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Electrical energy storage (ESS) systems -
Part 5-4: Safety test methods and procedures for grid integrated EES systems - Lithium ion battery-based systems

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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Electrical energy storage (EES) systems - Part 5-4: Safety test methods and procedures for grid integrated EES systems - Lithium ion battery-based systems

FOREWORD

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IEC 62933-5-4 has been prepared by IEC technical committee 120: Electrical Energy Storage (ESS) systems. It is an International Standard.

This International Standard is to be used in conjunction with IEC 62933-5-2:2025.

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

Draft	Report on voting
120/448/FDIS	120/456/RVD

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

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

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

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

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

– reconfirmed,
– withdrawn, or
– revised.

INTRODUCTION

The general safety requirements for EES systems are provided in IEC 62933-5-1. The safety requirements for battery energy storage systems (BESS) with subsystems utilizing electrochemical-based batteries are described in IEC 62933-5-2. In this document, among the safety provisions specified in IEC 62933-5-2, tests methods and procedures specific to the safety of BESS using lithium ion batteries in the subsystem are specified. This document is prepared for the following reasons:

a) To provide additional test methods and procedures specifically for lithium ion battery-based energy storage systems.

b) This document was developed based on the investigation results of BESS accidents that occurred over the world.

1 Scope

This part of IEC 62933 primarily describes the safety test methods and procedures for grid-connected energy storage systems where a lithium ion battery-based subsystem is used.

This document provides test methods and procedures to validate safety issues specifically related to the use of a lithium ion battery-based subsystem, primarily based on IEC 62933-5-1, which establishes criteria for ensuring the safe applications and use of electrical energy storage systems of any type or size, and IEC 62933-5-2, which further specifies safety provisions arising from the use of an electrochemical storage subsystems in EES systems.

All test methods and procedures are based on the requirements of IEC 62933-5-2. This document includes only the test methods specifically related to lithium ion battery-based BESS and is based on actual tests.

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

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

IEC 61000-4-18, *Electromagnetic compatibility (EMC) - Part 4-18: Testing and measurement techniques - Damped oscillatory wave immunity test*

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

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

IEC 62933-5-2:2025, *Electrical energy storage (EES) systems – Part 5-2: Safety requirements for grid-integrated EES systems – Electrochemical-based systems*

IEC 63056, *Secondary lithium cells and batteries for use in electrical energy storage systems - General requirements and methods of test*

CISPR 11, *Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement*

CISPR 16-1-2, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-2: Radio disturbance and immunity measuring apparatus - Coupling devices for conducted disturbance measurements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62933-1, IEC 62933-5-1, IEC 62933-5-2 and the following apply.

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

– IEC Electropedia: available at https://www.electropedia.org/

– ISO Online browsing platform: available at https://www.iso.org/obp

3.1
state of charge
EESS SOC
amount of stored electric charge (IEV 113-02-10) of the accumulation subsystem, related to the actual capacity (IEV 482-03-14)

Note 1 to entry: The EESS SOC is frequently intended as a synonym of EESS state of energy and, therefore, evaluated at EES system level. As defined in IEC 61427-2 and in many other standards the state of charge is related to electric charge (IEV 113-02-10), usually expressed in coulombs (C) or amperes-hours (Ah) and should be used only for some storage technologies (e.g. batteries, capacitors).

[SOURCE: IEC 61427-2:2015, 3.42, modified – original definition has been particularized for the EES system, the notes to entry have been removed and a new note has been added.]

3.2
state of energy
EESS SOE
ratio between the available energy from an EES system and the actual energy storage capacity

Note 1 to entry: The state of energy is generally expressed in percentage. ESS system empty implies EESS SOE = 0 % (empty state of energy) and EES system full implies EESS SOE = 100 % (full state of energy).

