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Grid Code Specifications for Grid Energy Storage Systems SJV2019

Contents

1 Introduction

This document contains the Grid Code Specifications for Grid Energy Storage Systems (hereinafter referred to as “Specifications”) required by Fingrid Oyj (hereinafter referred to as “Fingrid”), by virtue of the system responsibility imposed on Fingrid, of converter-connected grid energy storage systems which are to be connected to the Finnish power system and which provide system services. In addition to these Specifications, connecting parties shall fulfil Fingrid’s General Connection Terms (YLE) valid at the time of connection, the terms specified in the Main Grid Contract and the connection terms set by the relevant network operator.

The requirements have been set on the basis of the connection technology which is identical to power park modules. If other types of grid energy storage systems are to be connected to the power system, Fingrid will determine their requirements separately. The European grid connection network codes do not currently set any requirements on grid energy storage systems. These Specifications were established taking into account the shared goals of European grid connection network codes: to guarantee equal and non-discriminatory conditions for competition on the internal energy market, to ensure system security and to create harmonised connection terms for grid connections.

Nationally, the purpose of the Grid Code Specifications for Grid Energy Storage Systems is to ensure that:

- the grid energy storage system withstands the voltage and frequency fluctuations occurring in the power system,
- the grid energy storage system supports the operation of the power system during disturbance situations, and works reliably during and after such situations,
- while connected to the power system, the grid energy storage system does not cause any adverse impacts to the other installations connected to the power system, and
- the relevant network operator and Fingrid obtain the data on the grid energy storage system, necessary in the planning of the power system and its operation and in the maintaining of system security.

2 Terms and definitions

Voltage controller: Voltage controller controls the reactive power generated by the grid energy storage system by using either the terminal voltage of the grid energy storage system's converter or the voltage of the connection point as a reference point.

System services: System services are services that support the use of an electricity transmission grid or distribution network, including reserve and balancing power markets, or network load balancing and control.

K-factor: Defines a grid energy storage system's fault current feed in relation to the remaining voltage during a fault.

$$k = \frac{\frac{\Delta I_q}{I_n}}{\frac{\Delta U}{U_n}}$$

where I_q is the reactive current, I_n is the grid energy storage system's nominal current, U is the remaining voltage during the fault, U_n is the nominal voltage.

Demand mode: In demand mode, the grid energy storage system consumes active power from the electricity network and charges the grid energy storage system.

Commissioning tests: Commissioning tests related to the Grid Code Specifications for Grid Energy Storage Systems.

Grid energy storage system owner: A party whose grid energy storage system is connected to the power system or the owner of a property to which a grid energy storage system is connected.

Connection point: Ownership limit as specified in the connection agreement.

Connection agreement: An agreement between the grid energy storage system owner and the relevant network operator, specifying the terms and conditions for connecting the grid energy storage system to the relevant network operator's network.

Reactive power: Imaginary component of the apparent power; unit Mvar.

Reactive power capacity: The highest reactive power measured at a connection point that the grid energy storage system can continuously generate or consume without a time limit.

Slope: The relative change of reactive power generated by a grid energy storage system in relation to the voltage change.

Rated capacity in demand mode ($P_{max,d}$): A grid energy storage system's rated capacity in (the) demand mode is its highest active power level measured at the connection point that the system can draw; the capacity has been specified in the connection agreement or otherwise determined by the relevant network operator and the grid energy storage system owner.

Rated capacity in production mode ($P_{max,p}$): A grid energy storage system's rated capacity in production mode is its highest active power level measured at the connection point that the system can supply to the network; the capacity has been specified in the connection agreement or otherwise determined by the relevant network operator and the grid energy storage system owner.

Normal operating voltage: The voltage at the connection point as specified by the relevant network operator (voltage corresponding to the 100% value). Expressed as a per unit value, the normal operating voltage is 1.0 pu.

Step-up Transformer: A transformer between the busbar and connection point of a grid energy storage system, through which transformer the power generated or consumed by the grid energy storage system is transferred between the grid energy storage system and the power system.

Numerical: Data is indicated digitally as numbers in a computer-readable and modifiable format; for example a measurement time series in commissioning testing.

Apparent Power: Product of voltage and current at fundamental frequency; unit MVA.

House Load: Active power and reactive power consumed by the house load equipment of a grid energy storage system. House load equipment covers those grid energy storage system equipment and machines that are needed at the grid energy storage system to maintain the capability for production and demand.

pu: per unit value. A variable is compared to a predetermined base value.

Black start capability: The ability of a grid energy storage system to start the electricity production mode without any external power supply from the electricity network and the ability to supply electric power to the network and to maintain stable voltage and frequency in the electricity network.

PSS: Power system stabiliser. An additional function of an AVR, aiming to improve the damping of low-frequency power oscillations with regard to inter-area oscillation of the power system.

Active power: Real component of the apparent power; unit MW.

Droop: Relative change of active power generated by a grid energy storage system in relation to the frequency change.

Grid energy storage system: A unit or an economic ensemble of units capable of storing electricity, which is connected to the network through power electronics, and which also has a single connection point to a transmission system, distribution system, closed distribution system, HVDC system or a real property's electricity network.

Control mode: Various modes of control of a grid energy storage system, such as constant active power control, frequency control, constant reactive power control, or constant voltage control.

Frequency control: The grid energy storage system is capable of changing its active power production and demand as a linear function of frequency in accordance with the established droop. In this way, the grid energy storage system supports frequency stability in the power system.

Mode: See control mode.

Production mode: In production mode, the grid energy storage system supplies active power to the electricity network and discharges the grid energy storage.

Specifications: Grid Code Specifications for Grid Energy Storage Systems SJV2019.

YLE: Fingrid’s General Connection Terms.

3 Scope

These Specifications shall apply to those converter-connected grid energy storage systems connected or to be connected to the Finnish power system that produce system services and whose rated capacity in production mode is at least 0.8 kW. The Specifications vary according to the grid energy storage system's rated capacity and the connection point's voltage level.

The Specifications do not apply to uninterruptible power supplies (UPS) or systems the purpose of which is to secure uninterrupted power supply to a load during network disturbances. The UPS must meet the Grid Code Specifications for Grid Energy Storage Systems if it provides system services.

The Specifications are applied to new grid energy storage systems to be connected to the power system, but they shall also apply to existing grid energy storage systems when their system characteristics are changed. Notification of a change must be given in compliance with the procedure outlined in Section 6.2.

The grid energy storage system owner must fulfil and maintain the specifications that were in force when the grid energy storage system's connection agreement was concluded. The Specifications shall be fulfilled at the connection point or at a point defined separately by a specific requirement.

The Specifications are staggered according to type categories based on the grid energy storage system's rated capacity in production mode and the connection point's voltage level. The type categories applied in this document are presented in Table 3.1.

Table 3.1. The grid energy storage system's type classification based on rated capacity in production mode and the connection point's voltage level.

Type category	Connection point's voltage level	Term/ condition	Grid energy storage system's rated capacity in production mode $P_{max,p}$
Type A	The connection point's voltage level is less than 110 kV[1]	and *	The grid energy storage system's rated capacity in production mode is at least 0.8 kW but less than 1 MW. ($0.8\ kW \le P_{max,p} < 1\ MW$)
Type B	The connection point's voltage level is less than 110 kV[1]	and *	The grid energy storage system's rated capacity in production mode is at least 1 MW but less than 10 MW. ($1\ MW \le P_{max,p} < 10\ MW$)
Type C	The connection point's voltage level is less than 110 kV	and *	The grid energy storage system's rated capacity in production mode is at least 10 MW but less than 30 MW. ($10\ MW \le P_{max} < 30\ MW$)
Type D	The connection point's voltage level is at least 110 kV	or +	The grid energy storage system's rated capacity in production mode is at least 30 MW ($P_{max,p} \ge 30\ MW$)

[1] Regardless of the connection point's voltage under the connection agreement, the voltage level of the connection point of type A and B grid energy storage systems is considered to be the voltage level to which the grid energy storage system's main transformer is connected or the voltage level to which the grid energy storage system is connected directly without a main transformer.

The grid energy storage system can be connected to the power system behind a separate connection point or as part of an existing connection, for example the medium voltage busbar of a power plant or a demand system. The Grid Code Specifications for Grid Energy Storage Systems are determined according to Table 3.1, and as a rule, they are not dependent on the rated capacities or specifications of other production or demand systems connected to the same connection point. If the grid energy storage system owner wants to integrate the resources of the grid energy storage system into the control system of a power plant or a demand system, the specifications can be reviewed as a whole. The specifications are based on the rated capacity of the integrated system and the connection point's voltage level. Fingrid will provide detailed specifications in each case upon the connecting party's request.

4 Confidentiality

In terms of confidentiality obligations, the following national principles, which are based on and adapted from the European Commission Regulation 2016/631, Article 12, are applied:

1. Any confidential information received, exchanged or transmitted pursuant to the Specifications shall be subject to the conditions of professional secrecy laid down in paragraphs 2, 3 and 4.

2. The obligation of professional secrecy shall apply to any persons, regulatory authorities or entities subject to the provisions of the Specifications.

