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Title: BS EN IEC 62933-3-1 Electrical energy storage (EES) systems

Part 3-1: Planning and performance assessment of electrical energy storage systems - General specification

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



120/328/CD

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IEC TC 120 : ELECTRICAL ENERGY STORAGE (EES) SYSTEMS

SECRETARIAT:

Japan

SECRETARY:

Mr Hideki HAYASHI

OF INTEREST TO THE FOLLOWING COMMITTEES:

TC 8, TC 21, TC 22, TC 57, TC 69

PROPOSED HORIZONTAL STANDARD:



Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.

FUNCTIONS CONCERNED:

☐ EMC

☐ ENVIRONMENT

☐ QUALITY ASSURANCE

☐ SAFETY

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TITLE:

Electrical energy storage (EES) systems - Part 3-1: Planning and performance assessment of electrical energy storage systems - General specification

NOTE FROM TC/SC OFFICERS:

In accordance with the decisions taken by 120/260/Q and 120/269/RQ, TC 120 WG 3 has prepared a first CD of IEC 62933-3-1.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTRICAL ENERGY STORAGE (EES) SYSTEMS –**Part 3-1: Planning and performance assessment of
electrical energy storage systems – General specification**

FOREWORD

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- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical Specification IEC 62933-3-1 has been prepared by IEC technical committee TC 120: Electrical Energy Storage (EES) Systems.

220 The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
120/118/DTS	120/123/RVDTS

221
222 Full information on the voting for the approval of this technical specification can be found in the
223 report on voting indicated in the above table.

224 This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

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

227 The committee has decided that the contents of this publication will remain unchanged until the
228 stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to
229 the specific publication. At this date, the publication will be

- 230 • transformed into an International standard,
231 • reconfirmed,
232 • withdrawn,
233 • replaced by a revised edition, or
234 • amended.

235 A bilingual version of this publication may be issued at a later date.

236

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237

238

239

INTRODUCTION

240 IEC 62933-2-1 should be used as a reference when selecting testing items and their
241 corresponding evaluation methods as well as principal parameters. Principal terms used in this
242 document are defined in IEC 62933-1. Environmental issues are covered by IEC TS 62933-4-1.
243 The personnel safety issues are covered by IEC TS 62933-5-1.

244

245

ELECTRICAL ENERGY STORAGE (EES) SYSTEMS –

Part 3-1: Planning and performance assessment of electrical energy storage systems – General specification

1 Scope

This part of IEC 62933 is applicable to EES systems designed for grid-connected indoor or outdoor installation and operation. This document considers

- necessary functions and capabilities of EES systems
- sizing and design of EES system
- operation of EES system
- test items and performance assessment methods for EES systems
- requirements for monitoring and acquisition of EES system operating parameters
- exchange of system information and control capabilities required
- maintenance of EES system

Stakeholders of this document comprise personnel involved with EES systems, which include

- planners of electric power systems and EES systems
- owners of EES systems
- operators of electric power systems and EES systems
- constructors
- suppliers of EES systems and its equipment
- aggregators

Use-case-specific technical documentation, including planning and installation specific tasks such as system design, monitoring, measurement, tests, operation and maintenance, are very important and can be found throughout this document.

NOTE This document has been written for AC grids, however parts can also apply to DC grids.

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 61850-7-420, *Communication networks and systems for power utility automation –Part 7-420: Basic communication structure – Distributed energy resources logical nodes*

IEC 62351 (all parts), *Power systems management and associated information exchange – Data and communications security*

IEC 62443 (all parts), *Industrial communication networks – Network and system security*

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

IEC 62933-2-1, *Electrical energy storage (EES) systems – Part 2-1: Unit parameters and testing methods – General specification*

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

ISO/IEC 27000, *Information technology – Security techniques – Information security management systems – Overview and vocabulary*

3 Terms, definitions and symbols

3.1 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>

Note 1 to entry: The definition is loosely based on IEC 60050-447:2010, 447-05-08.

3.2 Symbols

P active power

Q reactive power

S apparent power

U voltage

I current

$\cos\varphi$ power factor

f frequency

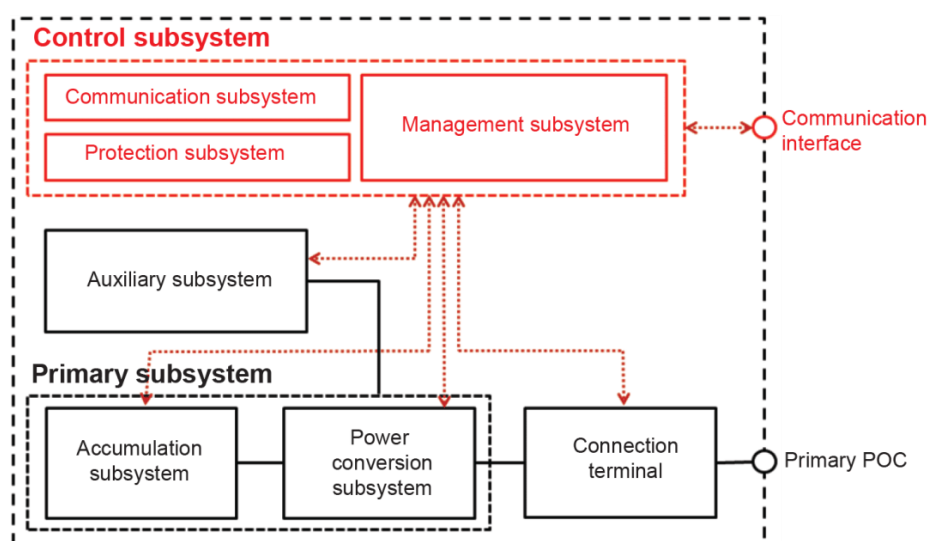
4 General about EES systems

4.1 Main functional aspects

According to IEC 62933-1 an EES system is a grid-connected installation with defined electrical boundaries, comprising at least one electrical energy storage unit, which extracts electrical energy from an electric power system, stores this energy internally in some manner and injects electrical energy into an electric power system. An EES system can include civil engineering works, energy conversion equipment and related ancillary equipment. The EES system is controlled and coordinated to provide services to the electric power system operators or to the electric power system users.