Note 2 to entry: The state of energy can be linked to accessible energy storage capacity or effective energy storage capacity. The relation with effective energy storage capacity is different. In the case of state of energy related to accessible energy storage capacity, fixed energy reserves are present on both sides (below the empty state of energy and above the full state of energy); for example, by considering the above-mentioned state of charge, its range related to accessible energy storage capacity is 0 % ÷ 100 %, so the range linked to effective energy storage capacity can be -20 % ÷ 120 %.

Note 3 to entry: In the calculation of EESS SOE linked to accessible energy storage capacity (SOE_{US}), the actual energy storage capacity linked to accessible energy storage capacity with the used energy storage capacity is used. In the calculation of EESS SOE linked to effective energy storage capacity (SOE_{EFF}), the actual energy storage capacity linked to effective energy storage capacity with the used energy storage capacity is used. In the calculation of EESS SOE linked to output energy storage capacity (SOE_{OUT}), the actual energy storage capacity linked to output energy storage capacity with the available energy during discharge is used. In the calculation of EESS SOE linked to input energy storage capacity (SOE_{IN}), the actual energy storage capacity linked to input energy storage capacity with the available energy during discharge is used.

$$SOE_{US} = \frac{E_{A,SDE}}{E_{C,ACT,US}} \qquad SOE_{EFF} = \frac{E_{A,SDE}}{E_{C,ACT,EFF}} \qquad SOE_{IN} = \frac{E_{A,DIS}}{E_{C,IN}} \qquad SOE_{OUT} = \frac{E_{A,DIS}}{E_{C,OUT}}$$

Only SOE_{US} and SOE_{OUT} can reach the entire interval 0 % ÷ 100 %, SOE_{EFF} (because of the non useful energy) and SOE_{IN} (because of energy losses) cannot reach the 100 %.

3.3
short-circuit
accidental or intentional conductive path between two or more conductive parts forcing the electric potential differences between these conductive parts to be equal to or close to zero

[SOURCE: IEC 60050-151:2001, 151-12-04]

3.4
AC short-circuit
accidental or intentional conductive path between two or more conductive parts of the grid and power conversion subsystem (PCS) forcing the electric potential differences between these conductive parts to be equal to or close to zero

3.5
DC short-circuit
accidental or intentional conductive path between two or more conductive parts of the power conversion subsystem (PCS) and electrochemical accumulation subsystem forcing the electric potential differences between these conductive parts to be equal to or close to zero

3.6
switching element short-circuit
accidental or intentional conductive path between two or more conductive parts of the upper-arm and lower-arm of the power conversion subsystem (PCS) switching element forcing the electric potential differences between these conductive parts to be equal to or close to zero

3.7
earth fault
occurrence of an accidental conductive path between a live conductor and the earth

[SOURCE: IEC 60050-194:2021,195-04-14, modified – “ground fault” has been removed from the term, “part” has been replaced with “conductor” and the note has been removed.]

3.8
AC earth fault
occurrence of an accidental conductive path between a live conductor and the earth at a point between the grid and power conversion subsystem (PCS)

3.9
DC earth fault
occurrence of an accidental conductive path between a live conductor and the earth at a point between power conversion subsystem (PCS) and electrochemical accumulation subsystem

3.10
venting
release of excessive internal pressure from a cell, module, battery pack, or battery system in a manner intended by design to preclude rupture or explosion

[SOURCE: IEC 62619:2022, 3.14]

3.11
battery management system
BMS
electronic system associated with a battery which has functions to control current in case of overcharge, overcurrent, overdischarge, and overheating and which monitors and/or manages the battery's state, calculates secondary data, reports that data and/or controls its environment to influence the battery's safety, performance and/or service life

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

3.12
power management system
PMS
system that monitors the status information of PCS and protects BESS from abnormal conditions, and delivers information necessary for charge/discharge control to PCS

3.13
rated current
current value determined under specified conditions and declared by the BESS system manufacturer

3.14
DC contactor
electrically controlled device designed to switch current on and off

3.15
upper limit charging voltage
highest charging voltage in the cell operating region specified by the cell manufacturer

