

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**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**



THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2024 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

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

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

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or request further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Discover our powerful search engine and read freely all the publications providing graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Recherche de publications IEC -

webstore.iec.ch/advsearchform

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, ...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications, symboles graphiques et le glossaire. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

Electropedia - www.electropedia.org

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 500 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 25 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**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**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 13.020.30

ISBN 978-2-8322-9374-4

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	9
2 Normative references	9
3 Terms and definitions	12
4 Basic approach for safety considerations of EES systems	16
5 Hazard considerations for EES systems	17
5.1 Electrical hazards	17
5.2 Mechanical hazards	17
5.3 Energy hazards.....	17
5.3.1 Explosion hazards	17
5.3.2 Hazards arising from electrical, magnetic, and electromagnetic fields.....	18
5.4 Fire hazards.....	18
5.5 Temperature hazards.....	18
5.6 Chemical hazards	18
5.7 Unsuitable working conditions.....	18
6 EESS risk assessment.....	19
6.1 EESS structure	19
6.1.1 General characteristics.....	19
6.1.2 Specific characteristics	19
6.2 Description of storage conditions	20
6.2.1 Types of grids, applications and locations.....	20
6.2.2 Vulnerable elements	20
6.2.3 Special provisions for EES systems in generally accessible locations.....	21
6.2.4 Sources of external aggression.....	21
6.2.5 Unattended operation	21
6.2.6 Unintentional islanding	21
6.3 Risk analysis	21
6.3.1 General	21
6.3.2 Components	22
6.3.3 Risk considerations	22
6.3.4 System level risk analysis.....	23
7 Requirements necessary to reduce risks	24
7.1 General measures to reduce risks.....	24
7.2 Preventive measures against damage to neighbouring inhabitants.....	26
7.3 Safety-related design review.....	26
7.3.1 General	26
7.3.2 Initial safety design review.....	27
7.3.3 Subsequent design revisions	27
7.4 Preventive measures against damage to workers and other persons at risk	27
7.4.1 Protection from electrical hazards.....	27
7.4.2 Protection from mechanical hazards	30
7.4.3 Protection from high pressure hazards.....	30
7.4.4 Protection from explosive atmosphere hazards.....	31
7.4.5 Protection from hazards arising from electric, magnetic, and electromagnetic fields.....	32

7.4.6	Protection from fire hazards.....	32
7.4.7	Protection from thermal hazards.....	33
7.4.8	Protection from chemical hazards.....	34
7.4.9	Protection from workplace hazards.....	35
7.4.10	Staff training.....	36
7.5	EESS disconnection and shutdown.....	36
7.5.1	General.....	36
7.5.2	Grid-disconnected state.....	37
7.5.3	Stopped state.....	38
7.5.4	EESS shutdown.....	38
7.5.5	Partial disconnection.....	38
7.5.6	Equipment guidelines for emergency shutdown.....	38
7.6	Cyber security.....	39
7.7	Remote monitoring and unattended operation.....	39
8	System testing.....	40
8.1	General.....	40
8.2	Validation and testing of EESS – Electrical hazards.....	42
8.2.1	General.....	42
8.2.2	Accessibility to hazardous live parts.....	42
8.2.3	Protection from exposure to moisture and pollution.....	42
8.2.4	Electrical insulation and protection against electrical shock tests.....	43
8.2.5	Protection against out of normal operation range tests.....	45
8.2.6	Anti-islanding.....	47
8.3	Validation and testing of EESS – Mechanical hazards.....	47
8.3.1	Enclosure strength against impact.....	47
8.3.2	Enclosure strength against static force.....	48
8.3.3	Containment of hazardous moving parts.....	48
8.3.4	Mounting means and handle robust test.....	48
8.3.5	Impact and vibration during transportation and seismic events.....	49
8.4	Validation and testing of EESS – Fluid hazards (high or low temperature, high pressure, flammable, corrosive, caustic, or toxic).....	49
8.4.1	General.....	49
8.4.2	Hazardous fluid containing parts strength test.....	49
8.4.3	Hazardous fluid containing parts leakage test.....	50
8.4.4	Start-to-discharge pressure test.....	51
8.5	Validation and testing of EESS – Explosion and combustible concentrations hazards.....	52
8.5.1	Gas detection and off-gas detection.....	52
8.5.2	Mechanical ventilation evaluation.....	52
8.6	Validation and testing of EESS – Hazards arising from electric, magnetic and electromagnetic fields.....	52
8.7	Validation and testing of EESS – Fire propagation hazards.....	53
8.8	Validation and testing of EESS – Temperature hazards.....	53
8.8.1	General.....	53
8.8.2	Containment of hazardous temperature (low or high) fluids.....	53
8.8.3	Temperature under normal operation tests.....	53
8.9	Validation and testing of EESS – Chemical effects.....	53
8.9.1	Strength tests.....	53
8.9.2	Leakage tests.....	53