3. Confidential information received by the persons, regulatory authorities or entities referred to in paragraph 2 in the course of their duties may not be divulged to any other person or authority, without prejudice to cases covered by national law, the other provisions of these Specifications or other relevant Union law.

4. Without prejudice to cases covered by national or Union law, regulatory authorities, entities or persons who receive confidential information pursuant to these Specifications may use it only for the purpose of carrying out their duties under these Specifications.

5 Specific study requirements

The grid energy storage system owner shall request from Fingrid the assessment of a need for a specific study during the preliminary planning stage of the grid energy storage system if the grid energy storage system belongs to type category D (table 3.1). Fingrid assesses the need for a specific study with regard to at least the following issues: subsynchronous interaction, geomagnetically induced currents, power oscillation damping and low short circuit ratio.

If the technical execution of a grid energy storage system connection requires specific studies, the grid energy storage system owner shall conduct the studies in co-operation with Fingrid and the relevant network operator no later than during the planning stage of the grid energy storage system grid connection. The grid energy storage system owner is responsible for executing and co-ordinating the specific studies.

If the specific studies indicate that the connection of the grid energy storage system requires specific measures in order to ensure the technical feasibility of the grid energy storage system, the measures are treated as equivalent to the Specifications, and the grid energy storage system owner is responsible for their execution.

6 Compliance process of the Specifications, continuous monitoring, and related responsibilities

This section defines the compliance process of the Specifications, continuous monitoring of compliance and the operational notification procedure for grid energy storage systems. Moreover, this section defines the responsibilities, obligations and rights of the grid energy storage system owner, relevant network operator and Fingrid during the compliance process and continuous monitoring. The details of the responsibilities, obligations and rights for specific requirements are recorded in Sections 7–16 of this document.

The grid energy storage system owner must take into account that the Specifications compliance process described in this document does not include the grid energy storage system's connection process in its entirety. The compliance process is described solely in terms of verifying the system's technical capabilities. The grid energy storage system owner must always agree on the connection with the relevant network operator before the connection is planned. The grid energy storage system owner and the relevant network operator conclude a connection agreement that specifies the detailed connection terms. A connection cannot be made without the relevant network operator's permission.

6.1 Responsibilities, obligations and rights during the compliance process and during continuous monitoring

6.1.1 Responsibilities, obligations and rights of the grid energy storage system owner and the relevant network operator

The grid energy storage system owner is responsible for the compliance process and fulfilment of the Specifications as well as for the associated costs. The grid energy storage system owner is responsible for fulfilling and maintaining operations according to the Specifications throughout the grid energy storage system's lifetime.

The grid energy storage system owner shall notify the relevant network operator of the planned test schedules and procedures to be followed for verifying the grid energy storage system's compliance with the Specifications, in due time and prior to their launch. The relevant network operator shall specify the date of the notification. The relevant network operator shall approve in advance the planned test schedules and procedures. Such approval by the relevant network operator must be given in a timely manner and shall not be unreasonably withheld. The relevant network operator may participate in such tests and record the performance of the grid energy storage system.

The relevant network operator has the right to specify additional requirements if they are needed because of an electricity network located close to the grid energy storage system. Potential conflicts between the Specifications and the additional requirements specified by the relevant network operator shall be resolved between Fingrid and the relevant network operator.

The relevant network operator shall supervise the compliance process of the Specifications during the grid energy storage project, and take care of the data exchange required by the process with the grid energy storage system owner and Fingrid. The relevant network operator shall verify the data supplied by the grid energy storage system owner and assess whether the grid energy storage system is in compliance with the Specifications, and shall notify the grid energy storage system owner of the outcome of the assessment.

The relevant network operator shall have the right to request that the grid energy storage system owner carry out compliance tests and simulations according to a repeat plan or general scheme or after any failure, modification or replacement of any equipment which may have an impact on the grid energy storage system's compliance with the Specifications.

The relevant network operator shall make publicly available a list of information and documents to be provided as well as the requirements to be fulfilled by the grid energy storage system owner within the framework of the compliance process.

The relevant network operator shall make public the allocation of responsibilities between the grid energy storage system owner and the network operator for compliance testing, simulation and monitoring.

The relevant network operator may fully or partially delegate the performance of its compliance monitoring to third parties. In such cases, the relevant network operator shall continue ensuring compliance with the confidentiality obligations (Section 4), including entering into confidentiality commitments with the assignee.

If compliance tests or simulations cannot be carried out as agreed between the relevant network operator and the grid energy storage system owner due to reasons attributable to the relevant network operator, then the relevant network operator shall not unreasonably withhold the operational notification according to the compliance process (Section 6.4).

The grid energy storage system owner shall maintain the operation of the grid energy storage system in accordance with the Specifications also after the accepted execution of the compliance process of the Specifications. If the grid energy storage system owner discovers that the operation of the grid energy storage system is in conflict with the Specifications, the grid energy storage system owner shall inform the relevant network operator and Fingrid of this without delay, and take the necessary measures to eliminate the conflict.

The relevant network operator shall inform the grid energy storage system owner and Fingrid without delay if the relevant network operator discovers at any stage of the grid energy storage project or during the normal operation of the grid energy storage system that the grid energy storage system derogates from the Specifications.

6.1.2 Fingrid's responsibilities, obligations and rights

The responsibilities, obligations and rights of the relevant network operator apply to Fingrid when the grid energy storage system is connected to Fingrid's grid.

If Fingrid receives information or discovers that the grid energy storage system derogates from the Specifications at any stage of the grid energy storage project or during the normal operation of the grid energy storage system, Fingrid may require additional clarifications and measures to correct the derogation. If the shortcomings in the operation of the grid energy storage system related to the Specifications influence the operation of the power system, Fingrid, as the transmission system operator, has the right to restrict the operation of the grid energy storage system and to impose conditions related to the operation of the grid energy storage system. Fingrid has the right to keep the restrictions imposed in force until the shortcomings detected in the operation of the grid energy storage system have been corrected and the capability of the grid energy storage system to fulfil the Specifications has been verified.

Fingrid's representative has the right to participate in commissioning testing when the grid energy storage system is connected to the electricity network of a third party.

6.2 Amendment of grid energy storage system's technical characteristics

If changes are made to a type C or D grid energy storage system which is in operation or to the equipment or systems influencing its technical characteristics, the grid energy storage system owner shall, before making the changes, inform the relevant network operator of the changes and of their impact on the capability of the grid energy storage system to fulfil the Specifications.

It is the relevant network operator's responsibility to evaluate and set new requirements for the equipment and systems being changed, in accordance with the Grid Code Specifications for Grid Energy Storage Systems valid at the time.

The relevant network operator must update the existing connection agreement to include information about the equipment to be changed and the Specifications to be applied. If the relevant network operator considers the scope of the change (modernisation or replacement of equipment) to be such that it requires a new connection agreement, the network operator must agree on the terms of a new connection agreement with the grid energy storage system owner.

If the relevant network operator and the grid energy storage system owner cannot agree on the connection terms, the matter must be taken to the Finnish Energy Authority. The Energy Authority must decide whether the connection agreement that is in effect should be amended or a new one should be drawn up, as well as the extent to which the Specifications must be complied with.

6.3 Grid energy storage system projects progressing in stages

The grid energy storage system owner shall take into account the trend in the capacity of the grid energy storage system during the various stages of the project, as well as the grid energy storage system's final rated capacity in production mode. With grid energy storage system projects progressing in stages, the Specifications are determined on the basis of the grid energy storage system's final rated capacity in production mode.

It is the grid energy storage system owner's responsibility to verify that the grid energy storage system fulfils the Specifications if at least one of the following conditions are met:

1) the grid energy storage system's rated capacity in production mode or the connection point's voltage level exceeds the type limit related to the Specifications, shown in table 3.1 ,

2) the structure or functionalities of the grid energy storage system change in a way which affects the technical characteristics and functionalities of the grid energy storage system.

6.4 Compliance process of Specifications and operational notification procedure for grid energy storage systems

6.4.1 Compliance process and operational notification procedure for a type A grid energy storage system

The operational notification procedure for the connection of each new type A grid energy storage system must include submitting an installation document. The grid energy storage system owner shall ensure that the required information is filled in on the installation document obtained from the relevant network operator and is submitted to the relevant network operator.

Separate installation documents shall be provided for each grid energy storage system.

The relevant network operator shall specify the contents of the installation document, which shall have at least the following information:

a) the location at which the physical connection is made;

b) the date of the connection;

c) the rated capacity in production mode and demand mode of the installation in kW;

d) the type of the grid energy storage system

e) reference to equipment certificates issued by an authorised certifier used for equipment that is in the site installation;

f) as regards equipment for which an equipment certificate has not been received, information shall be provided as directed by the relevant network operator; and

g) the contact details and signatures of the grid energy storage system owner and the installer.

Finnish Energy's (Energiateollisuus) general information form "PIENTUOTANTOLAITTEISTON JA/TAI SÄHKÖVARASTON LIITTÄMINEN SÄHKÖVERKKOON" (Connecting small-scale production equipment and/or battery energy storages to the network) can be used as the installation document.

6.4.2 Compliance process and operational notification procedure for type B and C grid energy storage systems

In the operational notification procedure concerning the connection of type B and C grid energy storage systems, the use of equipment certificates issued by an authorised certifier is permitted.

