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

**Systèmes de stockage de l'énergie électrique (EES) –
Partie 5-1: Considérations de sécurité pour les systèmes EES intégrés au réseau – Spécifications générales**

IEC 62933-5-1:2024-07(en-fr)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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ELECTRICAL ENERGY STORAGE (EES) SYSTEMS –

Part 5-1: Safety considerations for grid-integrated EES systems – General specification

FOREWORD

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IEC 62933-5-1 has been prepared by IEC technical committee TC 120: Electrical Energy Storage (EES) systems. It is an International Standard.

This first edition cancels and replaces the first edition of IEC TS 62933-5-1 published in 2017. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to IEC TS 62933-5-1:2017:

a) Revising “should” statements to “shall” statements for all requirements and move some “should” statements clauses to Annex B for informative purposes.
b) Update standard references (normative).
c) Update definitions and add or remove definitions where necessary.

d) Revise criteria in Clause 6 and Clause 7 to be actionable and add standard references where necessary.

e) Revise Clause 8 for more thorough test method and criteria, add tests where necessary.

f) Add markings and instruction criteria.

g) Revise Annex A to add technology safety information on gravitational and thermal EESS.

h) Add Annex B and Annex C for safety considerations for EESS and test method for mechanical EESS.

i) Add informative list of standards and update bibliography.

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

Draft	Report on voting
120/368/FDIS	120/377/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.

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INTRODUCTION

Many governments' plans for how electricity will be generated and managed in the future have been determined. Such current plans cannot be implemented without long-term storage with capacities in the large scale range.

There are a number of types of storage technologies that have emerged. Examples of these technologies are pumped hydro storage (PHS), electrochemical batteries, flywheel storage systems and hydrogen and synthetic natural gas (SNG). Pumped hydro storage has been widely used in terms of the total amount of stored energy. A flywheel is a model of kinetic energy storage with a high power density, excellent cycle stability and long life. While some flywheels are intended for short term operation, others can operate over longer periods of time of up to a few hours. Batteries require development primarily to decrease cost, and for some technologies to increase energy density as well. Hydrogen and synthetic natural gas (SNG) added to natural gas are likely to be essential elements of future electric grids because of their energy storage duration and capacity. Hydrogen and SNG should be further researched and developed across a broad front, including physical facilities, interactions with existing uses of gas for supply and distribution network, optimal chemical processes, safety, reliability and efficiency. The IEC White Paper on electrical energy storage can provide further background information concerning EES systems.

For mature EES systems, various IEC standards exist, covering technical features, testing and system integration. For other technologies, there are only a few standards, covering special topics.

Up to now no general standard addressing safety for EESS integration into an electrical grid has been developed.

The rapid growth and the new technologies involved in electrical energy storage in the near future, as well as their installation by consumers will impose particular requirements for safety. At the same time, society and governments will need assurance of safety before the much-needed systems can be deployed.

This document stands as a decisive step towards the gradual alignment with specific technologies and applications concerning the safety of packaged or site-assembled grid-integrated EESS.

Additional criteria specific to electrochemical type electrical energy storage (EES) systems are given in IEC 62933-5-2.

ELECTRICAL ENERGY STORAGE (EES) SYSTEMS –

Part 5-1: Safety considerations for grid-integrated EES systems – General specification

1 Scope

This part of IEC 62933 specifies safety considerations (e.g. hazards identification, risk assessment, risk mitigation) applicable to EES systems integrated with the electrical grid.

This document provides criteria to enable the safe application and use of electrical energy storage systems of any type or size intended for grid-integrated applications.

This document can be applied to all EESS technologies, but for requirements specific to electrochemical EES systems, reference is also made to IEC 62933-5-2.

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 60079-2:2014, *Explosive atmospheres – Part 2: Equipment protection by pressurized enclosure "p"*

IEC 60204-1, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

IEC 60204-11, *Safety of machinery – Electrical equipment of machines – Part 11: Requirements for equipment for voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV*

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

IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric* shock
IEC 60364-4-41:2005/AMD1:2017

IEC 60364-4-43, *Low-voltage electrical installations – Part 4-43: Protection for safety – Protection against overcurrent*

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 supply systems – Part 1: Principles, requirements and tests*

IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC 60730-1:2020, *Automatic electrical controls – Part 1: General requirements*

IEC 60730-2-9, *Automatic electrical controls – Part 2-9: Particular requirements for temperature sensing controls*

IEC 60947-5-1, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*

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 61000-6-1, *Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity standard for residential, commercial and light-industrial environments*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity standard for industrial environments*

IEC 61000-6-3, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for equipment in residential environments*

IEC 61000-6-4, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments*

IEC 61000-6-5, *Electromagnetic compatibility (EMC) – Part 6-5: Generic standards – Immunity for equipment used in power station and substation environment*

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 TR 61340-1, *Electrostatics – Part 1: Electrostatic phenomena – Principles and measurements*

IEC 61439-1, *Low voltage switchgear and control gear assemblies – Part 1: General rules*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61511 (all parts), *Functional safety – Safety instrumented systems for the process industry sector*

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

IEC TS 61936-2, *Power installations exceeding 1 kV AC and 1,5 kV DC – Part 2: DC*

IEC 62061, *Safety of machinery – Functional safety of safety-related control systems*

IEC 62109-1, *Safety of power converters for use in photovoltaic power systems – Part 1: General requirements*

IEC 62109-2, *Safety of power converters for use in photovoltaic power systems – Part 2: Particular requirements for inverters*

IEC 62116:2014, *Utility-interconnected photovoltaic inverters – Test procedure of islanding prevention measures*

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

IEC 62443-3-3, *Industrial communication networks – Network and system security – Part 3-3: System security requirements and security levels*

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

IEC 62477-2, *Safety requirements for power electronic converter systems and equipment – Part 2: Power electronic converters from 1 000 V AC or 1 500 V DC up to 36 kV AC or 54 kV DC*

IEC 62689-2, *Current and voltage sensors or detectors, to be used for fault passage indication purposes – Part 2: System aspects*

IEC 62909-1, *Bi-directional grid-connected power converters – Part 1: General requirements*

IEC 62909-2, *Bi-directional grid-connected power converters – Part 2: Interface of GCPC and distributed energy resources*

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

IEC 62933-5-2, *Electrical energy storage (EES) systems – Part 5-2: Safety requirements for grid-integrated EES systems – Electrochemical-based systems*

ISO 1182, *Reaction to fire tests for products – Non-combustibility test*

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

ISO 12100:2010, *Safety of machinery – General principles for design – Risk assessment and risk reduction*

ISO 13849 (all parts), *Safety of machinery – Safety-related parts of control systems*

ISO 15649, *Petroleum and natural gas industries – Piping*

ASME B31.1, *ASME B31 Code for Pressure Piping, Section 1: Power Piping*

ASME B31.3, *ASME B31 Code for Pressure Piping, Section 3: Process piping*

IEEE Std 1547.1-2020, *Standard Conformance Test Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces*

3 Terms and definitions

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

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

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

3.1
access to EESS

3.1.1
restricted access area
area to which only skilled persons with the proper authorization have access

[SOURCE: IEC 60050-195:2021, 195-04-04, modified – the words "electrically" and "and electrically instructed persons" have been removed.]

3.1.2
unrestricted access area
area that is not a restricted access area

3.2
operation status

3.2.1
commissioning
activities undertaken to prepare a system or product prior to demonstrating that it meets its specified requirements

[SOURCE: IEC 60050-821:2017, 821-12-09]

3.2.2
decommissioning
administrative and technical actions taken to allow the removal of some or all of the EESS regulatory controls from a facility

Note 1 to entry: These actions can include the processes of discharging and dismantling.

[SOURCE: IEC 60050-395: 2014, 395-08-28, modified – the term "regulatory controls" is replaced with "EESS" and the term "decontamination" with "discharging"]

3.3
EESS

3.3.1
hybrid EESS
EESS that incorporates multiple storage technologies into one system

EXAMPLE: Hybrid EESS that incorporates batteries and electric double layer capacitors in one EESS.

3.3.2
multi-part EESS
electrical energy storage system consisting of assemblies or equipment interconnected in the field to comprise a complete system

3.4
electrical installation
assembly of electrical equipment which is used for the generation, transmission, conversion, distribution and/or use of electric energy

Note 1 to entry: The electrical installation includes energy sources such as batteries, capacitors and all other sources of stored electric energy.

[SOURCE: IEC 60050-651:2014, 651-26-01]

3.5
energized, adj.
live, adj.
at an electric potential different from that of earth at the worksite and which presents an electrical hazard

Note 1 to entry: A part is energized when it is electrically connected to a source of electric energy. It can also be energized when it is electrically charged and/or under the influence of an electric or magnetic field.

[SOURCE: IEC 60050-651:2014, 651-21-08]

3.5.1
hazardous live part
live part that, under certain conditions, can give a harmful electric shock

Note 1 to entry: A hazardous voltage can be present on the accessible surface of solid insulation. In such a case, this surface is considered to be a hazardous live part.

[SOURCE: IEC 60050-195:2021, 195-06-05]

3.6
harm
physical injury or damage to persons, property, and livestock

[SOURCE: IEC 60050-903:2013, 903-01-01]

3.7
hazard
potential source of harm

Note 1 to entry: In English, the term "hazard" can be qualified in order to define the origin of the hazard or the nature of the expected harm (e.g. "electric shock hazard", "crushing hazard", "cutting hazard", "toxic hazard", "fire hazard", "drowning hazard").

Note 2 to entry: In French, the synonym "risque" is used together with a qualifier or a complement to define the origin of the hazard or the nature of the expected harm (e.g. "risque de choc électrique", "risque d'écrasement", "risque de coupure", "risque toxique", "risque d'incendie", "risque de noyade").

Note 3 to entry: In French, the term "risque" also denotes the combination of the probability of occurrence of harm and the severity of that harm, in English "risk" (see 3.9).

[SOURCE: IEC 60050-903:2013, 903-01-02]

3.8
major incident
event or situation resulting from uncontrolled developments in the course of the operation of the EESS and leading to serious harm to human health or the environment, immediate or delayed, inside or outside the establishment, which requires special arrangements to be implemented by one or more emergency responder agency

3.9
protective measures and safeguards

3.9.1
personal protective equipment
PPE
device or appliance designed to be worn or held by an individual for protection against one or more health and safety hazards whilst performing live working

[SOURCE: IEC 60050-651:2014, 651-23-01, modified – "or held" has been added to the definition.]

3.9.2
protective measure
measure intended to achieve adequate risk reduction, implemented by the designer (inherent design, safeguarding and complementary protective measures, information for use) and by the user (organization: safe working procedures, supervision, training; permit-to-work systems; provision and use of additional safeguards; use of personal protective equipment)

[SOURCE: IEC 60050-903:2013, 903-01-17]

3.10
risk
combination of the probability of occurrence of harm and the severity of that harm

Note 1 to entry: In French, the term "risque" also denotes the potential source of harm, in English "hazard" (see 3.7).

[SOURCE: IEC 60050-903:2013, 903-01-07]

3.10.1
tolerable risk
risk which is accepted in a given context based on the current values of society

[SOURCE: IEC 60050-903:2013, 903-01-12]

3.11
risk and hazard analysis

3.11.1
failure mode
manner in which failure occurs

Note 1 to entry: A failure mode may be defined by the function lost or other state transition that occurred.

[SOURCE: IEC 60050-192:2015, 192-03-17]

3.11.2
failure modes and fault tree analysis
FMEA
qualitative method of analysis that involves the study of possible failure modes and faults in sub items, and their effects at various system and subsystem levels

[SOURCE: IEC 60050-192:2015, 192-11-05, modified – the term "indenture" has been replaced with "system and subsystem" and the note has been removed.]

3.11.3
failure modes, effects and criticality analysis
FMECA
quantitative or qualitative method of analysis that involves failure modes and effects analysis together with a consideration of the probability of the failure mode occurrence and the severity of the effects

[SOURCE: IEC 60050-192:2015, 192-11-06, modified – the note has been removed.]

3.11.4
fault tree analysis
FTA
deductive analysis using fault trees

[SOURCE: IEC 60050-192:2015, 192-11-08]

3.11.5
hazard and operability studies
HAZOP studies
structured and systematic technique for examining a defined system with the objective of identifying potential hazards in the system and identifying potential operability problems with the system and, in particular, identifying causes of operational disturbances and production deviations likely to lead to non-conforming products

Note 1 to entry: The hazards involved can include both those essentially relevant only to the immediate area of the system and those with a much wider sphere of influence, for example some environmental hazards

3.11.6
risk analysis
systematic use of available information to identify hazards and to estimate the risk

[SOURCE: IEC 60050-903:2013, 903-01-08]

3.11.7
risk assessment
overall process comprising a risk analysis and a risk evaluation

[SOURCE: IEC 60050-903:2013, 903-01-10]

3.11.8
risk evaluation
procedure based on the risk analysis to determine whether the tolerable risk has been achieved

[SOURCE: IEC 60050-903:2013, 903-01-09]

3.12
reasonably foreseeable misuse
use of a product, process or service in a way not intended by the supplier, but which can result from readily predictable human behaviour

[SOURCE: IEC 60050-903:2013, 903-01-14]

3.13
safety-related system
designated control system that implements the required safety functions necessary to achieve or maintain a safe state for the EESS; and is intended to achieve, on its own or with other risk reduction measures, the necessary risk reduction in order to meet the required tolerable risk

[SOURCE: IEC 61508-4:2010, 3.4.1, modified – revise “EUC” to “EESS”, delete “other E/E/PE safety-related systems and”, revise "the necessary safety integrity for the required safety functions" to “the necessary risk reduction in order to meet the required tolerable risk”.]

3.14
shutdown
transitional state of an EESS from operational state (either charging from the grid or output power to the grid) to standstill or idling state

[SOURCE: IEC 60050-415:1999, 415-01-09, modified – revise “a wind turbine between power production and” to “an EESS from operational state (either charging from the grid or output power to the grid) to”.]

3.14.1
emergency shutdown
rapid shutdown of EESS triggered by a protection system or by manual intervention to avoid equipment damage, or personnel hazards or both

[SOURCE: IEC 60050-415:1999, 415-01-11, modified – revise “the wind turbine” to “EESS”, and add “intervention to avoid equipment damage, or personnel hazards or both”.]

3.14.2
normal shutdown
shutdown of EESS in which all stages of the shutdown are under the control of the control system

[SOURCE: IEC 60050-415:1999, 415-01-10, modified – add “of EESS”]

3.15
skilled person
qualified person
person with relevant education, training, knowledge and experience to enable him or her to perceive risks and to avoid danger which electricity can create

[SOURCE: IEC 60050-651:2014, 651-26-11]

4 Basic approach for safety considerations of EES systems

The approach taken in this document is shown in Figure 1. The first aspect covered in Clause 5 is the identification of the different hazards associated with an EESS based on its system type, location, size and how it can impact or be impacted by its surroundings. The second aspect, covered in Clause 6 is the conduct of a risk assessment that is determined based upon considerations identified in Clause 5, according to operational use. The third aspect covered in Clause 7 deals with the measures to implement to reduce the risk based on the assessment conducted under Clause 6.

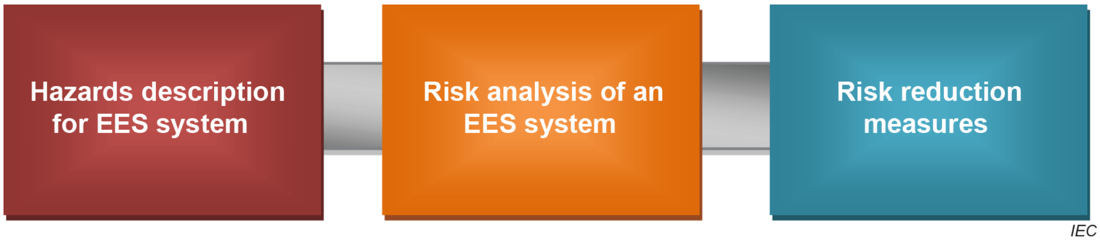

Figure 1 – General description of the approach to address hazards in EES systems

5 Hazard considerations for EES systems

5.1 Electrical hazards

EES systems that contain hazardous voltage levels can pose an electric shock hazard to persons. Voltage limits above 30 V AC RMS/42,4 V AC peak or 60 V DC are considered hazardous voltage.

NOTE 1 In IEC 62477-1 DVC As levels are 30 V AC RMS/42,4 V AC peak or 60 V DC for dry condition. Voltages above these levels are considered as hazardous voltage.