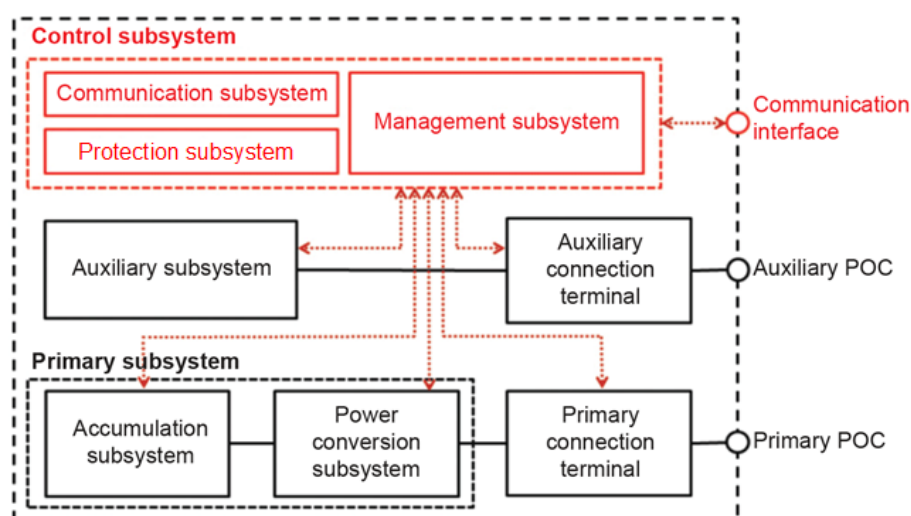
4.2 Architecture of an EES system

The typical architecture of an EES system, which internally feeds the auxiliary subsystem, is given in Figure 1 a).



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a) EES system without auxiliary POC



b) EES system with auxiliary POC

Figure 1 – Typical architectures of EES systems

If the auxiliary subsystem is fed from another feeder, the optional architecture of an ESS system is shown in Figure 1 b).

4.3 Subsystem specifications

4.3.1 General

To meet the requirements of the entire EES system, it is necessary to break down the system requirements to the requirements of the subsystems. The requirements for the subsystems shall be formulated in a general and technology-independent manner. But requirements arising from the subsystems (e.g. regarding safety or maintenance), which are technology dependent, shall also be considered.

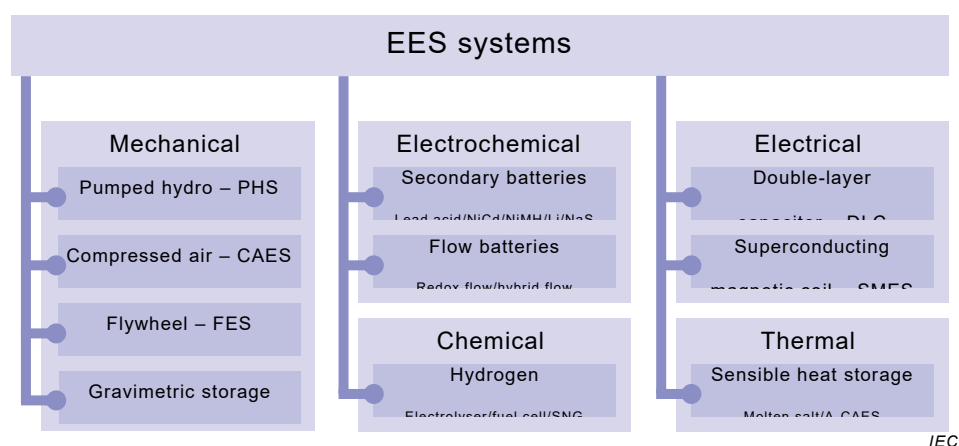
Constraints and deratings regarding power rating, available energy, ambient conditions and other internal/external aspects shall also be considered for all subsystems.

The requirements of the subsystems of an EES system are described in sub-clauses 4.3.2 to 4.3.5. In general, for all subsystems, the contribution to the overall system efficiency, for example roundtrip efficiency, shall be indicated.

4.3.2 Accumulation subsystem

The energy storage capacity of the accumulation subsystem of the EES system has to be evaluated in an appropriate way with respect to the energy form (e.g. mechanical or electrochemical). The energy storage capacity of the accumulation subsystem directly influences the rated input and output energy capacity at the primary POC, i.e. it influences the active input and output power values at the primary POC as well as the duration the active input and output power can be applied at the primary POC.

A widely-used approach for classifying EES systems is the determination according to the form of energy used in the accumulation subsystem. A classification example of EES systems according to energy form in the accumulation subsystem is shown in Figure 2.



IEC

Figure 2 – Example of classification of EES systems according to energy form

Accumulation subsystems shall meet performance specifications such as enough energy storage capacity throughout their service life. This includes their service life under use conditions such as operation patterns (see IEC 62933-1:2018, Figure 1), environmental conditions, maintenance cycle, etc.

a) General requirements

The following information shall be provided irrespective of the technology applied:

For each accumulation subsystem the energy storage capacity and the maximum charge and discharge power shall be considered because this has a direct influence on the overall EES system.

Also, the present energy content is important for the EES system. A forecast method, i.e. how the resulting energy content after charging or discharging with a certain power for a certain time can be estimated, shall be given.

Typical service life values (possibly differentiated into cyclical and calendrical ageing) shall be specified. Information on the energy and power density shall also be given to be able to make a comparison with other accumulation subsystems if necessary.

Information about necessary service and maintenance cycles shall be given. The auxiliary power demand of the accumulation subsystem shall also be provided, if applicable. Furthermore, efficiency parameters of the accumulation subsystem shall be provided:

- charging efficiency of the accumulation subsystem;
- discharging efficiency of the accumulation subsystem;
- self-discharge or “energy storage efficiency” of the accumulation subsystem.

b) Specific requirements

If there are requirements that are specific to the accumulation technology applied, then these requirements shall be provided. For example, if a reduction in charging or discharging power is necessary in certain operating areas, this shall be indicated. If special regulations have to be considered for the accumulation subsystem (for example, for disposal), this shall be specified, as it could be relevant for planning. If galvanic isolation between POC and accumulation subsystem is provided, this shall also be given.

4.3.3 Power conversion subsystem

The power conversion subsystem converts the power of the accumulation subsystem into electrical power at the POC, typically AC output power during discharge of the accumulation subsystem and can convert grid AC input power to suitable power for charging the accumulation subsystem. This conversion can be performed by electrical and/or mechanical systems. The power conversion subsystem influences the apparent power characteristic of the EES system. The power conversion subsystem can also influence the power quality at the POC.

