IEC TS 62933-3-3

Edition 1.0 2022-11

TECHNICAL SPECIFICATION

colour inside

**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 62933-3-3:2022-11(en)

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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

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

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

Draft	Report on voting
120/262/DTS	120/275/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/standardsdev/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.

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- withdrawn,
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INTRODUCTION

Electrical energy storage (EES) systems can provide solutions to multiple energy storage scenarios. The objective of this document is to provide requirements, guidelines and references when EES systems are designed, controlled and operated for energy intensive, islanded grid and backup power supply applications.

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

1 Scope

This part of IEC 62933 provides requirements, guidelines and references when EES systems are designed, controlled and operated for energy intensive, islanded grid and backup power supply applications. In energy intensive applications, the EES system provides long charge and discharge phases at variable powers to the supported grid or user equipment. In islanded operation, the EES system provides energy to the islanded grid and coordinates other power generation systems in the islanded grid. In backup power supply and emergency support, the EES system provides energy to the internal grid or a set of emergency loads when the main grid power supply is not available.

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

IEC TR 61850-90-9, *Communication networks and systems for power utility automation – Part 90-9: Use of IEC 61850 for Electrical Energy Storage Systems*

IEC 62933-1:2018, *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 62933-2-2, *Electrical energy storage (EES) systems – Part 2-2: Unit parameters and testing methods – Application and performance testing*

IEC TS 62933-3-1:2018, *Electrical energy storage (EES) systems – Part 3-1: Planning and performance assessment of electrical energy storage systems – General specification*

IEC TS 62933-3-2:2022, *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*

3 Terms, definitions, abbreviated terms 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 https://www.electropedia.org/;
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1.1
backup power supply
provision of power to all internal loads connected to user side equipment during a specified time period without relying on an external power source in the event of electrical grid outage

3.1.2
black start capability
capability of the EES system to start the electric power system (IEV 601-01-01) only with internal energy resources

3.1.3
allowed charging time
time period when an EES system is allowed to charge the accumulation subsystem in the peak shaving application

3.1.4
allowed discharging time
time period when an EES system is allowed to discharge the accumulation subsystem in the peak shaving application

3.1.5
duty cycle roundtrip efficiency
energy discharged measured at the primary POC divided by the energy absorbed by the EES system, as a sum of what is measured at all the POCs (primary and auxiliary), during duty cycles in a specified operating mode at continuous operating conditions with the same final state of charge as the initial state of charge

[SOURCE: IEC 62933-1:2018, 4.12.1, modified – the notes have been deleted.]

3.1.6
emergency load
set of devices and equipment that should be operated during electrical grid outage

3.1.7
emergency support
provision of power to emergency loads within a specified time and duration without relying on an external power source in the event of electrical grid outage

3.1.8
energy intensive application
EES system application generally not very demanding in terms of step response performances but with long charge and discharge phases at variable powers

[SOURCE: IEC 62933-1:2018, 3.12, modified – the terms “long duration application” and “long term application” have been deleted and the notes have been deleted.]

3.1.9
fluctuation reduction of consumption
reduction of power oscillation of power consumption at the grid connection point by absorbing the active power of the grid by EES systems at low power demand phases and by feeding in additional active power by EES systems at high power demand phases

3.1.10
islanded grid
part of an electric power system that is electrically disconnected from the remainder of the interconnected electric power system but remains energized from the local electric power sources

3.1.11
islanded operation
function to provide power to the islanded grid and to control the coordination with other power generation systems and the system voltage and frequency

3.1.12
load profile
line graph illustrating the variation in loads over a specific time

3.1.13
peak shaving
limitation of the power consumption from the power grid to a maximum value by providing the power exceeding the maximum value from other active power sources

3.1.14
rated AC current
AC current that the EES system can provide to the grid continuously and can accept from the grid continuously without exceeding the maximum operating temperature of the EES system

3.1.15
self-discharge
phenomenon by which the EES system accumulation subsystem loses energy in other ways than by discharge through the primary POC

[SOURCE: IEC 62933-1:2018, 4.12.7, modified – the note has been deleted.]

3.2 Abbreviated terms and symbols

3.2.1 Abbreviated terms

ACB	air circuit breaker
ATS	automatic transfer switch
BMS	battery management system
CVCF	constant voltage constant frequency
DER	distributed energy resources
DNP	distributed network protocol
EES	electrical energy storage
EMS	energy management system
GHG	greenhouse gas
HVAC	heating, ventilation, and air conditioning
PCS	power conversion system
PMS	power management system
POC	point of connection
PV	photovoltaics
SOC	state of charge
SOH	state of health
TR	transformer

UVRT under voltage ride through

VT voltage transformer

3.2.2 Symbols

f frequency

P active power

Q reactive power

S apparent power

Y star configuration

Δ delta configuration

4 General planning and performance assessment considerations for EES systems

Clause 4 presents the general and common requirements for various applications of EES systems. IEC TS 62933-3-1 shall be applied. Clause 4 of IEC TS 62933-3-2:2022 is also applicable.

5 Peak shaving and load levelling

5.1 Application of EES system

5.1.1 Functional purpose

The EES system performs a shift, in time, of available energy to achieve more uniformity in power generation and consumption pattern. With this activity, peaks in power consumption and associated power generation demand are smoothed. This results in a reduction in behind-the-meter demand charges by an appropriate timing of the activation of power generation or power storage assets.

NOTE This document covers peak shaving and load levelling application from the perspective of behind the meter.

5.1.2 Application related requirements

5.1.2.1 General

In the peak shaving and fluctuation reduction of consumption applications, in addition to the application independent requirements listed in 4.1.2 of IEC TS 62933-3-2:2022, the following application specific requirements shall be considered.

5.1.2.2 Specific requirements

In energy fluctuation reduction applications, the following application specific recommendations should be considered:

- load profile;
- charging-discharging time;
- rated AC current;
- duty cycle efficiency.

5.2 Conditions and requirements for connection to the grid

Subclause 4.2 of IEC TS 62933-3-2:2022 is applicable.

5.3 Design of the EES systems

5.3.1 Structure of the EES systems

The EES system structure and components defined in 4.3.2 of IEC TS 62933-3-2:2022 shall also be applied to the peak shaving and fluctuation reduction of consumption applications.

5.3.2 Subsystem specifications and requirements

Subclause 4.3.3 of IEC TS 62933-3-2:2022 is applicable. Further, additional technology dependent requirements are defined in Annex B.

5.3.3 Grid integration of the EES systems

Subclause 4.3.4 of IEC TS 62933-3-2:2022 is applicable. Further, additional technology dependent requirements are defined in Annex A.

5.3.4 Operation and control

5.3.4.1 Overview

Subclause 4.3.5 of IEC TS 62933-3-2:2022 is applicable. In addition, the following recommendations should be considered.

5.3.4.2 General

There are three types of operation periods of the EES system for peak shaving and fluctuation reduction of consumption applications, namely peak period, idle period, and off-peak period. The EES system operation modes for each operation period are listed in Table 1.

Table 1 – Operation modes of EES system for peak shaving and fluctuation reduction of consumption

Operation mode (type of period)	Discharge (peak period)	Standby (idle period)	Charge (off-peak period)
Scheduling principle	Try not to take power from the grid.	Minimize the interaction with the grid.	Try not to discharge to the grid.
Approach	The EES system discharges to the grid.	Avoid charging and discharging from the grid to EES system.	EES system charges from the grid.
Purpose	Reduce the pressure on the grid during peak period.	Maintain stable operation of the grid.	Restore EES system to a predefined SOC. Absorb excess energy from the grid and increase energy efficiency.

The EES system for peak shaving and fluctuation reduction of consumption can be operated to provide one or multiple charge and discharge sequences or cycles per day. Figure 1 shows the operation modes and effect of the EES system using "one charging and one discharging" as an example. In Figure 1, the dashed line indicates the target input power from the grid and the solid line indicates the load over time. When the load level is below the target input power during the off-peak period, the EES system charges from the grid. When the load level exceeds the target input power during the peak period, the EES system performs a discharging operation.

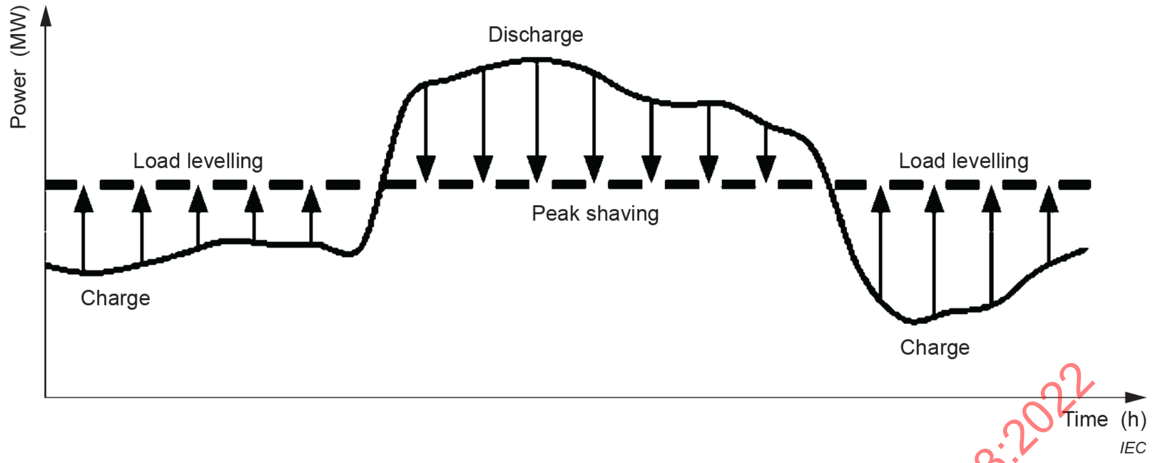


Figure 1 – Example of peak shaving and fluctuation reduction of consumption consisting of charge and discharge events

5.3.4.3 Operation modes of control subsystem

The operation modes of the EES system are charge, discharge, and standby. The operation modes over time are determined by a duty cycle. When determining the duty cycle, the following recommendations should be considered.

- The EES system should be charged at the off-peak period (usually at night), and the EES system should be put into standby mode after the accumulation subsystem is fully charged.
- The EES system can be operated in various duty cycles, such as "one charge and one discharge", "one charge and two discharges", "two charges and two discharges", and "multiple charges and multiple discharges". The specific charge-discharge power and time of the EES system are set by the operating mechanism and the scheduling mechanism.
- The scheduling mechanism manages the EES system at peak period to discharge, and the power response time of the EES system does not exceed a predetermined time.
- The EES system can automatically receive the dispatching curve issued by the grid system and operate according to the power generation plan curve. The deviation between the actual output curve and the scheduling command curve needs to be determined before this operation.

In the case that the power curve is not formulated by the grid dispatch organization, the EES system should distribute the charge-discharge power and time according to the loads and the internal constraints of the EES system.

