" BESS, the acceptance criteria are as follows:

– In the case of a BESS installed in a container, water should not leak out of the container.
– In the case of a BESS installed in a place where external personnel can come into contact, an alarm and signal indicating that it is a toxic substance should be generated.

H.2.8 Hazards arising from auxiliary, control and communication system malfunctions test procedure and test method in 8.2.8

For the observation and general control of the BESS system state (current, voltage, SOC, temperatures, etc.), the BMS, PMS (or energy management system), etc. should exchange information based on various communication protocols (CAN, Modbus, TCP/IP, etc.).

The purpose of this test is to confirm whether the BESS system's protection system operates when communication ceases, regardless of the communication protocol. Figure H.16 is the circuit composition for the communication error test.

Communication errors refer to situations where data that should normally be exchanged are not due to physical faults in the communication cables (separation, damage, etc.) between BMS or the BMS and the PMS (or energy management system).

For category "E-LI or E-LS" BESS, the test procedure are as follows:

a) Operate the power conversion system in charge mode and charge to the rated capacity.
b) While the lithium-ion secondary battery system charges, confirm that data in the BMS, PMS, and so on (voltage, current, SOC, and other manufacturer-supplied measurements/calculations) are being exchanged properly.
c) Choose a random rack and separate the communication cables between any two module battery management systems.
d) Check that the BESS system ends charging (or discharging) and enters standby mode. If it enters standby mode, attempt to operate again in charge mode (or discharge mode) and confirm whether the lithium-ion secondary battery system charging (or discharging) resumes.

e) Restore the BESS system to the state prior to the test and repeat b) to d) in discharge mode.

f) Change c) to apply to communication cables between the BMS and the PMS and repeat a) to e) for each.

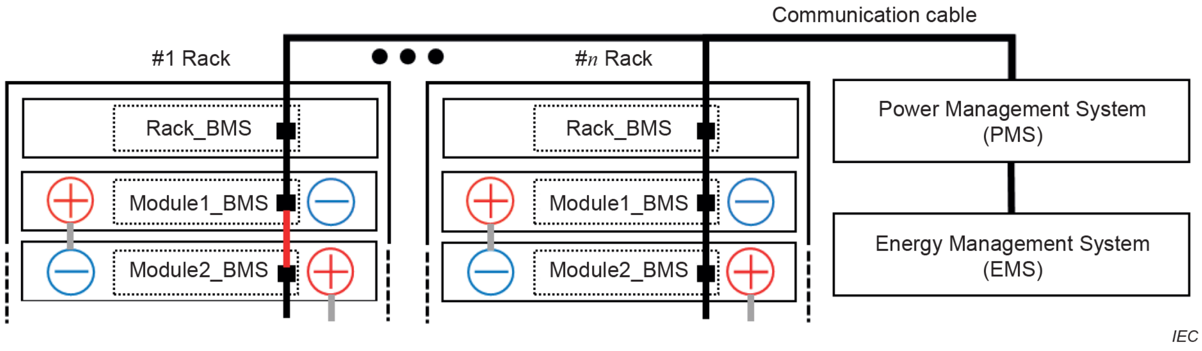


Figure H.16 – Circuit composition for communication error test

The acceptance criteria are as follows:

– The PMS (or energy management system) should detect the physical anomaly in the communication cables within the time suggested by the manufacturer.

– If tested in charge or discharge mode, the power conversion system should end the charging or discharging of the BESS system and enter standby mode.

– If tested in standby mode, BESS should be kept standby mode even when charging or discharging is attempted.

– Standby mode should be maintained even when a charge or discharge command occurs while the cables are separated.

H.2.9 Hazards arising from environments test procedure and test method in 8.2.9

H.2.9.1 Exposure to moisture ingress

Table H.6 – IP rate of BESS installed locations

Type	Indoor	Outdoor	Immersion
E-S	IPX1	IPX4	Over IPX6
E-LI or E-LS (Batt.)	IPX1	IPX4	Over IPX6
E-LI or E-LS (PCS)	IPX1	IPX4	X

Table H.6 shows IP rate of BESS installed locations.

For BESS that can be installed outdoors: (S-O)

a) Verify that the E-S BESS satisfies the IPX4 according to IEC 60529. After the IP test, all functions of BESS should operate normally. Additionally, perform the dielectric withstand voltage test for the subsystem according to IEC 60664-1 and verify that the internal insulation is not damaged.

b) Immerse the entire E-S BESS system in 5 % NaCl aqueous solution at the speed of 15 cm/min.