Generally, the power conversion subsystem is connected to the accumulation subsystem and to the (primary) connection terminal. For planning issues, the power conversion subsystem shall also include all power transfer apparatus between the connection terminal and the accumulation subsystem, for example any kind of power transformer, sine filter or switching elements.

a) General requirements

The following information shall be provided irrespective of the technology applied:

The auxiliary power demand of the power conversion subsystem shall be given, if applicable. If galvanic isolation between the POC and accumulation subsystem is provided, this shall also be stated. Furthermore, efficiency parameters of the conversion subsystem shall be provided:

- charging efficiency of the power conversion subsystem;

- discharging efficiency of the power conversion subsystem.

b) Specific requirements

If there are requirements that are specific to the power conversion technology applied, then these requirements shall be provided. The conversion type (AC/DC, AC/AC, pump/generator, etc.) as well as the operational ranges, for example the DC voltage or frequency range, shall be given.

4.3.4 Auxiliary subsystem

All necessary equipment intended to perform the EES system's auxiliary functions shall be considered, for example, HVAC (heating, ventilation, and air conditioning system) and fire suppression system.

a) General requirements

The following information shall be provided irrespective of the technology applied:

The overall auxiliary power demand of the EES system which has to be handled by the auxiliary subsystem shall be given. Auxiliary power demand for every noteworthy operational state of the EESS shall be provided. Information regarding the structure of the auxiliary subsystem shall be given.

Furthermore, requirements regarding redundancy and buffered power supply (in case of an outage of the supplying power source) shall be provided, if applicable.

b) Specific requirements

If there are requirements that are specific to the auxiliary subsystem technology applied, then these requirements shall be mentioned.

4.3.5 Control subsystem

A system for monitoring and controlling the EES system shall be used. A control subsystem may include a communication subsystem, protection subsystem and management subsystem. During the planning phase the required remote control capabilities and the operation modes that the control system will support shall be stated, considering the applicable local grid code requirements.

The EES system shall be designed in such a way that a supply outage does not affect the EES system security and the ability of the EES system to start up again. The maximum outage duration should be considered (for example a specific back-up power has to be designed). A safe disconnection and safe system shutdown concept shall be agreed between the supplier and user of the EES system.

All protection functions of the EES system (e.g., over-discharging protection) shall be described with functionality and trigger values.

a) General requirements

The typical architecture of the EES system shown in Figure 3 depicts the management subsystem as a single system. When an EES system is designed and installed, it is common to provide separate management systems for the accumulation subsystem and power conversion subsystem. In addition, an energy management system can be added to control the internal operation of the EES systems and to interact with the grid power systems. Figure 3 depicts the

detailed structure of the management subsystem including the management system for the accumulation subsystem, the management system for the power conversion subsystem, and the energy management system. Depending on the design, these systems can be provided as separate systems or as functions within a single system.

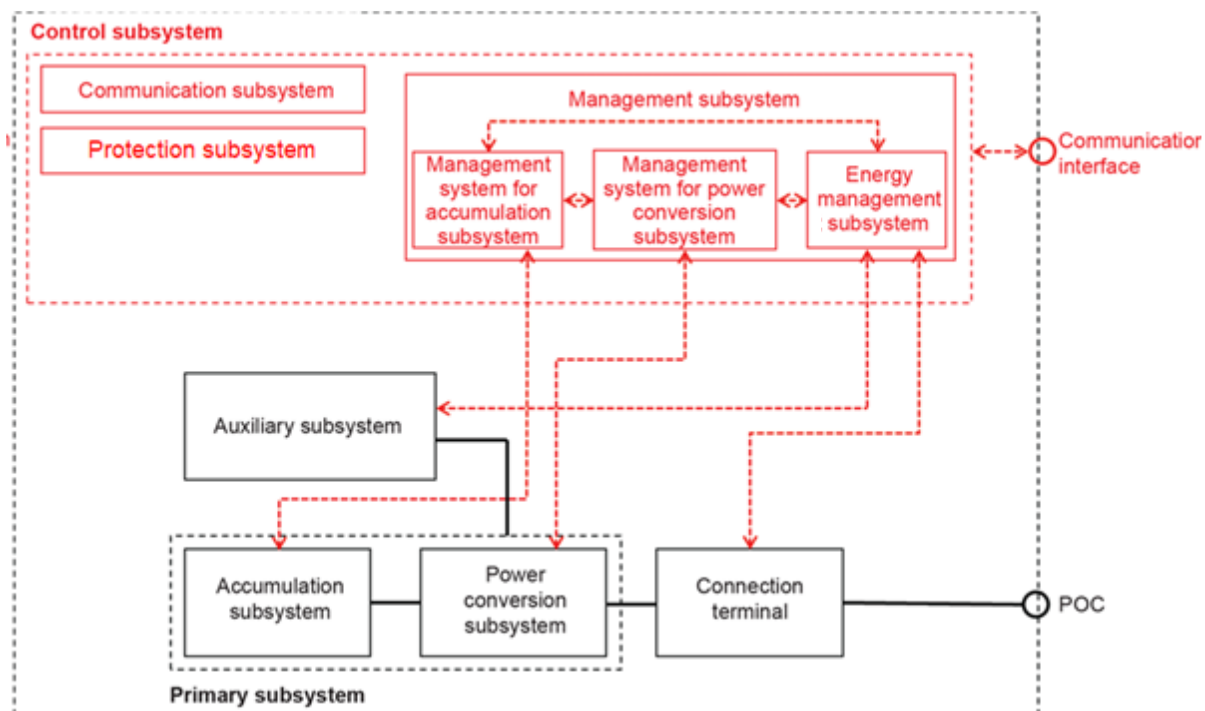


Figure 3 – EES system typical architecture with detailed structure of management subsystem

The functional requirements of the control subsystem may include:

- measurement functions;
- monitoring functions;
- calculation functions (for example load change forecast, charge/discharge power, statistics);
- recording functions;
- data export functions;
- operation and control functions e.g. local or remote control selection or service functionality selection (peak shaving, frequency support, etc.);
- communication functions (for example communication with EES system subsystems and grid power systems);
- protection functions;
- energy management functions

b) Specific requirements

If there are requirements that are specific to the control subsystem technology applied, then these requirements shall be provided.

