

TECHNICAL SPECIFICATION



**Electrical energy storage (EES) systems –
Part 3-2: Planning and performance assessment of electrical energy storage
systems – Additional requirements for power intensive and renewable energy
sources integration related applications**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 13.020.30

ISBN 978-2-8322-6326-6

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	7
INTRODUCTION.....	9
1 Scope.....	10
2 Normative references	10
3 Terms, definitions, abbreviated terms and symbols.....	11
3.1 Terms and definitions.....	11
3.2 Abbreviated terms and symbols	12
3.2.1 Abbreviated terms	12
3.2.2 Symbols	13
4 General planning and performance assessment considerations for EES systems	14
4.1 Applications of EES systems.....	14
4.1.1 Functional purpose of the EES systems.....	14
4.1.2 Application related requirements.....	15
4.2 Conditions and requirements for connection to the grid.....	18
4.2.1 General	18
4.2.2 Grid parameters at the intended POC	18
4.2.3 Service conditions	18
4.2.4 Requirements and restrictions of the grid or system operator.....	19
4.2.5 Standards and local regulations.....	21
4.3 Design of the EES systems	22
4.3.1 General	22
4.3.2 Structure of the EES systems	22
4.3.3 Subsystem specifications.....	23
4.3.4 Grid integration of the EES systems	27
4.3.5 Operation and control	28
4.3.6 Monitoring	29
4.3.7 Maintenance.....	29
4.3.8 Communication interface	30
4.4 Sizing and resulting parameters of the EES systems.....	30
4.4.1 General	30
4.4.2 Sizing	30
4.4.3 Characteristics and restrictions of the EES systems	33
4.5 Service life of the EES systems	35
4.5.1 General	35
4.5.2 Installation.....	35
4.5.3 Performance assessment	35
4.5.4 Operation and control	36
4.5.5 Monitoring	38
4.5.6 Maintenance.....	38
5 Frequency regulation/control	42
5.1 Primary and secondary frequency regulation.....	42
5.1.1 Applications of the EES systems.....	42
5.1.2 Conditions and requirements for connection to the grid.....	44
5.1.3 Design of the EES systems.....	44
5.1.4 Sizing and resulting parameters of the EES systems	47
5.1.5 Service life of the EES systems	49

5.2	Fast frequency control	55
5.2.1	Applications of the EES systems.....	55
5.2.2	Conditions and requirements for connection to the grid.....	58
5.2.3	Design of the EES systems.....	58
5.2.4	Sizing and resulting parameters of the EES systems	60
5.2.5	Service life of the EES systems	61
6	Grid voltage support ($Q(U)$), volt/var support	62
6.1	Applications of the EES systems.....	62
6.1.1	Functional purpose of the EES systems.....	62
6.1.2	Application related requirements.....	63
6.2	Conditions and requirements for connection to the grid.....	63
6.3	Design of the EES systems	63
6.3.1	Structure of the EES systems	63
6.3.2	Subsystem specifications.....	64
6.3.3	Grid integration of the EES systems	64
6.3.4	Operation and control	64
6.3.5	Communication interface	65
6.4	Sizing and resulting parameters of the EES systems.....	65
6.4.1	Sizing	65
6.4.2	Characteristics and restrictions of the EES systems	66
6.5	Service life of the EES systems	66
6.5.1	Installation.....	66
6.5.2	Performance assessment	66
6.5.3	Operation and control	67
6.5.4	Monitoring	67
7	Voltage sag mitigation ($P(U)$).....	67
7.1	Applications of the EES systems.....	67
7.1.1	Functional purpose of the EES systems.....	67
7.1.2	Application related requirements.....	68
7.2	Conditions and requirements for connection to the grid.....	69
7.3	Design of the EES systems	69
7.3.1	Structure of the EES systems	69
7.3.2	Subsystem specifications.....	70
7.3.3	Grid integration of the EES systems	70
7.3.4	Operation and control	70
7.3.5	Communication interface	71
7.4	Sizing and resulting parameters of the EES systems.....	71
7.4.1	Sizing	71
7.4.2	Characteristics and restrictions of the EES systems	72
7.5	Service life of the EES systems	73
7.5.1	Installation.....	73
7.5.2	Performance assessment	73
7.5.3	Operation and control	73
7.5.4	Monitoring	73
8	Renewable energy sources integration related applications	74
8.1	Renewable energy sources (power) smoothing	74
8.1.1	Applications of the EES systems.....	74
8.1.2	Conditions and requirements for connection to the grid.....	75
8.1.3	Design of the EES systems.....	75

