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TECHNICAL SPECIFICATION

Electrical energy storage (EES) systems –
Part 2-2: Unit parameters and testing methods – Application and performance testing

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ELECTRICAL ENERGY STORAGE (EES) SYSTEMS –

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FOREWORD

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IEC 62933-2-2 has been prepared by IEC technical committee TC 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
120/249/DTS	120/264A/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.

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.
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INTRODUCTION

Considering the wide variety of applications of EES systems, it is becoming important to define the typical application of each EES system depending on its purpose and control types, and also important to define the corresponding performance testing methods and procedures of the EES system.

IEC 62933-2-1 describes the general specification of unit parameters and testing methods for EES systems, in which details of duty cycles for typical grid applications and the associated performance metrics and testing methods are not covered.

This part of IEC 62933 focuses on developing generic duty cycles for applications, identifying relevant performance metrics and developing performance testing methods and procedures for EES systems.

ELECTRICAL ENERGY STORAGE (EES) SYSTEMS –

Part 2-2: Unit parameters and testing methods – Application and performance testing

1 Scope

This part of IEC 62933 defines testing methods and duty cycles to validate the EES system's technical specification for the manufacturers, designers, operators, utilities and owners of the EES systems which evaluate the performance of the EES systems for various applications. The following items are covered in this document. The energy storage devices and technologies are outside the scope of this document:

– application;
– performance testing methods;
– duty cycles for specific application.

This document will be used as a reference when selecting testing items and their corresponding evaluation methods.

This document considers applications such as:

- frequency control;
- primary/secondary/tertiary frequency control;
- fluctuation reduction of PV and wind farm;
- reactive-power voltage control;
- power quality events mitigation;
- peak shaving;
- renewable firming;
- back-up power;
- islanded grid.

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

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

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62933-1 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

3.2 Abbreviated terms

EES: Electrical energy storage

EESS SOC: State of charge of EES system

POC: Point of connection

UPS: Uninterruptable power systems

4 Application of EES system

4.1 General

The applications of EES systems differ according to their purposes. The applications of EES systems are classified into three classes:

a) class A applications: short duration/power intensive applications (with a duty cycle of less than 1 h);

b) class B applications: long duration/energy intensive applications (with a duty cycle of more than 1 h), and

c) class C applications: back-up applications.

IEC 62933-2-1 provides classification details. The typical application of each class will be described hereinafter.

4.2 Class A applications

4.2.1 Frequency control

EES systems provide a grid frequency control function to increase the frequency by discharging and to reduce the frequency by charging. The system frequency will be controlled within a predetermined bandwidth. The control subsystem in the EES system continuously measures the frequency and then sends a control signal to the power conversion subsystem to increase or decrease the amount of active power injected into the grid or the amount of load on the grid.

4.2.2 Primary/secondary/tertiary frequency control

In this application, there is a sudden loss of generation which leads to be made up through a discharge from the EES system. In the case of a sudden loss of load in the grid, energy is charged into the EES.

Generally, the definition of each control is based on the control order and control time period. The following are example cases for reference.

Primary frequency control comes first and usually it is automatically initiated. It is activated within a few seconds and lasts up to a few minutes.

Primary frequency control is followed by secondary frequency control if necessary and is initiated automatically or manually. It should have an activation time typically between 30 s and up to15 min.

Tertiary frequency control is used to resolve any additional imbalance that exists after the primary and secondary frequency control has been carried out. It should have an activation time typically between 15 min and several hours.

The activation time period of these controls is usually set in the grid code of each country or region.

4.2.3 Fluctuation reduction of PV and wind farms

An EES system is used to reduce the rapid fluctuations of the power output from PV and wind farms. The purpose of fluctuation reduction of the power output from PV and wind farms is to help to meet the ramp rate requirements. This action will mitigate frequency variation and stability issues at both feeder and transmission levels particularly with high penetration PV and wind farm scenarios.

At the feeder level, fluctuation reduction of PV and wind farm is implemented to mitigate voltage flicker and voltage deviations from desired bands. At the transmission level, PV and wind farm variability can require an additional operating reserve to be set aside. This can cause traditional power generation facilities to be cycled on/off more often than desirable.