Arc flash boundaries shall be determined to establish appropriate levels of personal protective equipment for workers involved in maintenance and other actions on energized equipment. The arc flash boundary shall be the distance at which the incident energy equals 5 J/cm^2.

NOTE 2 NFPA 70E provides guidance on worker electrical safety including electric shock and arc flash hazards associated with work on electrically live parts. The arc flash boundary of 5 J/cm^2 is noted in this document.

The EESS shall also be evaluated for potential hazards due to static electricity, which can lead to hazardous conditions especially within areas of flammable or explosive concentrations of gases or dust.

Electric hazards can also arise from inappropriate electric firefighting procedures. Emergency response guidelines for the EESS shall address appropriate firefighting procedures applicable to that EESS technology.

5.2 Mechanical hazards

Moving parts that present potentially hazardous kinetic energy shall be enclosed or contained to prevent exposure to the moving parts during operation or as a result of a fault in the system, such as worn bearings, loss of vacuum, overspeed conditions, and damaged or blocked rotors.

Parts containing hazardous pressure shall have sufficient strength to safely withstand those pressures. Local regulations for design of parts containing hazardous pressure can apply. Pressure relief devices shall be provided to prevent an overpressure condition.

5.3 Energy hazards

5.3.1 Explosion hazards

Explosions endanger the lives and health of those exposed as a result of the uncontrolled effects of flame and pressure, the presence of noxious reaction products, the discharge of shrapnels, and the consumption of oxygen in the ambient air.

The hazardous risk assessment of the EESS shall determine if there is a potential for an explosion hazard from the EESS during normal and abuse conditions.

5.3.2 Hazards arising from electrical, magnetic, and electromagnetic fields

Exposure to radio frequency energy of sufficient intensity at frequencies between 3 kHz and 300 GHz that can adversely affect personnel working around the EESS shall be prevented.

Risks caused by radioactive substances (radiation and ingestion) are out of the scope of this document.

5.4 Fire hazards

It shall be determined whether combustible materials exist or can exist in the EESS, and in what quantity and distribution.

In assessing the fire hazard, the existence and quantity of fire supporting substances, for example oxygen producing substances, and the potential for their occurrence shall be determined.

Ignition sources, for example hot wires, electrical arcs, friction between moving parts (see Annex B for more information of ignition sources), that exist in EESS or in the vicinity of the EESS or that can occur under some circumstances shall be determined.

5.5 Temperature hazards

EESS shall be designed to prevent inadvertent exposure of persons to hot or cold parts or fluids that can result in an injury.

Emergency response guidelines shall provide instructions to avoid the potential for exposure to excessive heat or hot smoke.

5.6 Chemical hazards

The EESS can contain chemicals that are hazardous to persons if they are exposed to these chemicals. Chemical hazards associated with the EESS shall be identified.

5.7 Unsuitable working conditions

All EES systems shall be arranged to facilitate access to and egress from the area in which the system is installed or enclosed to prevent persons from becoming trapped. Working space and conditions shall be adapted to prevent the risk of musculoskeletal disorders (MSD) injury (see Annex B) which depends on work positions and postures, how often the task is performed, the level of required effort and how long the task lasts.

When evaluating working space for electrical installation and maintenance work, there shall be sufficient space to safely work on the system without the risk of electrical hazards to personnel performing the installation or maintenance. Local regulations can apply.

NOTE 1 Article 110 of NFPA 70:2023 has specific criteria for safe electric working space that are voltage dependent.

Noise from the EESS shall be within specified limits of safety by protective measures including warning markings, and the wearing of hearing protection shall be implemented as determined necessary based upon the limits of the installation. Local regulations can apply.

NOTE 2 Examples of limits imposed in the workplace are: the NIOSH sound level limit for 8 h exposure is 85 dB; the EU sound level limit for 8 h exposure is 87 dB; the OSHA sound level limit for 8 h exposure is 90 dB.

The EESS shall not have sharp edges that can cause a physical injury to personnel.

6 EESS risk assessment

6.1 EESS structure

6.1.1 General characteristics

A risk assessment that includes measures for risk reduction shall be conducted on the EESS. The principles and methodology of ISO 12100 can be used for the risk assessment. IEC/ISO 31010 documents many different techniques that can be used for the risk assessment and provides guidance on their applicability as well as the applicable reference documents for each technique.

NOTE 1 This document covers gravity energy storage systems, which can be considered as a machine. For other EESS, ISO 12100 can also be used as a reference standard for risk assessment.

NOTE 2 Some of the methods covered in IEC/ISO 31010 include primary hazard analysis, structured what if technique (SWIFT), failure modes and effects analysis (FMEA), failure modes, effects and criticality analysis (FMECA), hazard and operability studies (HAZOP studies) and fault tree analysis (FTA).

NOTE 3 In many cases, for example for V-L type EESS that are connected to LV grid with limited power and energy, a risk assessment based on a risk analysis limited to single-fault conditions will be sufficient. In other cases, for example for V-H type EESS that are connected to HV grid with high power and energy, in order to provide a comprehensive evaluation of specific and overall aspects of the EESS and the surrounding environment, if a risk assessment based on a risk analysis limited to single-fault condition is insufficient, a double-fault analysis can be done.

To conduct the risk assessment, a description of the EESS is required. The following general characteristics shall be noted:

- type, power, energy, rated life according to calendar or cycling ageing (guaranteed lifetime, number of cycles),
- application type,
- hazardous materials contained (formulas, physical state, quantities, safety data sheets),
- general functions, safety and security functions, programming functions,
- self-test functions, remote control, staff presence,
- auxiliary devices included in the system,
- measures taken to ensure the design safety and the reliability of the system,
- measures available to mitigate the risks,
- operating parameters,
- known hazards associated with any components of the EESS,
- instructions for use and maintenance.

6.1.2 Specific characteristics

Table 1 lists specific characteristics that shall be considered during the risk assessment.

Table 1 – EESS characteristics for risk assessment consideration

Type of EESS [a]	Grid connection type	Application	Location	Voltage at point of connection
mechanical – pumped hydro (PHS) – compressed air (CAES) – flywheel (FES) – gravitational (GES) **electrochemical** – secondary batteries – flow batteries – supercapacitors (generally combined with batteries in a hybrid EES) **thermal** – latent heat storage – sensible heat storage – thermochemical storage (adsorption and absorption) **chemical** – hydrogen	– transmission grids – distribution grids – commercial grids – industrial grids – residential grids – islanded grids	– peak shaving (long duration application) – load levelling (long duration application) – frequency regulation (short duration application) – stabilizing renewable energy (short duration application) – backup power – combined applications (multiple use applications)	– residential including group of households – commercial and public access buildings – industrial – utility – outdoor enclosed or unenclosed, or both – indoor enclosed or unenclosed, or both – underground	V-L: ≤ 1 000 V AC or ≤ 1 500 V DC V-H: >1 000 V AC or > 1 500 V DC

[a] Annex A gives a short description of the main risks of different mechanical, electrochemical and chemical storage technologies. Some EESS can be a combination of the different types of technologies in one system as a type of hybrid system.

6.2 Description of storage conditions

6.2.1 Types of grids, applications and locations

Refer to Table 1 for types of grids, for EESS applications and locations that will impact the risk assessment.

6.2.2 Vulnerable elements

To assess the severity of a potential accident or incident, it is essential to clearly identify the elements of the environment that could be affected. Generally, the following elements shall be considered:

- people (e.g. site staff concerned, resident populations or people working around the site, including number, time of presence, distance from the plant and type of persons and their limitations);
- facilities and equipment not directly in the field of study;
- essential safety equipment;
- devices relying on the EESS;
- properties and structures;
- natural environment (e.g. groundwater, rivers, soil, atmosphere, wind direction, seismic levels, lightning levels, and altitude).

6.2.3 Special provisions for EES systems in generally accessible locations

The design of the EESS shall ensure that unauthorized persons (e.g. general public) cannot access any dangerous parts or system controls.

EESS connected to residential grids or in applications where there can be vehicle access shall be provided with protection to prevent damage from inadvertent impact from vehicles, such as located in garages or near roadways.

If EESS are located within residences, local planning and building code criteria can apply for EES systems.

Use of EES systems in residential grids can limit some technologies, where hazards cannot be sufficiently mitigated in a residential setting.

6.2.4 Sources of external aggression

Some sources of aggression shall be identified:

- on site sources: other facilities and hazardous equipment, vehicles and other moving objects, work, utility losses, malicious acts;
- natural sources: extreme weather conditions (frost, wind, snow, fog, etc), landslides and earthquakes, lightning, flooding with fresh or salt water, and damage from vermin.

6.2.5 Unattended operation

An EESS designed for unattended operation can be exposed to a variety of external aggressions and internal trouble during its use. In such operating conditions, it is possible that potentially alerting signs of fault conditions such as unusual vibrations, sounds or odours generated from the EESS, cannot be detected on site due to lack of operating staff or nearby inhabitants. A remote monitoring system can send a fault signal to the operator control station. The operator takes the necessary actions remotely, and the operating signals are delivered to the system. Both the risks associated with wrong signals back and forth and the risks associated with human errors shall be considered.

6.2.6 Unintentional islanding

Unintentional islanding is an unwanted condition of part of the power system, with respect to which the grid connection rules normally specify protection measures. See Annex B for more information of unintentional islanding.

Unless designed for intentional islanding, measures shall be taken to prevent the islanding operation by detecting it directly or indirectly using the protection relay or other methods and swiftly disconnecting the EESS from the distributing network.

6.3 Risk analysis

6.3.1 General

During the risk assessment, the impact of the hazards shall be considered for all stages of the life cycle (design and planning, transport, installation, commissioning, operation, maintenance and repair, and end of service life and decommissioning).

Furthermore, the total energy stored in the EESS and the potentially exposed population in the area shall be considered.

6.3.2 Components

All EESS components such as power conversion subsystems, generators, hydro turbines and pumps, energy storage devices (battery, flywheel, etc.), transformers, system controllers, breakers, fuses, wiring, filters, tanks, pipes, blowers, control power sources, etc., shall be designed, manufactured and tested based on relevant standards for their safety compliance and used within their specifications. See Annex D for a list of potential EESS component safety standards. The connections between components, such as main circuit connections, control signal wiring, communication signal wiring, pipes, control power lines, fasteners to buildings, trenches, etc., shall be suitable for use in the EESS and reliably secured to prevent loosening or disconnection and potential hazards due to loosening or disconnection over the life of the EESS.

The combination of EESS components shall not be assumed as safe when installed in the system, and therefore a risk assessment due to the integration of the various components is necessary. In particular, the risk of incompatibility of some components resulting from the integration shall be assessed by appropriate risk assessment methods.

Hybridization of EES combining several energy storage subsystems shall be given special consideration regarding their safe operation. All energy storage subsystems shall be analysed under all operating conditions (e.g.: the 'stand-by' status of one subsystem of such an EES shall not preclude any state-of-safety consideration and safety-focused monitoring of this stand-by subsystem.)

6.3.3 Risk considerations

6.3.3.1 General

The risk assessment of the EESS shall include, but not be limited to, the risk considerations in 6.3.3.2 to 6.3.3.9. Provisions to reduce these risks are given in Clause 7.

Significant failure of some EES systems can result in fire, explosion, or hazardous chemicals release. In addition, shrapnel could be expelled during an explosion. Such hazards can cause serious injury or death. Consideration of these serious hazard risks is necessary for the appropriate design of the EESS. The EESS risk assessment shall review these hazards.

6.3.3.2 Insufficient safety policies

Safety policies shall be in place to minimize hazards due to foreseeable human error, improper design or installation, insufficient inspection or maintenance, and inadequate training and signage. The EESS risk assessment shall review these hazards.

6.3.3.3 Ineffective warnings, protection mechanisms and procedures for incident response

Ineffective warnings, protection mechanisms and procedures for extinguishing fires, ineffective evacuation plans, route and procedures can magnify fire, explosion and chemical hazards and risks. The EESS risk assessment shall review for these hazards.

6.3.3.4 Ineffective access control

Ineffective access control or lack of access control or unsafe access provisions (e.g. lack of space for maintenance operations), inadequate design, size of emergency exits or other shortcomings of protection can trigger special causes of hazards. The EESS risk assessment shall review these hazards.

6.3.3.5 Ineffective protection coordination

Ineffective protection coordination can possibly cause a fire or electric hazards. For example, when the protection device cannot interrupt high current in case of accidental short circuit, some parts of the system can become overheated and fire can result. The EESS risk assessment shall review these hazards.

6.3.3.6 Ineffective malfunction detection

The absence or ineffective operation of malfunction detection can give rise to electrical hazards, mechanical hazards, explosion, fire, etc. For example, when an electrical fault gives rise to leakage or earth fault current and is not detected, electric shock hazards can result. When the malfunction is not detected, the EESS might be operable beyond the safety limit. Explosion or fire can result. The EESS risk assessment shall review these hazards, at the level of their elementary subsystem and overall operation.

6.3.3.7 System control malfunction

System control malfunction and operation beyond the safety limit of the EESS can cause electrical hazards, mechanical hazards, explosion, fire, etc. System control malfunction and operation beyond the safety limits of the EESS can possibly be caused by lost external communication, communication lost between equipment, short or open circuiting of the control signal line, control signal error, malfunction of equipment, control power lost, etc. When large amounts of energy, material or chemical quantities, stored in the EESS are released, an explosion, fire, dispersion of chemicals, flooding or other severe damage can result. The EESS risk assessment shall review these hazards.

6.3.3.8 Auxiliary subsystem malfunction

Auxiliary subsystem malfunctions can cause various hazards such as temperature hazards, chemical hazards, explosion hazards and fire hazards. For example, an air conditioner malfunction can cause the operating temperature of some components to be exceeded. A ventilation malfunction can cause chemical poisoning or a combustible concentration. The EESS risk assessment shall review these hazards.

6.3.3.9 Improper working environment, conditions, and equipment

Improper working environment, conditions and equipment can cause many hazards. The EESS shall be designed and constructed to ensure that it is suitable for the environment in which it is to be used. Factors such as humidity, temperature, altitudes, and flooding amongst many others shall be addressed in the design criteria. The EESS risk assessment shall review these hazards.

6.3.4 System level risk analysis

6.3.4.1 General

One key action to keep an EESS safe is to use analysis techniques for system reliability such as the procedures outlined in IEC/ISO 31010.

The result of risk analysis shall be documented and the study shall be kept available for the organizations responsible for operating, monitoring and supervising the EESS. The risk analysis shall identify those components and parts of the system that provide a safety function. Where there is reliance on electric, electronic and software controls for critical safety, these controls shall be subjected to analysis for functional safety. One of the following standards as applicable to the system, shall be used for this analysis:

- IEC 61508 series,
- IEC 61511 series,
- ISO 13849 series,

- IEC 60730-1: 2020, Annex H,
- IEC 62061, or
- other suitable functional safety standard for the application shall be used.

6.3.4.2 Cyber security

As part of the risk analysis, cyber security shall be a focal point, including risks associated with communication lines.

7 Requirements necessary to reduce risks

7.1 General measures to reduce risks

As a result of the system level risk analysis, the necessary prevention and protection measures shall be taken to prevent accidents and limit their consequences. This means that for all the scenarios for which the probability or the severity of consequences, or both, leads to an intolerable risk, measures of risk reduction shall be proposed in accordance with Figure 2 using the methods in accordance with Clause 6.

The manufacturer shall determine the specific risk methodologies for the analysis type used and how they meet the criteria. Persons involved with conducting the risk analysis shall have the necessary competence to conduct the analysis.