8.1.4	Sizing and resulting parameters of the EES systems	77
8.1.5	Service life of the EES systems	78
8.2	Renewable energy sources (energy) generation firming	80
8.2.1	Applications of the EES systems.....	80
8.2.2	Conditions and requirements for connection to the grid.....	80
8.2.3	Design of the EES systems.....	81
8.2.4	Sizing and resulting parameters of the EES systems	81
8.2.5	Service life of the EES systems	82
8.3	EES systems in electric charging stations in combination with renewable energy sources	83
8.3.1	Applications of EES systems	83
8.3.2	Conditions and requirements for connection to the grid.....	83
8.3.3	Design of the EES systems.....	83
8.3.4	Sizing and resulting parameters of the EES systems	84
8.3.5	Service life of the EES systems	85
9	Power oscillation damping (POD)	88
9.1	Applications of the EES systems	88
9.1.1	Functional purpose of the EES systems.....	88
9.1.2	Application related requirements.....	89
9.2	Conditions and requirements for connection to the grid	90
9.3	Design of the EES systems	90
9.3.1	Structure of the EES system	90
9.3.2	Subsystem specifications.....	91
9.3.3	Grid integration of the EES systems	91
9.3.4	Operation and control	91
9.3.5	Communication interface	92
9.4	Sizing and resulting parameters of the EES systems.....	93
9.4.1	Sizing	93
9.4.2	Characteristics and restrictions of the EES systems	95
9.5	Service life of the EES systems	95
9.5.1	Installation.....	95
9.5.2	Performance assessment	96
9.5.3	Operation and control	96
9.5.4	Monitoring	97
Annex A (informative) Key performance indicators metrics relevant to each EES system application		98
Annex B (informative) Default assignment of permissions to roles		99
Annex C (informative) Specific maintenance requirements in terms of EES technologies		104
C.1	General.....	104
C.2	Electrochemical energy storage	104
C.2.1	Lead-acid battery.....	104
C.2.2	Lithium ion battery	106
C.2.3	Sodium sulphur battery	107
C.2.4	Flow battery.....	107
C.3	Mechanical energy storage	108
C.3.1	Compressed air energy storage	108
C.3.2	Flywheel energy storage.....	109
C.4	Electrical energy storage	109

C.4.1 Supercapacitor energy storage 109

C.4.2 Superconducting magnetic energy storage (SMES) 110

Bibliography..... 112

Figure 1 – Typical architectures of EES systems.....23

Figure 2 – EES system typical architecture with detailed structure of management subsystem 26

Figure 3 – Overview of EES planning and design aspects..... 31

Figure 4 – Example of EES planning process with multi-function applications 32

Figure 5 – Example of frequency control block diagram 42

Figure 6 – Example of frequency regulation time/duration schematic diagram 43

Figure 7 – Example of the system structure of the EES system for frequency regulation in conjunction with generator 44

Figure 8 – Example of droop control with frequency dead band..... 45

Figure 9 – Example of EES system sizing process for primary frequency regulation 47

Figure 10 – Example of EES system sizing process for secondary frequency regulation 48

Figure 11 – Example of control strategy of the EES system participating in primary frequency regulation 50

Figure 12 – Example of SOC thresholds and storage modes of the EES system 51

Figure 13 – Example of EES system participating in secondary frequency regulation..... 53

Figure 14 – Example of control strategy of EES system participating in secondary frequency regulation 54

Figure 15 – Example of frequency curve with fast frequency control 56

Figure 16 – Example of operation regions of different frequency response types 57

Figure 17 – Example of frequency and EES system output power curve with time..... 57

Figure 18 – Example of the system structure of EES systems for fast frequency control application in conjunction with renewable energy sources 58

Figure 19 – Frequency deviation curve 59

Figure 20 – Example of EES system sizing process for fast frequency control 60

Figure 21 – Example of control strategy of the EES system participating in fast frequency control 62

Figure 22 – Example of the system structure of the EES system for grid voltage support 64

Figure 23 – Example of reactive voltage support schematic diagram..... 65

Figure 24 – Example of EES system sizing process for voltage support..... 66

Figure 25 – Example of voltage sag 67

Figure 26 – Example of compensation time of the EES system for voltage sag mitigation 68

Figure 27 – Example of regulation time of the EES system for voltage sag mitigation..... 69

Figure 28 – Example of the system structure of the EES system for voltage sag mitigation 70

Figure 29 – Example of control strategy for the voltage sag mitigation application 71

Figure 30 – Example of EES system sizing process for voltage sag mitigation 71

Figure 31 – Example of the system structure of the EES system connected with renewable energy sources 76