4.4 Main electrical parameters of EES systems

4.4.1 General

For EES systems subclauses 4.4.2 to 4.4.11 include the main electrical parameters related to system performance at the (primary) POC, possibly including effects at the auxiliary POC. The main parameters representing the electrical performance of the EES system may include, but should not be limited to, the values given in subclause 5.9.

In the planning phase, the EES system should be designed and reviewed based on the requirements at the POC and on the customer requirements. During this process, the planner should focus on the performance parameters from the specification and related data, ensuring the coordination of each subsystem and/or equipment provided by each respective supplier (see Table 1). During the planning phase, the performance degradation of the EES system should also be considered.

Constrains and deratings regarding power rating, available energy, ambient conditions and other internal/external factors shall be considered.

Grid-connected EES systems shall meet performance specifications throughout their service life. This includes their service life under use conditions such as operation patterns (see IEC 62933-1:2018, Figure 1), environmental conditions, maintenance cycle, etc.

Table 1 – Points of attention for planning phase

Energy storage capacity values	Input and output power values (active and reactive)	Round trip efficiency	End-of-service life values	Response time parameters	Reliability, availability and outage duration
Rated energy storage capacity values to achieve service life Necessary energy storage capacity values for the specified application	Rated input and output power Rated power for on-grid and off-grid use Short-term power ratings	Round trip energy efficiency Duty cycle round trip energy efficiency for the specified application Power consumption in auxiliary and control subsystem and internal losses Loss of energy due to self-consumption / self-discharge	Satisfactory design and maintenance plan to keep specified values of performance parameters	Required response times (for autonomous operation, load-following operation, scheduled operation and remote dispatch) Required response time from standby state to start up Response time from active input power state to active output power state	maximum acceptable forced and scheduled outage duration

4.4.2 Active input and output power rating

The rated active input and output power should be chosen according to the intended usage of the EES system. Both rated power values shall be valid till end-of-service life.

Rated active input and output power values shall be defined at the (primary) POC and shall be equal to the '*rated input active power*' and the '*rated output active power*' defined in IEC 62933-1. The short duration input and output power values shall be equal to the '*short duration input power*' and '*short duration output power*' defined in IEC 62933-1.

The selection and specification of both the power conversion subsystem and accumulation subsystem of the EES system shall be considered during the planning phase.

NOTE The rated input and output power can be different in EES systems.

4.4.3 Rated energy storage capacity

In order to provide the required rated energy storage capacity and the required active input and output power values at the primary POC for the specified duration, the accumulation subsystem of the EES system should be designed appropriately during the planning phase.

For EES system planning the rated energy storage capacity shall be the capacity value at the end-of-service life considering the worst case operation limits (e.g. degradation due to highest or lowest operation temperature).

The '*rated active power output duration*' (according to IEC 62933-1) shall be the minimum time duration with which the EES system is able to deliver the '*rated output active power*' (according to IEC 62933-1) continuously, starting from full state of charge, providing continuously the rated output active power, measured at the primary POC, and finally reaching the end-of-discharge condition. The '*rated active power output duration*' is intended at the end of the service life.

The '*rated output energy capacity*' (according to IEC 62933-1) shall be derived by multiplying the '*rated output active power*' with the '*rated active power output duration*'. It is assured that at the end-of-service life the EES system can provide the '*rated output active power*' at the primary POC for a certain duration.

The '*rated active power input duration*' (according to IEC 62933-1) shall be the minimum time duration with which the EES system is able to consume continuously the '*rated input active power*' (according to IEC 62933-1), starting from an empty state of charge, providing the rated input active power continuously, measured at the primary POC, and finally reaching the end-of-charge condition. The '*rated active power input duration*' is intended at the end of the service life.

The '*rated input energy capacity*' shall be derived by multiplying the '*rated input active power*' with the '*rated active power input duration*'.

4.4.4 Response time performances

Response time parameters (for example '*step response time*' in IEC 62933-1) shall be designed from the time when the EES system receives the command signal or detects changes in the nominated grid parameter, to the time when the system reaches a specified response.

4.4.5 Rated reactive power

The EES system shall be capable of dispatching both leading and lagging reactive power at the POC, up to the rated apparent power regardless of whether the battery is being simultaneously discharged or charged.

The EES system converters shall be designed to meet the reactive power requirements in both inverter and rectifier operation up to rated active power across the specified AC voltage range of the grid.

It shall be possible to fully utilize the inherent reactive capability of the converters across the complete active power operating range.

4.4.6 Auxiliary power consumption

Auxiliary power consumption shall be considered during the planning phase.

NOTE Explanations about auxiliary power consumption are included in IEC 62933-2-1:2017, Clause 5.

4.4.7 Self-discharge

Self-discharge shall be considered during the planning phase. Refer to IEC 62933-1 and IEC 62933-2-1.

4.4.8 Roundtrip efficiency

The EES system should have a round-trip AC-AC energy efficiency that, in coordination with all other design and operational features of the EES system, reduces overall life-cycle cost to the extent possible.

The losses of each equipment/system included in the scope of supply shall be taken into account in the determination of the total losses. The energy consumption of an auxiliary subsystem shall be taken into consideration for the calculation of the roundtrip efficiency.

NOTE 1 Explanations about roundtrip efficiency are included in IEC 62933-2-1:2017, Clause 5, and the definition of roundtrip efficiency is included in IEC 62933-1.

NOTE 2 The terms duty cycle and duty cycle roundtrip efficiency are defined in IEC 62933-1. The EES system supplier will state in the planning phase the idle times needed when operating the system to perform the user's duty cycle.

4.4.9 Duty cycle roundtrip efficiency

For duty cycle and duty cycle roundtrip efficiency refer to IEC 62933-1 and IEC 62933-2-1.

4.4.10 Recovery times

The duration necessary to recover the EES system for the next duty cycle shall be considered during the planning phase.

4.4.11 Asset lifetime and end-of-service life values

In the planning phase the expected service life needed shall be specified.

At the end-of-service life, EES systems no longer comply with the end-of-service life values (see IEC 62933-1). Examples are:

- The actual energy storage capacity or the actual input or output energy capacity of the EES system is less than the end-of-service life value.
- The power during system charging or discharging is less than the end-of-service life value.
- The roundtrip efficiency is less than the end-of-service life values.
- The response time parameters deteriorate for the end-of-service life values.