For the purpose of the operational notification procedure for the connection of each new type B grid energy storage system, a grid energy storage system document (Table 7.1), which shall include a statement of compliance, shall be provided by the grid energy storage system owner to the relevant network operator.

For the purpose of the operational notification procedure for the connection of each new type C grid energy storage system, grid energy storage system documents (tables 7.2 and 7.3), which shall include a statement of compliance, shall be provided by the grid energy storage system owner to the relevant network operator.

In the statement of compliance, the grid energy storage system owner shall indicate each delivered document or file name in the reference column in the table in Section 7 and confirm with a signature that the grid energy storage system fulfils the set Specifications.

Separate grid energy storage system documents shall be provided for each grid energy storage system.

The grid energy storage system owner shall perform commissioning tests to verify that the grid energy storage system operates in compliance with the Specifications and shall provide the relevant network operator with data conforming to the Specifications after the commissioning tests.

Once the grid energy storage system owner has carried out the measures required by the compliance process of the Specifications, the relevant network operator shall review the data delivered by the grid energy storage system owner and give a statement of the compliance monitoring of the Specifications. The relevant network operator, on acceptance of a complete and adequate grid energy storage system document, shall issue a final operational notification to the grid energy storage system owner.

After the giving of a final operational notification, the relevant network operator shall deliver the data conforming to the Specifications to Fingrid. If the relevant network operator refuses to issue a final operational notification, the reasons for such refusal and measures required to rectify the matter must be presented to the grid energy storage system owner.

The documentation and delivery of grid energy storage system data is specified in Section 7. The real-time measurements and instrumentation are specified in Section 9. The compliance process of the Specifications by means of commissioning tests is specified in Section 14. Modelling requirements and compliance process are specified in Section 15.

The measures related to the compliance process of the Specifications shall be successfully completed no later than 12 months from the date on which the grid energy storage system supplied active power to the power system for the first time.

The grid energy storage system owner shall ensure that the relevant network operator and Finnish Energy Authority are notified about the permanent decommissioning of a grid energy storage system.

6.4.3 Compliance process and operational notification procedure for a type D grid energy storage system

The grid energy storage system owner and the relevant network operator must carry out a compliance process and operational notification procedure for a type D grid energy storage system in stages according to Table 6.1 . The procedure presented in Table 6.1 is described in detail in stages in the sub-sections of this section.

Once the grid energy storage system owner has carried out the measures conforming to the Specifications in each stage in the required scope, the relevant network operator shall verify the data supplied and confirm the execution of the required measures in each stage, as well as deliver the energisation operational notification (EON) or operational notification required after each stage to the grid energy storage system owner. The relevant network operator shall supervise the compliance process of the Specifications, including the commissioning tests during the grid energy storage project, and take care of the data exchange required by the process with the grid energy storage system owner and Fingrid. The relevant network operator shall deliver the data conforming to the Specifications to Fingrid after the confirmation of each stage of the process.

The documentation and delivery of grid energy storage system data is specified in Section 7. The real-time measurements and instrumentation are specified in Section 9. The compliance process of the Specifications by means of commissioning tests is specified in Section 14. Modelling requirements and compliance process are specified in Section 15. The tables for the follow-up and documentation of the process stages are presented in Appendix A.

The grid energy storage system owner shall ensure that the relevant network operator and Finnish Energy Authority are notified about the permanent decommissioning of a grid energy storage system.

Table 6.1. Compliance process of the Specifications, operational notification procedure and schedule requirements for type D grid energy storage systems.

Process stage	Condition	Schedule requirement and additional information
Energisation operational notification (EON)	The physical grid connection is ready for commissioning.	The connection must be implemented according to the terms of the connection agreement. Upon receiving the EON, the grid energy storage system owner shall have the right to energise the network beyond the connection point.
Stage 1 (Planning): • Planning data • Modelling data • Required calculations • Project-specific preliminary settings • Real-time measurement data delivery • Statement of compliance	The grid energy storage system owner can deliver the Stage 1 data as soon as they are available.	The Stage 1 data and real-time measurement must be delivered as early as possible so that the grid energy storage system's interim operational notification can be processed. The data to be delivered is listed in Section 7.4.
Interim operational notification (ION)	The grid energy storage system owner has delivered the Stage 1 data and carried out a real-time measurement. The relevant network operator has confirmed the implementation of the required measures.	Upon receiving an interim operational notification (ION), the grid energy storage system owner shall have the right to operate the grid energy storage system and supply power to the connection point for no more than 18 months.
Stage 2 (Commissioning and compliance): • Changes and updates to stage 1 data • Planning and implementation of commissioning testing • Reporting of test results • Validation of modelling data • Final settings of control devices and protection • Statement of compliance	The relevant network operator has given an interim operational notification (ION)	The grid energy storage system owner must deliver the commissioning testing plan to the relevant network operator no later than 2 months before the planned start of the tests. The commissioning tests shall be performed in an approved manner within 9 months and the Stage 2 measures within 12 months from the date on which the grid energy storage system supplied active power to the power system for the first time. The data to be delivered is listed in Section 7.4.
Stage 3 (Review and approval): • Review of delivered data • Approval of the process	The grid energy storage system owner has delivered the Stage 2 data and carried out the measures, and the relevant network operator has confirmed that the required measures have been implemented.	The relevant network operator must review the delivered data and confirm that the required measures have been carried out. The relevant network operator must deliver a statement on compliance with the Specifications no later than three months after receiving the Stage 2 data.
Final operational notification (FON)	The relevant network operator has confirmed the implementation of the Stage 3 measures.	Upon receiving the FON, the grid energy storage system owner shall have the right to operate the grid energy storage system and supply power to the connection point until further notice.

6.4.3.1 Construction of a physical connection, and the energisation operational notification (EON)

A physical grid connection is implemented according to the connection agreement concluded between the grid energy storage system owner and the relevant network operator. When the connection is ready to be commissioned, the relevant network operator shall review compliance with the terms of the connection agreement and give the grid energy storage system owner an EON.

The EON gives the grid energy storage system owner the right to energise the network and the auxiliaries of the grid energy storage system beyond the connection it controls.

6.4.3.2 Stage 1 (Planning) and interim operational notification (ION)

In Stage 1, the grid energy storage system owner shall deliver to the relevant network operator the data listed in Section 7.4 and carry out real-time measurement in accordance with the instructions in Chapter 9.

The grid energy storage system owner shall deliver a statement of compliance as part of the delivery of the Stage 1 data. In the statement of compliance, the grid energy storage system owner shall indicate each delivered document or file name in the reference column in Table 7.2 and confirm with a signature that the grid energy storage system fulfils the set Specifications.

The Stage 1 data and real-time measurement must be delivered as early as possible so that the grid energy storage system's interim operational notification can be processed. Once the grid energy storage system owner has delivered the Stage 1 data and carried out a real-time measurement, the relevant network operator shall review the delivered data, confirm the execution of the required measures and deliver an interim operational notification (ION) to the grid energy storage system owner.

The ION is valid for a period of 18 months, during which time the grid energy storage system owner shall have the right to operate its grid energy storage system and supply power to the connection point.

The period of validity of the ION may be extended on justified grounds for no more than 6 months. An extension of the period of validity must be requested from the relevant network operator and Fingrid, which may, by a unanimous decision, extend the period of validity of the ION. If there is a still a further need to derogate from this, a request for such derogation must be requested in accordance with the procedure laid down in Section 8.

6.4.3.3 Stage 2 (Commissioning and compliance)

In Stage 2, the grid energy storage system owner carries out the planning and implementation of the grid energy storage system's commissioning tests and delivers the data listed in Section 7.4 to the relevant network operator. In addition, any possible changes and updates to the Stage 1 data shall be delivered to the relevant network operator during Stage 2.

The grid energy storage system owner shall deliver a statement of compliance as part of the delivery of the Stage 2 data. In the statement of compliance, the grid energy storage system owner shall indicate each delivered document or file name in the Reference column in Table 7.3 and confirm with a signature that the grid energy storage system fulfils the set Specifications.

The condition for the Stage 2 measures is an interim operational notification (ION). All Stage 2 measures must be completed while the ION is valid.

With respect to the planning of commissioning tests, the grid energy storage system owner must deliver the commissioning testing plan to the relevant network operator no later than 2 months before the planned start of the tests. The commissioning tests shall be performed in an approved manner within 9 months and the Stage 2 measures within 12 months from the date on which the grid energy storage system supplied active power to the power system for the first time.

6.4.3.4 Stage 3 (Review and approval) and final operational notification (FON)

In Stage 3, the relevant network operator reviews all data delivered during the process and confirms that the required measures have been carried out. The relevant network operator must deliver a statement on compliance with the Specifications no later than three months after receiving the Stage 2 data. If there are no comments to be made on the data delivered during the process, the relevant network operator must issue a final operational notification (FON).

The FON is valid until further notice and it entitles the grid energy storage system owner to use the grid energy storage system and to supply power to the connecting point.