8.10	Validation and testing of EESS – Hazards arising from the environment	54
8.10.1	General	54
8.10.2	Ingress of moisture	54
8.10.3	Exposure to marine environments	54
8.11	Validation and testing of EESS – Hazards arising from auxiliary, control and communication subsystem malfunctions	54
8.11.1	General	54
8.11.2	Auxiliary system malfunction	55
8.11.3	EES control subsystem malfunction	57
8.11.4	EESS internal communication malfunction	58
8.11.5	EESS external communication malfunction	59
9	Instruction manuals and guidelines	59
9.1	General	59
9.2	Installation manual	60
9.3	Maintenance manual	61
9.3.1	General	61
9.3.2	Personal protective equipment (PPE) guidelines	61
9.4	Operator manual	61
9.5	Emergency procedure manual	62
9.6	First response manual	62
10	Markings and signage	63
10.1	General	63
10.2	Nameplate	63
10.3	Cautionary markings and signage	63
Annex A	(informative) Main risks of different storage technologies	64
A.1	General	64
A.2	Pumped hydro storage	64
A.3	Flywheel	65
A.4	Gravitational EESS	65
A.5	Battery energy storage systems	66
A.6	Hydrogen and synthetic natural gas	66
A.7	Thermal EESS technologies	67
A.8	Other EESS technologies	68
Annex B	(informative) Safety considerations	69
B.1	General	69
B.2	Electrical hazards	69
B.3	Mechanical hazards	70
B.4	Energy hazards	70
B.4.1	Explosion hazards	70
B.4.2	Hazards arising from electrical, magnetic, and electromagnetic fields	71
B.5	Fire hazards	71
B.6	Temperature hazards	72
B.7	Chemical hazards	73
B.8	Unsuitable working conditions	73
Annex C	(normative) Test methods for mechanical EESS using a flywheel accumulation subsystem	74
C.1	General	74
C.2	Purpose	74
C.3	Requirement	74

C.4 Method	74
Annex D (informative) Component safety standards	75
Bibliography	78
Figure 1 – General description of the approach to address hazards in EES systems	17
Figure 2 – Iterative checking sequence in general risk assessment procedures	24
Figure 3 – General risk reduction measures to minimize hazards	25
Figure 4 – Damage propagation from a contained incident to a major incident, and layered measures to minimize damage	25
Figure 5 – Initial safety design review and design revision	27
Figure 6 – Examples of different EESS architectures	37
Figure 7 – EESS architecture in the two main EESS configurations	41
Figure B.1 – Islanding of the EESS	70
Table 1 – EESS characteristics for risk assessment consideration	20
Table 2 – Test parameters for the strength test	50
Table 3 – Test parameters for the leakage test	51
Table A.1 – Main risk scenarios for pumped hydro storage	64
Table A.2 – Main risk scenarios for flywheel	65
Table A.3 – Main risk scenarios for gravitational EESS	66
Table A.4 – Main risk scenarios for hydrogen storage	67
Table A.5 – Main risk scenarios for thermal EESS	68
Table D.1 – Examples of component safety standards for use in EESS	75

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTRICAL ENERGY STORAGE (EES) SYSTEMS –**Part 5-1: Safety considerations for grid-integrated EES systems –
General specification**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. For this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publications"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at <https://patents.iec.ch>. IEC shall not be held responsible for identifying any or all such patent rights.

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 content 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.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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 EES 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)*