The BESS should be completely immersed, or portions of the BESS that would be impacted by water immersion are to be immersed for 2 h or until reactions appear to have stopped.

Moisture can enter the interior of the BESS during the immersion test, but explosion or fire should not occur.

NOTE Even if the BESS will be installed outside, if the subsystem has an individual enclosure, additionally it will be checked whether the enclosure of all subsystems meets IPx1 according to IEC 60529.

For BESS to be installed only indoors: (S-U):

It should be checked whether the enclosure of the BESS satisfies IPx1 according to IEC 60529. After the IP test, all functions of the BESS should operate normally. In addition, the subsystem performs a withstand voltage test according to IEC 60664-1 to confirm that the internal insulation is not damaged.

If the subsystem of the BESS has individual enclosures, it should be checked whether the enclosures of all subsystems satisfy IPx1 according to IEC 60529.

H.2.9.2 Exposure to marine environments (salt mist)

The BESS intended for installation outdoors near marine environments (e.g. near seashores, on docks, etc.) in accordance with the installation instructions, where they will be subject to salt mist exposure, should be tested in accordance with IEC 60068-2-52 for test method 1 or 2.

NOTE 1 IEC 60068-2-52 defines test method 1 or 2 for equipment which is continuously used in or around a marine environment.

Test method 1:

One cycle is seven days. One cycle should consist of spraying the specimen with a salt solution at 35 °C ± 2 °C for 2 h, followed by the humid condition at 40 °C ± 2 °C, 93 % ± 3 % RH for six days and 22 h. The required number of cycles is four (28 days).

In the case of manual handing, the transition time (maximum 2 h) should be included in the humid condition period of six days and 22 h.

Test method 2:

One cycle is one day. One cycle should consist of spraying the specimen with a salt solution at 30 °C ± 2 °C for 2 h, followed by the humid condition at 40 °C ± 2 °C, 93 °C ± 3 % RH for 22 h. The required number of cycles is three (three days).

In the case of manual handling, the transition time (maximum 2 h) should be included in the humid condition period of 22 h.

For category "E-S" BESS, the test method is as follows (SAT):

a) E-S BESS is tested with the finished product.

For category "E-LI or E-LS" BESS, the test method is as follows (SAT):

a) E-LI or E-LS BESS is tested in subsystem units.

The acceptance criteria are as follows:

– Explosion or fire should not occur during the salt spray test.
– If toxic gas and liquid is generated, the BESS's gas detection system and fluids detection system should detect them.

NOTE 2 The activation of detection system is verified only when the detection system is installed within the BESS.

– After the salt spray test, perform the dielectric withstand voltage test according to IEC 60664-1 and verify that the internal insulation of BESS is not damaged.

If toxic gas and liquid are generated during salt spray test, the dielectric withstand voltage test should not be performed.

H.2.10 IP rating of BESS enclosure and protective guards test procedure and test method in 8.2.10

For all category BESS, the test method is as follows:

a) Verify that E-S BESS satisfies the IP2X according to IEC 60529.

NOTE 1 It is a product in which all subsystems are protected within one enclosure, and the IP test is performed on the enclosure of BESS.

NOTE 2 If the subsystems of the BESS have an enclosure individually, each subsystem is tested.

NOTE 3 If the IP rating specified the manufacturer is higher than IP2X, the test is performed in the IP rating specified by the manufacturer.

Annex I
(informative)

Risk analysis

The objectives of a What-If risk analysis are:

a) the identification and evaluation of hazards and problems due to operation deviations, which can generate scenarios that identify potential risks to users, environment and the system itself;
b) the identification of all the project, management and user-oriented documentation safeguards in places that can reduce the probability of incidental events or that can mitigate the consequences of such events;
c) the identification, whenever is necessary, of recommendations for new solutions to improve the design and management of the systems, with the goal of reducing the probability of incidental events or mitigating the consequences.

A What-If risk analysis consists of a structured brainstorming method of determining what can go wrong and judging the likelihood and consequences of those situations occurring. What-If risk analysis involves asking a series of guided standard questions based on a structured checklist as a means of identifying hazards. This technique can study and analyse both technical and operational/procedural aspects that can affect the safety and the productivity/functionality of the system.

The What-If risk analysis is developed through the following steps:

a) brainstorming session on errors and failures considered during normal and abnormal use by the user, maintenance activity and start-up/shutdown of the system. In order to ensure a systematic approach, the What-If analysis requires the use of a checklist to guide the team brainstorming;
b) answering the list of What-If questions, assessing all possible hazards and problems related to the main components and functionalities of the BESS system, the causes that generate them (failures, human errors, external events), the effects for safety, environment, asset and reputation;
c) risk assessment, by means of likelihood and severity evaluation for the identified hazardous scenarios, considering all possible safeguards in place;
d) risk reduction measures, discussion by identification of project and/or management solution to improve the system in order to prevent or mitigate the hazardous scenario.