From the viewpoint of service life, performance parameters are typically categorized into two types of degradation characteristics as shown in Figure 4:

- a) The performance is deteriorated over time: for example actual energy storage capacity and round trip energy efficiency.
- b) The performance is not significantly deteriorated over time: for example input and output power rating.

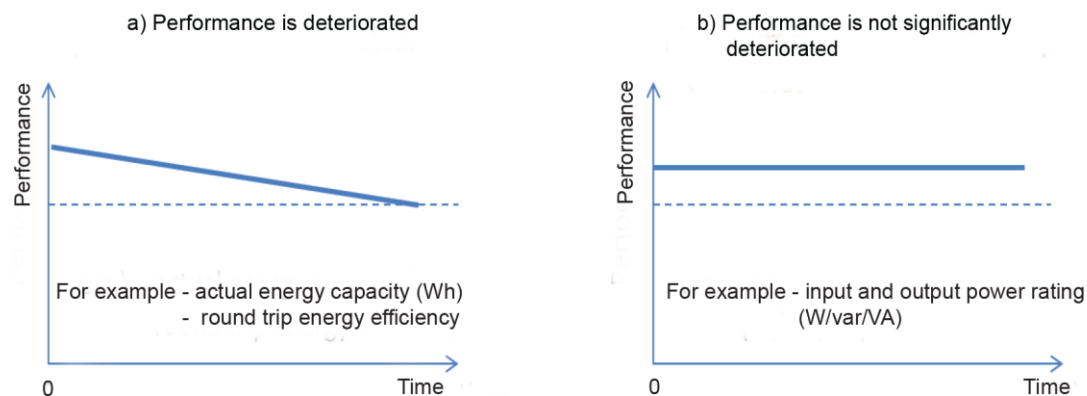


Figure 4 – Sample performance versus time characteristics for EES systems

The performance degradation in EES systems is generally caused by ageing or charge and discharge cycles, as well as by some failures. If performance degradation has occurred in the EES system but is recovered by maintenance or repair work, the EES system is still considered in service life.

NOTE If the system parts replacement or the maintenance services periods are not performed as expected, the service life is no longer assured.

Typical items to consider for the design of service life of the EES system are shown in Figure 5. Both degradation characteristics and maintenance plan should be taken into consideration to set the service life, which should be subjected to agreement between the user and system supplier.

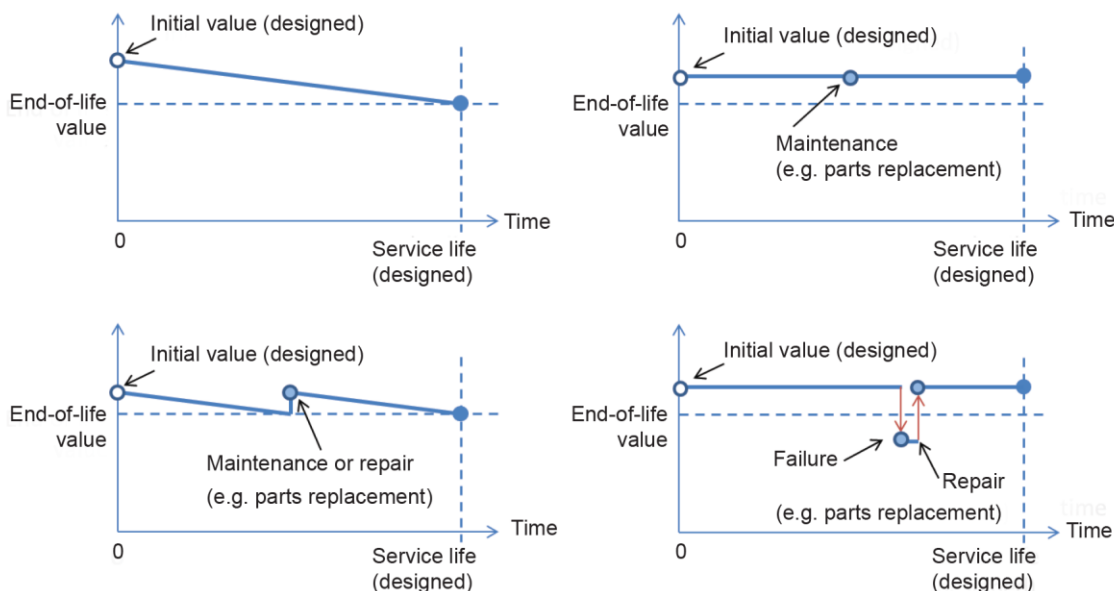


Figure 5 – Sample consideration to design the service life of EES systems

5 Planning and design of EES systems

5.1 General

The planning of an EES system is dependent on the characteristic of the grid as well as on the power demand and generation available at the POC. There is a wide variety of grids that have EES systems connected. These variations impact EES system specifications including:

- functionality (peak shaving, frequency support, virtual synchronous machine behavior, etc.),
- accumulation subsystem (energy storage capacity, charge and discharge power, etc.),
- power conversion subsystem (response time, droop control, active and reactive power, short-circuit power, etc.),
- grid characteristics (voltage and frequency ranges, harmonics and power quality, earthing system, protection requirements, etc.)

The EES system requirements should be clearly outlined in order to provide the best solution and to maximize system adaptability and performance benefits. The needs of the electrical grid may also need to be considered (e.g. grid codes). During the planning phase, at the system level and after the application has been defined, the EES system requirements have to be specified according to the application.

Clause 5 helps the planner to size the EES system and to define the specifications in such a way that EES system suppliers have all the relevant information to design a system.

Clause 5 provides information needed to assess the performances of a system. This ensures that potential users (such as a utility) can have the necessary information about the EES system from the system supplier. In particular maintenance requirements and end-of-service life values shall be provided and be compatible with the application.

In general the rated value of a quantity is used for specification purposes, established for a specified set of operating conditions of a component, device, equipment, or system. When specifying the rated values for planning purposes of an EES system, the critical operating limits of the power capability chart, capability reductions due to ageing, altered environmental conditions and other limiting factors shall be taken into account. All rated values used for planning purposes shall be values related to the end-of-service life.

Other parameters such as availability shall be provided and taken into account during the planning phase.