6.4.3.5 Limited operational notification (LON)

A limited operational notification procedure enters into effect when significant and unforeseen modifications take place at the grid energy storage system and affect its ability to fulfil the Specifications. A grid energy storage system owner to whom a FON has been granted shall inform the relevant network operator immediately in the following circumstances:

- the grid energy storage system is temporarily subject to either significant modification or loss of capability affecting its performance; or
- an equipment failure leading to non-compliance with some relevant Specifications is observed.

The grid energy storage system owner shall apply for a limited operational notification (LON) from the relevant network operator if the grid energy storage system owner reasonably expects the above-mentioned circumstances to persist for more than three months.

A LON shall be issued by the relevant network operator and shall contain the following information which shall be clearly identifiable:

- the unresolved issues justifying the granting of the LON;
- the responsibilities and timescales for the expected solution; and
- a maximum period of validity which shall not exceed 12 months. The initial period granted may be shorter with the possibility of an extension if evidence is submitted to the satisfaction of the relevant network operator demonstrating that substantial progress has been made towards achieving full compliance.

The FON shall be suspended during the period of validity of the LON with regard to the items for which the LON has been issued.

A further extension of the period of validity of the LON may be granted upon a request for a derogation made to the relevant network operator before the expiry of that period, in accordance with the derogation procedure described in Section 8 .

The relevant network operator shall have the right to refuse to allow the operation of the grid energy storage system once the LON is no longer valid. In such cases, the FON shall automatically become invalid.

If the relevant network operator does not grant an extension of the period of validity of the LON when a request for derogation has been made or if it refuses to allow the operation of the grid energy storage system once the LON is no longer valid, the grid energy storage system owner may refer the issue for decision to the Finnish Energy Authority within six months after the notification of the decision of the relevant network operator.

7 Documentation and delivery of grid energy storage system data

7.1 Data to be delivered for a type A grid energy storage system

The relevant network operator specifies the data to be delivered for a type A grid energy storage system, in accordance with the instructions in Section 6.4.1.

7.2 Data to be delivered for a type B grid energy storage system

The data specified in Table 7.1 shall be delivered on type B grid energy storage systems. The grid energy storage system owner shall submit this grid energy storage system data to the relevant network operator as electronic documents after the commissioning testing. The data to be submitted shall be clear and unambiguous in terms of its layout and structure. The relevant network operator shall deliver the data to Fingrid.

The grid energy storage system owner shall deliver a statement of compliance as part of the data to be delivered. In the statement of compliance, the grid energy storage system owner shall indicate each delivered document or file name in the Reference column in Table 7.1 and confirm with a signature that the grid energy storage system fulfils the set Specifications.

Table 7.1. Data to be delivered for a type B grid energy storage system.

		Reference
1	General data	
1.1	Single line diagram	
1.2	Grid energy storage type (e.g. battery, fuel cell...)	
1.3	Location data (municipality, area, connection point, coordinates)	
2	Technical details of transformers:	
2.1	Number, supplier and type details of the grid energy storage system's transformers	
2.2	Documentation and data sheets of transformers	
	Power [MVA], current [A], transformation ratio [primary, secondary], short-circuit impedance [%], short-circuit resistance [%], vector group and earthing details, control range and step of on- or off-load tap-changer [%, %], number of steps of on- or off-load tap-changer and selected step [quantity, step]	
3	Technical details of grid energy storage system:	
3.1	Number, supplier and type details of grid energy storage system units	
3.2	Documentation and data sheets of grid energy storage system units	
	Rated capacity in production mode [MW], Rated capacity in demand mode [MW], Current [A], Voltage[V]	
3.3	Dependence of production power on operating conditions (e.g. temperature)	
3.4	Potentially used compensation devices and/or devices used for the correction of power factor	
	Number, type, rated values of devices (power, current, voltage, frequency)	
	If used for the filtering of harmonics, data on the structure and tuning frequency	
4	Grid energy storage system's operational characteristics:	
	The following items may be replaced, for example, by the manufacturer's device documents, testing documentation according to the IEC 61400-21 standard or other testing documentation	
4.1	Reactive power capacity of the grid energy storage system and units	
4.2	Ability to operate at undervoltage and overvoltage	
4.3	Ability to operate at underfrequency and overfrequency	
4.4	Rate of change of frequency withstand capability	
4.5	Ability to operate during voltage disturbances	
4.6	Fault current injection during a voltage disturbance	
4.7	Active power control characteristics	
4.8	Voltage control characteristics	
5	Protection details of the grid energy storage system:	
5.1	Relay protection diagram	
5.2	Final relay protection setpoints	
5.3	Data on the operating principle of island protection	
6	Commissioning documents:	
6.1	Commissioning records	
6.2	Final setpoint values and mode of voltage control	
	Statement of compliance	
	The grid energy storage system owner's representative confirms with a signature that the documents referred to in this table's reference details prove that the grid energy storage system meets the Specifications set for it. Place, date, signature and printed name:	

7.3 Data to be delivered for a type C grid energy storage system

For type C grid energy storage systems, the data specified in tables 7.2 and 7.3 must be delivered. The grid energy storage system owner shall submit this grid energy storage system data to the relevant network operator as electronic documents after the commissioning testing. The data to be submitted shall be clear and unambiguous in terms of its layout and structure. The relevant network operator shall deliver the data to Fingrid.

The grid energy storage system owner shall deliver a statement of compliance as part of the data to be delivered. In the statement of compliance, the grid energy storage system owner shall indicate each delivered document or file name in the reference column in tables 7.2 and 7.3 and confirm with a signature that the grid energy storage system fulfils the set Specifications.

7.4 Data to be delivered for a type D grid energy storage system

7.4.1 Delivery and schedule of grid energy storage system data

The grid energy storage system owner shall deliver grid energy storage system data on type D grid energy storage systems to the relevant network operator in accordance with the compliance process of the Specifications for the grid energy storage system, specified in Section 6.4.3:

1) The data specified in Table 7.2 shall be delivered in Stage 1 of the compliance process.

2) The data specified in Table 7.3 shall be delivered in Stage 2 of the compliance process.

The grid energy storage system owner shall submit this grid energy storage system data to the relevant network operator as electronic documents in accordance with the compliance process. The data to be submitted shall be clear and unambiguous in terms of its layout and structure. The relevant network operator shall deliver the data to Fingrid.

The grid energy storage system owner shall deliver a statement of compliance as part of the data to be delivered. In the statement of compliance, the grid energy storage system owner shall indicate each delivered document or file name in the reference column in tables 7.2 and 7.3 and confirm with a signature that the grid energy storage system fulfils the set Specifications.

7.4.2 Data to be delivered

The data to be delivered on type D grid energy storage systems is specified in tables 7.2 and 7.3. With some of the data to be delivered, the tables make reference to the sections of this document where the topic and the data to be delivered have been elaborated.

Table 7.2. Data to be delivered for type C and D grid energy storage systems. The data in the table for type D grid energy storage systems must be delivered in Stage 1 of the compliance process.

	Stage 1 (Planning)	Reference
1	General data	
1.1	Name and contact details of project, connection point, relevant network operator and contact details	
1.2	Single line diagram	
	The main components of the grid energy storage system and the electricity network that connects the components	
	Electric parameters of the components and conductors presented in the single line diagram	
1.3	Grid energy storage type (e.g. battery, fuel cell...)	
1.4	Location data (municipality, area, connection point, coordinates)	
2	Technical data	
2.1	Number, supplier and type details of grid energy storage system units	
2.2	Documentation and data sheets of grid energy storage system units	
	Rated capacity in production mode [MW], Rated capacity in demand mode [MW], Current [A], Voltage[V]	
2.3	Documentation and data sheets of transformers	
	Power [MVA], current [A], transformation ratio [primary, secondary], short-circuit impedance [%], short-circuit resistance [%], vector group and earthing details, control range and step of on- or off-load tap-changer [%, %], number of steps of on- or off-load tap-changer and selected step [quantity, step]	
2.4	Documentation and data sheets of other components	
	Where applicable, the same data as on grid energy storage units (section 2.2) and transformers (section 2.3) as well as all data that is relevant in terms of the Specifications (e.g. structure, filter tuning frequency)	
3	Operating voltage and frequency range	
3.1	Ability to operate at undervoltage and overvoltage (section **10.2.1 or 10.5.1**)	
3.2	Ability to operate at underfrequency and overfrequency (section **10.2.1 or 10.5.1**)	
3.3	Data on the rate of change of frequency withstand capability (section **10.2.2**)	
4	Fault-ride-through capability	
4.1	Calculation of the operation of the grid energy storage system during voltage disturbance, and potential reports on factory testing (section **10.3.2 or 10.5.3**)	
4.2	Data on fault current injection during a voltage disturbance (section **10.3.3**)	
4.3	Data on active power recovery after a voltage disturbance (section **10.3.4**)	
5	Active power control and frequency control	
5.1	Documentation and description of active power control and frequency control (chapter **11 or 16**)	
	Documentation on the control system's implementation and technical characteristics.	
	Functional block diagram on the implementation of control described as transfer functions.	
5.2	Parameters and operating delays set for controllers	
6	House load and changes in production and demand	
6.1	Data on the operation of the grid energy storage system in house load operation (section **11.3.2**)	
	House load power consumption, operating time in house load operation, potential delays in terms of transition to house load operation.	
6.2	Changes in production power	
	Changes in production power in conjunction with frequency and voltage fluctuations	
	Dependence of production power on operating conditions (e.g. temperature)	
	Rate of change of production power, functionality and constraints of limiters of rate of change	

Table 7.2 continues.