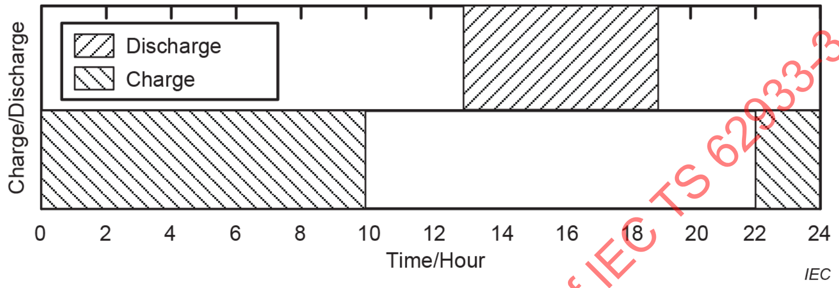
Subclause 5.3.4.3 presents one charge and one discharge duty cycle, and two charges and two discharges duty cycle as examples. Other duty cycles may be used depending on the situation, and are presented in IEC 62933-2-1 and IEC TS 62933-2-2.

a) One charge and one discharge duty cycle

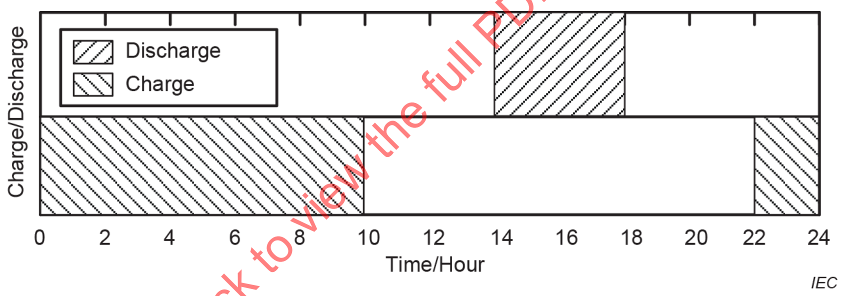
   Figure 2 displays the example of duty cycles for a midnight-to-midnight day with an afternoon peak. Each duty cycle in the figure consists of a total of 12 h duration for charging. The required discharge duration and a standby duration after charge and discharge bring the total duration for each of the A, B, and C duty cycles to one 24 h cycle. The peak period for discharging starts at 13:00 for duty cycle A, 14:00 for duty cycle B, and 15:00 for duty cycle C, respectively. Prior to the peak period, the EES system should be charged to maximum SOC. When operating the A, B, and C cycles, the EES system should be returned to the same SOC as the SOC at the start of the duty cycle, which in this case is the maximum SOC. Thus, each duty cycle A, B, and C consists of a discharge followed by standby, charge, and standby to bring the EES system to the initial SOC.

   - Off-peak period (charge mode): During the off-peak period, the EES system is charged generally with a sequential constant power–constant voltage charging profile to bring the accumulation subsystem of the EES system to its upper SOC limit. The exact profile and associated conditions are specified by the manufacturer of the battery system.

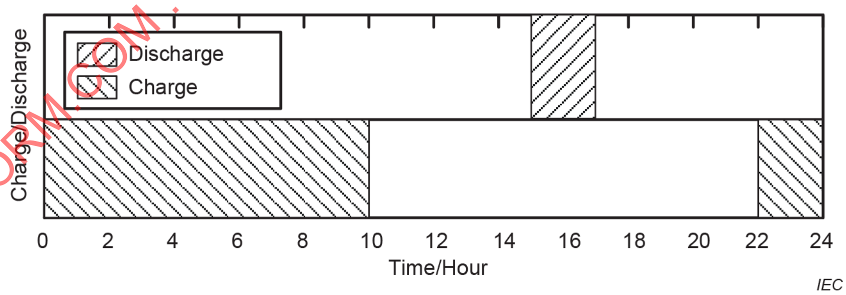
- Peak period (discharge mode): During the peak period, the EES system is discharged at constant power until the minimum SOC level for the discharge power is reached. The minimum SOC level is specified by the EES system operator.
- Idle period (standby mode): During the idle period, the EES system does not perform a charge or discharge operation to an external load of EES system. When the EES system does not have an auxiliary POC, the lower SOC limit might not be maintained and the operation of any internal support loads for the EES system, such as, but not limited to, heating, ventilation, and air-conditioning systems, continues to operate as required in accordance with the EES system manufacturer's specifications and operating instructions. Discharging of the EES system that does not serve a load external to the EES system is permitted during the idle period.



a) Peak shaving duty cycle A, 6 h discharge



b) Peak shaving duty cycle B, 4 h discharge



c) Peak shaving duty cycle C, 2 h discharge

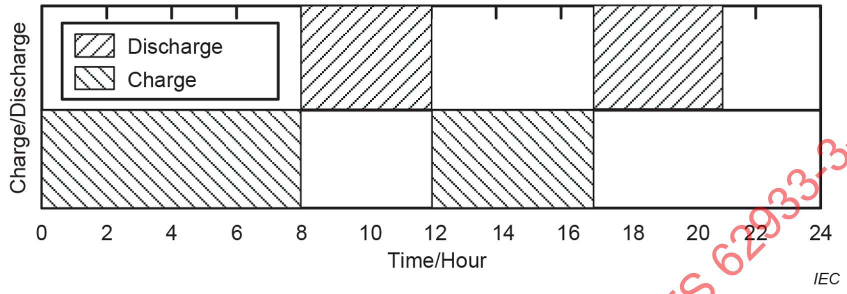
[Source: IEC TS 62933-2-2.]

Figure 2 – One charge and one discharge duty cycle for peak shaving application

b) Two charges and two discharges duty cycle

Figure 3 displays an example of duty cycle for a midnight-to-midnight day with a morning peak and an evening peak. The duty cycle has a total of 13 h duration for charging and a total of 8 h duration for discharging. The required off-peak periods are 00:00 ~ 8:00 and 12:00 ~ 17:00. The required peak periods are 8:00 to 12:00 and 17:00 to 21:00. The required peak period and required off-peak period are set by the EES system operator according to the investigated load profiles. There is an idle period between 21:00 and 00:00 that brings the total duration for each duty cycle to one 24 h period. The EES system starts with a charge at 00:00 for a duty cycle. The EES system will be charged and discharged two times a day in an optimal capacity configuration, which can effectively achieve the function of peak shaving and fluctuation reduction of consumption, and economic efficiency.

When applying the duty cycle shown in Figure 3, the duty cycle might not be adequate depending on the type of accumulation subsystem. For example, in a battery-based accumulation subsystem, a two-cycles per day with charge, discharge, charge and discharge with no rest time can decrease battery life. Depending on the cell/module temperature, it could be necessary to wait some time until the temperature decreases below a safe level between each consecutive phase of charge or discharge.



[Source: IEC TS 62933-2-2]

Figure 3 – Two charges and two discharges duty cycle for peak shaving application

5.3.5 Monitoring

Subclause 4.3.6 of IEC TS 62933-3-2:2022 is applicable.

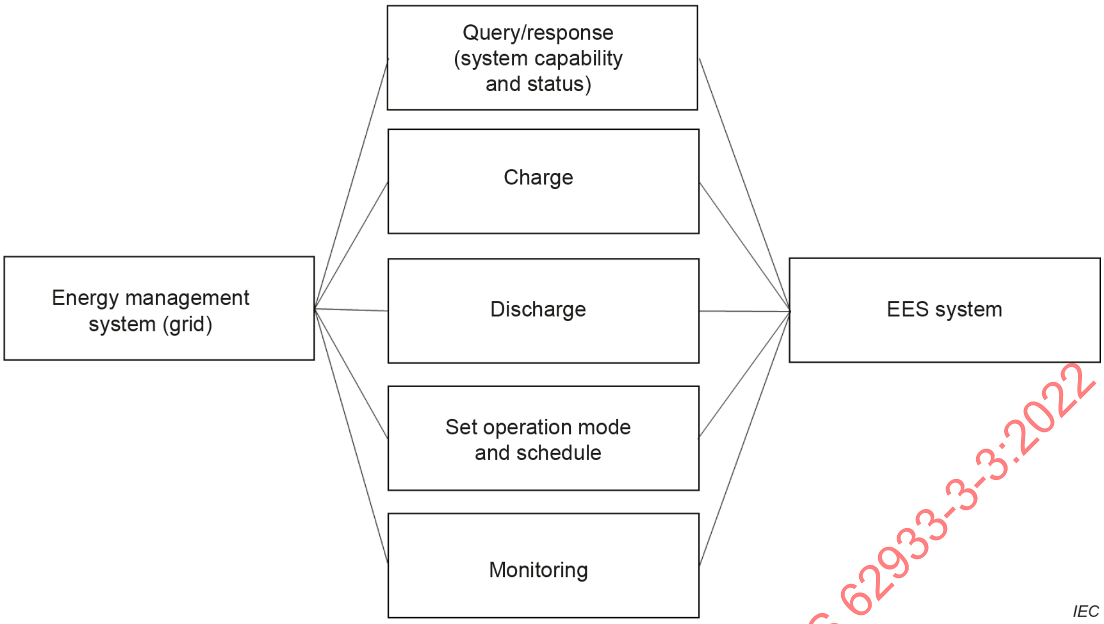
5.3.6 Maintenance

Subclause 4.3.7 of IEC TS 62933-3-2:2022 is applicable.

5.3.7 Communication interface

Subclause 4.3.8 of IEC TS 62933-3-2:2022 is applicable. In addition, the following recommendations should be considered. Further additional technology dependent requirements are defined in Annex B.

An EES system interacting, as distributed energy source, with a transmission, distribution or islanded grid, should exchange relevant information with their management entities as defined in IEC 61850-7-420 and IEC TR 61850-90-9. The operational procedures for information exchange shown in Figure 4 are presented in IEC TR 61850-90-9.



[Source: IEC TR 61850-90-9]

Figure 4 – Use case for information exchange between grid and EES system

5.4 Sizing and resulting parameters of the EES system

5.4.1 Sizing

5.4.1.1 General

Subclause 4.4.2 of IEC TS 62933-3-2:2022 is applicable. In addition, the following recommendations should be considered.

5.4.1.2 Sizing and planning process of the EES system

The general sizing and planning process of the EES system applied in the peak shaving and fluctuation reduction of consumption applications is depicted in Figure 5.