Auxiliary power consumption may vary throughout the service life of the EES system and shall therefore be assessed for the whole service life of the unit and for the environmental conditions expected at the installation site. The influence on the overall EES system efficiency of the extreme weather conditions should also be considered (see 5.6.4).

NOTE End-of-service life value definitions are given in IEC 62933-1. The test of auxiliary power consumption is included in IEC 62933-2-1.

5.2 Overview EES system planning and design process

When performing the sizing and planning process of EES systems, the following requirements shall be met:

- Power capabilities and energy storage capacity shall be met.
- Appropriate control strategies shall be used.
- Lifetime and ageing of components and subsystems, charge-discharge characteristics and charge-discharge cycles shall be considered.

- In general, all requirements in subclauses 5.4 to 5.11 shall be investigated and considered in the EES planning and design process.

Figure 6 is the illustration of some of the main topics that shall be investigated in the EES system planning and design process.

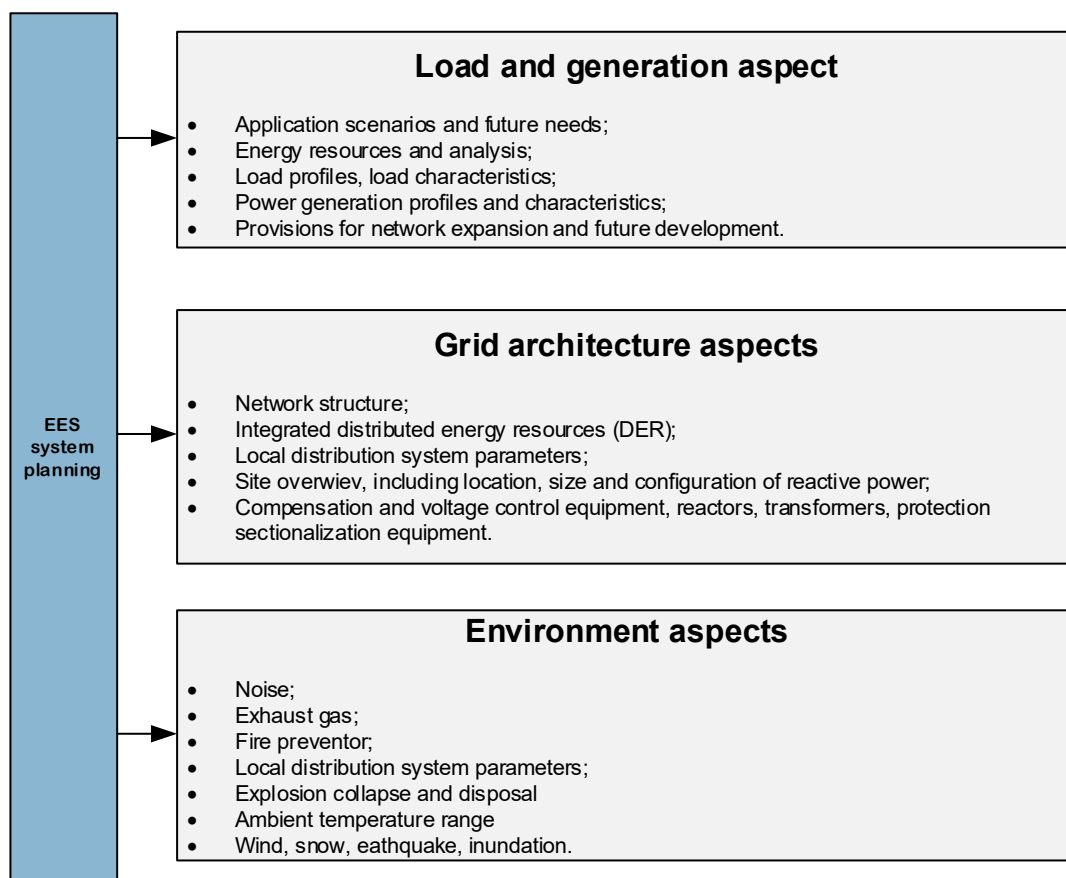


Figure 6 – Overview about the aspects of planning of EES systems

For preliminary and final sizing of the EES systems all the requirements and restrictions of subclauses 5.4 to 5.8 shall be considered. During the planning phase, possible performance degradation of the EES system over lifetime shall also be considered. The necessary maintenance cycles and service conditions shall be taken into account as well.

The following list shows a possible procedure for the planning, sizing and design of EES systems:

1. Choose intended application(s) of EES system (subclause 5.3).
2. Select the primary POC for connection of EES system, specify the (design) duty cycle and calculate preliminary power and energy requirements at selected primary POC (*possibly: simulations are necessary with generic model of an EES system*) (subclause 5.4).
3. Derive the required accessible energy storage capacity, maximum power values and power rates and check if power and energy requirements of the (design) duty cycle can be fulfilled at primary POC.
4. Choose service life of the EES system and indicate when the duty cycle shall be met.
5. Choose technology for accumulation and power conversion subsystem, which fulfill power demands and clarify efficiency values of the subsystems.
6. Derive energy storage capacity to be installed from accessible energy storage capacity, subsystem efficiency values and specified service life.

7. Check size and footprint.
8. Check economical requirements
→ **preliminary sizing results.**
9. Adapt sizing according to further requirements
 - a. EES system environment (subclause 5.6)
 - b. Requirements and restrictions of the grid or system operator (subclause 5.7)
 - c. Operational requirements (subclause 5.8)
- **final sizing results.**
10. Control subsystem recommendations / requirements (subclause 5.10).
11. Communication interface recommendations / requirements (subclause 5.11).

Figure 6 shows the flowchart of the energy storage planning and design mentioned above.