The method by which the EES system can provide reduction of PV and wind farm output power fluctuation is to absorb or supply active/reactive power at appropriate times as determined by a control system resulting in a less variable composite power signal at the feeder and/or transmission level.

4.2.4 Reactive-power voltage control

The reactive-power voltage control application addresses the fluctuations in the grid voltage by providing reactive power support. EES systems inject reactive power as the grid voltage dips and absorb reactive power as the grid voltage increases.

4.2.5 Voltage sag mitigation

The sag or interruption in voltage potentially causes power disturbances that negatively impact power quality. EES systems mitigate voltage sags by discharging real power for up to a few tens of seconds. The application of an EES system to improve power quality does not require the EES system to provide enough energy for customers to ride through sag or interruption.

NOTE An event duration of more than 1 min is considered as outage mitigation.

4.3 Class B applications

4.3.1 Peak shaving

The EES system discharges stored energy into the grid upon an excess or peak of demand or absorbs excess energy, available in the grid, for storage. With this balancing a time shift between power generation and electricity usage is achieved.

Examples of this application include energy time shift of conventional/wind/solar/base load-generation, and include transmission/distribution grid congestion relief.

4.3.2 Renewable firming

Renewable firming is the use of an EES system to provide energy to supplement renewable power generation such that their combination produces steady power output over a desired time window. More precisely, the purpose of renewable firming is to provide energy (or conversely, to absorb energy) when renewable generation falls below some threshold (or conversely, exceeds this threshold).

This service is performed to provide steady power output over a desired time window, usually a period of multiple hours. Typically, the threshold is based upon the forecasted nominal renewable power generation over the desired time window. Thus, the EES system is compensating for the forecast uncertainty in actual renewable generation during that time window.

The method by which the EES system performs this service is described as follows. The EES system discharges power during periods for which renewable generation falls short of the threshold and absorbs power when renewable generation exceeds this threshold.

4.3.3 Islanded grid

The EES supports in islanded grids their multiple loads, distributed energy generation and storage resources. In such a service the EES system provides energy to the load of the islanded grid. The EES system converter typically operates in the voltage/frequency mode to control the islanded grid.

The EES systems supply the islanded grid for a limited time when the power supply from the other grid is interrupted for some reason.

4.4 Class C applications

EES systems used as back-up power are independent sources of electrical power that support critical loads on loss of normal power supply. Back-up power systems are, for example, installed to protect life and property from the consequences of loss of primary electric power supply. Uninterruptable power systems (UPS) are out of the scope in this application.

5 Parameter testing methods for application

5.1 Parameter tests

5.1.1 General

Parameter tests shall be conducted for all EES systems regardless of intended application(s) in accordance with Clause 5, and the results shall be used to determine EES system performance that can be subsequently used as a baseline to assess any changes in the condition of the EES system and performance over time and use. Parameter tests shall be conducted to determine baseline performance of the EES system prior to duty cycle testing.

5.1.2 Actual energy capacity

The actual energy capacity of the EES system shall be tested at rated power, and at short duration input power or at additional power values different from rated power if such parameters are required.

The energy capacity shall be evaluated as the product of the rated output power and the output duration time. The values of the output power from the EES system shall be obtained at the point of connection (POC) by placing calibrated power meters at the POC and auxiliary feed points (in case of auxiliaries fed from a substation).

The actual energy capacity is defined in IEC 62933-1. Also, the actual energy capacity test shall be performed in accordance with the test methods defined in IEC 62933-2-1.

5.1.3 Roundtrip efficiency

The roundtrip efficiency test shall be conducted to determine the amount of energy output that the EES system can deliver, relative to the amount of energy input into the EES system during the preceding charge and discharge.

The roundtrip efficiency test shall be performed in accordance with the test methods defined in IEC 62933-2-1.

5.1.4 Step response time and ramp rate

The step response time of the EES system is the duration of the time interval between the instant when the set point value is received at the EES system and the instant when the active power at the POC starts to stay within ±2 % of deviation from the set point. The ramp rate of the EES system is the average rate of active power variation per unit time.