The What-If risk analysis should consider hazards due to:

a) ESS systems failure;
b) ESS use;
c) ESS failure due to external factors;
d) ESS unauthorized uses.

The minimum set of What-If questions a risk analysis should consider is:

1) What if the battery (string) is overcharged?
2) What if the battery (string) is over-discharged?
3) What if the battery (string) SOC is less than the mininum allowed?
4) What if the battery cell/module is over the maximum temperature allowed?
5) What if the battery bank is in over the maximum temperature allowed?
6) What if the battery is subjected to production quality issues (defects)?
7) What if the battery is subjected to maintenance activity/ commissioning?
8) What if the battery is subjected to insulation breakdown?
9) What if the battery is in a high voltage condition?
10) What if in case of arc flash during maintenance or commissioning operations?
11) What if one cell/module does not work?
12) What if one battery bank does not work?
13) What if bank battery management system does not work?
14) What if one rack does not work?

Annex J
(informative)

Aisle and access requirements

The width of aisles and access areas should meet the requirements Annex J for work, operational access, emergency access, emergency evacuation and for transport of equipment.

Accessible indoor and outdoor EESS should be provided with suitable lighting for routine operations.

Current applicable international or national standards and regulations can apply for emergency/auxiliary levels and lighting should be provided if necessary; this can be a fixed installation or portable equipment.

Current applicable international or national standards and national regulations for lighting levels can apply.

Maintenance and operating areas comprise aisles, access areas, handling passages and escape routes.

Aisles and access areas should be adequately dimensioned for carrying out work, operating switchgear and transporting equipment.

The minimum aisle width should be 800 mm.

The width of the aisles should not be reduced even when equipment projects into the aisles, for example permanently installed operating mechanisms or switchgear trucks in isolated positions, should not reduce the aisle width below 800 mm.

The minimum clear width of evacuation pathway should be 500 mm. This requirement applies to components such as removable parts or open doors, which intrude into the escape routes.

Figure J.1 is the image of minimum width of aisle.

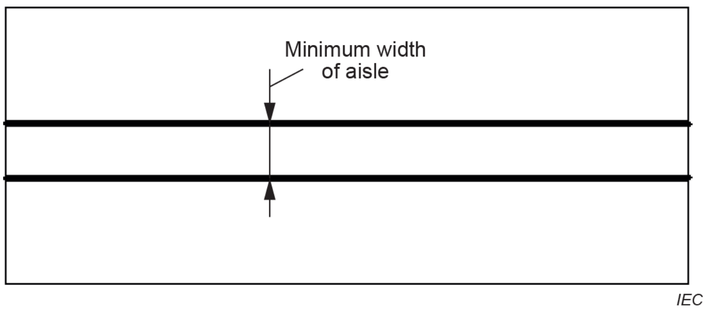


Figure J.1 – Minimum width of aisle

The maximum escape route within the EESS should not exceed 10 m. Exits should be arranged accordingly.

Figure J.2 is the image of maximum length of escape route.

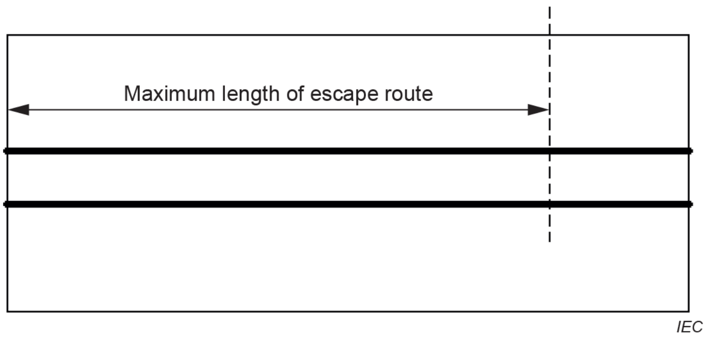


Figure J.2 – Maximum length of escape route

Current applicable international/local standards and regulations for width and length of can apply. In any case the maximum escape route within the EESS should not exceed 10 m.