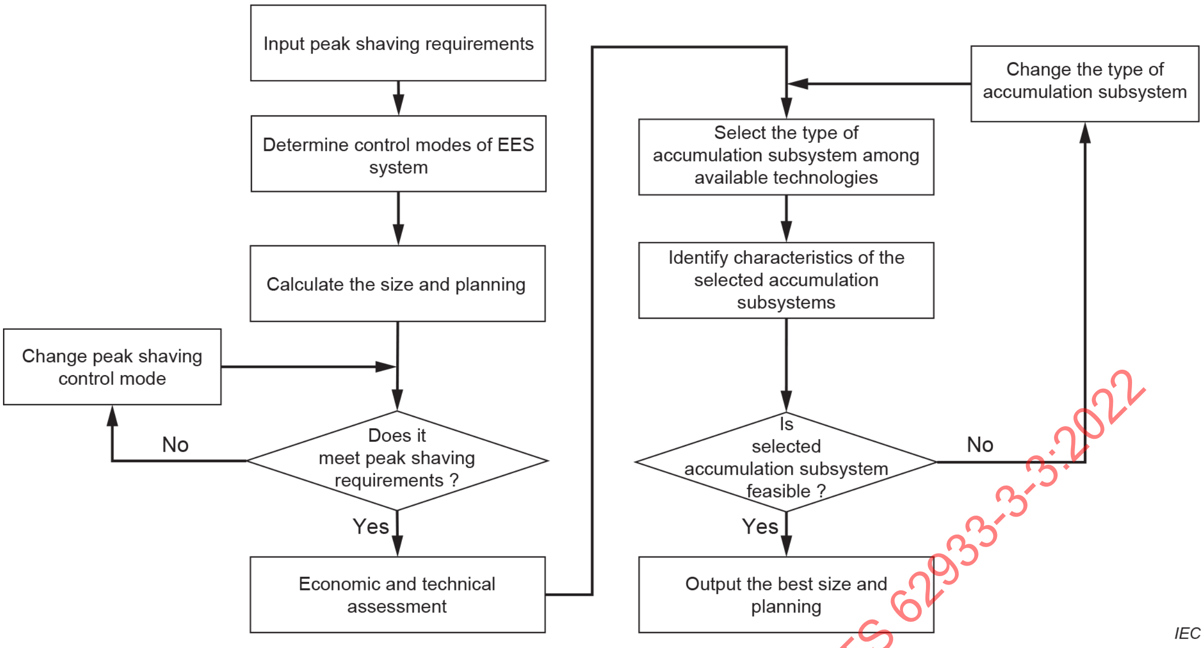


Figure 5 – Process to determine the sizing and planning of the EES system applied in peak shaving and fluctuation reduction of consumption applications

5.4.1.3 Requirements for sizing and planning

When performing the sizing and planning process of EES system, the following recommendations should be met:

- the effect of different types of energy storage technologies on peak shaving/fluctuation reduction of consumption;
- the charge and discharge power, and energy storage capacity of the EES system;
- different control strategies;
- the life of the accumulation subsystem, the charge-discharge characteristics and the optimal charge-discharge cycles.

The sizing and planning of the EES system shall be set according to the power and the operation mode of the accumulation subsystem. The initial accumulation subsystem size can be configured as 5 % to 20 % of the transformer capacity interconnecting the EES system and grid, and subsequently determined after calculation.

5.4.2 Characteristics and restrictions of the EES system

Subclause 4.4.3 of IEC TS 62933-3-2:2022 is applicable.

5.5 Service life of the EES system

5.5.1 Installation

Subclause 4.5.2 of IEC TS 62933-3-2:2022 is applicable.

5.5.2 Performance assessment

Subclause 4.5.3 of IEC TS 62933-3-2:2022 is applicable.

5.5.3 Operation and control

5.5.3.1 General

Subclause 4.5.4 of IEC TS 62933-3-2:2022 is applicable. In addition, the following recommendations should be considered. Further additional technology dependent requirements are defined in Annex B.

5.5.3.2 Control process of the EES system

The EMS determines the working state of the EES system by predicting the load demand (MW) and the real-time power value (MW) of the power grid, and calculates the charge-discharge power of the EES system under the different states defined in Table 1. The example control process of the EES system for charging in the peak shaving and fluctuation reduction of consumption is shown in Figure 6. Additional descriptions for the numbered processes in Figure 6 are as follows.

1) During the system status check in (1), the functions of the distribution panel, power conversion subsystem, accumulation subsystem, air conditioning and ventilation system, fire extinguishing system, and emergency stop function should be checked.
2) The allowed charging time period in (2) is determined by checking the allowed charging period, configured charging time, or off-peak period.
3) The configured threshold value for the charging state in (4) depends on the type of accumulation subsystem. For example, a SOC of 95 % can be the threshold in the battery-based accumulation subsystem.
4) The configured charging power value in (5) can be set according to the charging time schedule.
5) The charging power limit in (6) is determined by the characteristics of the accumulation subsystem.

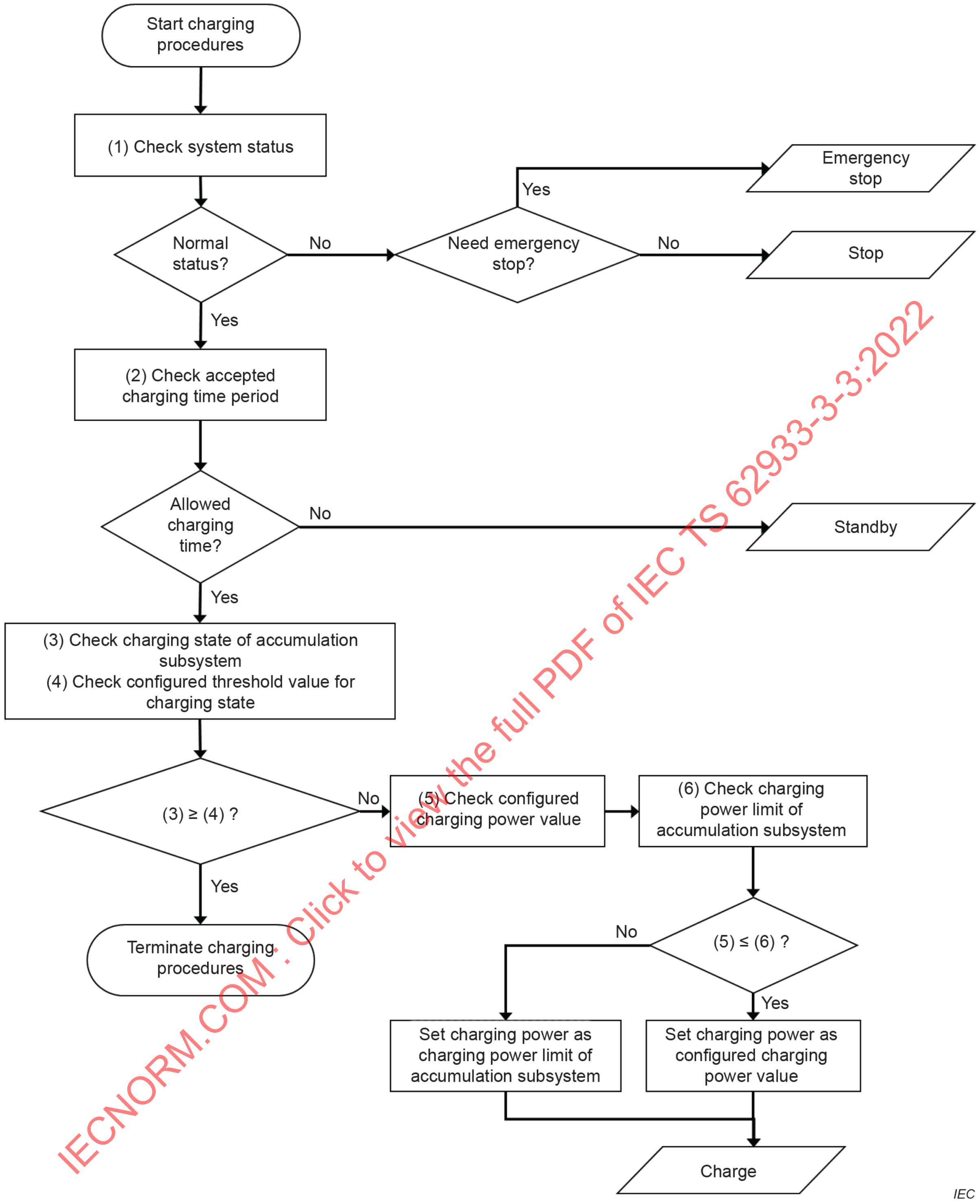


Figure 6 – Sequence of charging events in the peak shaving application

The example control process of the EES system for discharging in the peak shaving and fluctuation reduction of consumption is shown in Figure 7. Additional descriptions for the numbered processes are as follows.

a) During the system status check in (1), the functions of the distribution panel, power conversion subsystem, accumulation subsystem, air conditioning and ventilation system, fire extinguishing system, and emergency stop need to be checked.

b) The allowed discharging time period in (2) is determined by checking the allowed discharging period, configured discharging time, peak period, or real time peak shaving function.

c) The configured threshold value for the discharging state in (4) depends on the type of accumulation subsystem. For example, a SOC of 5 % can be the threshold in the battery-based accumulation subsystem.

d) The configured discharging power value in (5) can be set according to the discharging time schedule or real time peak shaving function.

e) The discharging power limit in (6) is determined by the characteristics of the accumulation subsystem.