7	Reactive power capacity	
7.1	Reactive power capacity calculation (section **12.2.4**)	
7.2	PQ diagrams	
	PQ diagrams of grid energy storage system units and data on their voltage-frequency dependence. The setpoints used in the reactive power limiters shall be specified in the PQ diagrams.	
7.3	Other components influencing reactive power	
	Components that generate (e.g. capacitor or STATCOM) and consume reactive power, and their operation as a function of the variables (e.g. voltage, active power) influencing the components	
8	Voltage control and reactive power control	
8.1	Documentation and description of voltage control and reactive power control (chapter **13**)	
	Documentation on the control system's implementation and technical characteristics.	
	Functional block diagram on the implementation of control described as transfer functions.	
8.2	Parameters and operating delays set for controllers	
8.3	Voltage control performance calculation (section **13.2.2.1**)	
9	Protection details and impact on power quality	
9.1	Protection settings (section **10.3.5**)	
	Relay protection diagram and settings	
9.2	Impact on power quality (section **10.4.3**).	
	Description of the grid energy storage system impact on power quality and potential reports of factory testing.	
10	Dynamic models	
	Project-specific data or simulation models required for modelling the dynamic operation in accordance with the Specifications (chapter **15**)	
11	Real-time measurement data and instrumentation	
11.1	Method of delivery and verification of real-time measurement data (section **9.3**)	
11.2	Technical data and the setpoints of disturbance and swing recorders	
12	Specific study requirements	
	Required specific studies related to the Specifications (chapter **5**)	
13	Project's schedule and commissioning	
	Schedule of the project and the planned timing of the commissioning tests relating to the Specifications.	
	Statement of compliance	
	The grid energy storage system owner's representative confirms with a signature that the documents referred to in this table's reference details prove that the grid energy storage system meets the Specifications set for it. Place, date, signature and printed name:	

Table 7.3. Data to be delivered for type C and D grid energy storage systems. The data in the table for type D grid energy storage systems must be delivered in Stage 2 of the compliance process.

	Stage 2 (Commissioning and compliance)	Viite
1	Changes and further specifications	
	Further specifications to the data delivered in stage 1 of the compliance verification process	
2	Data related to commissioning tests	
2.1	Commissioning test plan (section **14.3.1**)	
	Detailed commissioning testing plan, commissioning instructions provided by the grid energy storage system supplier and a description of the practical arrangements of the tests for verifying compliance with the Specifications shall be submitted to the relevant network operator at the latest **two months before the tests are started.**	
2.2	Commissioning schedule (section **14.3.1**)	
	Commissioning schedule; subsequent changes to the commissioning schedule shall be co-ordinated with the relevant network operator and Fingrid.	
2.3	Measurement arrangements (section **14.3.1**)	
	Plan of the execution of measurements for the tests related to the Specifications. Data on both fixed measuring equipment and measuring equipment only used during the commissioning tests.	
3	Results of commissioning tests	
3.1	Commissioning report on tests related to the Specifications (section **14.3.3**)	
3.2	Key results of commissioning tests in numerical format (Table **15.2**)	
4	Verified modelling data	
	Validated data required for the modelling of dynamic operation, or simulation models (chapter **15**)	
5	Final controller settings	
	Final settings of the controllers of active power and frequency as well as of the controllers of voltage and reactive power.	
6	Final protection settings	
	Final protection settings of the grid connection and the grid energy storage system.	
	Statement of compliance	
	The grid energy storage system owner's representative confirms with a signature that the documents referred to in this table's reference details prove that the grid energy storage system meets the Specifications set for it. Place, date, signature and printed name:	

8 Derogations

The grid energy storage system owner can deviate from the Specifications if the conditions laid down in this section are met. The grid energy storage system owner shall request a derogation from the Specifications from Fingrid in writing no later than at the procurement stage of the main components of the grid energy storage system if a need to deviate from the Specifications emerges at that stage. At the same time, the grid energy storage system owner shall forward the information on requesting a deviation to the relevant network operator.

Fingrid may grant a derogation of the Specifications if the following conditions are met:

1) the derogation does not compromise the system security of the power system;

2) the derogation does not restrict the transmission capacity of the power system;

3) the grid energy storage system does not cause disturbance to the other parties connected to the power system;

4) the grid energy storage system supports the operation of the power system during disturbance situations, and works reliably during and after such situations,

5) the derogation is technically and commercially justified; and

6) the derogation may be granted in the future in a similar situation impartially and without discriminating against any future grid energy storage system projects.

Fingrid grants the requested derogation, grants it with obligatory additional terms, or rejects it. Fingrid is required to provide information on the decision with justification to the grid energy storage system owner and to the relevant network operator no later than within 60 working days from receiving of the request. If Fingrid rejects the requested derogation, the grid energy storage system cannot be connected to the Finnish power system.

If the grid energy storage system owner requests a derogation when the grid energy storage system is to be connected to the network of a third party, Fingrid shall hear the relevant network operator when Fingrid makes the decision.

9 Real-time measurements, data exchange and instrumentation

9.1 Real-time measurements and data exchange for type A grid energy storage systems

Real-time measurements are not required for type A grid energy storage systems. The relevant network operator determines the notification procedure before the grid energy storage system is connected.

9.2 Real-time measurements and data exchange for type B, C and D grid energy storage systems

The grid energy storage system owner shall deliver to the relevant network operator the real-time active power and reactive power measurement data, as well as status information on the switchgear.

The relevant network operator shall deliver or oblige the grid energy storage system owner to deliver to Fingrid the real-time measurement data on the grid energy storage systems connected to the electricity network of the relevant network operator.

The update cycle of the real-time data may be no more than 60 s. The measurement data shall be available to Fingrid before the grid energy storage system begins to supply active power to the power system.

Before the grid energy storage system begins to supply active power to the power system, the grid energy storage system owner shall inform the relevant network operator of this.

The detailed requirements for real-time information exchange are outlined in Fingrid's application instruction *Real-time information exchange*.

9.3 Instrumentation for type C and D grid energy storage systems

Disturbance and swing recorders must be installed in type C and D grid energy storage systems. This recording system consisting of disturbance and swing recorders allows the recording of the grid energy storage system's and its controllers functionality during disturbance and change situations in the power system. The recording system can also be implemented with disturbance recorders integrated in relays. A separate swing recorder is not necessary if the disturbance recorder's recording time covers the requirements set for the swing recorder.

The recording system shall meet the following requirements:

1. The disturbance recorder must measure and record the voltages at the connection point and the currents supplied by the grid energy storage system as momentary values in stages. The disturbance recorder must be triggered when:

    - the protective relay works
    - the voltage is lower than 0.95 or higher than 1.05 pu

2. The swing recorder must measure and record the voltages at the connection point and the currents supplied by the grid energy storage system to the connection point as RMS values in stages, as well as record the phase angles of the voltages and currents. If the phase angles are not recorded, the grid energy storage system's active and reactive power must be recorded. The frequency must also be recorded. The swing recorder must be triggered when:

    - the protective relay works
    - the voltage is lower than 0.95 or higher than 1.05 pu
    - the frequency falls below 49.80 Hz or exceeds 50.20 Hz

3. In addition to the variables cited in items 1 and 2 above, recording the controlling devices' operating points and the SCADA system logs is recommended

4. The sampling and recording frequency of the disturbance recorder shall be high (1 kHz or greater). The recording period shall be a few seconds.

5. The sampling frequency of the swing recorder shall be high (1 kHz) and the recording frequency can be low (50 Hz or higher). The recording period shall be a few dozen seconds.

6. Both recorders must record a sample before the trigger point. When the recorder is triggered at 0.0 s, the recorders must record a set pre-fault time and post-fault time. These pre- and post-fault times are as follows:

    - for the disturbance recorder: (pre) 0.5...1 s / (post) 2...n s
    - for the swing recorder: (pre) 1...5 s / (post) 15...n s

7. The recording systems shall be implemented in such a way that Fingrid has access to the system records no later than within 24 hours from Fingrid's request to the grid energy storage system owner.

10 General requirements

10.1 Power system voltages and frequencies

The normal operating voltage (voltage corresponding to the 100% value) at the connection point is case dependent, and the grid energy storage system owner must always find out what the voltage is from the relevant network operator. The relevant network operator determines the voltage fluctuation range in its electricity network in normal, disturbance and exceptional situations. In a normal situation, the voltage fluctuation range must be at least 0.90–1.05 pu of the normal operating voltage.

The nominal voltage levels in Finland's main grid are 110 kV, 220 kV and 400 kV. The normal operating voltages of the main grid's connection point on which the design of the connection are based are, correspondingly, 118 kV, 233 kV and 410 kV.