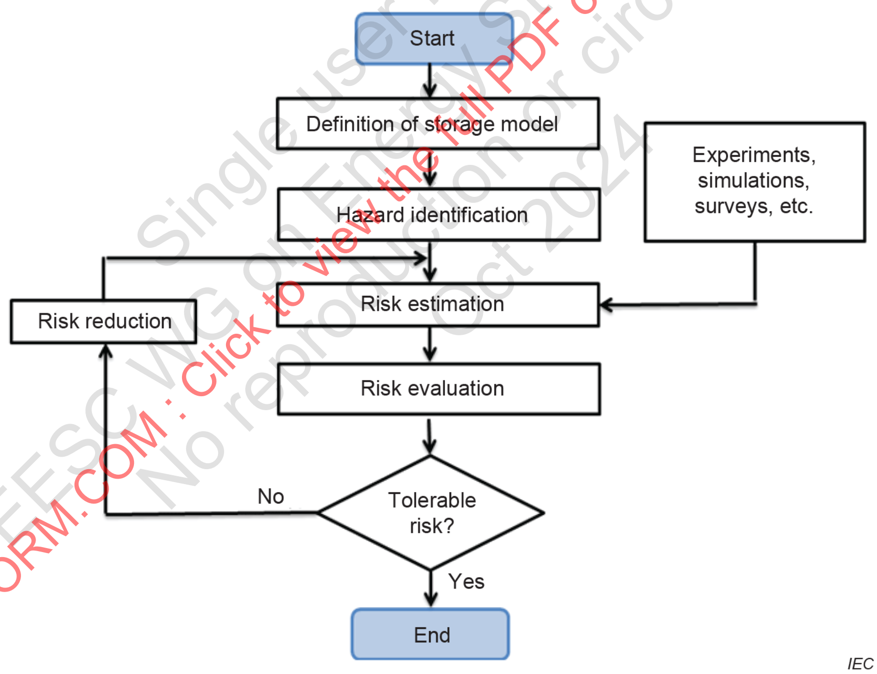

Figure 2 – Iterative checking sequence in general risk assessment procedures

The scenarios considered in the risk analysis shall include catastrophic external effects on the system from both severe natural disasters and negative social or human impact. Natural disasters include all kinds of natural disasters, some of which are seasonal and some of which come with little forewarning such as an earthquake, flooding and a tsunami. Negative social or human impact includes human errors, sabotage by person(s), social turmoil, terrorism and cyberattacks.

Preventive measures to be used depend on the location of the system, but measures shall be identified even for rare external events that can have significant impact on the EESS. Preventive measures to be identified here are the measures to avoid the impact, to minimize the system damage and to mitigate catastrophic system damage.

In spite of the preventive measures, partial damage can take place, and measures to suppress the propagation of the damage shall be immediately taken. Proven firefighting, internal propagation reduction means, emergency fire extinguishers and emergency shutdown are also part of this prevention. Further call-up of the emergency incident responders is included depending upon the level of damage.

Figure 3 indicates general risk reduction measures for an EESS. When a hazardous incident occurs, measures to control the propagation of the damage shall be considered in the layers of prevention and mitigation. Additionally, plant emergency response procedures and area emergency response procedures shall be planned and prepared in advance to minimize the magnitude of the hazard.

Figure 4 indicates damage propagation from an incident to hazards, and layered measures to minimize damage. A minor incident such as external impact, hardware or software and system malfunction, and reasonably foreseeable misuse, can cause partial damage to the system. If the partial damage propagates to a wider area of the system, a more severe accident can happen. The necessity of layered measures to control the damage propagation shall be considered apart from the normal control and monitoring.

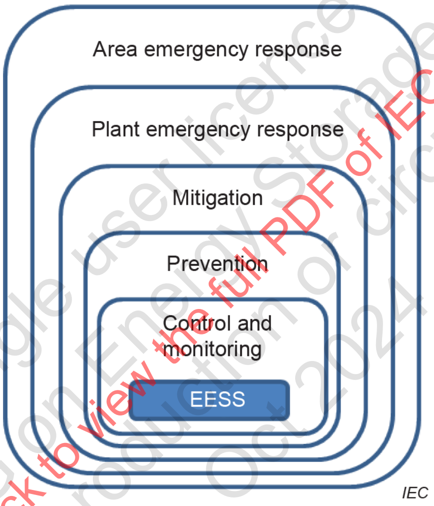

Figure 3 – General risk reduction measures to minimize hazards

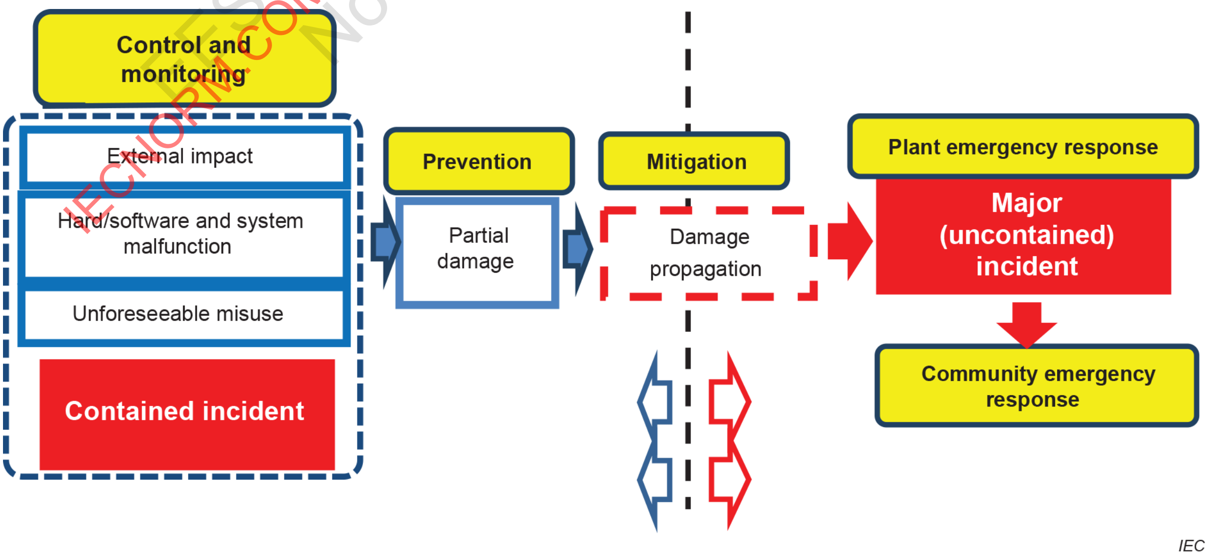

Figure 4 – Damage propagation from a contained incident to a major incident, and layered measures to minimize damage

7.2 Preventive measures against damage to neighbouring inhabitants

Attention shall be paid to accidental phenomena causing a major incident likely to affect neighbouring inhabitants and environment. The detailed credible events shall be identified, documented and mitigation methods shall be provided in the emergency response plan. Examples of major incident can be emission of dangerous substances (e.g. chemicals, gas, heat), fire, explosion, flooding, etc., of a magnitude outside the normal operational capabilities of establishment safety staff.

Operators, installers, maintenance technicians and others responsible for the EESS shall have a suitable plan based upon the risk analysis of Clause 6 to take all necessary measures to prevent major incidents, to mitigate their consequences and to take recovery measures. The plan shall include information on hazards and mitigation methods applicable to the EESS technology to inform the emergency response plan for the installation site. Any local regulation or code criteria can be taken into consideration when developing the plan.

When the risk assessment concerning fire, explosion, flooding or toxic substance discharge shows an intolerable occurrence possibility, the EESS shall have a safety-related system (SRS) in accordance with IEC 61508 (all parts) or other functional safety standard approaches in accordance with 6.3.4.1, to decrease the hazard risk to tolerable levels.

7.3 Safety-related design review

7.3.1 General

EES systems are expected to operate for a given life expectancy provided that they are properly maintained. During this life expectancy, the operation of the EESS is likely to be affected by a variety of factors, such as but not limited to:

- component technology changes;
- local environmental factors;
- market conditions;
- new regulations.

The effect of these factors on the EESS shall not compromise its safe operation. For this to be achieved, a safety-related design review shall be carried out when changes occur. It can also be necessary to review the design of the EESS and therefore the risk analysis and assessment of the EESS if other information becomes available, such as:

– operational experience;
– component failure;
– software failure;
– inherent design issues.

Figure 5 shows this process over the lifetime of the EESS.

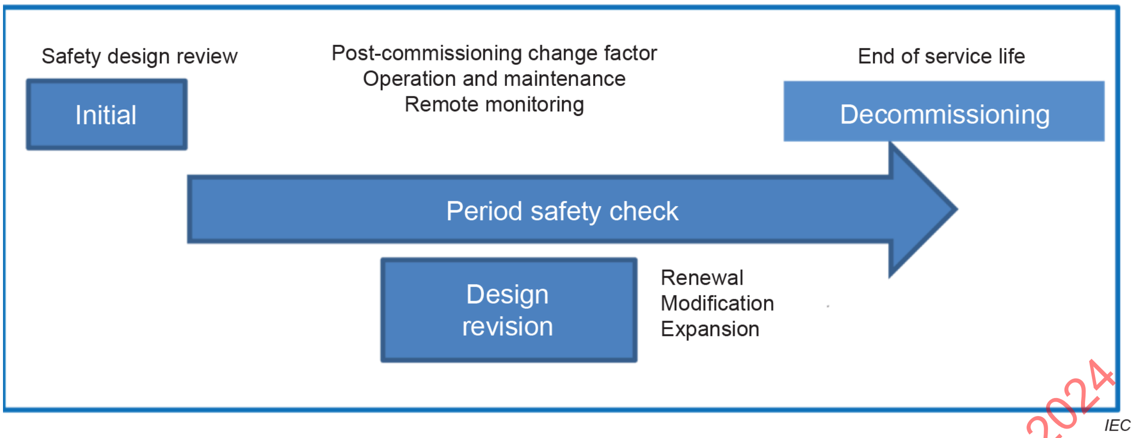

Figure 5 – Initial safety design review and design revision

7.3.2 Initial safety design review

Safety design review is first done at the beginning of the whole system design. The initial safety design review is based upon the risk assessment and is concluded when the system has been determined to meet the appropriate levels of safety.

The safety design review shall be repeated periodically over the EESS life as determined by the risk assessment and other factors such as the examples noted in 7.3.1.

7.3.3 Subsequent design revisions

7.3.3.1 General

If the system undergoes a variety of changes, then, when necessary, a safety design review shall be conducted again. During the safety redesign, the risk analysis (e.g. FMEA) shall be conducted again.

7.3.3.2 Design revision for minor and major system changes

When the system undergoes minor changes, a risk analysis with a limited FMEA can be more practical. When a major change takes place, for example a total storage capacity expansion (e.g. BESS) or major changes in the surrounding environment, not only the whole system but also the boundary region between the system and the surrounding environment shall be taken into account when conducting the risk analysis.

7.4 Preventive measures against damage to workers and other persons at risk

7.4.1 Protection from electrical hazards

7.4.1.1 General electrical safety

Depending upon the system design, the manufacturer shall identify the applicable electrical standards that apply to their system. Standards to address electrical safety design are:

- EES systems that are V-L in accordance with Table 1: the electrical safety approach shall be in accordance with either the relevant parts of IEC 60364 series or IEC 60204-1; or
- EES systems that are V-H in accordance with Table 1: the electrical safety approach shall be in accordance with IEC 61936-1 or IEC TS 61936−2 or IEC 60204-11.

7.4.1.2 Accessibility to hazardous live parts

All sources of electrical energy in the EESS shall be controlled in such a way as to minimize human exposure to electrical hazards and prevent access to the EESS by fauna and flora. Live parts of EES systems that have hazardous voltage circuits shall be guarded against accidental contact by an enclosure or by other means such as fencing or guarding, to prevent inadvertent access to the live parts in accordance with IPXXB or IP2X of IEC 60529.

Interlocks, when used to protect against hazardous voltage circuits, shall comply with the requirements for interlocks outlined in IEC 60204-1 and switches utilized for that purpose shall comply with IEC 60947-5-1.

The EES and associated electrical equipment that is likely to require examination, adjustment, servicing, or maintenance while energised shall be designed to minimise the risk of electric shock or electrical burn injury. In circumstances where it is impractical to prevent access to dangerous live parts, warning notices shall be fixed to warn qualified persons of the hazards.

Compliance is checked by the test of 8.2.2.

7.4.1.3 Protection from exposure to moisture and pollution

Electrical components and circuits impacting safety (i.e. above SELV/PELV voltage levels and other circuits impacting safety) shall be protected from ingress and exposure to moisture and pollution driven contamination. When electrical wiring and components are exposed to excessive moisture, they can become damaged due to mildew or corrosion, and electrical creepage and clearance distances can be reduced to unsafe levels. This damage can result in insulation or termination failures and can generate additional electrical hazards. Enclosures of electrical equipment and the electrical equipment that is not enclosed shall be suitable for the intended exposure in accordance with IEC 60529 or similar evaluation methods.

Compliance is checked by the test of 8.2.3.

7.4.1.4 Electrical insulation and protection against electrical shock

Electrical insulation shall be suitable for the voltages in the circuit and there shall be two levels of protection between hazardous voltage circuits and accessible parts (e.g., double insulation or reinforced insulation in accordance with IEC 60364-4-41). For those systems designated as V-L in Table 1, the creepage and clearance distances shall be in accordance with IEC 60664-1. The protection approach outlined in IEC 60364-4-41 shall be utilized for those systems designated as V-L in Table 1.

Exception: IEC 60204-1 can be used as an option for requirements for electrical insulation and protection against electrical shock for V-L EESS.

For those systems designated as V-H in Table 1, the creepage and clearance distances and electrical protection mechanisms outlined in IEC 61936-1 or IEC TS 61936-2 shall be utilized as applicable.

Exception: IEC 60204-11 can be used as an option for requirements for electrical insulation and protection against electrical shock for V-H EESS.

Preventive measures for electrical hazards shall consider the following:

- earth fault detection (e.g. IEC 62689-2);
- over voltage detection (e.g. IEC 60730-1, IEC 61439-1);
- over voltage protection (e.g. IEC 60730-1);
- over current detection (e.g. IEC 60730-1);

- over or under temperature detection or protection (e.g. IEC 60730-2-9);
- lightning protection (e.g. IEC 62305-2);
- electrostatic dissipation (e.g. IEC TR 61340-1); and
- overcurrent protection (e.g. IEC 60364-4-43).

To evaluate an EESS having suitable electrical insulation and protection against electrical shock, the following tests shall be conducted: dielectric voltage withstand, impulse, insulation resistance and a check of the earthing and bonding system.

Compliance shall be determined through a review of construction and the tests of 8.2.4.

7.4.1.5 Protection against out of normal operation range

An EESS shall be protected from working out of its normal operation range, including its working voltage, current and temperatures of each subsystem and whole system. Working out of normal operation range can lead to electric shock, fire or other hazards. Preventive measures shall consider the following as applicable to the EESS:

- over or under voltage detection (e.g. IEC 61439-1) and protection;
- over or under current detection (IEC 60730-1);
- overcurrent protection (e.g. IEC 60364-4-43);
- over or under temperature detection or protection (e.g. IEC 60730-2-9).

Over current protection design, which includes location, capacity and protection coordination, shall be determined by calculation considering the level of potential fault current, the current carrying capability of the conductors in the circuit under consideration, the operating current of the protective device and time to operate, and the location of the protective device in the circuit. The calculation(s) for validating the circuit's ability to safely withstand a fault current condition shall be documented and maintained. For this purpose, IEC 60364-4-43 shall be used for determining a suitable over current protection design.

Compliance shall be determined through a review of EESS construction and documentation of the analysis used to determine type, ratings and location of protective devices and testing in accordance with 8.2.5 to evaluate the suitability of all the protections.

7.4.1.6 Electrical components impacting safety

Electrical components that impact the safety of the EESS as identified in the risk analysis of Clause 6, shall comply with an applicable IEC safety standard for that component if a standard is available, and shall be suitable for the application and used within its ratings. Where a component standard is not available, the component shall be evaluated in accordance with the requirements of this document. See Annex D for guidance on potential component safety standards.

7.4.1.7 Unintentional islanding

EESS that operate in parallel with an electric utility system or grid can pose an unintentional islanding risk. Unintentional islanding protection and testing are required by most international grid codes and the EESS system shall comply with the grid code rules for the installation location. Two commonly used unintentional islanding test procedures are given in 8.2.6.

An unintentional islanding can result in system failure with corresponding consequences even in the case where the system is designed for islanding. When maintenance operations are planned, analysis of the electric isolation of the concerned parts of the grid shall be performed and documented before any intervention operation.

Compliance is checked by the test of 8.2.6.

7.4.2 Protection from mechanical hazards

The basic safeguard against mechanically caused injury is a function of the specific EESS. Basic safeguards can include:

- enclosure structural requirements (rounded edges and corners; enclosure to prevent a moving part from being accessible);
- safety interlock to control access to a moving part posing a risk of injury;
- means to stop the motion of a moving part;
- means to stabilize the equipment;
- robust handles;
- robust mounting means;
- means to contain parts expelled during explosion or mechanical failure.

When relying upon guards and protective devices to protect against moving parts hazards, the procedures outlined in ISO 12100:2010, 6.3.2 and 6.3.3, shall be utilized for determining the suitability of the protection. Guidance is provided in ISO 12100 on types of protection devices to be implemented (e.g. guards, light curtains, sensors, etc.). The choice as well as number of and location of safeguard(s) implemented to protect against moving parts hazards shall be determined as part of the risk analysis of the EESS. Interlocks to prevent access to hazardous parts shall comply with the requirements of ISO 12100 for hazardous moving parts and operate in accordance with the risk assessment. Switches used as interlocks for mechanical guards shall comply with IEC 60947-5-1.