Figure 32 – Example of control strategy for the renewable energy sources (power) smoothing application 76

Figure 33 – Example of the EES system sizing process for renewable energy sources (power) smoothing 77

Figure 34 – Example of renewable energy sources (power) smoothing basic procedures..... 78

Figure 35 – Example of the EES system for renewable energy sources (power) monitoring system..... 79

Figure 36 – Example of control strategy for the renewable energy sources (energy) firming application..... 81

Figure 37 – Example of EES system sizing process for renewable energy sources (energy) generation firming 82

Figure 38 – Example of the system structure of the EES system in electric charging stations in combination with renewable energy sources 84

Figure 39 – Example of EES system sizing process of the EES system in electric charging stations in combination with renewable energy sources 85

Figure 40 – Example of EV charging mode selection..... 86

Figure 41 – Example of electric charging stations monitoring system architecture in combination with renewable energy sources and EES system 87

Figure 42 – Schematic diagram of the system structure of a single infinite bus system connected with the EES system 88

Figure 43 – Schematic diagram of typical four-generators two-regions system structure connected with the EES system 88

Figure 44 – Example of damping power oscillation simulation with five BESSs in a transmission grid 90

Figure 45 – Example of the system structure of the EES system for POD 91

Figure 46 – Example of EES system sizing process for POD application..... 94

Figure 47 – Example of control strategy of the EES system participating in the POD 97

Table 1 – Typical multi-function applications of EES systems 33

Table 2 – Example of the definition of various states of charge 51

Table 3 – Example of information interaction between various systems..... 87

Table A.1 – Metrics relevant to each EES system application 98

Table B.1 – Default assignment of permissions to roles within different monitoring and maintenance states 100

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTRICAL ENERGY STORAGE (EES) SYSTEMS –**Part 3-2: Planning and performance assessment of electrical energy storage systems – Additional requirements for power intensive and renewable energy sources integration related applications**

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. To 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 Publication(s)”). 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) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC TS 62933-3-2 has been prepared by IEC technical committee 120: Electrical Energy Storage (EES) Systems. It is a Technical Specification.

This Technical Specification is based on IEC TS 62933-3-1:2018 and is to be used in conjunction with IEC TS 62933-3-3:2022.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
120/263A/DTS	120/278/RVDTS
	120/278A/RVDTS

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 Technical Specification 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,
- replaced by a revised edition, or
- amended.

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

This part of IEC 62933 should be used as a reference when planning, designing, controlling and operating power intensive and renewable energy sources integration related applications of EES systems.

ELECTRICAL ENERGY STORAGE (EES) SYSTEMS –

Part 3-2: Planning and performance assessment of electrical energy storage systems – Additional requirements for power intensive and renewable energy sources integration related applications

1 Scope

This part of IEC 62933 provides the requirements for power intensive and renewable energy sources integration related applications of EES systems, including grid integration, performance indicators, sizing and planning, operation and control, monitoring and maintenance. The power intensive applications of EES systems are usually used to improve the dynamic performance of the grid by discharging or charging based on corresponding control strategies. The renewable energy sources integration related applications of EES systems are usually used to mitigate short-term fluctuation and/or to keep long-term stability. This document includes the following applications of EES systems:

- frequency regulation/support;
- grid voltage support ($Q(U)$) (“volt/var support”);
- voltage sag mitigation;
- renewable energy sources integration related applications;
- power oscillation damping (POD).

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 60721-1, *Classification of environmental conditions – Part 1: Environmental parameters and their severities*

IEC 61850 (all parts), *Communication networks and systems for power utility automation*

IEC TS 62786, *Distributed energy resources connection with the grid*

IEC TS 62933-1:2018, *Electrical energy storage (EES) systems – Part 1: Vocabulary*

IEC TS 62933-3-1, *Electrical energy storage (EES) systems – Part 3-1: Planning and performance assessment of electrical energy storage systems – General specification*

IEC TS 62933-3-3, *Electrical energy storage (EES) systems – Part 3-3: Planning and performance assessment of electrical energy storage systems – Additional requirements for energy intensive and backup power applications*

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

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

IEC/IEEE 60255-118-1, *Measuring relays and protection equipment – Part 118-1: Synchrophasor for power systems – Measurements*

ISO 5660-1, *Reaction-to-fire tests – Heat release, smoke production and mass loss rate – Part 1: Heat release rate (cone calorimeter method) and smoke production rate (dynamic measurement)*

IEEE C37.118-2015, *IEEE Standard for Synchrophasors for Power Systems*