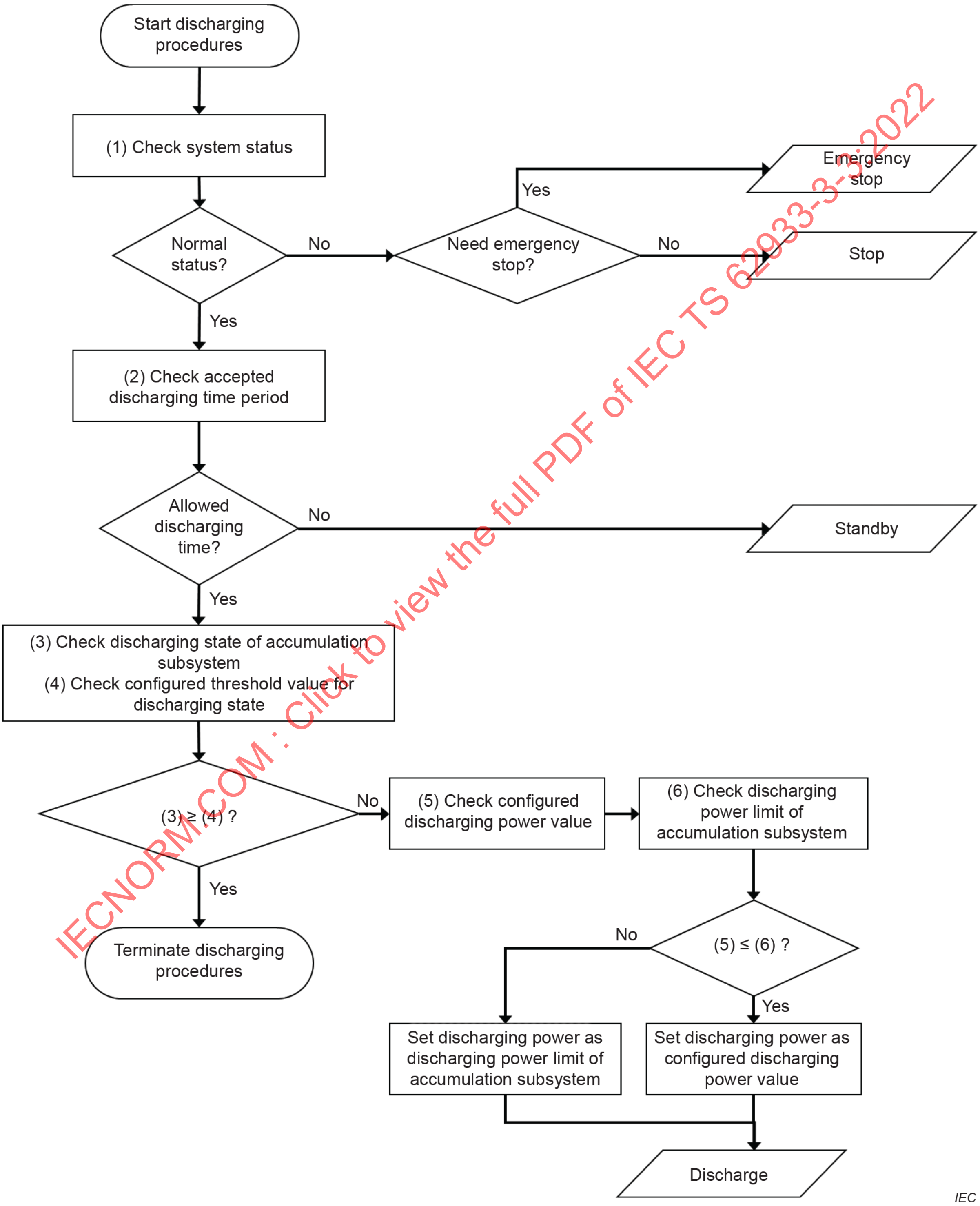


Figure 7 – Sequence of discharging events in peak shaving application

When charging or discharging is in progress and the following conditions occur, charging and discharging should be limited according to Table 2.

Table 2 – Conditions for charging/discharging limitation

Charging/discharging limit conditions	
Minimum and maximum limit of SOC	When the actual SOC reaches the configurated maximum and minimum threshold value any energy input or output shall be set respectively to zero.
Accumulation subsystem charging and discharging current/power limit	When the actual charging/discharging power or current level exceeds the configurated maximum threshold value, any further increase of its value shall be prevented.

5.5.4 Monitoring

Subclauses 4.3.6 and 4.5.5 of IEC TS 62933-3-2:2022 are applicable.

5.5.5 Maintenance

Subclauses 4.3.7 and 4.5.6 of IEC TS 62933-3-2:2022 are applicable.

6 Islanded grid application

6.1 Application of the EES system

6.1.1 Functional purpose

In an islanded grid, the EES system provides and stores electrical energy. The EES system also supports and controls the voltage and frequency of such a grid in coordination with subsidiary power generation systems also present.

NOTE In islanded grid application, energy is provided for a long duration. Thus, from that point of view, islanded grid application can be categorized as energy intensive application.

6.1.2 Applications related requirements

In the islanded grid applications, the applications requirements listed in 4.1.2 of IEC TS 62933-3-2:2022 shall be considered.

6.2 Conditions and requirements for connection to the grid

6.2.1 Grid parameters at the intended POC

The EES has to ensure that the relevant performance levels of the islanded grid are met and therefore all connected electrical loads can operate properly. Subclause 6.2 applies the same requirements as those indicated in 4.2.2 of IEC TS 62933-3-2:2022.

6.2.2 Service conditions

Subclause 4.2.3 of IEC TS 62933-3-2:2022 is applicable.

6.2.3 Requirements and restrictions of the grid or system operator

Subclause 4.2.4 of IEC TS 62933-3-2:2022 is applicable.

6.2.4 Standards and local regulations

Subclause 4.2.5 of IEC TS 62933-3-2:2022 is applicable.

6.3 Design of the EES system

6.3.1 Structure of the EES system

The EES system structure and components defined in 4.3.2 of IEC TS 62933-3-2:2022 are also applied to the islanded grid application. In addition, there exist additional considerations. An EES system for islanded grid application can be installed in conjunction with distributed energy resources (DER) such as PV, wind turbine, etc., in order to improve the effectiveness of islanded grid application. The supply of electricity can be unstable due to the intermittence of renewable energy sources if additional energy sources such as generators and EES systems do not exist. The EES system can mitigate the intermittent generation.

An example configuration of the EES system in conjunction with DER is shown in Figure 8. The EES system and DER are connected to a common AC bus. In the configuration, the PV and wind turbine are listed as DER, but other energy sources can be considered. The main energy sources of the islanded grid are the DER, the EES system and conventional generators that are installed to provide power when the output power shortages of the DER and EES system happen.

In the islanded grid, the EES system can be used to support stable power provision using the renewable energies. It is common to install a conventional generator in the islanded grid to provide power in case of generated power shortages from the renewable energy sources due to environmental reasons.

The DER and EES system which are connected to the AC bus can control output power in response to the load changes. The control subsystems in the EES system and DER are connected to the energy management system (EMS) through communication interfaces. Various communication protocols among the control subsystem, DER, and EMS can be used and the requirements for the communication interface are presented in 4.3.8 of IEC TS 62933-3-2:2022, as well as in 5.3.7 and 6.3.7 of this document. Each equipment is connected to the EMS via the communication network, so the EMS can perform optimal control when the load change or generation fluctuation of the DER happens. When the generation is less than the loads, the EMS sends a signal to the switch controller in order to start and connect the conventional generator to the AC bus. This configuration allows the easy extension of capacity and connection to the remote DER.

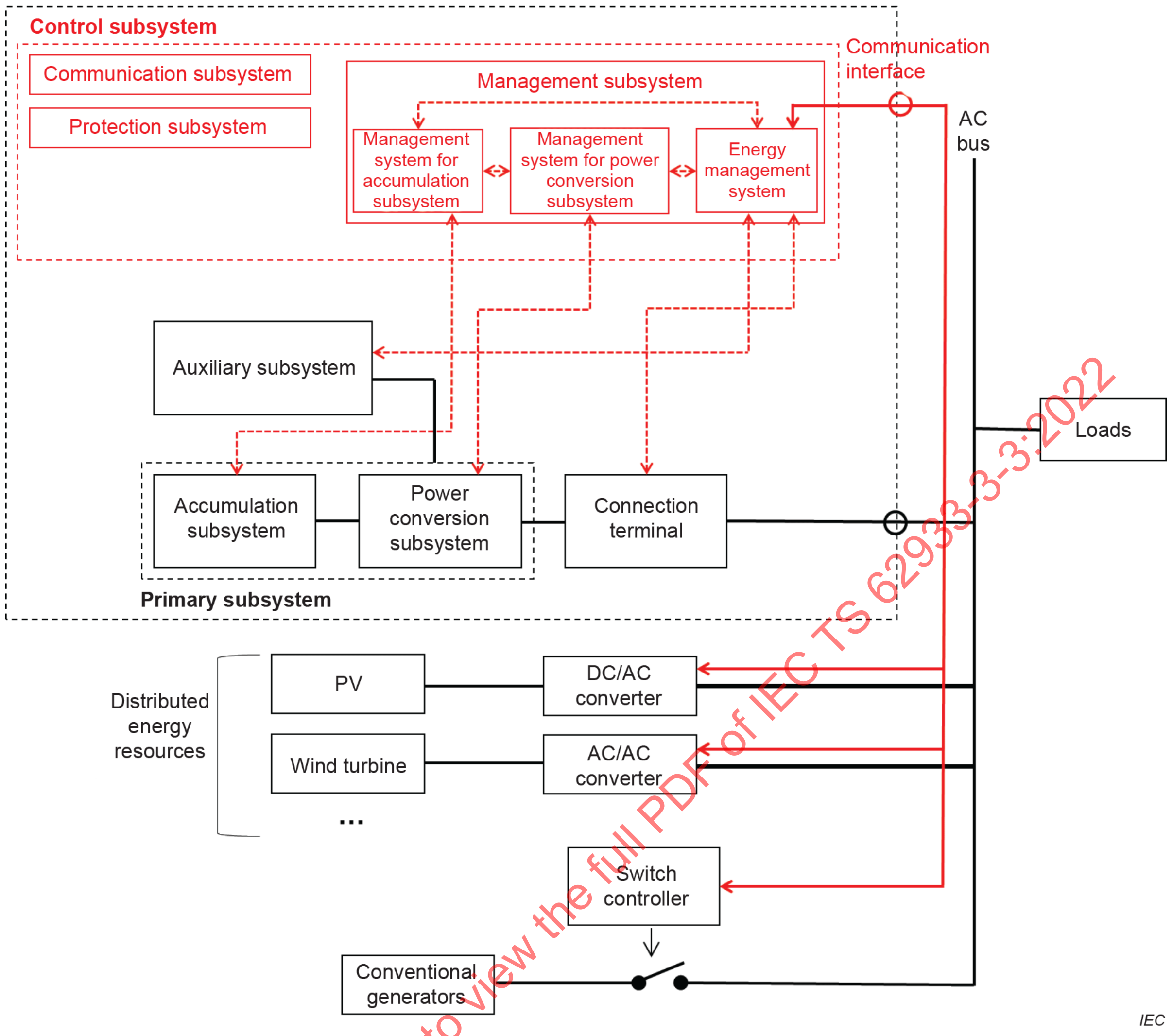


Figure 8 – Example configuration for applying an EES system to an islanded grid containing distributed energy resources

6.3.2 Subsystem specifications

Subclause 4.2.2 of IEC TS 62933-3-2:2022 is applicable. Further, additional technology dependent requirements are defined in Annex B.

6.3.3 Grid integration of the EES system

Subclause 4.3.4 of IEC TS 62933-3-2:2022 is applicable. Further, additional technology dependent requirements are defined in Annex A. In addition, the following recommendations should be considered.

A key safety issue in islanded grids is the fact that the peak of the short-circuit current or fault current level, which is mainly generated by electronic power converters, is limited. The short-circuit current level is often of the same magnitude as the rated continuous current level. Depending on the design of the fault detection scheme, fault events might not be well detected and then the tripping action of protection devices, such as circuit breakers, is not always guaranteed. Hence, specific attention should be paid to overcurrent level and short-circuit protection design scheme during the planning and designing phase.

6.3.4 Operation and control

Subclause 4.3.5 of IEC TS 62933-3-2:2022 is applicable.

6.3.5 Monitoring

Subclause 4.3.6 of IEC TS 62933-3-2:2022 is applicable.

6.3.6 Maintenance

Subclause 4.3.7 of IEC TS 62933-3-2:2022 is applicable.

6.3.7 Communication interface

Subclause 4.3.8 of IEC TS 62933-3-2:2022 is applicable. Further, additional technology dependent requirements are defined in Annex B.