If relying upon an EESS enclosure to prevent access to hazardous parts, the accessibility of the moving parts shall be checked by the appropriate access tool according to the IP rating of the enclosure.

Evaluation of mechanisms to protect against access to hazardous parts shall consist of a review of the construction and the tests in accordance with 8.3.

Handles or mounting means shall have sufficient strength to handle the weight they are supporting or carrying. Handles or mounting means robustness shall be tested in accordance with 8.3.4.

7.4.3 Protection from high pressure hazards

Pressure systems shall be designed to handle the level of pressure contained and be compliant with applicable regulations. Pressure vessels and piping shall be designed for the pressure and fluid they contain. The pressure systems shall be provided with pressure relief devices that prevent a hazardous over pressure condition.

Piping containing high pressure fluids shall comply with ISO 15649 or ASME B31.3 or ASME B31.1.

NOTE Fluids that are at pressures below 105 kPa (15 psi) are out of the scope of ISO 15649, ASME B31.3 and ASME B31.1. The scope of ISO 15649 and ASME B31.3 covers fluids in the temperature range of −29°C to 186°C. The scope of ASME B31.1 covers fluids at temperatures in excess of 250°C.

Parts or an assembly of parts under pressure shall be tested in accordance with 8.4. Parts such as pressure vessels that have already gone through evaluation for the intended pressures contained in accordance with the local or regional criteria, need not be tested.

7.4.4 Protection from explosive atmosphere hazards

The combination of an explosive atmosphere and an effective ignition source as a potential source of an explosion requires application of the basic principles of explosion prevention and protection in the following order:

a) Prevention:

- avoid or reduce explosive atmospheres; this objective can mainly be achieved by modifying either the concentration of the flammable substance to a value outside of the explosion range or the concentration of oxygen to a value below the limiting oxygen concentration (LOC);
- avoid any possible effective ignition source.

b) Protection:

- halting the explosion or limiting the range to a sufficient level through protection methods, for example isolation, venting, suppression and containment. In contrast to the two measures described in a), here the occurrence of an explosion is mitigated through suitable measures to reduce the risk.

NOTE NFPA 69 and NFPA 68 provide methods for prevention and protection against explosion hazards.

NFPA 69 is a standard that applies to the design, operation, maintenance and testing of systems to prevent explosion by the following prevention methods: control of oxidant concentration and control of combustible concentration. NFPA 69 also covers protection mechanisms such as pre-deflagration detection and control of ignition sources, explosion suppression, active isolation, passive isolation and deflagration pressure containment and passive explosion suppression.

NFPA 68 applies to the design, location, installation, maintenance, and use of explosion protection that vent the combustion gases and pressures resulting from a deflagration within an enclosure so that structural and mechanical damage is minimized.

The risk reduction can be achieved by applying one or more of the above prevention or protection principles. A combination of these principles can be applied.

The avoidance of an explosive atmosphere shall always be the first choice.

To allow selection of the appropriate measures, a risk reduction analysis in accordance with Clause 6 shall be developed for each individual case. Guidance on determining hazardous (classified) areas/zones to apply suitable protection means can be found in IEC 60079-10-1 and IEC 60079-10-2 as applicable. Equipment located within hazardous areas or zones shall be rated for the area or zone. IEC 60079-0 provides guidance on protection methods for equipment located in hazardous areas or zones. Maintenance procedures shall ensure that the protection after maintenance is suitable.

In the planning of explosion prevention and protection measures, consideration shall be given to the installation and commissioning process, and normal operation, which includes start-up and shut-down. Moreover, possible technical malfunctions as well as reasonably foreseeable misuse shall be taken into account. Application of explosion prevention and protection measures requires a thorough knowledge of the potential hazards. Persons conducting this analysis shall have relevant experience in this area and be qualified. Local regulations can apply.

If relying upon mechanical ventilation to eliminate or reduce hazardous (classified areas or zones) in the EESS, it shall be evaluated for suitability in accordance with 8.5.

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

EES systems shall be integrated with equipment that satisfies relevant IEC documents in 8.6 as applicable to the site of installation of the EESS so that they have sufficient immunity against electric, magnetic and electromagnetic disturbances to prevent hazards from arising, and they have electric, magnetic and electromagnetic emission as low as required for the application. The risk analysis shall set the performance criteria for the EES systems with regard to the EMC immunity. Local regulations can apply.

Sufficient EMC immunity of the components is confirmed in the single component EMC immunity testing, but it shall be considered that system interactions can amplify the magnetic and electromagnetic disturbances and can cause malfunction of individual components and communications between those components. In order to achieve essential safety, EESS protection controls shall be designed and tested in accordance with the applicable EMC standards listed in 8.6 considering the existence of EMC disturbances that can occur in the environment in which the EESS is located.

Protective measures from disturbance-induced malfunctions of the EESS shall be provided using suitable methods (see IEC 60364-4-44 for guidance).

Compliance is checked by the test of 8.6.

7.4.6 Protection from fire hazards

The basic safeguard against electrically-caused fire is that the temperature of a material, under both normal operating conditions and abnormal operating conditions, does not cause the material to ignite. The supplementary safeguard against electrically-caused fire reduces the likelihood of ignition or, in the case of ignition, reduces the likelihood of spread of fire.

Supplementary information is provided in IEC 60364-4-42 which deals with protection against thermal effects, including combustion and flames caused by electrical installations.

The following prevention and protection measures shall be considered to protect from fire hazards:

- The material of the enclosure of the system shall be noncombustible in accordance with ISO 1182. Local regulations can apply.

  NOTE ISO 1182 is a test where a material is exposed for a time period of 30 min to 60 min in a 750°C furnace to determine if the material is non-combustible. Combustible is defined in ISO 13943 as capable of combustion, which is an exothermic reaction of a substance with an oxidizing agent.

- Polymeric materials in direct support of hazardous live parts such as printed wiring boards and electrical insulation of terminals shall have a V-1 minimum flame rating in accordance with IEC 60695-11-10.
- The system shall eliminate or minimize the risk of overheating by analysing the process deviations which might lead to overheating and by testing.
- Where the possibility of a fire cannot be eliminated, the effects of that fire, including flames, heat and smoke, etc., shall be limited for example by shielding or enclosure of the storage to eliminate or minimize the risk of injury to persons, damage to property or the environment.
- Where the possibility of a fire cannot be eliminated, the effects of that fire, including flames, heat and smoke, etc., can be alternatively limited by appropriate use of integrated fire detection and firefighting systems (safety components), which comprise devices for the detection, control, alarm and extinguishing functions.
- Where the possibility of a fire cannot be limited inside the enclosure of an EESS, the potential fire area shall be covered by the firefighting system, and the protected area shall be isolated, for example, by an enclosure.

- Supplying comprehensive and understandable documentation to the users in order to ensure that they can keep the installations and the technical fire protection equipment in proper condition and ready for operation and, where necessary, initiating the required firefighting measures.

The level of fire detection and suppression required for an EESS is dependent upon the size, technology and location of the installation of the system as well as the quantity and geometry of hazardous substances. The protection can be as basic as instructions regarding the appropriate fire extinguishing materials to maintain within the location, installation instructions and basic housekeeping and safety procedures to follow, to installation of fire suppression systems at the location of installation of the EESS.

To determine the level and type of fire detection and fire suppression systems required, a fire risk assessment is to be conducted for EESS installations to ensure that suitable fire prevention and fire protection requirements for protecting persons, property and environment are met. Local codes and regulations can apply.

EESS installations required to be provided with fire suppression shall be provided with a means for fire detection and suppression in accordance with the siting of the system (i.e. indoors, etc.), the energy storage technology and the applicable installation, building and fire safety codes and regulations. If not provided as part of the EESS, guidance for choosing and installing suitable fire detection and suppression systems shall be provided in the installation and maintenance instructions for the EESS.

Fire propagation hazards test for EESS in given in 8.7.

7.4.7 Protection from thermal hazards

7.4.7.1 Protection from exposure to temperature hazards

In a system which contains hot parts (> 70 °C for metallic materials and > 95 °C for non-metallic materials), thermal insulation or appropriate protection means to guard the hot parts shall be provided.

In addition, in a system which contains extreme cold parts (≤ −10 °C for metallic materials and ≤ −25 °C for non-metallic materials), thermal insulation or appropriate protection means to guard the cold parts shall also be provided.

For some EESS designs, if the system deviates from normal operation, parts of the system can undergo a temperature rise above normal for those parts. Such parts are to be identified in the risk analysis of the system in accordance with Clause 6. Protection or appropriate signage, or both, shall be provided.

Temperature rise due to deviation from normal operation is to be continuously monitored by thermal sensors, and alarms for worker safety are to be provided according to the level of hazard to the worker as determined by the risk analysis of Clause 6. Leakage of high temperature liquids shall also be prevented through use of leak tight containment measures, routing of piping to prevent hazards and leak detection measures to sound an alarm when a leak of high temperature fluid occurs.

7.4.7.2 Protection of temperature sensitive parts

As part of the risk analysis of Clause 6, the thermal stability of EESS parts and materials that can impact safety if they deteriorate from temperature exposures shall be considered. The identified parts and materials that can impact safety in accordance with the risk assessment shall be resistant to deterioration as a result of the temperature exposure during operation. Determination of the suitability of parts and materials for use in the EESS shall be determined by the test in 8.8.

If determined according to the risk analysis of Clause 6, an EESS shall be provided with a heating, ventilation and air conditioning (HVAC) system or equivalent to maintain temperature sensitive parts within their limits. Ventilation openings shall not be blocked by other components or parts.

7.4.8 Protection from chemical hazards

The risk analysis of Clause 6 shall consider the potential for hazardous chemical effects from the EESS that contain hazardous substances. EES systems shall not vent or leak hazardous or toxic materials within access areas of the EESS or into the surrounding environment. Local codes and regulations can apply.

The basic safeguard against injury caused by hazardous substances is containment of the material.

Supplementary safeguards against injury caused by hazardous substances can include:

- a second container or a spill-resistant container with sufficient capacity to store the fluid within the EESS;
- containment trays;
- tamper-proof screws to prevent unauthorized access;
- instructional safeguards;
- sensors and alarms; and
- material resistance to chemicals contained.

If determined necessary by the risk assessment, provisions are to be provided for liquid leakage detection, toxic gas detection and spill detection.

Piping containing hazardous fluids shall comply with ISO 15649 or ASME B31.3.

NOTE Fluids that are at pressures below 105 kPa (15 psi) and that are not flammable or toxic are out of the scope of ISO 15649 and ASME B31.3.

If the possibility of toxic gas discharge exists, measures to prevent toxic gas accumulation shall be implemented. Toxic gas accumulation measures shall consider the topography around the EESS for outdoor installations, the building design for indoor installations as well as the physical characteristics of the gas.

Toxic gas detection and alarms can be used as part of these protection measures. See IEC 62990-2 for guidance on toxic gas detection.

Also, appropriate PPE shall be available to persons in the area in the event of a toxic gas discharge. Eye wash stations and emergency shower facilities shall be provided for staff in the case of a toxic release.

See IEC 62933-5-2 for BESS considerations regarding toxic gas safety considerations.

A compliance test to determine the suitability of parts containing hazardous fluids is given in 8.9.

7.4.9 Protection from workplace hazards

7.4.9.1 Remote controls and automatic controls

EES systems which have the ability to be controlled remotely shall be provided with a means to disable the remote control in order to perform inspection or maintenance. The use of a remote control system shall not lead to an unsafe condition as determined by the system hazard analysis and shall not be able to override local safety controls. The same requirements apply for local automatic controls without human intervention, in response to the occurrence of predetermined conditions.

NOTE There can still be the need for remote monitoring, even though the remote control ability is disabled.

7.4.9.2 Working space

Sufficient working space for EES systems and equipment likely to require examination, adjustment, servicing, or maintenance while energized shall be provided. Local codes and regulations can apply. Sufficient space shall be provided and maintained around EES systems to permit ready and safe operation and maintenance of such equipment.

NOTE NFPA 70, National Electrical Code (NEC) is an example of a regional code that provides criteria for minimum electrical working space based upon voltage levels that are required in the USA. NFPA 70E provides guidance on safety for live electrical work to provide electric shock and arc flash hazard protection procedures for technicians doing maintenance on live electrical equipment.

7.4.9.3 Egress and protection from physical hazards

EES systems that are located indoors or are located outdoors in a walk-in type enclosure shall be provided with at least one entrance of sufficient size to give access to and egress from the working space in the system. Local codes and regulations can apply.

Doors provided for egress from EES systems shall open in the direction of egress and be equipped with panic bars, pressure plates, or other devices that are normally latched but open under simple pressure from the inside. Doors shall be equipped with locks to prevent access by unqualified persons. The doors for entrance to and egress from EES systems shall also be in accordance with IEC 60204-1.

Entrances to EES systems or installation areas shall be restricted to authorized person and marked with warning signs forbidding unqualified persons to enter.

Areas of access within the walk-in type EESS shall be designed to prevent tripping, slipping or falling when persons enter or exit, or while within the system.

7.4.9.4 Ventilation

EES systems that are installed indoors, and enclosures associated with self-contained EES systems that can be fully entered by persons shall have adequate ventilation for persons working on the indoor EESS or within an EESS. Local regulations can apply.

7.4.9.5 Task lighting within EES systems

Illumination shall be provided for all working spaces within EES systems. The lighting outlets shall be arranged so that persons changing lamps or making repairs on the lighting system are not endangered by live parts or other equipment. See IEC 60204-1 for guidance on lighting for electrical equipment.

Emergency lighting and signage can be subjected to local regulations.

7.4.10 Staff training

Well-trained workers greatly increase safety at work. Any deviation from the desired process can be detected, and hence corrected, more quickly.

Workers shall be provided with training which informs them of the hazards at the workplace and the protective measures to be taken. This training shall explain how the different types of hazards arise and in what parts of the workplace they are present. The measures taken shall be listed and their operation explained. The correct way of working with the available equipment shall be explained. Workers shall be instructed in safe work practices in or near hazardous places. This also involves explaining the meaning of any cautionary markings or markings of hazardous places and specifying what mobile work equipment can be used there. Workers shall also be instructed in what PPE they shall wear to work in and around the EESS. The available operating instructions shall be covered during the training. See 9.3.1 for additional information on operating instructions.

Workers shall receive training:

- before initially starting work on the EESS;
- when work equipment is introduced for the first time or changed;
- when new technology is introduced.

Training of workers shall be repeated at suitable intervals. The workers' level of understanding shall be checked.

The duty to provide training also applies to the employees of outside contractors. Training shall be given by a competent person. Records shall be kept in writing of the date and content of training activities and the participants.

7.5 EESS disconnection and shutdown

7.5.1 General

Disconnection and shutdown procedures are important for ensuring safety during operation, routine maintenance or fault repair. They will depend on the design of the EESS, the technologies employed (see Figure 7), its size and the reason for the disconnection and shutdown. The EESS shall be capable of being disconnected partially or totally to reflect the likely operation, routine maintenance and credible fault repair activities required. Emergency shutdown shall also be provided and shall be in accordance with 7.5.4 and 7.5.6.

The main circumstances that can require conditions leading to the disconnection of the EESS or of some of its components are:

- regular maintenance;
- subsystem or component malfunction, or both;
- external constraints;
- system upgrades;
- end of service life.

Disconnection or partial disconnection can be achieved at different parts of the EESS:

– point of connection to the grid;
– AC facility including transformer;
– switching device (SW);
– power conversion subsystem;
– alternator;

– storage subsystem;
– auxiliary subsystem;
– smaller parts in subsystems.

Where the EESS has high energy levels or high stored energy, special precautions can be required as determined by the risk analysis of Clause 6. The disconnection or shutdown procedure shall not lead to the EESS becoming unsafe.