In Fingrid's grid, the voltage fluctuation ranges in normal, disturbance and exceptional situations are as follows: The normal fluctuation range of voltage in a grid with a nominal voltage of 400 kV is 395–420 kV, and in exceptional and disturbance situations the voltage range is 360–420 kV. The normal fluctuation range of voltage in a grid with a nominal voltage of 220 kV is 215–245 kV, and in exceptional and disturbance situations the voltage range is 210–245 kV. The normal fluctuation range of voltage in a grid with a nominal voltage of 110 kV is 105–123 kV, and in exceptional and disturbance situations the voltage range is
100–123 kV.

The Nordic power system's nominal frequency is 50 Hz and the frequency is normally 49.9–50.1 Hz. The frequency of the grid during normal use may vary between 49.0–51.0 Hz and exceptionally even between 47.5–51.5 Hz.

10.2 General requirements for a type A grid energy storage system

10.2.1 Operating voltage and frequency range of the grid energy storage system

The grid energy storage system shall be able to operate continuously and normally in the voltage range defined by the relevant network operator.

The grid energy storage system shall be able to operate continuously and normally when the electricity system's frequency is 49.0...51.0 Hz. The grid energy storage system must be able to operate for a period of 30 minutes when the electricity system's frequency is 51.0–51.5 Hz or 49.0–47.5 Hz.

10.2.2 Rate of change of frequency withstand capability

The grid energy storage system shall be capable of continuing to operate normally when the rate of change of frequency is less than 2.0 Hz/s.

The measurement of the rate of change of frequency shall not react to the sudden changes in the waveform of voltage caused by disturbances in the system.

Protection systems that identify the rate of change of frequency may only be used if the grid energy storage system's rated capacity in production mode is under 50 kW. The protection system may disconnect the grid energy storage system from the network if the rate of change of frequency exceeding the protection limit has been measured for at least 500 milliseconds. The risk of this kind of protection system malfunctioning is high, and unexpected disconnection may occur in the normal operating voltage and frequency range.

Protection based on frequency and voltage measurement is recommended to prevent island operation in radial grids.

10.2.3 Remote control capability

The grid energy storage system shall be equipped with a logic interface (input port) in order to cease active power output within five seconds following an instruction being received at the input port.

10.2.4 Automatic connection

The grid energy storage system may automatically connect to the electricity system if the following conditions are met:

- the electricity system's frequency is 49.0–51.0 Hz
- the connection point's voltage is in the normal range
- the maximum allowed rate of change of the grid energy storage system's active power is 100% of the rated capacity in production mode over a period of one minute
- the relevant network operator permits the installation of an automatic reconnection system and automatic connection 1–10 minutes after the disturbance.

10.3 General requirements for a type B grid energy storage system

The same general requirements (Section 10.2) apply to type B grid energy storage systems as those that apply to type A grid energy storage systems, with the exception of remote control capability (Section 10.2.3). A type B grid energy storage system must also fulfil the requirements set out in this section.

10.3.1 Remote control capability

The grid energy storage system must be equipped with a bus interface (input port), so that the production mode of active power can be changed (production/demand) and a setpoint can be given thereto. The bus interface must be compatible with the IEC 60870-6 (Elcom, ICCP/TASE.2), IEC 60870-5-104 or IEC 61850 protocols.

10.3.2 Fault-ride-through capability

The grid energy storage system shall be able to continue operation during and after disturbances in the power system. A grid energy storage system shall be designed in such a way that it can withstand a momentary voltage fluctuation as shown in Figure 10.1, occurring at the connection point, without being disconnected from the grid.

After a disturbance, the grid energy storage system shall be able to operate without being disconnected from the grid during momentary variations in voltage amplitude and phase angle caused by potential inter-area electromechanical oscillations following a voltage disturbance.

The fault-ride-through requirement is applicable to symmetrical faults (3-phase short circuits) and asymmetrical faults (2-phase short circuits and earth short circuits, 1-phase earth short circuits).

The fault-ride-through requirement has been specified for the following conditions:

- Before the voltage disturbance, the voltage of the connection point of the grid energy storage system is 1.0 pu.
- Before the voltage disturbance, the grid energy storage system does not supply reactive power to the connection point or take reactive power from the connection point.
- Before the voltage disturbance, the automatic voltage regulator (AVR) of the grid energy storage system is in operation.
- The short circuit current of the connection point is assumed to be at normal summertime level before and after the local fault.

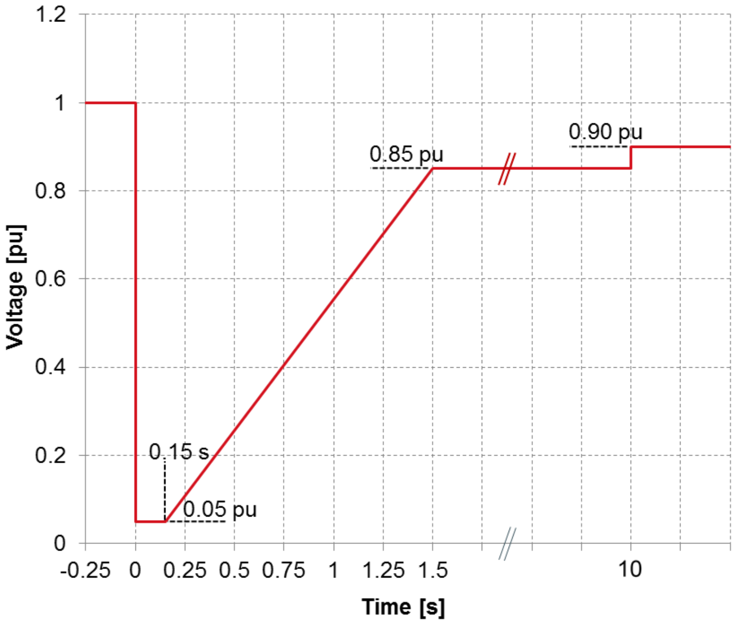

Figure 10.1. The voltage of a connection point corresponding to a momentary voltage disturbance, during and after which type B and C grid energy storage systems shall continue to operate normally. The per unit value 1.0 pu of voltage is the voltage before the disturbance. The voltage is 0.05 pu for 150 milliseconds.

The grid energy storage system may not automatically disconnect as a result of several consecutive voltage disturbances.

10.3.3 Fault current injection of a grid energy storage system

The fault current injection of a grid energy storage system must be activated either by

- ensuring the supply of the fast fault current at the connection point, or
- measuring voltage deviations at the terminals of the individual units of the grid energy storage system and providing a fault current at the terminals of these units.

A grid energy storage system's fault current injection during the fault must be set according to the following requirements:

- The fault current injection shall prioritise the reactive current (I_q).
- The fault current injection's k-factor must be 2.5, and in asymmetrical faults, the positive and negative sequence component must be supplied in the ratio defined by the k-factor. The grid energy storage system's rated current does not need to be over-dimensioned, instead the fault current injection may be limited to the rated current level of normal operation (typically 1.1–1.2 pu).
- The fault current's injection mode shall rise to the target value within 30–50 ms and settle to the target value (tolerance +20%...-10%) within 60–80 ms.

- The fault current's injection mode shall be activated when the phase voltage of terminals of the connection point or individual units of the grid energy storage system is less than 0.85 pu.
- The fault current's injection mode shall be disabled when the phase voltage returns to a level higher than 0.90 pu.

10.3.4 Recovery of active power after a voltage disturbance

After a momentary voltage disturbance (see Section 10.3.2 or 10.5.2) the grid energy storage system shall restore the active power which preceded the disturbance within 1-3 seconds of the start of the disturbance. Active power is considered restored when the active power measured at the connection point is at the pre-fault level (tolerance ±5% of the setpoint). No permanent power changes are accepted as a result of a voltage disturbance.

If the restoration of active power depends on the level of voltage at the connection point, said dependence and a description of its potential impact on power restoration shall be delivered to Fingrid and to the relevant network operator.

10.3.5 Protection

The relevant network operator shall specify the schemes and systems necessary for protecting the network, taking into account the characteristics of the grid energy storage system. The protection schemes needed for the grid energy storage system and the network as well as the settings relevant to the grid energy storage system shall be coordinated and agreed between the relevant network operator and the grid energy storage system owner.

The grid energy storage system owner is responsible for specifying the protection settings of the grid energy storage system and the grid energy storage system's connection in order to guarantee personal and equipment safety and to prevent equipment damage. The protection settings shall be set in such a way that the grid energy storage system remains connected to the grid during disturbances in the power system for as long as this is possible within the scope of the technology and operational safety of the grid energy storage system.

The grid energy storage system owner is responsible for ensuring that the planning of the protection of the grid energy storage system takes into account intense short-term changes in the voltages, currents and frequency of the power system caused by disturbances and faults, and the high-speed automatic reconnection and delayed automatic reconnection commonly used in restoring the operation of transmission lines. The settings shall be based on the capability of the equipment to withstand severe fluctuations in system frequency and in the voltage at the connection point. The protection of the grid energy storage system must not conflict with the Specifications.

Electrical protection of the grid energy storage system shall take precedence over operational controls, taking into account the system security and the health and safety of staff and of the public, as well as mitigating any damage to the grid energy storage system. The grid energy storage system owner shall organise its protection and control devices in accordance with the following priority ranking (from highest to lowest):

1. the protection of the electricity network and the grid energy storage system,
2. active power control and frequency control,
3. power restriction,
4. power gradient constraint.