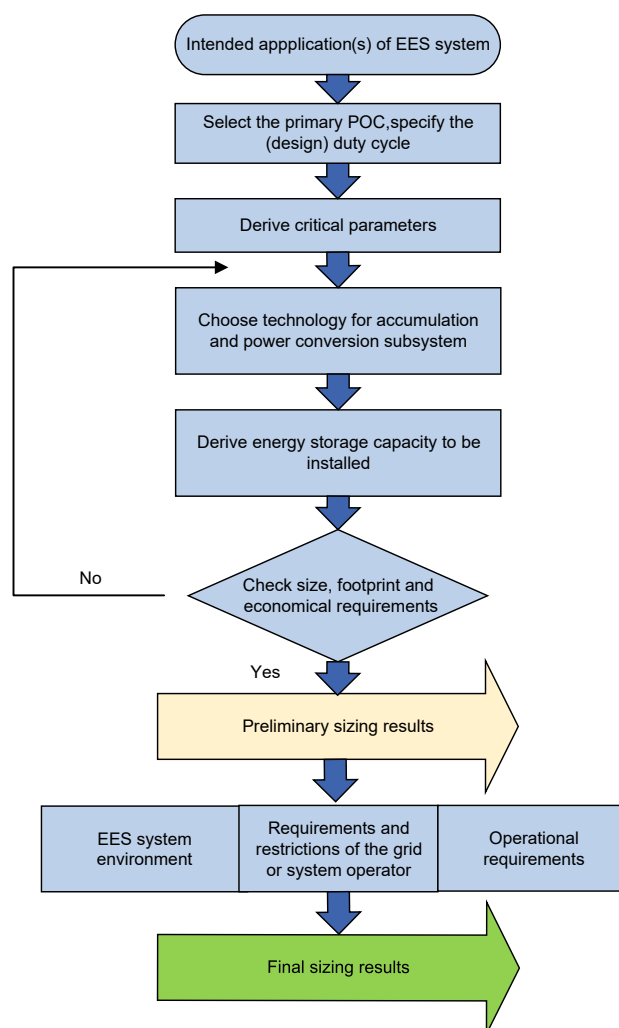


Figure 7 – Overview of EES system sizing process

5.3 Functional purpose and applications of EES systems

At the beginning of the design process of an EES system, it shall be determined which functions the EES system should have.

5.3.1 General

For the planning of EES systems, it is important to understand the purpose for which the EES systems are used. Therefore, possible applications of the EES systems in the grid to which they

are connected are described. It is also conceivable that EES systems can operate on more than just one application.

EES system applications can be distinguished according to various criteria:

- demands on energy content;
- demands on active power input and output;
- demands on the frequency of phase transitions during charging and discharging;
- demands on charging duration;
- demands on response time and ramp rate performance;
- demands on additional reactive power exchange with the power supply system;
- demands on stand-alone and black-start capabilities.

Besides pure active power and energy applications an EES system can provide a wide range of ancillary services. Subclauses 5.3.2 to 5.3.5 differentiate between power intensive applications as well as energy intensive and backup power applications.

5.3.2 Power intensive applications

EES systems for power intensive applications generally have demands for fast step response performances, for frequent charge and discharge phase transitions or for additional reactive power exchange with the electric power system. Several mature accumulation subsystem technologies, in particular superconducting magnetic energy storage (SMES), supercapacitor, flywheel energy storage (FES) and power type lithium batteries, have high power densities but low energy densities, and can be used in these applications. These applications include for example

- grid frequency support/regulation;
- grid voltage support;
- power quality support;
- reactive power flow control;
- power oscillation damping (POD).

For power intensive applications see also IEC TS 62933-3-2.

5.3.3 Renewable energy sources integration related applications

By integrating EES systems, various load, energy, power quality and operational management measures can be implemented, which can be used advantageously in combination with renewable energy sources. Such applications are for example

- power smoothing;
- energy generation firming;
- applications for electric charging stations in combination with renewable energy sources;
- load management (load fluctuation reduction);
- operational management, e.g. change operation mode of EES system.

For renewable energy sources integration related applications see also IEC TS 62933-3-2.

5.3.4 Energy intensive applications

The energy intensive applications can provide the required power over a long period of time. The islanded operation of the EES system provides the required power to the internal electric power grids without relying on an external power source. Energy intensive applications of EES systems are for example

- energy shifting; e.g. grid congestion management or energy arbitrage
- islanded grid operation.

For energy intensive applications see also IEC TS 62933-3-3.

5.3.5 Backup power applications

In case of external grid power outage, the backup power application can provide the required power to all loads, or the emergency loads only within the internal grid. A backup power application of EES systems is for example

- backup power supply and emergency support

For backup power applications see also IEC TS 62933-3-3.

5.3.6 Multi-function applications

In many cases, EES systems are planned with multi-scenario applications, which may include two or more applications given in above subclauses. Figure 8 gives an example of the first steps of the EES planning process with multi-scenario applications. The procedures to determine the design duty cycle include:

- identifying the functional objective: requirement of power dispatching and minimum of EES energy;
- considering constraints: EES energy balance, system power balance, SOC operation limit, etc.

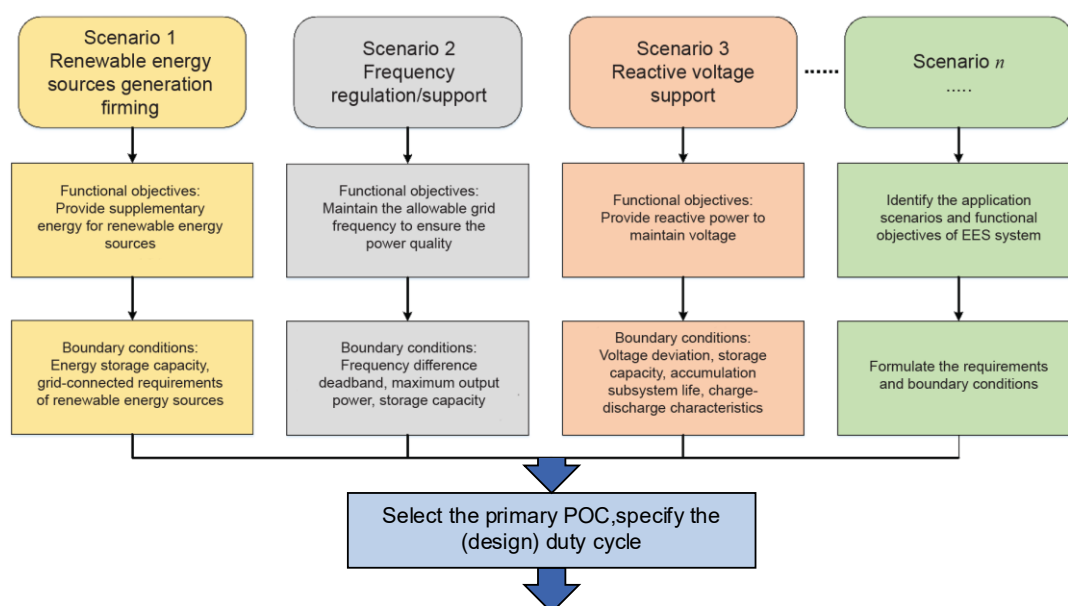


Figure 8 – Example of EES planning process with multi-scenario applications

Once the design duty cycle has been determined, the procedure is the same as shown in Figure 2. Typical multi-scenario applications of EES systems are shown in Table 2.