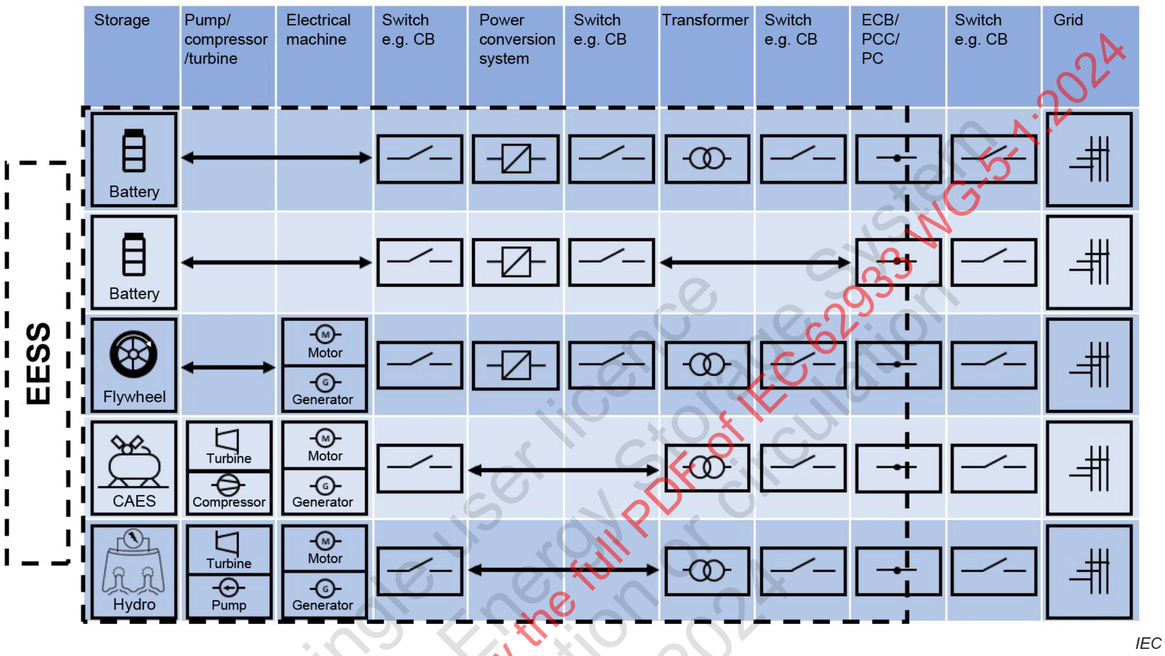

Figure 6 – Examples of different EESS architectures

As is shown in Figure 7, switching devices (SWs) are positioned differently for each technology. A detailed sequence of SW opening depends on the technology.

7.5.2 Grid-disconnected state

In the grid-disconnected state, the EESS will be electrically separated from the local grid connection. An EESS shall be provided with a disconnection means that disconnects the unearthed conductors between the EES primary subsystem and the primary point of connection with the grid. If not installed on the EESS, information on the disconnect shall be provided in the installation instructions to indicate:

- the type and rating of the disconnection means,
- that the disconnecting means shall be located where it is accessible and in sight of the EESS, and
- that the disconnecting means shall be provided with markings or signage to identify
  – the EESS output voltage ratings, and
  – the available short circuit current.

7.5.3 Stopped state

When the EESS is disconnected and the accumulation subsystem is not connected to the power conversion subsystem, the EESS is considered to be in a stopped state. In this state the accumulation system can be energized and cannot generally be de-energized without serious damage. In the stopped state, part of the auxiliary subsystem remains powered as it contains critical subsystems for safety and monitoring.

7.5.4 EESS shutdown

EESS shutdown is the command to move the EESS to the stopped state.

As determined by the risk analysis of the system in accordance with Clause 6, an EESS shall be provided with a means for both normal and emergency shutdown.

Conditions that can be safely controlled or that do not pose immediate hazard can be corrected with a normal shutdown of the EESS.

When voltage, current, temperature, pressure, or rotational speed, etc., exceed a safety limit, a hazardous event can occur. It can be the result of the malfunction of a system component or communication error, for example. Abnormal operating conditions that can give rise to a hazardous event shall be identified and processed to initiate an emergency shutdown. When actuated, the EESS is expected to return to a safe condition. The EESS shutdown function including the emergency stop, shall be provided with the means to enable the coordinated shutdown of all necessary parts of the system as well as with equipment upstream or downstream of the system, if continued operation can be hazardous.

An EESS is disconnected by appropriate switching device(s) or other alternative measures.

7.5.5 Partial disconnection

The design of the EESS can permit disconnection of the constituent parts of the EESS separately if appropriate as determined by the risk assessment of Clause 6. For those working on the EESS, it can be possible to disconnect only the parts to be worked on to permit safe access. However, consideration shall be given to risks posed by individual systems adjacent to those being worked on. In the case of appropriately designed multiple accumulation subsystems, individual subsystems can be disconnected for safe working while the EESS can remain operational.

For certain EES systems where it is difficult to de-energize the accumulation subsystem (e.g. battery energy storage systems), hazards shall be minimized in the system design.

NOTE In the case of a flywheel accumulator, it can stop by providing energy to the grid or to other units in the system. This procedure will contribute to minimizing the time that the system is in a hazardous situation.

7.5.6 Equipment guidelines for emergency shutdown

Emergency shutdown shall be incorporated into an EES storage system to avoid hazardous situations that cannot be corrected by other controls, as determined by a risk analysis of the system. This function shall:

– stop the hazardous condition without creating additional hazards,
– trigger or permit the triggering of certain safeguard actions where necessary,
– override those functions and operations as determined necessary by the risk analysis,
– be fitted with restart lock-outs to prevent an inadvertent restart,
– be on normal operation only after the restart lock-outs have been intentionally reset.

Manual emergency stops, if required by the risk analysis, shall be identifiable, clearly visible and accessible in accordance with ISO 13850. Local regulation can apply.

In case of a fault in the control system logic or failure of, or damage to, the control system hardware, the following system requirements shall be met:

- once the emergency stop command has been given, the EESS shall not allow its shutdown sequence to be interrupted,
- the protection devices shall remain fully effective,
- the EESS shall not re-connect or restart unexpectedly.

When a protective device or interlock causes an EESS safety shutdown, that condition shall be signaled to the logic of the control system. The activation and the reset of the shutdown function shall not initiate any hazardous condition as determined by a risk analysis of the system and the fault condition tests of Clause 8. Control or monitoring systems that can operate safely in the hazardous situation can be left energized to provide system information.

7.6 Cyber security

Cyber security is important not only for remote monitoring and control but also for the system connected to the internet. The IEC 62443 series provides guidance and criteria for cyber security.

Industrial or utility scale EESS that are connected to the internet shall be provided with protection against cyber-attack in accordance with IEC 62443-3-3 or an equivalent standard. The level of protection against cyber-attack shall be determined in accordance with the risk assessment.

7.7 Remote monitoring and unattended operation

In order to efficiently perform preventive maintenance, it is crucial to monitor the system regularly and it is in most cases done remotely. Monitoring of the frequency of warnings of EESS parameters such as system efficiency or temperature could be an early indicator of malfunction of a subsystem or components.

Remote monitoring system implementation shall be considered in order to check if the system is operating safely. The data provided automatically by the EESS or through an EESS inquiry can help to evaluate its state of health and the remaining life of its components. Diagnosis is performed by monitoring the change of capacity (e.g. BESS) or changes in the evolution of measured parameters. This data can be transmitted through an information network in a timely manner.

In the case of remote monitoring, reliability of the monitored value is essential to keep the EESS safe. Detection of the measuring system malfunction and measured value error shall be considered.

For unattended operation, the EESS shall be capable of monitoring and detecting abnormal conditions and automatically entering a safe state without the need for operator interaction.

Preventive maintenance schemes to prevent unanticipated conditions are also important for remotely monitored and controlled systems.

The test to determine the reliability of remote monitoring is given in 8.11.

8 System testing

8.1 General

In order to confirm the EESS design and the proper implementation and functionality of the safety mechanisms identified in the risk analysis, the system response to potential failure conditions shall be evaluated. Verification and validation of items shall be determined based on the system level safety analysis in accordance with Clause 6.

In addition, the EESS shall have a safety-related system (SRS) evaluated to an appropriate functional safety standard in accordance with 6.3.4.1.

NOTE 1 The EESS components can be designed, verified and validated based on other IEC standards, for example, a lithium-ion battery energy storage system can satisfy IEC 62619, but it is considered that risks can be induced due to the system integration. Refer to 6.3 for system level risk analysis.

The system components used for integration and any communication malfunction shall not affect the safety at the system level.

NOTE 2 The various components within the system can impact each other. For example, electromagnetic noise induced by the power conversion system can cause the malfunction of the energy storage management central processing unit (CPU) and affect the energy storage device operation. The noise tolerance of the EESS components can satisfy IEC 61000 (all parts), but there is some possibility that one of the system components can fail because of the noise induced by the power conversion subsystem. Additionally, the accidental malfunction of the components can also occur.

The EESS includes primary, auxiliary and control subsystems as shown in Figure 7. Each subsystem contains various components. Also, internal communication lines between those components, monitoring lines and control signal lines exist in the EESS.

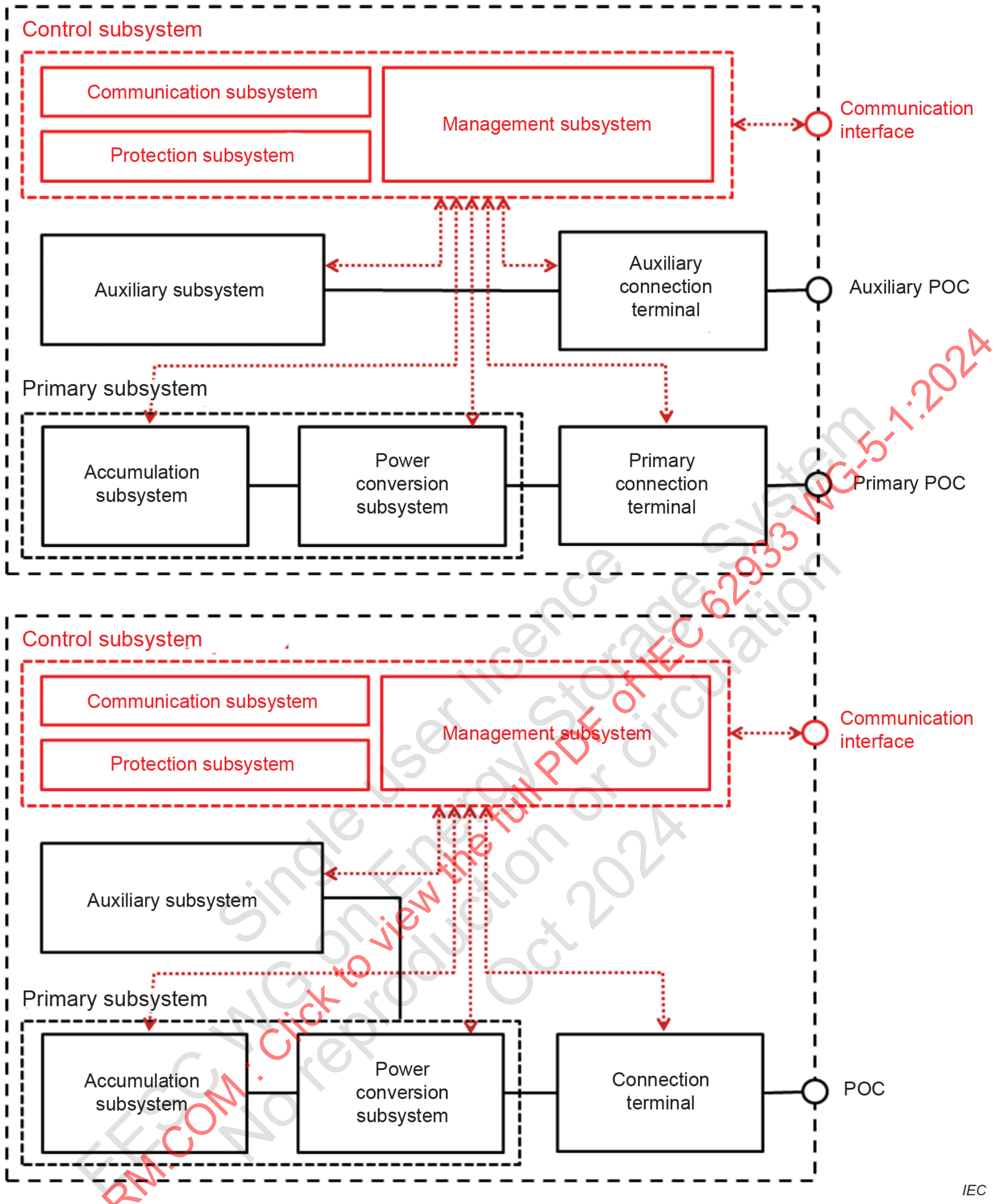

Figure 7 – EESS architecture in the two main EESS configurations

Test equipment, facilities or the on-site test environment shall be appropriate for test purposes, possible test results, sample size and performance.

Appropriate PPE, standard operating procedures and facilities to protect personnel during testing shall be provided.

Standard procedures for the safe storage, handling, operating, testing and disposal of test samples shall be provided.

Samples used for testing shall be representative of production samples. Testing can be conducted on subassemblies if demonstrated to be representative of the complete EESS to satisfy particular test purposes.

The possibility to do the testing at full scale of the EESS shall be investigated. In case it is proven not feasible, testing shall be conducted at subassemblies level, or through technical assessment, simulation or calculation.

Unless otherwise noted in the test methods, the testing is conducted at ambient temperature conditions in the range specified for the EESS. The ambient conditions during testing shall be measured and documented for each test.

Ultimate conditions are considered to have occurred when either protection mechanisms identified in the risk analysis operate as intended to bring the system to a safe state or noncompliant conditions identified for the specific test method occur.

8.2 Validation and testing of EESS – Electrical hazards

8.2.1 General

Electrochemical EESS (BESS) shall be tested for electrical hazards in accordance with IEC 62933-5-2.

For EES systems that are designated as V-H, the electrical safety approach shall be protected in accordance with IEC 61936-1 or IEC 61936−2 or IEC 60204-11 for electrical hazards. Any tests that are required for V-H ESS systems shall be overseen by competent person familiar with the system design.

8.2.2 Accessibility to hazardous live parts

a) Purpose:

The EESS shall be designed to prevent direct access to hazardous live parts.

NOTE Hazardous live parts are those that are at voltages above the limits for PELV or SELV as defined in IEC 60364-4-41.

Electrochemical EESS (BESS) shall be evaluated in accordance with IEC 62933-5-2 for access to energized parts.

b) Requirement:

There shall be no access to hazardous live parts in accordance with 7.4.1.2 and IEC 60529 as a result of the applied protection method.

c) Method:

The effectiveness of the safeguards used to prevent user access to the live parts shall be tested in accordance with the protection provided by the enclosure requirements for IPXXB or IP2X in accordance with IEC 60529 to prevent access to hazardous live parts.

8.2.3 Protection from exposure to moisture and pollution

a) Purpose:

This test is intended to evaluate the suitability of enclosures specified to prevent ingress of moisture that can impact safety as indicated by the planned installation (e.g. outdoor use).

It is also intended to address ingress of pollution in the form of dust if specified in the EESS installation.

Electrochemical EESS (BESS) shall be evaluated in accordance with IEC 62933-5-2 for ingress.

b) Requirement:

The enclosure shall comply with the specified IP rating for ingress of moisture for the EESS as noted in 7.4.1.3. There shall be no wetting of live parts or evidence of dielectric breakdown.

c) Method:

The EESS enclosures shall comply with their IP rating for ingress of moisture and pollution in accordance with IEC 60529. At the conclusion of the exposure, the system shall be subjected to a dielectric voltage withstand test of 8.2.4.2 and examined for ingress of moisture or pollution that can create a hazard.

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

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

There are two exceptions:

- Exception 1: Another method for evaluating ingress of moisture and dust pollution can be used (e.g. NEMA type rating) if specified for the enclosure.
- Exception 2: An EESS enclosure that has been tested and rated for ingress of moisture in accordance with the manufacturer and installation specifications need not be tested.

8.2.4 Electrical insulation and protection against electrical shock tests

8.2.4.1 General

The following tests shall be conducted to determine compliance with the criteria for electrical insulation and protection against electrical shock according to 7.4.1.4.

Electrochemical EESS (BESS) shall be evaluated in accordance with IEC 62933-5-2.

Power electronic converter systems shall be either evaluated in accordance with:

– IEC 62477-1, IEC 62909-1 and IEC 62909-2 if applicable, or IEC 62109-1 and IEC 62109-2 if applicable in case of V-L type EESS, or

– IEC 62477-2 in case of V-H type EESS, or

– tested in accordance with the following tests of 8.2.4.2 to 8.2.4.6 as part of EESS.

8.2.4.2 Dielectric voltage withstand

a) Purpose:

The electrical insulation of EES systems including creepage and clearance distances shall be sufficient to prevent insulation breakdown due to a voltage surge that can be encountered.