6.4 Sizing and resulting parameters of the EES system

6.4.1 Sizing

6.4.1.1 Sizing and planning process of the EES system

The general sizing and planning process of the EES system applied in the islanded grid applications is depicted in Figure 9. After the initial survey on the target site, the technical aspects and requirements of the energy system design are considered, to determine optimal design. When the simulated design is technically feasible, the value of energy efficiency and demand management is determined in the energy efficiencies and load assessment process. Then, a design economics assessment process is performed to determine if it is economically feasible. If the determined design is not feasible in terms of technology or economics, the sizing and planning process is repeated with changed requirements. If no design is feasible, then the related issue is identified and reported. If a simulated design is feasible, it is presented in the output report.

The input design requirement process consists of two types of constraints, fixed and variable. Fixed constraints indicate non-flexible requirements such as physical constraints including geographic data or a case-specific requirement for the projected reliability. Variable constraints indicate all constraints that are flexible and can be changed under given conditions, such as renewable generation penetration, minimizing greenhouse gas (GHG) emissions, and design cost.

In the load profile estimation process, energy efficiency, demand side management, and future demand need to be considered. In the energy technologies selection process, available energy resources, energy requirements, and energy storage technologies should be considered. The available energy resources can consist both of renewable and conventional resources (e.g. diesel, gasoline, natural gas, etc.). The resources have to be compatible with the demand profile. Energy requirements determine if there is any constraint or requirement that excludes or limits the available energy technologies. An example could be a geographic constraint where only a limited area can be used for PV panels, for example it is only allowed to install PV panels on house rooftops. An important aspect in islanded grid design phase is the consideration of accumulation subsystem technologies, especially with the consideration of significant renewable energy penetration.

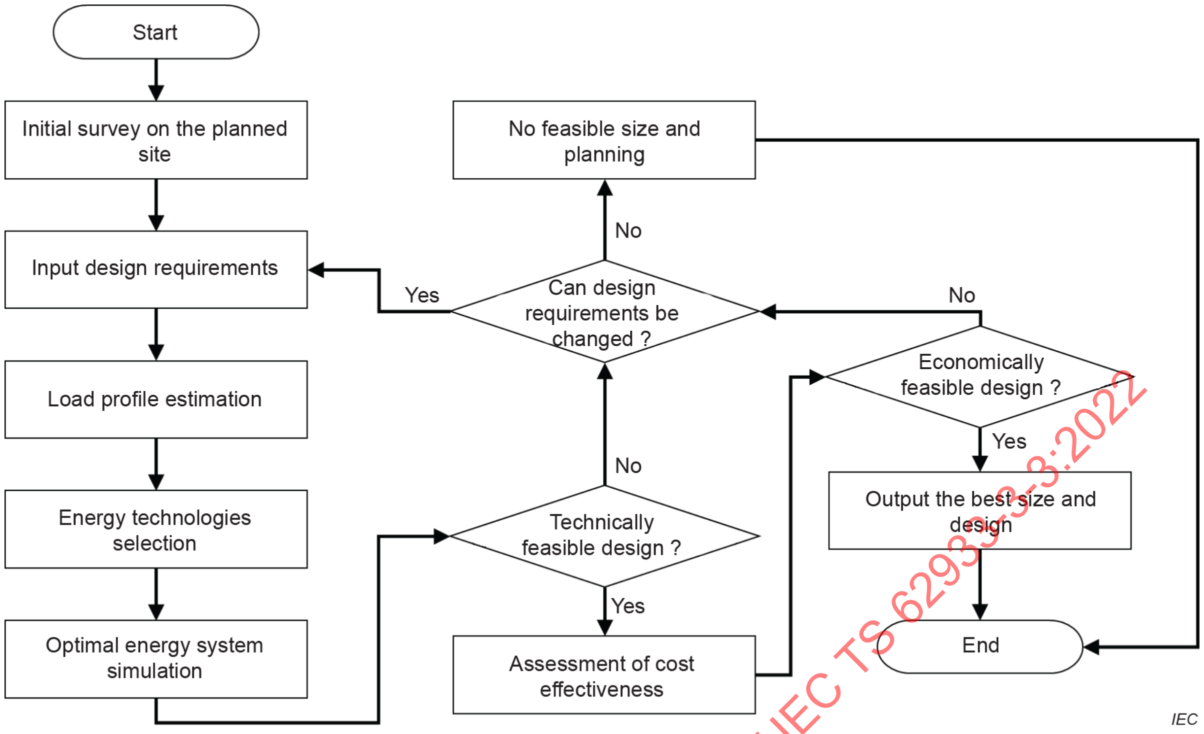


Figure 9 – Example process to determine the sizing and planning of the EES system applied in islanded grid application

When the EES system is used for an islanded grid application, the following information should be identified and considered:

- survey of the planned islanded grid site, including the types of DER, forecasted profiles of loads, equipment for site, etc.;
- location, size, and configuration of voltage regulation equipment, reactors, protective equipment, and transformers;
- islanded grid system's black start, abnormal voltage, and frequency ride-through capabilities;
- acceptable range of voltage, frequency, and harmonic;
- monitoring system and requirements;
- maximum acceptable rate of change of frequency for supplied power;
- acceptable imbalance of voltage at a specific point in the system;
- acceptable dynamic stability limits;
- ratings and types of switching devices;
- protection equipment and settings;
- consideration for future expansion;
- load analysis including three-phase detail, historical load profiles, customer composition, large spot loads such as motors, and forecasted load profiles.

This information is sufficient for developing an engineering model to understand how much power production capacity is necessary to meet the islanded load. If the capacity of the DER in the planned islanded grid is not enough to cover the full loads, peak shaving and fluctuation reduction of consumption schemes can be necessary. This includes the determination of critical and non-essential loads. The installation of an emergency generator and an automatic transfer switch can be sized to support critical loads.

The islanded grid has to be designed in order to provide the real and reactive power requirements of the loads within the islanded grid and serve the range of load operating conditions. The equipment in islanded grid shall be able to regulate the frequency and voltage of the grid within the designed ranges. Voltage regulation equipment within the islanded grid can be modified in its functionality because the functional requirements for the islanded grid system can be different from the grid connected system.

6.4.1.2 Requirements for sizing and planning

When determining the size of an islanded grid, a reserve margin which is a function of the load factor, the magnitude of the load, the load shape, reliability requirements of the load, and the availability of DER should be considered. To balance the load and generation within the islanded grid, various load control schemes may be used. This functionality includes peak shaving and fluctuation reduction of consumption when the DER cannot serve all connected loads. The DER has to be able to maintain acceptable voltage and frequency throughout the islanded grid during all expected load and DER changes.

In the islanded grid application, there is a need to provide dynamic response from the DER. The DER should have adequate real and reactive power capability and response characteristics. Loads can have a variety of issues, including active and reactive demand profiles, step loads, motor starts, voltage imbalance, current imbalance, and power factor. On an islanded grid, the loads can cause more issues than on a grid connected system because the grid connected power systems have stronger and larger generation sources, and aggregate more loads, which can have a balancing effect. For example, if a motor start requires a large amount of inrush current, there should be sufficient reactive power capacity to correctly maintain voltage and frequency stability or current limiting equipment can be installed in the islanded grid. Otherwise, the islanded grid system needs to manage the motor loads by sectionalizing the loads into segments and staged starting.

6.4.2 Characteristics and restrictions of the EES system

Subclause 4.4.3 of IEC TS 62933-3-2:2022 is applicable.

6.5 Service life of the EES system

6.5.1 Installation

Subclause 4.5.2 of IEC TS 62933-3-2:2022 is applicable.

6.5.2 Performance assessment

Subclause 4.5.3 of IEC TS 62933-3-2:2022 is applicable.

6.5.3 Operation and control

6.5.3.1 General

Subclause 4.5.4 of IEC TS 62933-3-2:2022 is applicable. Further, additional technology dependent requirements are defined in Annex B. In addition, the recommendations in 6.5.3.2 should be considered.

6.5.3.2 Control process of the EES system

When operating an islanded grid system, there exist several issues to be considered as follows:

- The islanded grid system needs to monitor and control generation output to ensure power is balanced in real time so that acceptable frequency and voltage are maintained. Load control schemes may be implemented to ensure this.

- Additions and changes to significant loads and generation capacity should be evaluated. Forecasted load growth should be planned into the islanded grid system design and verified regularly.
- Time synchronization may be necessary due to accumulated effects of off-rated frequency operation.
- Training for all personnel involved with the islanded grid system operations and maintenance is necessary.

When operating an islanded grid, load imbalance within the islanded grid shall be investigated. One issue with loads in the islanded grid system is that the loads can be extremely imbalanced. The individual phase currents of the loads can have considerable imbalance even though the phase-to-neutral voltages or phase-to-phase voltages can be reasonably balanced. Therefore, the load configuration needs to be investigated and can be modified to facilitate an islanded grid configuration.

Imbalances in the distribution system or load imbalance can cause negative sequence currents that might damage equipment. Three-phase DER and motors have limited negative sequence capability and can be damaged by imbalanced load conditions. Use of a negative sequence current relay can mitigate damage to three-phase rotating machinery. The islanded grid system customers can make modifications to protect their equipment for use in the islanded grid.

There are three types of control strategy for the islanded grid, as follows:

1) Centralized control: A central control system provides commands to the entire islanded grid system in what is effectively a master-slave configuration between the central control system and distributed equipment.
2) Distributed control: Control is accomplished with independent controls communicating with one another. This strategy uses intelligent devices that are strategically located to detect the conditions and initiate the required actions.
3) Autonomous control: Control is accomplished with independent controls without communication with other devices.

The islanded grid systems operating outside normal utility parameters can cause equipment performance problems because of equipment operating ranges, safety concerns, or customer needs. However, the islanded grid systems may operate outside normal utility parameters if acceptable to all interested parties.

6.5.4 Monitoring

Subclauses 4.3.6 and 4.5.5 of IEC TS 62933-3-2:2022 are applicable.

6.5.5 Maintenance

Subclauses 4.3.7 and 4.5.6 of IEC TS 62933-3-2;2022 are applicable. In addition, the following recommendations should be considered.

As a periodic testing and maintenance, the islanded grid system design should be re-evaluated to ensure proper capabilities in terms of load and generation. Also, periodic confirmation that the planned assets and equipment are still connected and operational is necessary.

Load monitoring and control can be employed to manage the islanded grid systems. There should be sufficient monitoring to operate and understand the status of the islanded grid.

The islanded grid systems with multiple DER require communications among the DER. Their operation should be managed and coordinated to effectively meet the needs of the islanded grid.

In islanded grid application, it is difficult to repair or perform maintenance because maintenance operation can cause grid outage. Therefore, setting a maintenance plan should be considered grid outage.

7 Backup power supply and emergency support

7.1 Applications of the EES system

7.1.1 Functional purpose of the EES system

In the event of electrical grid outage, an EES system can provide power to all internal loads or only to the emergency loads.