10.4 General requirements for a type C grid energy storage system

The same general requirements as for type A and B grid energy storage systems (sections 10.2 and 10.3) are applicable to type C grid energy storage systems, with the exception of remote control capability (sections 10.2.3 and 10.3.1). A type C grid energy storage system must also fulfil the requirements set out in this section.

10.4.1 Control and remote use of the grid energy storage system

The grid energy storage system must be equipped with a bus interface (input port), so that the production mode of active power can be changed (production/demand) and a setpoint can be given thereto. The bus interface must be compatible with the IEC 60870-6 (Elcom, ICCP/TASE.2), IEC 60870-5-104 or IEC 61850 protocols.

The operator responsible for the operation of the grid energy storage system can control it remotely or locally. The operator responsible for the operation of the grid energy storage system shall change the mode or setpoint of the grid energy storage system's active power control or reactive power control within the limits set by grid energy storage system technology if Fingrid's Main Grid Control Centre or the relevant network operator so requests. The requested change must be achieved 15 minutes after the request is made.

The grid energy storage system owner shall inform Fingrid and the relevant network operator of the contact information of the operator responsible for the operation of the grid energy storage system, no later than when the grid energy storage system begins to supply active power to Finland's power system. The grid energy storage system owner is responsible for ensuring that the responsible operator is available 24 hours a day, 7 days a week.

10.4.2 Requirements relating to stability

With regard to voltage stability, the grid energy storage system may be capable of automatic disconnection when voltage at the connection point exceeds, in continuous state, normal levels specified by the relevant network operator (see Section 10.1). The relevant network operator may also specify voltage levels outside the normal levels at which the grid energy storage system must disconnect.

In the event of power oscillations, the grid energy storage system shall retain steady-state stability when operating at any operating point of the P-Q-capability diagram.

The grid energy storage system shall be capable of remaining connected to the network and operating without power reduction, as long as voltage and frequency remain within the limits defined in these Specifications.

The grid energy storage system shall be capable of remaining connected to the network during single-phase or three-phase auto-reclosures on meshed network lines, if the connection point of the grid energy storage system is not part of a network section that is disconnected.

10.4.3 Power quality

With regard to the power quality, the design of the grid energy storage system shall take into account the factors and emission limits affecting the power quality described in the report “Power quality in Fingrid’s 110 kV grid”. The report is available on Fingrid’s website.

The grid energy storage system owner is obliged to follow the power quality requirements imposed by the relevant network operator. The grid energy storage system owner shall deliver the information and reports requested by the relevant network operator, on the basis of which information and reports the relevant network operator can evaluate the impacts of grid energy storage system on the power quality before the grid energy storage system is connected to the grid.

The grid energy storage system owner shall be prepared for the power quality specified by the relevant network operator.

10.4.4 Earthing of the neutral point of the main transformer

Earthing arrangement of the neutral point at the high-voltage side of the main transformer of the grid energy storage system owner shall comply with the specifications of the relevant network operator.

10.4.5 Black start capability and island operation

Black start and island operation arrangements are agreed upon separately by the grid energy storage system owner and the relevant network operator. The grid energy storage system owner shall inform the relevant network operator if the grid energy storage system can be used for black start.

10.5 General requirements for a type D grid energy storage system

The same general requirements as for type A, B and C grid energy storage systems (sections 10.2, 10.3 and 10.4) are applicable to type D grid energy storage systems, with the exception of remote control capability (sections 10.2.3 and 10.3.1), automatic connection (Section 10.2.4) and fault-ride-through (Section 10.3.2). A type D grid energy storage system must also fulfil the requirements set out in this section.

10.5.1 Operating voltage and frequency range of the grid energy storage system

The grid energy storage system shall be able to operate continuously and normally when the voltage at the connection point is 90–105% of the normal operating voltage and the frequency is 49.0–51.0 Hz. If the voltage, frequency or both at the connection point differ from these values, the grid energy storage system shall remain connected to the network for at least the periods of time specified in Figure 10.2.

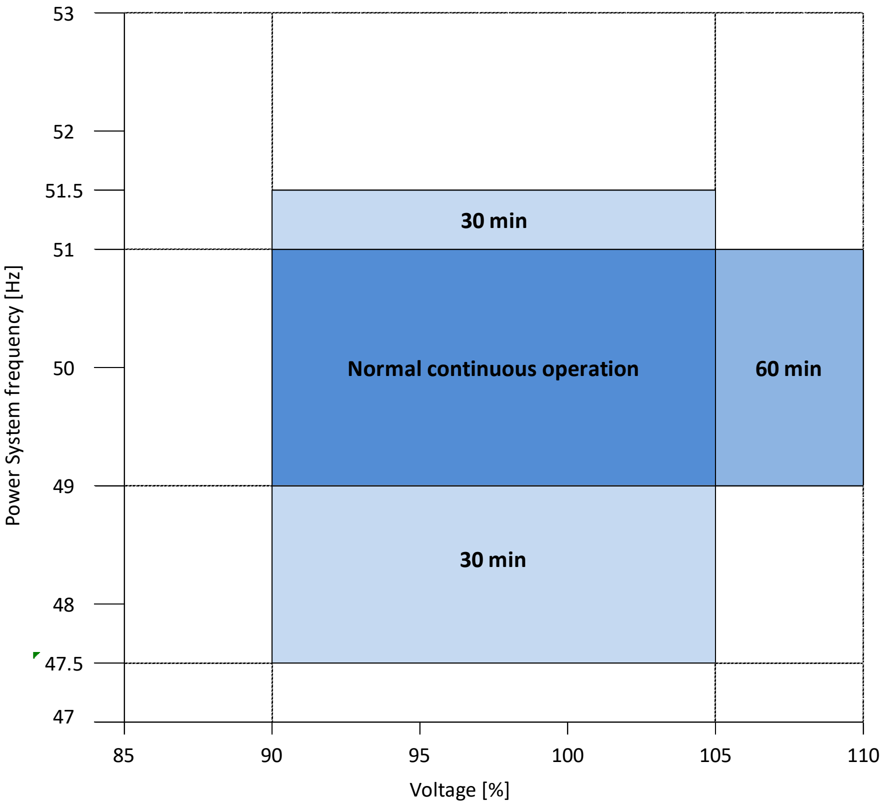

Figure 10.2. The grid energy storage system must remain connected to the network at the different frequencies and voltages at the connection point set out in the figure. The 100% voltage of the continuous operating range in the 400 kV grid is always 400 kV. At other voltages, the voltage corresponding to the 100% value shall be inquired from the relevant network operator.

10.5.2 Fault-ride-through capability

The grid energy storage system shall be able to continue operation during and after disturbances in the power system. A grid energy storage system shall be designed in such a way that it can withstand a momentary voltage fluctuation as shown in Figure 10.3, occurring at the connection point, without being disconnected from the grid.

After a disturbance, the grid energy storage system shall be able to operate without being disconnected from the grid during momentary variations in voltage amplitude and phase angle caused by potential inter-area electromechanical oscillations following a voltage disturbance.

The fault-ride-through requirement is applicable to symmetrical faults (3-phase short circuits) and asymmetrical faults (2-phase short circuits and earth short circuits, 1-phase earth short circuits).

The fault-ride-through requirement has been specified for the following conditions:

- Before the voltage disturbance, the voltage of the connection point of the grid energy storage system is 1.0 pu.
- Before the voltage disturbance, the grid energy storage system does not supply reactive power to the connection point or take reactive power from the connection point.
- Before the voltage disturbance, the automatic voltage regulator (AVR) of the grid energy storage system is in operation.
- The short circuit current of the connection point is assumed to be at normal summertime level before and after the local fault.

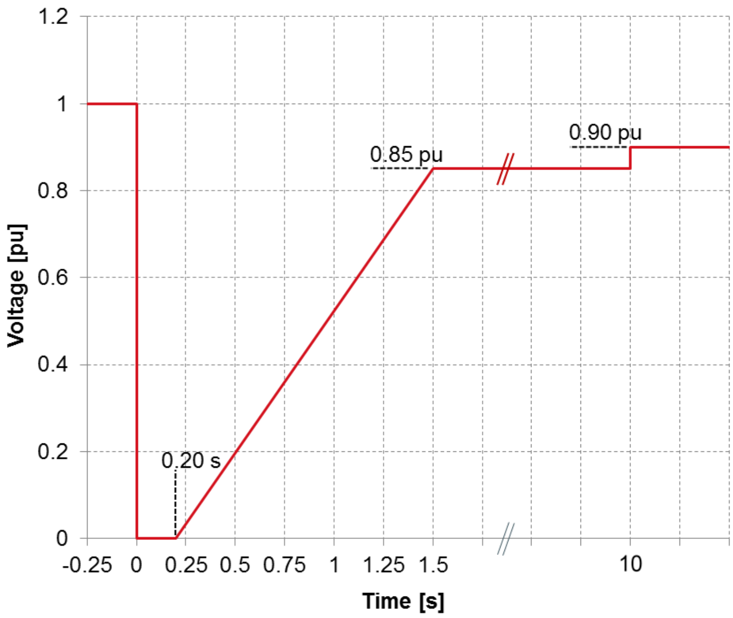

Figure 10.3. The voltage of a connection point corresponding to a momentary voltage disturbance, during and after which type D grid energy storage systems shall continue to operate normally. The per unit value 1.0 pu of voltage is the voltage before the disturbance. The voltage is 0.00 pu for 200 milliseconds.