Electrochemical EESS (BESS) shall be evaluated in accordance with IEC 62933-5-2 for the dielectric voltage withstand test.

b) Requirement:

There shall be no evidence of dielectric breakdown when subjected to the applied test voltages.

c) Method:

The dielectric test on an EESS shall be tested in accordance with the dielectric test in IEC 60664-1:2020, 6.5.

8.2.4.3 Impulse test

a) Purpose:

The EESS shall be protected against voltage impulses that can occur due to lightening or surges that can arise within the system that can create a breakdown of insulation.

Electrochemical EESS (BESS) shall be evaluated in accordance with IEC 62933-5-2 for the impulse test.

b) Requirement:

The system shall safely withstand the applied impulse levels.

c) Method:

The impulse test shall be tested in accordance with the impulse test in IEC 60664-1:2020, 6.2.2.1.

8.2.4.4 Insulation resistance

a) Purpose:

The electrical insulation shall have adequate resistance to protect against the potential for electrical shock.

Electrochemical EESS (BESS) shall be evaluated in accordance with IEC 62933-5-2 for the insulation resistance test.

b) Requirement:

The insulation resistance measurements shall meet or exceed the limits outlined in IEC 60364-6:2016, Table 6.1.

c) Method:

The insulation resistance test shall be tested in accordance with the insulation resistance in IEC 60364-6:2016, 6.4.3.3 and 6.4.3.4.

8.2.4.5 Earthing and bonding system test

a) Purpose:

The earthing circuit of the EESS shall have sufficiently low impedance to prevent a hazard in the case of a fault.

Electrochemical EESS (BESS) shall be evaluated in accordance with IEC 62933-5-2 for the earthing and bonding system.

b) Requirement:

The impedance of the bonding circuit (earth fault loop impedance) at the areas measured shall be low enough to provide protection as outlined in IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, 415.2.

c) Method:

The earthing and bonding system impedance of an EESS shall be confirmed in accordance with the methods noted below. The measurements shall be made between any two locations of the earthing system in accordance with IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017, 415.2.

8.2.4.6 Earth fault protection

a) Purpose:

If determined from the risk assessment that an earth fault monitoring and protection system is required, the earth fault protection shall prevent a hazardous condition as a result of an applied earth fault.

Electrochemical EESS (BESS) shall be evaluated in accordance with IEC 62933-5-2 for evaluation of an earth fault protection system.

b) Requirement:

As a result of the applied faults, the EESS earth fault protection shall prevent damage to the EESS that would result in a hazardous condition. The protection mechanisms shall operate as designed.

c) Method:

Upon installation, an EESS shall be tested during a normal charging operation with the fault event listed below:

- short circuit between one phase line and earth by a resistive device with a resistance of 50 mΩ

8.2.5 Protection against out of normal operation range tests

8.2.5.1 General

a) Purpose:

The EESS shall be provided with protections that prevent the system from going outside the normal ranges if that condition can result in a hazard as noted in 7.4.1.5.

Electrochemical EESS (BESS) shall be evaluated in accordance with IEC 62933-5-2 for protection against out of normal operation range type tests.

b) Requirement:

The protection mechanisms shall operate to prevent an out of normal range condition of the EESS that can result in a hazardous condition.

All functions of the energy accumulation subsystem shall be fully operational as designed during the test.

c) Method:

The EESS shall be subjected to simulated out of normal parameters conditions as determined by the risk analysis to determine if the protection mechanisms operate as intended to prevent a hazardous condition. These conditions can be over or under temperature, overspeed or other out of normal parameters as applicable to the EESS technology.

8.2.5.2 Overload and short-circuit protection

The EESS shall be protected from overload and short-circuit at all output terminals and interconnecting terminals where power can be delivered out as listed below:

a) any AC or DC output terminals of EESS, including the output cable, if employed;
b) output terminal of each power conversion subsystem, including output cables, if employed;
c) output terminal of each energy accumulation subsystem including any interconnecting cables and busbars until the overcurrent protection device in power conversion system;

d) output terminals of any modules of energy accumulation subsystem that will be interconnected in field, with or without interconnecting cables.

Before the overload or short circuit test, the energy accumulation subsystem shall be in a state of fully charged condition and the EESS input terminal shall be connected as intended.

8.2.5.3 Overload test

a) Purpose:

The EESS shall be provided with overload protections for each output terminal if determined from risk assessment that these overload protections are necessary in order to prevent a hazardous overload condition.

Electrochemical EESS (BESS) shall be evaluated in accordance with IEC 62933-5-2 for protection against overload hazards.

This test does not apply to EESS where the overload protections are integrated into some components (e.g. the PCS) and has been verified in according to the relevant components standards, and the overload condition verified in the components can be representative of the overload condition in the EESS.

b) Requirement:

The provided overload protections shall operate to prevent a hazardous condition. As a result of the overload test, there shall be no fire or explosion of the EESS system.

c) Method:

For each DC output, the positive terminal/conductor and negative terminal/conductor of the output shall be overloaded at 135 % of the current rating of the main protective device for that DC output utilizing suitable load until the EESS temperature becomes stable, or any protective device switches off the DC output under test and the EESS temperature returns to ambient temperature.

For each AC output, a live and neutral wire of the output shall be overloaded one at a time at 135 % of the current rating of the main protective device for that AC output utilizing suitable load until the EESS temperature becomes stable, or any protective device switches off the AC output under test and the EESS temperature returns to ambient temperature.

8.2.5.4 Short circuit test

a) Purpose:

The EESS shall be provided with short circuit protections for each output terminal if determined from risk assessment that these short circuit protections are necessary in order to prevent a hazardous short circuit condition.

Electrochemical EESS (BESS) shall be evaluated in accordance with IEC 62933-5-2 for protection against short circuit hazards.

This test does not apply to EESS where the short circuit protections are integrated into some components (e.g. the PCS) and has been verified in accordance with the relevant components standards, and the short circuit condition verified in the components can be representative of the short circuit condition in the EESS.

b) Requirement:

The short-circuit protection shall operate to prevent damage to the EESS that can result in a hazardous condition.

c) Method:

For each DC output, the positive terminal/conductor and negative terminal/conductor of the output shall be short circuited by a resistance no greater than 50 mΩ until the EESS temperature becomes stable or any protective device switches off the DC output under test and the EESS temperature returns to ambient temperature.

For each AC output, the live and neutral conductors of the output, two phase lines of the output if applicable, shall be short circuited one at a time by a resistance no greater than 50 mΩ until the EESS temperature becomes stable or any protective device switches off the AC output under test and the EESS temperature returns to ambient temperature.

8.2.6 Anti-islanding

a) Purpose:

EES systems that are not intended to operate in islanded mode, shall be designed to prevent this operating condition in accordance with 7.4.1.7.

If this test has been performed as a type test on the power conditioning system (PCS) it is not necessary to repeat this test on the EESS.

b) Requirement:

The EESS shall shut down in accordance with the requirements of the standard utilized to evaluate the system. Local regulations regarding anti-islanding can apply.

c) Method:

The unintentional islanding test shall be conducted according to IEC 62116:2014, Clause 6, or IEEE Std 1547.1™-2020, 5.10, or another method. Local regulations for anti-islanding can apply.

8.3 Validation and testing of EESS – Mechanical hazards

8.3.1 Enclosure strength against impact

a) Purpose:

The enclosure of an EESS that is provided to prevent access to hazardous parts and protect internal insulation, shall have sufficient impact strength when tested.

This test applies to an EESS located in an unrestricted access area.

Electrochemical EESS (BESS) are evaluated in accordance with IEC 62933-5-2 for the impact test.

b) Requirement:

As a result of the impact force, there shall be no damage that would result in exposure of hazardous parts as determined by the application of the articulate probe in accordance with 8.2.2, and there is no evidence of dielectric breakdown.

c) Method:

Enclosures of EES systems located in unrestricted access area shall be tested in accordance with IEC 62477-1:2022, 5.2.2.4.3. After the application of the force, the enclosure is examined for signs of damage that can result in access to hazardous parts or loosening of protective barriers through a visual inspection and if openings are created, by using the method outlined in 8.2.2.

To determine damage to insulation or reduced creepage and clearances, the dielectric voltage withstand test of 8.2.4.2 is conducted.

8.3.2 Enclosure strength against static force

a) Purpose:

The enclosure of an EESS that is provided to prevent access to hazardous parts and protect internal insulation, shall have sufficient strength against static forces when tested.

This test applies to an EESS located in an unrestricted access area.

Exception: This test can be waived for EESS with enclosure having enough strength to resist static force based on safety risk analysis.

Electrochemical EESS (BESS) shall be tested in accordance with IEC 62933-5-2 for the static force test.

b) Requirement:

As a result of the static force, there shall be damage that would result in exposure of hazardous parts as determined by the application of the articulated probe in accordance with 8.2.2 and there is no evidence of dielectric breakdown.

c) Method:

Enclosures of EES systems located in unrestricted access area shall be tested in accordance with IEC 62477-1:2022, 5.2.2.4.2.3. After the application of the force, the enclosure is examined for signs of damage that can result in access to hazardous parts or loosening of protective barriers through a visual inspection and if openings are created, by using the method outlined in 8.2.2.

To determine damage to insulation or reduced creepage and clearances, the dielectric voltage withstand test of 8.2.4.2 is conducted.

8.3.3 Containment of hazardous moving parts

EESS containing hazardous kinetic energy, such as flywheel energy storage systems, shall be tested as outlined in Annex C.

8.3.4 Mounting means and handle robust test

a) Purpose:

This test applies to EESS that contain handles for carrying or have mounting means such as a rack assembly that have to hold the weight of the supported parts to prevent a hazard as determined by the risk analysis.

Electrochemical EESS (BESS) are tested in accordance with IEC 62933-5-2.

b) Requirement:

As a result of the applied force, there shall be no damage to the mounting apparatus or support structure and the securement means when testing when subjected to a force representative of the supported weight with some additional safety factor. As a result of the applied force, there shall be no damage to handles or the handle mounting or securement means of the equipment under test (EUT).

c) Method:

For the wall mounted apparatus or other support structures, a force equal to 4 times the weight of the EESS parts that the mounting is intended to support is applied to the centre of the mounting or the support structure in a downward direction. The force shall be held for 1 min.

For EESS parts with (a) carrying handle(s), the EUT shall be supported by the carrying handles and a force equal to 4 times the weight of the EUT is applied in a downward direction. If more than one carrying handle is provided, the added weight shall be distributed between the handles.

8.3.5 Impact and vibration during transportation and seismic events

Impact and vibration during transportation and seismic events shall be taken into account as far as relevant in particular when the EESS can be transported. Electrochemical EESS (BESS) shall be tested in accordance with IEC 62933-5-2 for these hazards.

8.4 Validation and testing of EESS – Fluid hazards (high or low temperature, high pressure, flammable, corrosive, caustic, or toxic)

8.4.1 General

These tests are applicable to systems containing fluids for their operation that are at pressures of 103 kPa or greater; fluid temperatures above 50 °C; fluid temperatures lower than or equal to −10 °C for metallic materials and −25 °C for non-metallic materials; and systems that contain flammable, corrosive or caustic (pH ≤ 2 or pH ≥ 12,5) or toxic fluids.

For parts that have met the applicable local regulations (e.g. pressure directives), it is not necessary to be subjected to this testing.

8.4.2 Hazardous fluid containing parts strength test

a) Purpose:

Parts containing hazardous fluids as outlined in Table 2 shall have sufficient strength to prevent hazards. These parameters can vary depending upon applicable regulations.

b) Requirement:

As a result of the containment strength test, there shall be no fracture, distortion, rupture or other damage to the fluid containing parts.

c) Method:

Parts of the EESS containing hazardous fluids (gases or liquids) shall be subjected to a hydrostatic strength test of 1,5 times the design pressure of the system for a period of 1 min after reaching the maximum pressure. The pressure shall be gradually increased until the maximum pressure is reached in approximately 1 min using either the liquid used in the system or water. Testing is done at room ambient temperature.

As an alternate method, hazardous fluid containing parts of the EESS can be subjected to a pneumatic strength test of 1,3 times the design pressure of the system for a period of 1 min after reaching the maximum pressure. The pressure shall be gradually increased until the maximum pressure is reached in approximately 1 min using either air or inert gas. Testing is conducted at room ambient temperature.

Table 2 – Test parameters for the strength test

Fluid hazard	Test type	Test parameter[a]
Flammable, corrosive/caustic[e] or toxic	Hydrostatic	1,5 times design pressure
	Pneumatic	1,3 times design pressure
High temperature[b]	Hydrostatic	1,5 times design pressure
	Pneumatic	1,3 times design pressure
Low temperature[c]	Hydrostatic	1,5 times design pressure
	Pneumatic	1,3 times design pressure
High pressure[d]	Hydrostatic	1.5 times design pressure
	Pneumatic	1.3 times design pressure

[a] The term "design pressure" is the maximum pressure that the system can achieve under all operating parameters as determined through the operating pressure of the pressure relief device.

[b] Temperature greater than or equal to 50 °C.

[c] Temperature lower than or equal to −10 °C for metallic materials and −25 °C for non-metallic materials.

[d] Pressures greater than or equal to 105 kPa.

[e] Corrosive is defined as anything with a pH less than or equal to 2 or a pH greater than or equal to 12,5.

8.4.3 Hazardous fluid containing parts leakage test

a) Purpose:

Parts containing hazardous fluids as outlined in Table 3 shall be designed to prevent leakage hazards. These parameters can vary depending upon applicable regulations.

b) Requirement:

As a result of the containment leakage test, there shall be no fracture, distortion, rupture or other damage to the fluid containing parts and there shall be no evidence of leakage.

For flammable fluids containment, if relying upon mechanical ventilation to prevent a combustible concentration to maintain a less than or equal to 25 % lower flammability limit (LFL) concentration, the mechanical ventilation evaluation test of 8.5.2 shall additionally be conducted if there is evidence of leakage during this test.

c) Method:

Parts of the EESS containing hazardous fluids (gases or liquids) shall be subjected to a hydrostatic leakage test of 1,5 times the maximum operating pressure of the system for a period of 1 min after reaching the maximum pressure. The pressure shall be gradually increased until the maximum pressure is reached in approximately 1 min using either the liquid used in the system or water. Testing is done at room ambient temperature.

Evidence of leakage when conducting a hydrostatic leakage test shall be determined through evidence of the liquid at piping connections or other areas of potential leakage or by evidence of a pressure decay during the 1 min hold period.

As an alternate method, the above parts of the EESS can be subjected to a pneumatic leakage test of 1,3 times the maximum operating pressure of the system for a period of 1 min after reaching the maximum pressure. The pressure shall be gradually increased until the maximum pressure is reached in approximately 1 min using either air or inert gas. Testing is conducted at room ambient temperature.

Evidence of leakage when conducting a pneumatic leakage test shall be determined through either the use of leakage detection fluids at piping connections areas and other areas of potential leakage or through evidence of a pressure decay during the 1 min hold period.

Table 3 – Test parameters for the leakage test

Fluid hazard	Test type	Test parameter[a]
Flammable, corrosive[e] or toxic	Hydrostatic	1,5 times the maximum operating pressure
	Pneumatic	1,3 times the maximum operating pressure
High temperature[b]	Hydrostatic	1,5 times the maximum operating pressure
	Pneumatic	1,3 times the maximum operating pressure
Low temperature[c]	Hydrostatic	1,5 times the maximum operating pressure
	Pneumatic	1,3 times the maximum operating pressure
High pressure[d]	Hydrostatic	1,5 times the maximum operating pressure
	Pneumatic	1,3 times the maximum operating pressure

[a] The term "maximum operating pressure" is the maximum pressure that the system can achieve under all conditions of normal operation.

[b] Temperature greater than or equal to 50 °C.

[c] Temperature lower than or equal to −10 °C for metallic materials and −25 °C for non-metallic materials.

[d] Pressures greater than or equal to 105 kPa.

[e] Corrosive is defined as anything with a pH less than or equal to 2 or a pH greater than or equal to 12,5.

8.4.4 Start-to-discharge pressure test

a) Purpose:

Pressure relief devices shall operate at the intended pressures to prevent a hazard.

This test does not apply to those pressure relief devices that have previously been evaluated to a suitable regional or international standard.

NOTE An example of a standard would be the ASME Boiler and Pressure Vessel code.

b) Requirement:

The start-to-discharge pressure measured shall be in the range of 90 % to 100 % of its rated start-to-discharge pressure setting.

c) Method:

For a resettable pressure relief valve, three samples of resettable pressure relief valve shall be tested, and each sample shall be subjected three times to a gradually increasing air pressure. The pressure at which the device begins to open shall be recorded using a calibrated pressure gauge having a range of at least 150 % of the anticipated maximum operating pressure of the pressure relief device. The start-to-discharge pressure of each sample is the average value of the three trials. The start-to-discharge value of the resettable pressure relief value is the highest average value for the three samples tested.