734

Table 2 – Typical multi-scenario applications of EES systems

Application functions	Typical scenarios				
	Renewable energy sources integration	Power generation side	Transmission and distribution side	User side	Grid with distributed energy sources
Frequency regulation	√	√	√	√	
Reactive voltage support	√		√		
Voltage sag mitigation				√	
Output power firming	√				√
Power oscillation damping (POD)	√	√	√		√
Peak shaving		√	√	√	
Black start		√			√
Backup power supply		√	√	√	√

735 Note: Not all application functions can be used simultaneously.

736 5.4 Duty cycle at primary POC

737 After determining the intended application(s) the primary POC of the electrical power grid shall
 738 be chosen to which the EES system shall be connected. Then the duty cycle(s) shall be
 739 specified, which is the basis for the sizing of the EES system.

740 The voltage level of the EES system shall meet the requirements of the application objects, and
 741 the voltage level shall be determined comprehensively according to the location, performance,
 742 and specific conditions of the EES system.

743 When selecting the POC to which the EES system is to be connected, the following aspects
 744 should be considered:

- 745 • grid characteristics (voltage and frequency ranges, etc.)
- 746 • requirements for grid security (earthing system, protection requirements, fault ride through
 747 capability, fault clearing time request, etc.)
- 748 • short-circuit capacity;
- 749 • load capacity;
- 750 • impact on power quality (harmonic voltage levels).

751 Sizing of EES systems is usually connected to the identification of one or more suitable duty
 752 cycles, which the EES system may typically have to perform at the primary POC to meet its
 753 operational requirements. Additionally, it is necessary to know the (minimum and maximum)
 754 recovery times which are available to restore the EES system between duty cycles. In addition,
 755 the required service life time of the EES system should be specified with regard to the proper
 756 consideration of system ageing and possibly necessary maintenance and refurbishment works.

757 The duty cycle specification should include

- 758 • duration of the duty cycle and the expected frequency (number of times per day/week/year);
- 759 • required pattern of the active power at the primary POC of the EES system, possibly
 760 including allowed tolerance ranges (maximum overshoot and/or undercut);

- required pattern of the reactive power at the primary POC of the EES system, possibly including allowed tolerance ranges (maximum overshoot and/or undercut).

The pattern of active and reactive power at the primary POC can include duration in which the active and/or reactive power is zero. From these patterns it should be possible to derive ramp rates of the active and reactive power.

Since the initial value at the beginning of each duty cycle should be within a certain energy content range, a recovery cycle may be necessary to bring back the EES system to a state where it is possible to perform duty cycles again. The degrees of freedom in recovery cycles depend mainly on grid requirements. With regard to sizing the EES system, the following characteristic values of the recovery process should be given:

- minimum duration
- maximum duration
- range of allowed active output or input power, including maximum and minimum active output or input power values
- possible requirements or constraints regarding reactive input and output power
- maximum allowed ramp rates of active and reactive power
- allowed range of power factor values at primary POC
- possible requirements regarding power factor

Regarding the operational features of the EES system, which should be represented by the identified duty cycles and recovery times, not all possible (worst) case situations of the electrical power grid regarding power and energy demand at the primary POC can be covered. But the required duty cycles and the specified recovery times should cover most probable grid situations. Future developments regarding power generation and power consumption in the electrical power grid as well as changes to the grid structure should also be considered when specifying duty cycles and recovery times.

For different operational requirements, sets of duty cycles with different time durations (short-term and long-term durations) and different maximum power values might be identified. In this case superposition of duty cycles for different operational features might be necessary to properly describe the overall operational capability of an EES system.

The following characteristics of the required duty cycles should be identified:

- response time
- overall duration
- initial energy content
- maximum energy content within the duty cycle
- minimum energy content within the duty cycle
- energy content value at the end of the duty cycle
- maximum value of active output power
- maximum value of active input power
- speed of change of active power values
- speed of change between active input or output power
- maximum partial energy output, i.e. maximum energy output in a time period within the duty cycle with only active power output at the (primary) POC. This maximum energy output value at the (primary) POC is the mathematical integral of active output power over the duration of the time period with only active power output
- maximum partial energy input, i.e. maximum energy input over a time period within the duty cycle with only active power input at the (primary) POC. This maximum energy input value

at the (primary) POC is the mathematical integral of active input power over the duration of this time period with only active power input

- maximum value of reactive output power
- maximum value of reactive input power
- speed of change of reactive power values
- speed of change between reactive input and output power

All (superposed) duty cycles which are necessary to describe the overall operational capability of the EES system should be taken into account to identify the characteristic values of duty cycles. The recovery cycles and their characteristic values may also be superposed.

Possibly simulations with generic models of EES systems are necessary to verify the duty cycles.

Examples of required duty cycles for some EES system applications are given in Annex A.

5.5 Selection of the EES system and preliminary sizing

5.5.1 Requirements and constraints for EES system sizing

The required duty cycles, the specified recovery times and the required service life can be used to derive the size of the EES system. From the duty cycle the following requirements can be derived:

a) Power requirements

To specify demands on power input and output the following power values can be used to define power related requirements for EES systems:

- rated active power P [W];
- rated reactive power Q [var];
- rated apparent power S [VA];
- input and output power ratings [W], if there are different input and output power ratings;
- (rated) short-duration input and output power [W];
- short-duration reactive power [var];
- power density [W/kg], [W/m³];
- ramp rate [W/min].

If applicable the power requirements should consider the power decrease and the resistance increase with time if necessary to fulfill its service life.

b) Time requirements

Time values to express the duration of a certain power application can be used to specify energy and power performance requirements for EES systems:

- rated charging/discharging duration;
- rated short-duration input/output power time.

c) Energy requirements

To specify demands on energy consumption and supply at the POC the following energy values can be used to define energy related requirements for EES systems at the POC:

- effective energy storage capacity at beginning of service life $EC_{effective,BOL}$ [kWh];