[SOURCE: IEC 62619:2022, 3.19]

3.16
ground fault device
GFD
device which prevents current from following any unintended paths during a ground fault

3.17
insulation monitoring device
IMD
device which monitors the ungrounded system between an active phase conductor and earth

3.18
PCS internal protection function
protection mechanisms embedded in the power conversion system (PCS) that are designed to interrupt charging/discharging or shut down operation in response to overcurrent, overvoltage, undervoltage, overheating, or loss of communication

4 Manufacturer

In this document, the term manufacturer refers to different responsible parties depending on the context. The roles and responsibilities of each type of manufacturer are defined as follows:

a) BESS system manufacturer or integrator

The organization responsible for the overall design, functional integration, and configuration of the battery energy storage system (BESS). This entity coordinates the interaction between subsystems (e.g. PCS, BMS, PMS, HVAC, gas detection), defines system-level protective functions, and serves as the primary contact for system-level testing and acceptance criteria.

b) PCS manufacturer

The manufacturer of the power conversion system (PCS), responsible for defining the electrical ratings, operating limits, and internal protection mechanisms of the PCS.

c) Battery subsystem manufacturer

The organization that provides the battery modules, racks, or cells used within the BESS. This includes specifications for the state of charge (SOC), state of energy (SOE), voltage thresholds, temperature limits, and the integrated battery management system (BMS).

d) BMS or PMS manufacturer

The party responsible for supplying the battery management system (BMS) or power management system (PMS), which monitors, communicates with, and protects the battery subsystem or the entire BESS. This manufacturer defines communication diagnostics, response time thresholds, and protective function triggers.

e) Protection device manufacturer

The manufacturer of protective components such as circuit breakers, fuses, contactors, and relays. These components are selected according to their rated capacity and application in both system operation and test facility protection.

f) Gas detection device manufacturer (GFD/IMD)

The manufacturer of ground fault detection (GFD) devices or insulation monitoring devices (IMD) used to detect abnormal gas emissions or electrical insulation failure. This manufacturer defines device sensitivity, detection delay, and resistance configuration settings.

NOTE In this document, the unqualified term “manufacturer” is generally used in relation to the BESS system manufacturer, unless otherwise specified in the context.

5 Test methods and procedures for EES system

5.1 General

The tests shall be conducted on a complete BESS representative of production or on a representative configuration of the complete BESS.

Representative configuration for the test shall be indicative of the complete BESS in terms of scalability and design of critical components so that test results can be accurately extrapolated to demonstrate the safety of the complete BESS.

The minimum representative configuration for the tests shall consist of one PCS and the corresponding battery racks.

NOTE 1 If a BESS with a maximum energy storage capacity of 1 MWh is divided into a total of four parts based on four PCSs, a test with a representative BESS can be performed with several battery racks (e.g. 3 to 4 racks) with a maximum energy storage capacity of about 250 kWh connected to a single PCS. Depending on the test objective and BESS architecture, the representative configuration can include other subsystems as necessary (e.g. PCS, battery racks, auxiliary systems). The specific configuration for testing can be selected to represent the most critical case for system safety validation.

Table 1 provides an overview of lithium ion battery-based BESS testing with reference to IEC 62933-5-2:2025, 8.1, Table 4.

NOTE 2 Only testing lists related to lithium ion-based BESS covered in this document are listed; other testing lists are excluded.

NOTE 3 Clause 5 describes system-level validation of lithium-ion-based BESS. In practice, equivalent tests conducted in accordance with IEC 62933-5-2 sometimes cover part of these requirements, and their results are occasionally used for the system under evaluation to avoid unnecessary duplication of test efforts. At the system level, consistency and integrity of evaluation are considered to be ensured when the procedures described in this document are applied. For detailed correspondence, see Annex C.

Informative guidance on fire hazard test methods and procedures for BESS-level evaluation is provided in Annex B.