For a non-resettable pressure relief device, three samples of the pressure relief device shall be tested, and each sample shall be subjected to a gradually increasing air pressure. The pressure at which the device begins to open shall be recorded using a calibrated pressure gauge having a range of at least 150 % of the anticipated maximum operating pressure of the pressure relief device. The start-to-discharge value of the non-resettable pressure relief device is the highest value for the three samples tested.

8.5 Validation and testing of EESS – Explosion and combustible concentrations hazards

8.5.1 Gas detection and off-gas detection

If the risk analysis according to the output of 6.3 shows that flammable gases can be emitted from EESS, the EESS shall be tested using a suitable test method to verify the effectiveness of the gas detection system.

The electrochemical EESS (BESS) shall be tested in accordance with IEC 62933-5-2 for gas detection and off-gas detection.

8.5.2 Mechanical ventilation evaluation

a) Purpose:

An EESS that relies upon mechanical ventilation to prevent combustible concentrations shall be evaluated to ensure that the ventilation is sufficient to prevent a combustible concentration (i.e. ≤ 25 % LFL).

The electrochemical EESS (BESS) shall be tested in accordance with IEC 62933-5-2 for ventilation.

b) Requirement:

During the period of release, the concentration of a test gas in the vicinity of potentially ignition-capable equipment that is outside the dilution area shall not exceed twice the value specified in IEC 60079-2:2014, Clause A.2, and shall be reduced below the specified value within 30 min.

c) Method:

A dilution test in accordance with IEC 60079-2:2014, 16.5.4.2, shall be conducted to evaluate the effectiveness of the mechanical ventilation.

8.6 Validation and testing of EESS – Hazards arising from electric, magnetic and electromagnetic fields

Electrochemical EESS (BESS) shall be tested in accordance with IEC 62933-5-2 for hazards arising from electric, magnetic and electromagnetic fields.

a) Purpose:

The EESS shall have sufficient immunity against electric, magnetic and electromagnetic disturbances to prevent hazards from arising. The safety-related functions of the EESS shall be evaluated for its reliability and safety when exposed to electric, magnetic and electromagnetic fields.

b) Requirement:

The EESS and the safety-related functions of the EESS shall function in accordance with the risk analysis after evaluating for EM exposure.

The EESS EM emissions shall not cause disturbance to the surrounding environment. Local regulation can apply.

c) Method:

The EESS shall be integrated with equipment that comply with IEC 61000-6-1, IEC 61000-6-2, IEC 61000-6-3, IEC 61000-6-4, IEC 61000-6-5 for EM exposure and EM emission as applicable. Other IEC or CISPR standards can be used depending on the site of installation. Local regulation can apply.

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

8.7 Validation and testing of EESS – Fire propagation hazards

If the risk analysis shows that there is a need for validation and testing of EESS for fire propagation hazards, this shall be considered. According to current understanding, BESS are the most concerned EESS with this fire propagation hazards issue.

Electrochemical EESS (BESS) shall be tested in accordance with IEC 62933-5-2 for fire propagation hazards.

8.8 Validation and testing of EESS – Temperature hazards

8.8.1 General

Electrochemical EESS (BESS) shall be tested in accordance with IEC 62933-5-2 for temperature hazards.

8.8.2 Containment of hazardous temperature (low or high) fluids

EESS that contain hazardous temperature fluids (50 °C or above or temperature lower than or equal to −10 °C for metallic materials and −25 °C for non-metallic materials) shall be subjected to the fluid containing parts strength test of 8.4.2 and fluid containing parts leakage test of 8.4.3.

8.8.3 Temperature under normal operation tests

a) Purpose:

The normal operations test is intended to ensure that the EESS operates as intended under maximum normal conditions of charging and discharging.

b) Requirement:

All the functions above shall operate as designed. Temperature of components and energy accumulation subsystems shall not be exceeded.

c) Method:

General temperature test under charging and discharging of the system by looking at temperatures on temperature sensitive components and checking of operating parameters.

The EESS shall be operated at maximum normal loading conditions for charging and discharging. During this operation, temperatures on temperature critical components including energy accumulation subsystems shall be monitored to determine whether or not they are operating within their specified temperature range.

8.9 Validation and testing of EESS – Chemical effects

8.9.1 Strength tests

EESS that contain hazardous fluids (toxic, corrosive or flammable) shall be subjected to the fluid containing parts strength test of 8.4.2.

8.9.2 Leakage tests

EESS that contain hazardous fluids (toxic, corrosive or flammable) shall be subjected to the fluid containing parts leakage test of 8.4.3.

8.10 Validation and testing of EESS – Hazards arising from the environment

8.10.1 General

The environmental exposure tests for electrochemical EESS (BESS) are covered in IEC 62933-5-2.

8.10.2 Ingress of moisture

The EESS shall be provided with sufficient protection against ingress of moisture for its specified installation and ratings to prevent a hazard. The protection from exposure to moisture test is covered in 8.2.3.

8.10.3 Exposure to marine environments

a) Purpose:

The EESS enclosure shall be provided with sufficient protection against salt fog exposure that can result in a hazardous condition if it is specified for installation in a marine environment.

NOTE 1 A marine environment installation would be considered an installation at the shore of a salt water body (e.g. harbour or dock) or on a vessel.

If there are openings in the enclosure, the evaluation shall also consider exposure of internal components. An enclosure IP rating of IP67 (dust ingress and water immersion) or equivalent or higher does not require a salt fog test to evaluate the exposure to internal components.

NOTE 2 NEMA Type 4X and 6P are considered suitable for outdoor installations where there can be salt fog exposure.

The ISO 12944 series coatings (corrosion protection of steel structures) rated C5M are considered resistant to exposure in marine environment and do not require further testing of the enclosure material resistance.

b) Requirement:

The EESS enclosure shall be sufficient to prevent deterioration that can result in a hazardous condition as a result of exposure to salt fog.

c) Method:

The EESS shall be subjected to the evaluation salt fog exposure in accordance with IEC 60068-2-52 using the test procedures for test method 1 (severity 1) for installations on board vessels or test method 2 (severity 2) for installations at the shore of a saltwater body.

For this test, representative subassemblies can be used.

At the conclusion of the conditioning, the EESS is examined for signs of damage that can result in a potentially hazardous condition.

8.11 Validation and testing of EESS – Hazards arising from auxiliary, control and communication subsystem malfunctions

8.11.1 General

The EESS includes primary, auxiliary and control subsystems as shown in Figure 7. A fault arising in any one of these subsystems can impact the overall system and result in a hazard to that system.

8.11.2 Auxiliary system malfunction

8.11.2.1 General

a) Purpose:

When the control power is lost, the protection mechanisms of the system cannot work properly. Control power low or high voltage excursions above specified levels can affect the devices and components that ensure the EESS safety.

b) Requirement:

No potential auxiliary system malfunction shall cause a fire, explosion or an unsafe EESS state. For all conditions tested, the EESS safety functionality shall not be compromised and shall react in accordance with the risk analysis' anticipated outcome.

c) Method:

The verification of auxiliary system fault conditions concerning safety identified by risk analysis, such as the following items shall include testing as applicable to the auxiliary subsystem:

1) complete loss of control power;
2) partial loss of control power;
3) temporary loss of control power;
4) control power voltage exceeding a tolerable voltage level;
5) control power voltage dropping below a tolerable voltage level;
6) cooling system malfunction;
7) temporary loss of control input;
8) other auxiliary subsystem malfunction.

8.11.2.2 Complete loss of control power to the auxiliary subsystem

With the EESS at approximately 50 % state of charge (SOC), it shall be subjected to a maximum power discharge. After 10 min of operation, 100 % of the control power (e.g. the power supply for the programmable logic controller (PLC)) is switched off while the system is still discharging. The system shall then be observed until ultimate results have occurred after the fault condition application.

NOTE 1 The state of charge cannot be critical, so the SOC can be at some mid-level of SOC.

NOTE 2 The 100 % of control power is the nominal power supply of the PLC.

NOTE 3 For systems that cannot sustain 10 min of operation at 50 % SOC, such as some flywheel systems, the EESS SOC can be adjusted to a higher value and the operation time before introducing the fault condition can be reduced to about half of total capable operation time at that SOC.

Repeat the test with the EESS subjected to a maximum power charging.

8.11.2.3 Partial loss of control power to the auxiliary subsystem

EESS shall be tested based on conditions of power supplies to the PLC for this test.

- If the power supply to the PLC is through one single device, this test does not apply.
- If the PLC is supplied by two sources (e.g. two power supplies):

  With the EESS at approximately 50 % state of charge, it shall be subjected to a maximum power discharge. After 10 min of operation, 50 % of the control power (e.g. power supply to the programmable logic controller) is switched off by switching off one out of two power supplies to the PLC while the system is still discharging. The EESS shall be observed until ultimate results occur after the fault condition application.

  NOTE 1 The state of charge cannot be critical, so the SOC can be at some mid-level of SOC.

NOTE 2 For systems that cannot sustain 10 min of operation at 50 % SOC, such as some flywheel systems, the EESS SOC can be adjusted to a higher value and the operation time before introducing the fault condition can be reduced to about half of total capable operation time at that SOC.

NOTE 3 If the power from different power supplies is not equal, each power supply providing a different power will be switched off during test, one at a time.

- If the PLC is supplied by three power sources (e.g. three power supplies):

  With the EESS at approximately 50 % state of charge, it shall be subjected to a maximum power discharge. After 10 min of operation, 33 % of the control power (e.g. power supply to the programmable logic controller) is removed by switching off one out three supplies and then 66 % of the control power is removed by switching off two out of three of power supplies while the system is still discharging. The EESS shall be observed until ultimate results occur after the fault condition application.

NOTE 4 This example refers to the case where there is a power supply for a single line PLC. Normally there are different power supply units in the EESS. The total number of power supply units on different lines of different PLCs (e.g. one power supply for line PLC 1 and one power supply for line PLC 2) will be considered. For this case, the test would be conducted by switching off one out of two of the supplies for 50 % of the control power switched off.

NOTE 5 The state of charge cannot be critical, so the SOC can be at some mid-level of SOC.

NOTE 6 For systems that cannot sustain 10 min of operation at 50 % SOC, such as some flywheel systems, the EESS SOC can be adjusted to a higher value and the operation time before introducing the fault condition can be reduced to about half of total capable operation time at that SOC.

Repeat the test with the EESS subjected to a maximum power charging.

8.11.2.4 Temporary loss of control power to the auxiliary power system

With the EESS at approximately 50 % state of charge, it shall be subjected to a maximum power discharge. After 10 min, 100 % of control power (e.g. power supply for the programmable logic controller) shall be switched off for 5 min while the system is still discharging. After the 5 min loss of power, 100 % of the power to the control is returned and the system is observed until ultimate results occur while the EESS is still operating.

Repeat the test with the EESS subjected to a maximum power charging.

NOTE 1 The state of charge cannot be critical, so the SOC can be at some mid-level of SOC.

NOTE 2 For systems that cannot sustain 10 min of operation at 50 % SOC, such as some flywheel systems, the EESS SOC can be adjusted to a higher value and the operation time before introducing the fault condition can be reduced to about half of total capable operation time at that SOC.

8.11.2.5 Temporary loss of control input

With the EESS at approximately 50 % state of charge, it shall be subjected to a maximum power discharge for 10 min. After 10 min, remove the control input of the EESS for 30 s and then reconnect it while the system is still discharging. The system shall be observed until ultimate results occur after the fault condition application.

Repeat the test with the EESS subjected to a maximum power charging.

NOTE 1 The state of charge cannot be critical, so the SOC can be at some mid-level of SOC.

NOTE 2 For systems that cannot sustain 10 min of operation at 50 % SOC, such as some flywheel systems, the EESS SOC can be adjusted to a higher value and the operation time before introducing the fault condition can be reduced to about half of total capable operation time at that SOC.

8.11.2.6 Control power voltage exceeds a tolerable voltage level

With the EESS at approximately 50 % state of charge, it shall be subjected to a maximum power discharge. After 10 min the control power voltage (e.g. power voltage supply of the PLC) is increased to 20 % above the maximum tolerable voltage of the PLC power supply voltage while the system is still discharging. The system shall be observed until ultimate results occur after the fault condition application.

NOTE 1 Normally the range of the PLC power supply voltage is 19 V DC to 30 V DC (voltage in this range is considered the tolerable voltage level).

NOTE 2 The state of charge cannot be critical, so the SOC can be at some mid-level of SOC.

NOTE 3 For systems that cannot sustain 10 min of operation at 50 % SOC, such as some flywheel systems, the EESS SOC can be adjusted to a higher value and the operation time before introducing the fault condition can be reduced to about half of total capable operation time at that SOC.

Repeat the test with the EESS subjected to a maximum power charging.

8.11.2.7 Control power voltage drops below a tolerable voltage level

With the EESS at approximately 50 % state of charge, it shall be subjected to a maximum power discharge. After 10 min, the control power voltage (power voltage supply of the PLC) shall be reduced to 20 % below the minimum tolerable voltage level while the system is still discharging. The system shall be observed until ultimate results occur after the fault condition application.

NOTE 1 Normally the range of the PLC power supply voltage is 19 V DC to 30 V DC (voltage in this range is considered the tolerable voltage level).

NOTE 2 The state of charge cannot be critical, so the SOC can be at some mid-level of SOC.

NOTE 3 For systems that cannot sustain 10 min of operation at 50 % SOC, such as some flywheel systems, the EESS SOC can be adjusted to a higher value and the operation time before introducing the fault condition can be reduced to about half of total capable operation time at that SOC.

Repeat the test with the EESS subjected to a maximum power charging.

8.11.2.8 Cooling system malfunction

With the EESS at the maximum state of charge in accordance with the manufacturer's specifications, subject the EESS to a maximum power discharge until the internal system ambient temperature of the EESS nears its highest temperature, with its cooling system operating. Then the cooling system is switched off to simulate a fault of the cooling system while the EESS is operating. The system shall be observed until ultimate results occur after the fault condition application.

Repeat the test with the EESS subjected to maximum power charging from an initial state of approximately 10 % state of charge.

8.11.2.9 Other auxiliary subsystem malfunction

The test mode for other auxiliary system malfunctions depends on the kind of auxiliary subsystem. Others auxiliary subsystem malfunctions to test shall be determined as result of the risk analysis. Some examples are:

- fire protection system malfunction;
- UPS malfunction.

8.11.3 EES control subsystem malfunction

a) Purpose:

When an EESS control subsystem provides incorrect control information to the power conversion subsystem processing unit, the EESS can be damaged and put into an unsafe state. The fault conditions concerning safety as identified in the risk analysis, such as an EESS management control failure, shall be tested.

b) Requirement:

For the conditions tested, the EESS safety functionality shall not be compromised, and the safety functions shall operate in accordance with the risk analysis anticipated outcomes.

c) Method:

The EESS shall be at a state of charge where there is sufficient energy for testing but not fully charged. The EESS shall be subjected to a maximum power discharge for 10 min.

After 10 min of discharge, apply the incorrect control of the EESS (e.g. set point of active power out of the capability limits of the PLC of the EESS). The system shall be observed until ultimate conditions have occurred after the fault condition application.

Repeat the test with the EESS subjected to a maximum power charging.

8.11.4 EESS internal communication malfunction

a) Purpose:

When the internal communication line is short or open circuited, or when the internal control signal is disturbed, it is possible that the EESS will not work properly.

NOTE All the communication lines inside the EESS (including communication lines between subsystems) are considered as the internal communication lines. Communication lines connected externally at the communication interface of EESS are considered as the external communication lines.

b) Requirement:

For all of the conditions tested, the EESS safety functionality shall not be compromised, and the safety functions shall operate in accordance with the risk analysis' anticipated outcome.

c) Method:

The internal communication fault conditions concerning safety that are identified by risk analysis such as those items noted below shall be tested:

1) Internal communication line is opened

   Start condition of the EESS with a state of charge where there is sufficient energy for testing but not fully charged, subjected to a maximum power discharge for 10 min. After 10 min open the internal communication line of the EESS. The system shall be observed until ultimate conditions have occurred after the fault condition application.

   Repeat the test with maximum power charging.

2) Internal communication line is short circuited

   Start condition of the EESS with a state of charge where there is sufficient energy for testing but not fully charged, subjected to a maximum power discharge for 10 min. After 10 min short circuit the internal communication line of the EESS. The system shall be observed until ultimate conditions have occurred after the fault condition application.