7.1.2 Applications related requirements

Subclause 4.1.2 of IEC TS 62933-3-2:2022 is applicable.

7.2 Conditions and requirements for connection to the grid

Subclause 4.2 of IEC TS 62933-3-2:2022 is applicable.

7.3 Design of the EES system

7.3.1 Structure of the EES systems

Subclause 4.3.2 of IEC TS 62933-3-2:2022 is applicable.

7.3.2 Subsystem specifications and requirements

Subclause 4.3.3 of IEC TS 62933-3-2:2022 is applicable. Further, additional technology dependent requirements are defined in Annex B.

7.3.3 Grid integration of the EES system

7.3.3.1 General considerations

Subclause 4.3.4 of IEC TS 62933-3-2:2022 is applicable. Further, additional technology dependent requirements are defined in Annex A. In addition, the following requirements shall be considered.

7.3.3.2 Specific requirements

In addition to the general considerations, 7.3.3.2 describes specific requirements. Figure 10 shows the example use case for backup power using a diesel generator. The emergency loads are connected to the backbone grid through a transfer switch. The diesel generator is also connected to the transfer switch. When power outage of the backbone grid happens, the transfer switch disconnects the emergency loads from the backbone grid and connects the diesel generator to the emergency loads.

NOTE Since a diesel generator is commonly used for backup power, 7.3.3.2 considers use cases related to a diesel generator. However, instead of a diesel generator, other types of generators such as a gas turbine generator can be used as backup power.

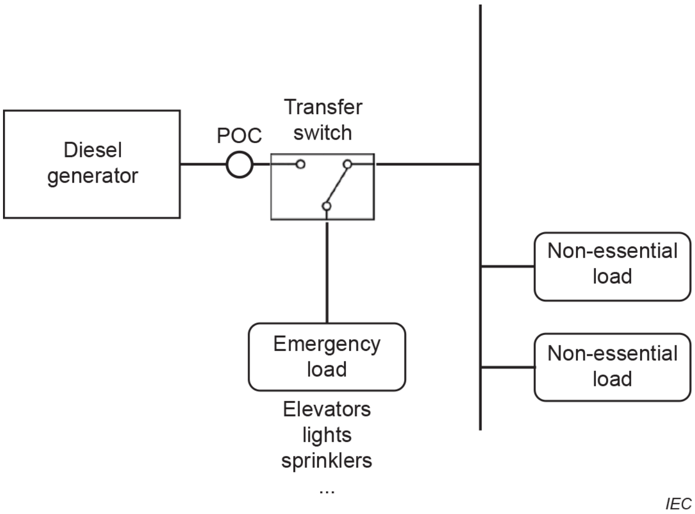


Figure 10 – Example use case for backup power using a diesel generator

Figure 11 shows the simple replacement of a diesel generator with an EES system for backup power support. The use case in Figure 11 is the same as in Figure 10 except that the diesel generator is replaced by the EES system. The disadvantage of this use case is the low use of the EES system because the EES system operates during backbone grid outage and does not support the EES system's own functions such as peak control.

When replacing the diesel generator with the EES system for backup power usage, there exist several requirements to be considered as follows:

- The emergency load shall be separated from non-essential load and be connected to the EES system by transfer switch when grid outage occurs.
- In the conventional diesel generator-based emergency load support case, power interruption happens to the emergency load due to the transfer time in the transfer switch. For some critical loads, voltage interruptions longer than a few cycles are not admissible. Thus, if power interruption is not allowed to emergency loads, the transfer switch shall be implemented by a static switch and the transfer time from grid to EES system shall be guaranteed.
- Since the capacity of the EES system for backup power supply can be limited, the capacity of the EES system shall consider the emergency load characteristics as described in 7.4.
- Once the grid voltage is returned, the EES system shall synchronize its own voltage to the voltage of the grid before transferring critical and emergency loads back to the grid.

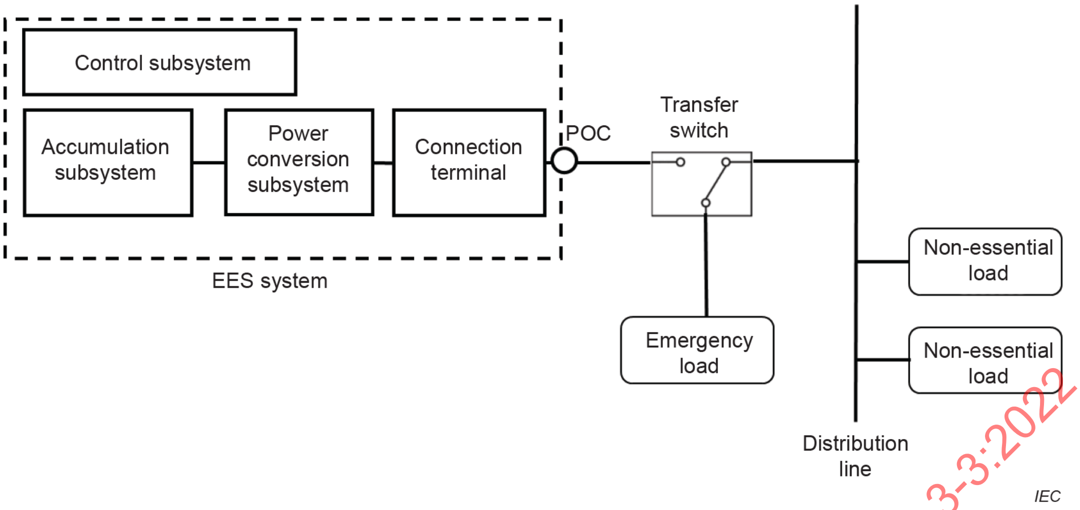


Figure 11 – Simple replacement of diesel generator with EES system for backup power support

The simple replacement of the conventional diesel generator with the EES system is not cost effective because the EES system is disconnected from loads and is not used during grid operation. Figure 12 shows the grid integration of the EES system in order to support both backup power and its own functions. In the use case, the EES system is connected to the non-essential loads and emergency loads in parallel with the backbone grid. Thus, the EES system can perform its own functions such as peak control during grid connection. When grid outage occurs, the disconnectors detect the power outage and disconnect the EES system and emergency loads from the grid. Then, the EES system feeds power to the emergency loads. In this use case, additional equipment for backup power (shown in the dotted blue line in Figure 12 can be necessary.

When the EES system is used for both backup power support and energy intensive application, there exist the following additional requirements in addition to the requirements described in Figure 11.

– When grid outage occurs, the disconnector shall be opened in order to disconnect the EES system and emergency loads from the distribution line and other loads.
– Since the EES system can be used for energy intensive application such as peak shaving, the minimum SOC to support emergency loads shall be maintained in case of grid outage.
– The operation of the EES system shall follow the control process described in 7.5.3.

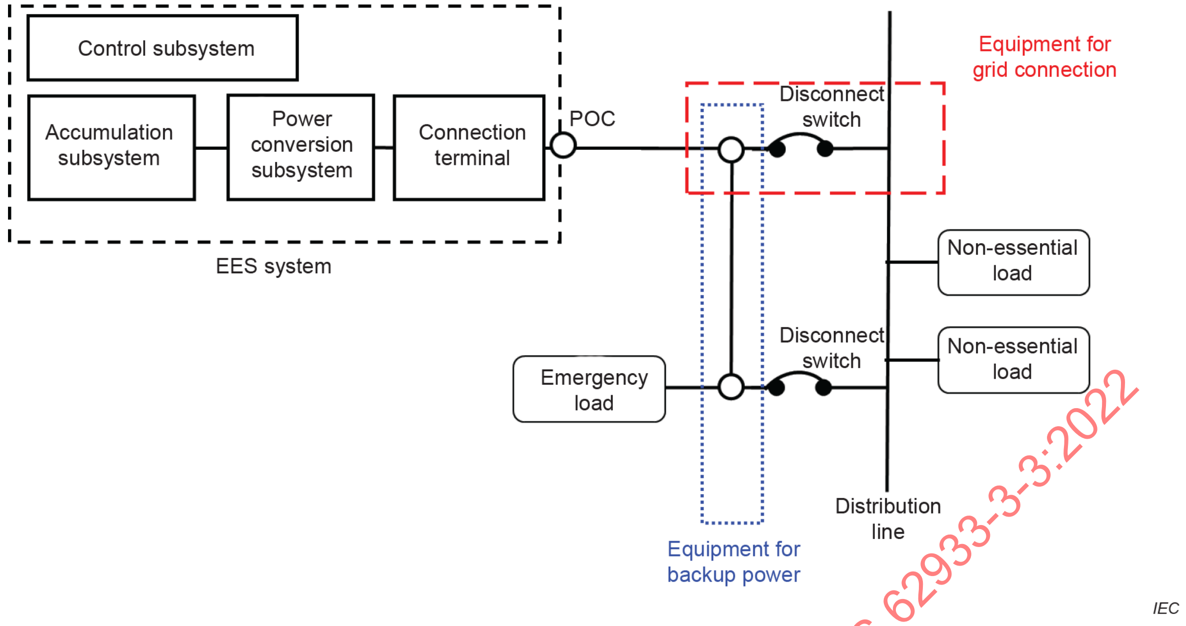


Figure 12 – EES system use case for both backup power and EES's own functions

Figure 13 shows the use case for grid integration of the EES system when a distribution panel is present and electrical loads are connected to the distribution panel. In this use case, the distribution panel is capable of communicating with the control subsystem in the EES system, so that the status of the EES system and the distribution panel can be exchanged. When there is an intelligent distribution panel which is capable of communicating with the EES system and separating the emergency loads from non-essential loads, the presented use case is applicable. When grid outage is detected, the EES system notifies the distribution panel to separate the emergency load. The EES system then provides power to the emergency load. When grid outage occurs, the disconnectors disconnect the EES system and electrical loads from the grid. The EES system notifies the backup power operation of the EES system to the distribution panel. On receiving the notification, the distribution panel disconnects non-essential loads and only the emergency loads are supported by the EES system.

When the EES system is used in the use case shown in Figure 13, there exist the following additional requirements in addition to the requirements described in Figure 11 and Figure 12.

a) The distribution panel shall be capable of separating emergency loads and non-essential loads.

b) The distribution panel shall be capable of disconnecting non-essential loads after grid outage.

c) The distribution panel shall be capable of reconnecting non-essential loads after grid recovery.

d) The distribution panel shall be capable of communicating with the EES system during grid outage.