Bibliography

IEC 60364-4-41, *Low-voltage electrical installations - Part 4-41: Protection for safety - Protection against electric shock*

IEC 60364-4-42, *Low-voltage electrical installations - Part 4-42: Protection for safety - Protection against thermal effects*

IEC 60364-4-43, *Low-voltage electrical installations - Part 4-43: Protection for safety - Protection against overcurrent*

IEC 60617 (all parts), *Graphical symbols for diagrams*

IEC 60721 (all parts), *Classification of environmental conditions*

IEC 60896-21, *Stationary lead-acid batteries - Part 21: Valve regulated types - Methods of test*

IEC 60896-22, *Stationary lead-acid batteries - Part 22: Valve regulated types - Requirements*

IEC 61000-6-1:2016, *Electromagnetic compatibility (EMC) - Part 6-1: Generic standards - Immunity standard for residential, commercial and light-industrial environments*

IEC 61000-6-2:2016, *Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environments*

IEC 61000-6-5:2015, *Electromagnetic compatibility (EMC) - Part 6-5: Generic standards - Immunity for equipment used in power station and substation environment*

IEC 61140, *Protection against electric shock - Common aspects for installation and equipment*

IEC 61427-1, *Secondary cells and batteries for renewable energy storage - General requirements and methods of test - Part 1: Photovoltaic off-grid application*

IEC 61427-2, *Secondary cells and batteries for renewable energy storage - General requirements and methods of test - Part 2: On-grid applications*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61511-1:2016, *Functional safety - Safety instrumented systems for the process industry sector - Part 1: Framework, definitions, system, hardware and application programming requirements*

IEC 62040-1, *Uninterruptible power systems (UPS) - Part 1: Safety requirements*

IEC 62040-2, *Uninterruptible power systems (UPS) - Part 2: Electromagnetic compatibility (EMC) requirements*

IEC 62116:2014, *Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures*

IEC 62351 (all parts), *Power systems management and associated information exchange - Data and communications security*

IEC TS 62351-2:2008*, Power systems management and associated information exchange - Data and communications security - Part 2: Glossary of terms*

IEC 62381:2012, *Automation systems in the process industry - Factory acceptance test (FAT), site acceptance test (SAT), and site integration test (SIT)*

IEC TS 62443-1-1:2009*, Industrial communication networks - Network and system security - Part 1-1: Terminology, concepts and models*

IEC 62443-2-4, *Security for industrial automation and control systems - Part 2-4: Security program requirements for IACS service providers*

IEC 62485-1, *Safety requirements for secondary batteries and battery installations - Part 1: General safety information*

IEC 62531:2012, *Property Specification Language (PSL)*

IEC TS 62686-1:2015, *Process management for avionics - Electronic components for aerospace, defence and high performance (ADHP) applications - Part 1: General requirements for high reliability integrated circuits and discrete semiconductors*

IEC 62909-1*, Bi-directional grid connected power converters - Part 1: General requirements*

IEC Guide 104, *The preparation of safety publications and the use of basic safety publications and group safety publications*

IEC White Paper, *Electrical Energy Storage*

ISO 917:2024, *Refrigerants - Designation and safety classification*

ISO 9241 (all parts), *Ergonomics of the human-system interaction*

ISO 13732-1: 2006, *Ergonomics of the thermal environment - Methods for the assessment of human responses to contact with surfaces - Part 1: Hot surfaces*

ISO 13850:2015, *Safety of machinery - Emergency stop function - Principles for design*

ISO 13857:2008, *Safety of machinery - Safety distances to prevent hazard zones being reached by upper and lower limbs*

ISO 13943:2008, *Fire safety - Vocabulary*

ISO/IEC14543-2-1:2006, *Information technology - Home electronic system (HES) architecture - Part 2-1: Introduction and device modularity*

"*Analysing system safety in lithium-ion grid energy storage*", D. Rosewater and A. Williams, Journal of Power Sources 300(2015) 460-471

ANSI/CAN/UL 9540:2023, *Standard for Energy Storage Systems and Equipment*

ASTM E918:2020, *Standard Practice for Determining Limits of Flammability of Chemicals at Elevated Temperature and Pressure*

BS EN 15967:2022, *Determination of maximum explosion pressure and the maximum rate of pressure rise of gases and vapours*

CISPR 11:2015+AMD1:2016+AMD2:2019 CSV, *Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement*

UL, *Firefighter Safety and Photovoltaic Installations Research Project*: November 29, 2011

UL 9540A:2019, *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*

N. Leveson and J. Thomas, *STPA Handbook*, 2018

NFPA 400:2019. *Hazardous Materials Code*

NFPA 704:2017, *Standard System for the Identification of the Hazards of Materials for Emergency Response*

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