   Repeat the test with maximum power charging.

3) Internal communication line is disturbed (applied noise on the communication line)

   Start condition of EESS with a state of charge where there is sufficient energy for testing but not fully charged, subjected to a maximum power discharge for 10 min. After 10 min apply noise to the internal communication line of the EESS. The system shall be observed until ultimate conditions have occurred after the fault condition application.

   Repeat the test with maximum power charging.

NOTE 1 The opening of the line (internal and external) can be achieved by pulling the plug out of the communication cable (example CAN BUS).

NOTE 2 The short circuit of the line (internal and external) can be achieved with a short circuit on at least two lines of the terminal of the communication cable (example CAN BUS) in accordance with the risk analysis.

NOTE 3 The disturbance of the line (internal and external) will be selected in reference to the environment of the site of installation (i.e. residential, industrial or substation). The following are the reference standards to select the disturbance to apply on the EESS: IEC 61000-1-2, IEC 61000-6-1, IEC 61000-6-2, IEC 61000-6-5, and IEC 61000-6-7.

8.11.5 EESS external communication malfunction

a) Purpose:

There are a number of factors that can affect the safe operation of the EESS, which are set out below. These factors shall have been considered during the design process; system level risk analysis (e.g. FMEA), and testing shall be performed to ensure that the EESS enters a safe state in each case:

1) external communication line is opened;
2) external communication line is short circuited;
3) external communication line is disturbed.

b) Requirement:

For all conditions tested, the EESS safety functionality shall not be compromised, and the safety functions shall operate in accordance with the risk analysis anticipated outcome.

c) Method:

1) External communication line is opened, test mode

   The start condition for the EESS is approximately 50 % state of charge and maximum power in discharge for 10 min. After 10 min open the external communication line of the EESS. The system shall be observed after the open circuit fault condition application until ultimate results occur.

   Repeat the test with maximum power in charge.

2) External communication line is short circuited, test mode

   The start condition for the EESS is approximately 50 % state of charge and maximum power in discharge for 10 min. After 10 min short circuit the external communication line of the EESS. The system shall be observed after the short circuit fault condition application until ultimate results occur.

   Repeat the test with maximum power in charge.

3) External communication line is disturbed, test mode

   The start condition for the EESS is approximately 50 % state of charge and maximum power in discharge for 10 min. After 10 min open the external communication line of the EESS and apply a noise on the internal communication line of the EESS. The system shall be observed after the noise fault condition application until ultimate results occur.

   Repeat the test with maximum power in charge.

NOTE 1 The opening of the line (internal and external) can be achieved by pulling the plug out of the communication cable (example CAN BUS).

NOTE 2 The short circuit of the line (internal and external) can be achieved with a short circuit on at least two lines of the terminal of the communication cable (example CAN BUS) in accordance with the risk analysis.

NOTE 3 The disturbance of the line (internal and external) will be selected in reference to the environment of the site of installation (i.e. residential, industrial or substation). The following are the reference standards to select the disturbance to apply on the EESS: IEC 61000-1-2, IEC 61000-6-1, IEC 61000-6-2, IEC 61000-6-5, and IEC 61000-6-7.

9 Instruction manuals and guidelines

9.1 General

The manuals shall include the EESS specifications including electrical input and output ratings, environmental ratings, system overall dimensions, weight and an overall description of the EESS and its operation. All markings and signage for the system shall be included in the manuals. The language for manuals shall either be in English or another language. Local regulations can apply.

The manuals for multi-part EESS shall include a description of all of the parts of the system, and the layout of the parts when installed as a system, with a single-line electrical diagram of the EESS identifying all interconnections and ports.

The electrical schematic and piping and instrument diagram of the systems if applicable shall be included in the manuals of the system.

The manuals shall provide contact information for support with installation, operation, and maintenance for the EESS. There shall also be emergency contact information in the event of a safety incident involving the EESS.

The manuals can be available in either hard copy or digital format (online) that can be printed. The manuals shall be in a format that is accessible when necessary over the life of the system.

If the information in the manuals is not clear or is incomplete in some aspect in the event of residual risk for some complex systems, the manufacturer will have to provide additional information or additional training to address missing or unclear information in the manuals.

9.2 Installation manual

An installation manual shall be provided. The installation manual shall contain at least the following related parts:

- a general description of the characteristics of the facility and system;
- the safety rules for installation including information on the appropriate PPE required to perform the various tasks of the installation;
- the instructions for installation;
- the instructions for commissioning;
- the instructions for the interface control;
- the instructions for troubleshooting during installation;
- instructions on any equipment that is installed on site that is part of the system such as HVAC;
- instructions on protection mechanisms that have to be installed on site such as fire detection and suppression systems;
- the instructions regarding how to decommission the EESS.

The installation information shall include instructions for making all necessary connections for electrical, communications, piping for fuels and other fluids, etc. as well as connections to other equipment that are part of the system. Multi-part EESS shall have all parts identified in the installation instructions with instructions for the installation and interconnection of those parts.

The instructions shall include information on electrical disconnects, shut off valves and other devices required to be installed with the system. The installation instructions shall include the parameters required for electrical connections and installed devices in electrical circuits (communication protocols, circuits and devices) as well as parameters for fuel and other fluid connections and control devices necessary for the operation of the EESS.

Environmental limits of the system installation shall be included in the installation instructions. These will include whether the system is intended for outdoor installations only, limitations regarding installations in seismic or in marine environments. Those EESS that require restricted access shall include instructions for installations in restricted access areas.

9.3 Maintenance manual

9.3.1 General

The EESS shall be provided with maintenance instructions for service personnel as well as a separate set of instructions for any basic maintenance procedures that would be handled by operators of the system. Maintenance instructions shall include instructions for minor repairs that can be considered as part of basic maintenance such as fuse replacement and instructions that indicate when the service personnel are required to handle the repair.

The maintenance instructions shall include safety measures to be followed during maintenance of the system whether by service personnel or for basic maintenance procedures handled by system operators.

Maintenance instructions shall include the frequency of routine maintenance to be performed including annual checks on any subsystems such as the accumulation subsystem including the batteries, any containment systems and pressure vessels, the auxiliary subsystem including any gas detection devices, HVAC systems, fire suppression system, etc., as well as any operational tests to be performed.

When maintenance operations are planned, appropriate analysis of the system shall be conducted prior to the start to ensure that the maintenance can be carried out in a safe manner. This includes determining of the need for electric isolation of any piece of equipment to be performed and documented before any maintenance.

9.3.2 Personal protective equipment (PPE) guidelines

Maintenance instructions shall include information on the appropriate PPE required to perform the various tasks. Areas within and around the EESS requiring special protection measures against inherent dangers (e.g., electrical, mechanical, chemical, heat and stored energy hazards) shall be provided with cautionary signage to identify the hazards and necessary precautions.

Maintenance instructions shall include information on safe working practices. Wherever possible, work shall commence only when conductors normally energized at a dangerous voltage have been securely isolated and earthed. Areas within and around the energy storage system requiring special protection measures against arc flash and shock hazards shall be provided with cautionary signage to identify the electrical hazards and necessary precautions. Where isolation is not possible, for example work on battery terminals, instructions shall be provided on the appropriate PPE required to perform the task.

Maintenance procedures shall ensure that the EESS is operating as intended after maintenance and that protective functions are functioning. Maintenance procedures for equipment and parts in hazardous areas or zones shall ensure that the hazardous area or zone protection is not compromised.

Instructions for walk-in systems and secured areas of the EESS shall indicate that sufficient precautions are to be taken to ensure there is no one is inside the door before locking it from the outside.

9.4 Operator manual

The operator manual shall contain at least the following related parts:

- general description of the characteristics of the EESS;
- main safety rules including information on the appropriate PPE required to perform the various tasks;
- instruction for operating the EESS and instructions for interface control;

- instructions regarding the different states of operation and meaning of indicators of operation and how to determine the state of operation;
- how to troubleshoot if there are incorrect state indications during the EESS operation that do not require further maintenance;
- instructions on communication protocols for the EESS;
- instructions on procedures in the event of warning indicators or alarms from the EESS and when to initiate emergency procedures.

If the system can be remotely operated, there shall be instructions regarding how to safely disconnect from remote operation and change to local control of the system. Once local control is no longer necessary, instructions for the safe reconnection of the remote control shall be included.

Instructions for walk-in systems shall indicate that sufficient precautions are to be taken to ensure there is no one inside the door before locking it from the outside.

9.5 Emergency procedure manual

The emergency procedure manual shall contain at least the following information:

Procedures for pre-planning of potential emergency events that can occur based upon the EESS technology, design and mode of operation (e.g., remote or local).

The EESS manufacturer shall provide information on the reasonably foreseeable emergency conditions with the EESS that could occur.

NOTE It is the responsibility of the owner or operator of the EESS that suitable and effective local emergency plans are in place.

The emergency procedure manual shall include:

- a description of the action which should be taken to control the conditions or events and to limit their consequences, including a description of the safety equipment and the resources available for all foreseeable conditions or events which could be significant in bringing about a major accident;
- arrangements for limiting the risks to persons on site including how warnings are to be given and the actions persons are expected to take upon receipt of a warning (first responder guidelines, emergency evacuation plan);
- arrangements for providing early warning of the incident to the authority responsible for setting the external emergency plan in motion, the type of information which should be contained in an initial warning and the arrangements for the provision of more detailed information as it becomes available;
- where necessary, arrangements for training staff in the duties they will be expected to perform and, as appropriate, coordinating this with off-site emergency services.

9.6 First response manual

The first response manual shall describe methods and general steps that have to be taken in the event of an emergency involving the EESS (e.g. fire mitigation, explosion risk prevention). Site specific procedures or instructions shall be developed, and roles and responsibilities clearly noted to identify the individuals required to perform the designated actions or steps.

The operation of an automatic fire suppression system shall be described and the precautions to take when triggered shall be given.

The first response manual shall also describe methods and general steps that shall be taken for other types of non-fire hazards such as chemical spills, electrical hazards, toxic gas releases, etc.

10 Markings and signage

10.1 General

Required markings including the nameplate and warning markings and signage shall be legible and permanent and located on the EESS where they will be visible when the EESS is installed.

10.2 Nameplate

The nameplate of the EESS shall include the manufacturer name or trademark, the model number of the EESS, input and output electrical ratings (voltage, current or power, frequency, phase), energy ratings (kWh, MWh), technology, special environmental limits (e.g. indoor only, seismic ratings), ambient temperature ratings, and emergency contact information or a digital link to emergency contact information, and date of manufacture.

The nameplate shall be located where it is visible on the system after installation.

A digital link (web address, QR code, bar code or other) to the system manuals shall be provided if digital manuals are provided.

For multi-part EES systems, a nameplate marking as noted above shall be provided on at least the accumulation subsystem, and it shall indicate that it is a multi-part EESS and it shall include a marking to read the instructions for additional information on the complete EESS. Other parts of the multi-part EES system shall be provided with their own nameplate marking reporting all the information related to the respective subsystems according to the relevant product standard.

10.3 Cautionary markings and signage

The need for cautionary markings or signage to be provided shall be determined by the risk analysis of the system. Cautionary markings and signage shall be designed in accordance with ISO 7010.

Examples of cautionary markings can include symbols and warnings regarding hot surface markings, electrical shock hazards, chemical hazards and hazardous moving parts hazards.

Cautionary markings and signage shall also be provided as applicable to the EESS technology and design. Local regulations can apply.

Annex A
(informative)

Main risks of different storage technologies

A.1 General

Annex A has information on potential failure modes or conditions and their consequences with various EESS technologies and is not a complete list of all hazards that can occur. It is not meant to replace a thorough risk assessment. It is the EESS manufacturers' responsibility to conduct a thorough risk assessment of their system in accordance with this document to identify and mitigate against the potential hazards of their system.

A.2 Pumped hydro storage

Pumped hydro storage is a particular type of hydroelectric facility. These plants have two interconnected water reservoirs located at different elevations. During off-peaks hours, water is pumped to the upper reservoir to store energy. Then, during periods of high electricity consumption, water is released, via water turbines, into the lower reservoir to produce electricity.

The main risk scenarios for pumped hydro storage are given in Table A.1.

Table A.1 – Main risk scenarios for pumped hydro storage

Causes	Failure modes or conditions	Hazard	Consequences
Earthquake, landslide, water infiltration which could damage the structure (dam or embankments)	• Rupture or breach in the dam or retention basin structure • Rupture of a drain device, pipe, turbine or electrical machine	• Formation of a flood wave • Sharp increase in the downstream flow	• Deadly currents sweeping away people • Drowning of people • Submersion of property
Avalanche causing a sudden rise in the water level			
External aggression on the dam or on the retention basin (vegetation, collision of vehicles or machines, burrowing fauna)			
Intrinsic dam or retention basin failure (corrosion, bottom erosion by water, damage to the liner)			
Domino effect by rupture of an upstream dam			
Exceptional flood exceeding the permitted rating			
Upstream intake with insufficient downstream flow			
Pumping causing an overfilling of the upper reservoir			
Failure of mechanical parts (corrosion, ageing, loss of seal…)			

A.3 Flywheel

A flywheel stores energy as kinetic energy. A wheel with significant mass at the rim serves as the storage medium. The wheel is typically sealed in a relative vacuum chamber to reduce kinetic energy loss due to friction forces. When it is necessary to store energy , the rotational speed of the wheel is increased, and when stored energy is to be released, the rotational speed of the wheel is decreased. Conversion of electrical energy to mechanical energy is done with an electrical machine which can function both as a motor and as a generator.

The main risk scenarios for flywheels are given in Table A.2.

See Annex C for tests to evaluate the containment of moving parts for an accumulation subsystem of a flywheel type mechanical EESS.

Table A.2 – Main risk scenarios for flywheel

Causes	Failure modes/conditions	Hazard	Consequences
Overspeed due to defective frequency inverter	• Material fatigue due to excessive stress • Rotor imbalance • Disintegration of rotor • Rotor not contained	• Machine at risk of sudden (violent) failure without warning • Excessive vibration, overheating of bearings, material fatigue • Fire (composite rotor), high speed projectiles (all rotors), forceful disintegration of machine (all rotors) • Forceful disintegration of machine, projectiles, fire	• Sickness, injury or death • Damage to buildings • System perturbation
Sensors disturbance			
Command control disturbance			
Insufficent heat dissipation			
External heat flux			
Defective vacuum pump or vacuum line			
Air intake caused by piercing of the enclosure (corrosion, breakage)			
Defective magnetic levitation of bearings			
Short circuit or rotor block in motor/generator			

A.4 Gravitational EESS

A gravity energy storage is a kind of mechanical energy storage, which lifts the weight to a high place through electricity to increase its gravitational potential energy to complete the energy storage process and converts the gravitational potential energy into kinetic energy through the falling process of the heavy object, and then into electrical energy. The weight can be either solid weight or water.

The main risk scenarios for gravitational EESS storage are given in Table A.3.

Table A.3 – Main risk scenarios for gravitational EESS

Causes	Failure modes/conditions	Hazard	Consequences
Earthquake, landslide, water infiltration which could damage the structure	• Mechanical rupture • Core weight blocked • Seal breakdown • Water leakage • Core weight dropped	• Machine at risk of sudden (violent) failure without warning • Excessive vibration, overheating of bearings, material fatigue • Projectiles and weight from high altitude • Loud noise	• Sickness, injury or death • Damage to buildings • Mechanical damage • Loss of capacity
Cable to lift the weight failure			
Control system to lift weight failure			
Corrosion of cables, and other mechanical parts			
Corrosion of water tank			
Failure or block of pump			
Damage to containment system			

A.5 Battery energy storage systems

The main risk scenarios associated with battery energy storage systems BESS are outlined in IEC 62933-5-2.

A.6 Hydrogen and synthetic natural gas

A typical hydrogen storage system consists of an electrolyser, a hydrogen storage tank and a fuel cell. An electrolyser is an electrochemical converter which splits water using electricity into hydrogen and oxygen. It is an endothermic process, i.e. heat is required during the reaction. Hydrogen is stored under pressure in gas bottles or tanks, or in the form of cryogenic liquid. Hydrogen can be stored by absorption or adsorption on solids or by chemical reaction. To generate electricity, both gases flow into the fuel cell where an electrochemical reaction which is the reverse of water splitting takes place: hydrogen and oxygen react and produce water, heat is released, and electricity is generated. For economic and practical reasons oxygen is not stored but vented to the atmosphere on electrolysis, and oxygen from the air is taken for the power generation.

The main risks scenarios for hydrogen storage are given in Table A.4.