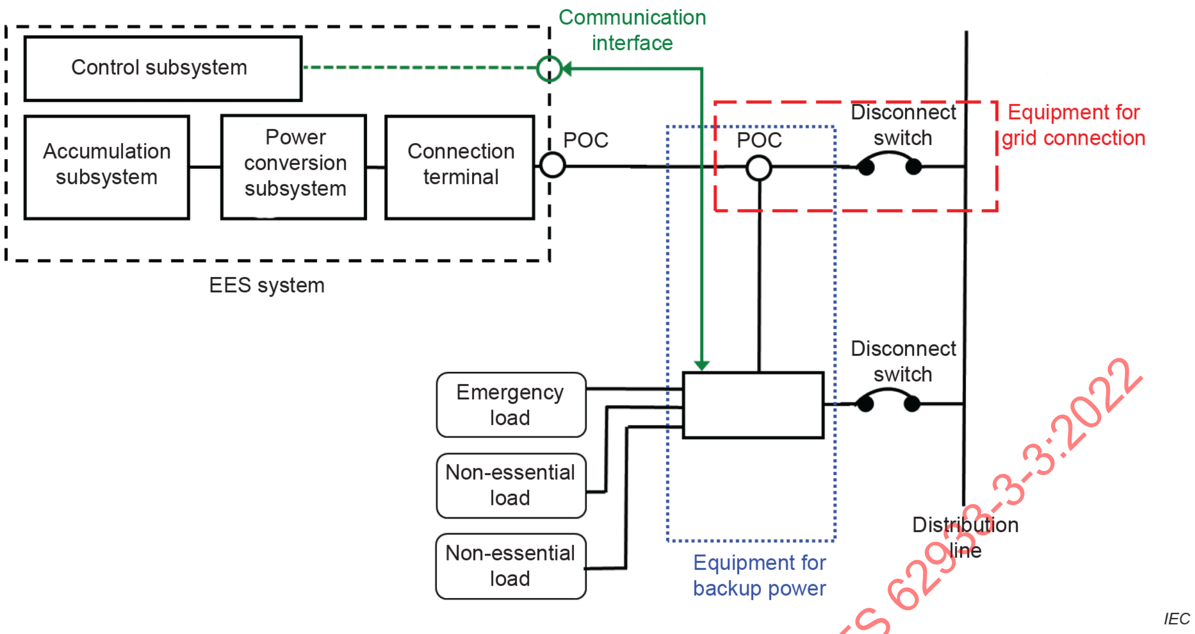


Figure 13 – EES system use case for communication with distribution panel

7.3.4 Operation and control

Subclause 4.3.5 of IEC TS 62933-3-2:2022 is applicable. In addition, the requirements in 7.3.4 should be considered.

When the grid is recovered from the outage, the EES systems start the reconnection process to the grid. The reconnection time for each EES system shall be coordinated with the wires owner and grid operator, to avoid a second disturbance when all the EES systems reconnect at the same time.

7.3.5 Monitoring

Subclause 4.3.6 of IEC TS 62933-3-2:2022 is applicable.

7.3.6 Maintenance

Subclause 4.3.7 of IEC TS 62933-3-2:2022 is applicable.

7.3.7 Communication interface

Subclause 4.3.8 of IEC TS 62933-3-2:2022 is applicable. Further, additional technology dependent requirements are defined in Annex B.

7.4 Sizing and resulting parameters of the EES system

7.4.1 Sizing

7.4.1.1 Sizing and planning process of the EES system

The general sizing and planning process of the EES system applied to the backup power supply and emergency support applications is depicted in Figure 14. In the input emergency load requirements process, the types and operation time for each emergency load are considered. The load profiles of the emergency loads are then analysed so as to determine the optimal starting sequences of the emergency loads. The size and design of the EES system are then determined. If the determined size does not meet the backup power support requirements, the processes are repeated with changed starting sequences of the emergency loads. When the determined size and design meet the backup power support requirements, economic assessment is performed. A suitable type of accumulation subsystem is then selected and checked if the characteristics of the selected accumulation subsystem satisfy the backup power support requirements.

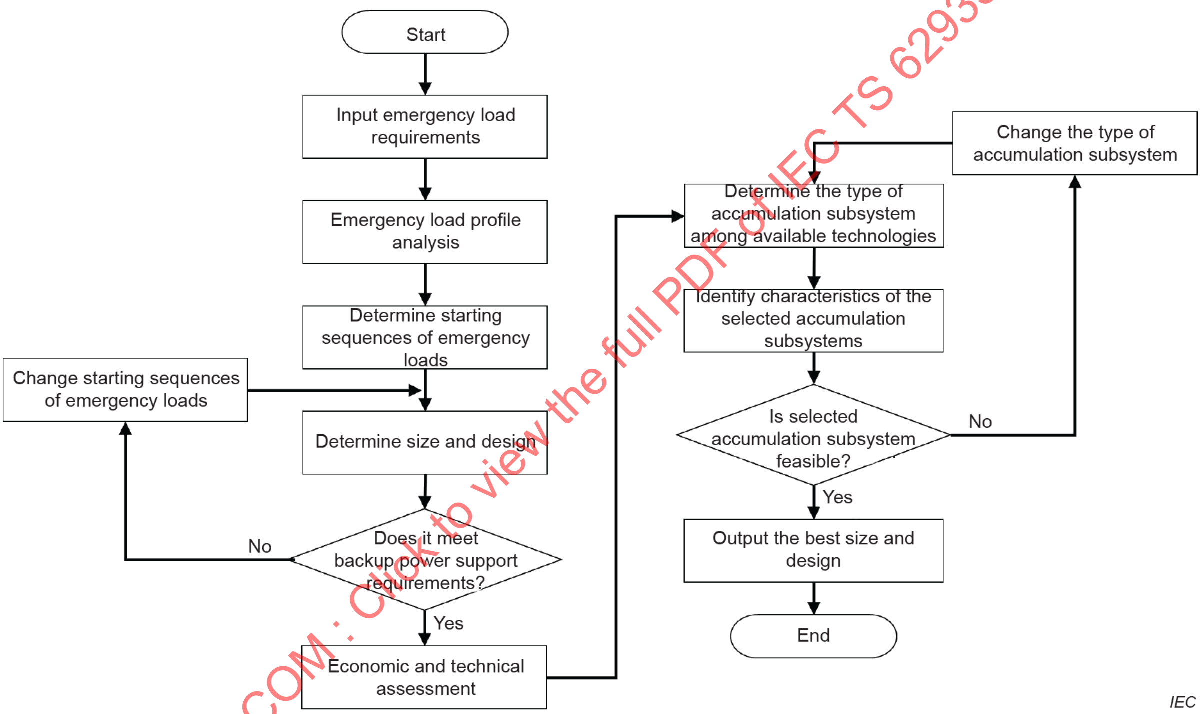


Figure 14 – Example process to determine the sizing and planning of the EES system applied to the backup power supply and emergency support application

A minimum capacity of the EES system to supply power to the emergency loads during the electrical grid outage should be maintained in order to comply with the relevant regulations for the required time to supply power to the emergency loads. Emergency loads consist of a fire suppression facility load and other emergency facility loads. The fire suppression facility load is the load used in the fire. For example, fire suppression facilities (fire extinguishing facilities, evacuation facilities, firefighting water facilities, firefighting activity facilities, etc.) and fire prevention and evacuation facilities (emergency elevators, evacuation elevators, drainage pump, fire extinguishing facility, fire partitioning facility, etc.) are generally considered. Other emergency loads include medical facilities or a drainage pump if there is an electric room or machinery room in the basement.

Table 3 shows an example of the operation time for emergency load facilities. During the grid outage, the EES system should provide power to the listed emergency loads for the required operation time. The operation time is determined according to local or regional regulations.

Table 3 – Example of the operation time for emergency load facilities

Types	Minimum required operation time
Indoor fire hydrant equipment	20 min
Sprinkler equipment	20 min
Foam-type fire extinguishing equipment	20 min
Fire extinguishing equipment such as water spray	20 min
Ventilation equipment	20 min
Emergency light	30 min
Emergency outlet equipment	20 min
Emergency elevator	120 min
Emergency drainage pump	30 min
Fireproof shutter	30 min

7.4.1.2 Requirements for sizing and planning

When estimating the capability of the power conversion subsystem in the EES system, not only the capacity of the accumulation subsystem, but also the capacity of the power conversion subsystem should be considered.

- Rated power estimation for power conversion subsystem
  - when estimating the power conversion subsystem's rated power, it should be calculated so as not to interfere with the operation of the emergency load facilities required by the relevant regulations.
- Capacity estimation for accumulation subsystem
  - the annual deterioration rate of the accumulation subsystem should be considered, and the capacity for the emergency load shall be preserved at all times;
  - estimated capacity should be calculated considering the power supply time of the fire load according to the size of the site;
  - when operating an isolation operation, it is necessary to preserve the minimum capacity required for heating, ventilation, and air conditioning (HVAC) and the control power operation, and consider the energy conversion loss due to charging and discharging of the accumulation subsystem;
  - the capacity of the accumulation subsystem should be calculated considering the power consumption, SOC operation range, line loss, EES system efficiency and power factor in accordance with the technical data provided by the manufacturer etc.

It is noted that the inrush current of the motor is higher than the normal load current, so the starting sequence of the emergency loads should be determined by considering the emergency load characteristics. The capacity of the EES system should then be determined by considering the starting sequence.

7.4.2 Characteristics and restrictions of the EES system

Subclause 4.4.3 of IEC TS 62933-3-2:2022 is applicable.

7.5 Service life of the EES system

7.5.1 Installation

Subclause 4.5.2 of IEC TS 62933-3-2:2022 is applicable.

7.5.2 Performance assessment

In backup power supply and emergency support applications, in addition to the application requirements listed in subclause 4.5.3 of IEC TS 62933-3-2:2022, the following recommendations should be considered.

The performance of the EES system's supporting backup power can be assessed by using the following performance indicators:

- the amount of time to supply power to emergency loads;
- the amount of emergency loads that the EES system is able to supply power to the emergency loads during the electrical grid outage;
- the amount of time spent before supplying power to the emergency loads after the electrical grid outage. Usually, diesel generators require tens of seconds to provide power to the emergency loads after electrical grid outage, however the EES system can perform within a second;
- inrush current and time of emergency load during backup power supply;
- shifting (exchange) time from the grid to the EES system at outage;
- return time from stand-alone to the grid;
- power quality of stand-alone mode (frequency, voltage, total harmonic etc);
- for some critical loads, voltage interruptions longer than a few cycles are not admissible. Therefore, the disconnector should be implemented by a static switch, and the transfer time from the grid to the EES system shall be guaranteed (i.e. < 20 ms). Once the grid voltage is returned, the EES system shall synchronize its own voltage to the grid's voltage before transferring critical and emergency loads back to the grid.

7.5.3 Operation and control

7.5.3.1 General

Subclause 4.5.4 of IEC TS 62933-3-2:2022 is applicable. Further, additional technology dependent requirements are defined in Annex B. In addition, the requirements in 7.5.3.2 to 7.5.3.4 should be considered.