The response time and ramp rate of the EES system shall be performed in accordance with the test methods defined in IEC 62933-2-1.

5.1.5 Auxiliary power consumption

The auxiliary power consumption shall be measured with the ESS system connected to the POC. The auxiliary power consumption of the EES system shall be tested in accordance with the test methods defined in IEC 62933-2-1.

5.1.6 Self-discharge

The self-discharge of the EES system is the energy loss of the EES system in the stopped state during the standard measurement time. The self-discharge of the EES system shall be tested in accordance with the test methods defined in IEC 62933-2-1.

5.1.7 SOC

The state of charge (SOC) of the EES system (EESS SOC) is the ratio between the available energy from the EES system and the actual energy capacity, expressed as a percentage. The available energy is defined in IEC 62933-1.

The testing methods of available energy are defined in IEC 62933-2-1.

5.2 Duty cycle performance tests

5.2.1 General

Duty cycle performance tests shall be conducted for each intended application of an EES system using the duty cycles as defined in Clause 6.

5.2.2 Duty cycle roundtrip efficiency

The duty cycle roundtrip efficiency is used in the determination of the performance of the EES system for each application duty cycles defined in Clause 6.

The duty cycle roundtrip efficiency of the EES system shall be tested in accordance with the test methods defined in IEC 62933-2-1.

5.2.3 Reference signal tracking

The ability of the EES system to respond to a signal for the duration of the duty cycle for each intended application of the EES system reflects the ability of the EES system to track the signal.

The tests of the ability should be conducted by Formula (1) to Formula (4) below separately for each intended application of the EES system while applying the duty cycle relevant to each intended application of the EES system. The procedures of the tests are as follows.

The ability should be defined and determined by the manufacturer of the EES system in accordance with the provisions of Clause 6. The signal should be changed in accordance with the duty cycle(s) for each intended application of the EES system.

The manufacturer of the EES system should also determine and report separately the total percentage tracking and the times when the EES system stops tracking and restarts tracking as an indication of whether the EES system is capable of tracking high peaks and/or high energy half-cycles.

The manufacturer should also determine whether the EES system can go through the required duration of the duty cycle without reaching the lower or upper EESS SOC limits. This should be performed during the application of the relevant duty cycle as described in Clause 6, and any time during that period when the EES system indicates an ability or inability to follow the signal should be reported.

An inability for the power signal to follow the signal shall be considered a situation where the EES system cannot deliver or absorb the required signal power during the duration when the signal is to be changed.

For the energy signal, an inability to follow the signal shall be considered a situation where the EES system cannot deliver or absorb the required energy signal during the duration when the energy signal remains positive or negative, respectively. Simulations of the signal can be applied for the testing.

NOTE There are some cases where the inability of the EES system to follow the signal is not caused by the EES system performance itself but by the external conditions such as energy capacity specified under some restrictions or changing of the SOC limits set-points by the external control system.

The ability of the EES system to respond to a signal should be measured during the duty cycle roundtrip efficiency test. The residual sum of squares or the sum of the square of errors between the power signal (P_{signal}) and the power delivered or absorbed by the EES system (P_{eess}) should be calculated in accordance with Formula (1) and used to estimate the inability of the EES system to track the signal.

$$APT = \frac{\sum \left(P_{signal} - P_{eess} \right)^2}{N} \quad (1)$$

where

APT is the ability of the power signal tracking,

P_{signal} is the power signal,

P_{eess} is the EES system power (watts), and

N is the number of data during one duty cycle.

The measurements should be taken at every point in time that the EES system receives a change in the power signal. The sum of the absolute magnitudes of the difference between the power signal and EES system power should be calculated in accordance with Formula (2).

$$APTA = \frac{\sum \left| P_{signal} - P_{eess} \right|}{N} \quad (2)$$

where

$APTA$ is the ability of power signal tracking in absolute.

The sum of the absolute magnitudes of the difference between the signal energy and EES system energy should be calculated in accordance with Formula (3) and reported by the manufacturer of the EES system to account for the inability of the EES system to follow the signal due to the EES system reaching the EESS SOC limits provided in the manufacturer's specifications and operating instructions.