7.5.3.2 Control process of EES system

When the EES system is used as a backup power, it has to support both the EES's own function and the backup power function. The EES's own function is performed during the normal electrical grid. In normal operation, the EES system shall be compliant with the corresponding grid code. One of the points that it shall comply with is the LVRT capability. The EES control system shall guarantee that the outage detection (i.e. anti-islanding system) and LVRT mechanism work harmoniously. The following lists operational considerations for EES system operation during normal electrical grid status and during electrical grid outage and backup power support. Figure 15 shows an example of operational flow of the EES system when grid outage happens. Figure 16 shows an example of operational flow of the EES system when the grid is recovered.

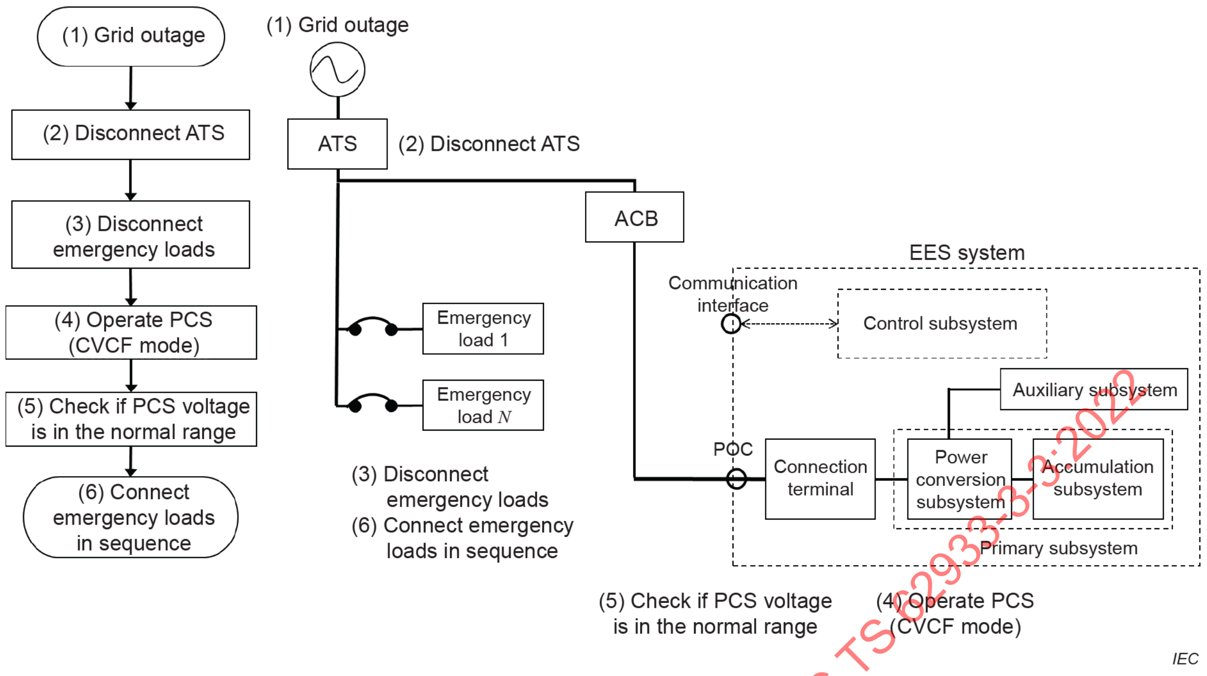


Figure 15 – Example operation flow for backup power support during grid outage

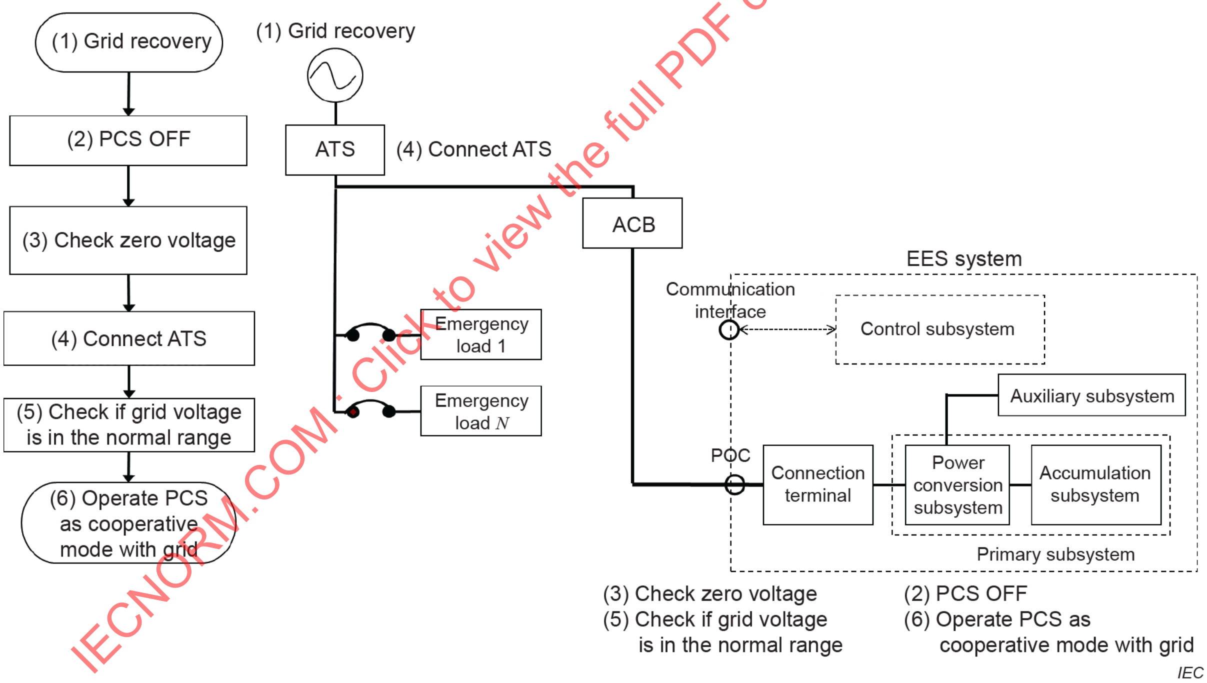


Figure 16 – Example operation flow for backup power support when grid is recovered

7.5.3.3 Operational considerations during normal grid status

In case of operation of the EES system during normal electrical grid status, the EES system has to cooperate with the protection system that separates the EES system from the grid in the event of power outage or fault including:

- fault or failure of the EES system;
- fault or failure of the grid system;
- isolated operation status.

7.5.3.4 Operational considerations for backup power support

In the event of a fault or failure of the electrical grid, the EES system should be disconnected from the grid before the reclosing of the relevant system in the grid. In addition, the EES system should be separated from the electrical grid until the voltage and frequency of the grid come within the normal range. In order to provide power to the emergency loads, the EES system should meet the following requirements.

- Backup power should be installed to provide power-only emergency loads during the electrical grid outage. Non-essential loads should not be powered from the backup power system during the electrical grid outage.
- It is necessary to provide required facilities such as ventilation in the space where the EES system is installed as the backup power supply for emergency.
- When the power outage happens in the electrical grid, the EES system should supply electricity to the emergency load reliably.
- The EES system should maintain the required amount of the accumulation subsystem's charging status specified by the relevant regulations in order to supply electricity to the emergency load during the grid power outage.

The EES system can be connected to low voltage (≤ 1 kV) equipment or high voltage (> 1 kV) equipment, so there exist different control system considerations for each voltage category.

There are two types of distribution line topology depending on the voltage. When the EES system for backup power support is connected to low voltage equipment (AC voltage less than or equal to 1 kV), the configuration shown in Figure 17 may be used and the following considered:

– switch gear should be installed in order to disconnect the emergency load and the EES system from the electrical grid in the event of electrical grid outage;
– when a grid outage occurs, the EES system should be operated after confirming whether the feeder breaker is open;
– in the event of a grid power outage the electrical grid should be disconnected and power should be supplied to the emergency load through the EES system;
– when the EES system is operated in parallel with an on-site diesel generator, voltage and frequency synchronizers are required;
– when the EES system is installed in a low voltage distribution line, a grid outage event can be linked to the unearthing on neutral wire. During the grid outage, earthing of the neutral wire should be guaranteed.

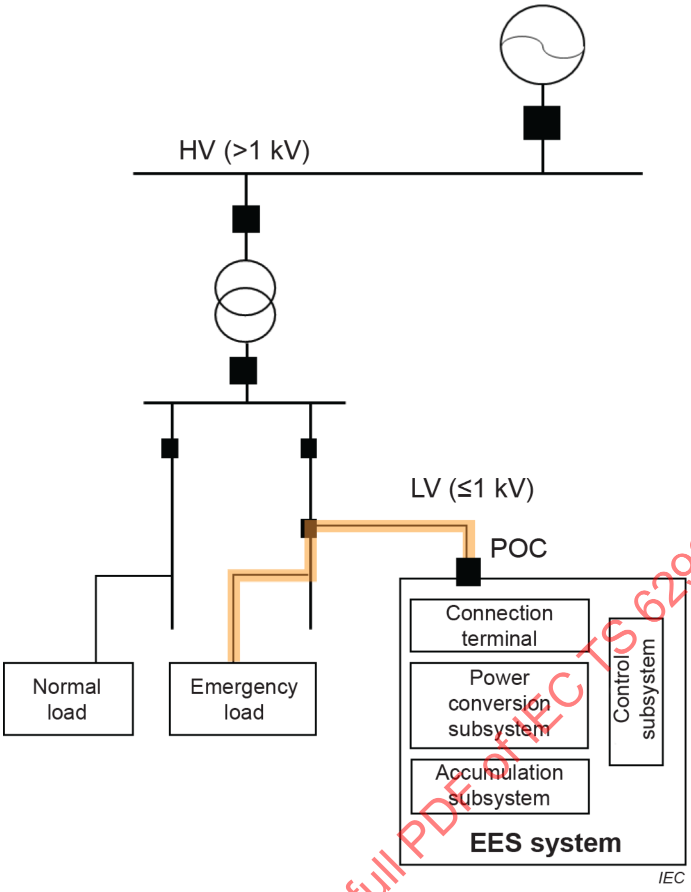


Figure 17 – Example of configuration for low voltage connection

When the EES system for backup power support is connected to high voltage equipment (AC voltage greater than 1kV), the configuration shown in Figure 18 may be used and the following considered:

- when supplying power to the emergency loads through both the electrical grid and the EES system in normal situation, power may be supplied to the emergency loads through the transformers because the voltage of the power conversion subsystem can be different from the voltage of the emergency loads;
- in case of an electrical grid outage, the EES system should provide power to emergency loads after confirming the emergency loads and the EES system are disconnected from the electrical grid;
- when an electrical grid outage occurs, the EES system should provide power to emergency loads after confirming the non-essential loads are disconnected from the EES system;
- the EES system can be installed with a transfer switch to separate the power line;
- when the EES system is operated in parallel with an on-site diesel generator, voltage and frequency synchronizers are required.