The grid energy storage system may not automatically disconnect as a result of several consecutive voltage disturbances.

10.5.3 Calculation of the operation of the grid energy storage system during voltage disturbance

A calculation of the fault-ride-through capability of the grid energy storage system shall be delivered to the relevant network operator in stage 1 of the compliance process of the specifications of the grid energy storage system. The calculation shall describe the dynamic operation of the grid energy storage system during voltage disturbances. The calculation criteria are shown in the table 10.1.

The voltage disturbance calculation shall be performed with the following assumptions:

- Before the voltage disturbance, the voltage of the connection point of the grid energy storage system is 1.0 pu.
- Before the voltage disturbance, the grid energy storage system does not supply reactive power to the connection point or take reactive power from the connection point.
- Before the voltage disturbance, the automatic voltage regulator (AVR) of the grid energy storage system is in operation.
- When viewed from the grid energy storage system, an equivalent circuit is made of the power system beyond the connection point. The equivalent circuit contains impedance describing the short circuit power of the power system and ideal voltage source connected in series (Thevenin equivalent). If the connection point of the grid energy storage system is at the 400 kV voltage level or electrically close to a 400 kV transmission grid, the modelling of the power system shall be agreed upon with Fingrid.
- The short circuit current of the connection point is assumed to be at normal summertime level before the disturbance. The relevant network operator shall notify the short circuit powers to be used in the calculation and presented in table 10.1 to the grid energy storage system owner.
- A description of the model used in the calculation, including the parameters used in the calculation and the block diagram presentations of the control systems, shall be delivered as part of the calculation to the relevant network operator.

Table 10.1. Input data used in the voltage disturbance calculation.

Input data	Fault 1	Fault 2
Fault time	200 ms	250 ms
Connection point’s voltage during the fault	0.0 pu	0.25 pu
Connection point’s short circuit current before the fau	Normal	Normal
Connection point’s short circuit current after the fault	Minimum	Normal

11 Active power control and frequency control of grid energy storage systems

11.1 Active power control and frequency control of type A grid energy storage systems

Type A grid energy storage systems shall have the functionalities required by active power control and frequency control and for maintaining power output as described in this section. If the grid energy storage system characteristics include other functionalities related to active power control and frequency control, Fingrid has the right, if necessary, to utilise these functionalities as described in Section 11.3.1.

11.1.1 Active power control

The grid energy storage system must be capable of maintaining active power according to the target value, regardless of changes in the frequency, except when any frequency control mode is active.

11.1.2 Limited frequency sensitive mode – overfrequency (LFSM-O)

In the active power production mode, the grid energy storage system must be capable of reducing its active power production as a linear function of frequency when the electricity system's frequency exceeds 50.5 Hz (see Figure 11.1).

In the active power demand mode, the grid energy storage system must be capable of increasing its active power demand as a linear function of frequency when the electricity system's frequency exceeds 50.5 Hz (see Figure 11.1).

The grid energy storage system must be capable of switching steplessly between the production and demand modes in accordance with the linear droop of LFSM-O.

It shall be possible to adjust the droop of LFSM-O between 2 and 12 per cent. The recommended setpoint is 4%.

A frequency response shall be activated with an initial delay that is as short as possible, within two seconds at the most, when the electricity system's frequency exceeds 50.5 Hz.

When a grid energy storage system achieves the rated capacity in demand mode, it must be able to continue its operations at that control level until the grid energy storage system's energy capacity is full.

The grid energy storage system shall be capable of operating stably during LFSM-O operation, and when LFSM-O is active, its setpoint will prevail over any other active power setpoints.

Limited frequency sensitive mode – overfrequency status must always be enabled.

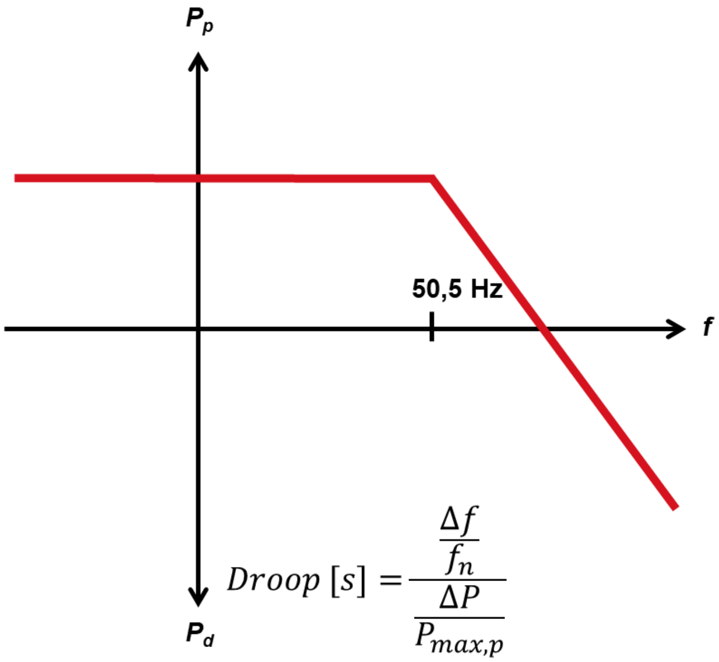

Figure 11.1. Limited frequency sensitive mode — overfrequency – (LFSM-O). In production mode, the grid energy storage system must be capable of reducing its active power production as a linear function of frequency when the electricity system's frequency exceeds 50.5 Hz. In the active power demand mode, the grid energy storage system must be capable of increasing its active power demand as a linear function of frequency when the electricity system's frequency exceeds 50.5 Hz. The grid energy storage system must be capable of switching steplessly between production and demand modes in accordance with the linear droop. It shall be possible to adjust the droop between 2 and 12 per cent. In the figure, f is the frequency, f_n is the nominal frequency (50 Hz), P is the grid energy storage system's active power, P_p is the grid energy storage system's active power in production mode, P_d is the grid energy storage system's active power in demand mode, $P_{max,p}$ is the grid energy storage system's rated capacity.

11.2 Active power control and frequency control of type B grid energy storage systems

Type B grid energy storage systems shall have the functionalities required by active power control and frequency control and for maintaining power output as described in Section 11.1. If the grid energy storage system characteristics include other functionalities related to active power control and frequency control, Fingrid has the right, if necessary, to utilise these functionalities as described in Section 11.3.1.

11.3 Active power control and frequency control of type C and D grid energy storage systems

In addition to what is set out in this section, type C and D grid energy storage systems shall have the LFSM-O functionalities as described in Section 11.1.2.

11.3.1 Fingrid's rights during disturbance in the power system

Fingrid has the right to demand grid energy storage systems to adjust themselves within the power control characteristics presented in this document, if the power system cannot be restored to the normal state after a disturbance.

11.3.2 Rated capacity, start-up, and house load operation of grid energy storage system

11.3.2.1 Rated capacity

The rated capacity must be reported separately for the production mode and demand mode of the grid energy storage system.

The dependence of active power production and demand of the grid energy storage system on external factors, such as the temperature of outdoor air, shall be reported as part of the data to be delivered.

If the grid energy storage system consists of several units and the rated capacity in production mode and demand mode is not evenly distributed between the units, the rated capacities of individual units shall also be reported as part of the data to be delivered alongside the rated capacities of the entire grid energy storage system.

11.3.2.2 Start-up of grid energy storage system

The connection of the grid energy storage system to the power system shall not cause a change in excess of 3 per cent in the voltage of the connection point of the grid energy storage system.

The grid energy storage system owner shall agree separately on the need to limit the rate of change in active power during the start-up of the grid energy storage system.

11.3.2.3 House load

The house load power of the grid energy storage system shall be reported as part of the data to be delivered.

11.3.3 Characteristics of active power control and frequency control

The active power control of the grid energy storage system shall allow the setting of the setpoint of active power and the adjustment of the active power on the basis of frequency measurement (frequency control).

11.3.3.1 Active power control

It must be possible to set the active power setpoint of the grid energy storage system in both the production and demand mode.

The actual value of active power must not exceed the active power control's setpoint when the actual value of active power is measured as 10-second averages. It shall be possible to set the setpoint at a minimum accuracy of 1 MW.

It shall be possible to set limiters to active power production and demand which are lower than the rated capacity in production mode and demand mode. It shall be possible to set the limiters at a minimum accuracy of 1 MW.

11.3.3.2 Restriction of rate of change of active power

It shall be possible to limit the rate of change of the grid energy storage system’s active power in the following situations: a new setpoint is given to the active power, the setpoint of the active power limiter is changed, the active power of the grid energy storage system changes in accordance with frequency control.

It shall be possible to specify the setpoint of the rate of change of active power in production mode and demand mode at least within a range where the minimum value is 10% of the rated capacity in production mode per minute and the maximum value is 100% of the rated capacity in production mode per minute ($0.1 \times P_{max,p}$/min...$1.0 \times P_{max,p}$/min). The smallest change in the setpoint shall be at least one megawatt per minute (1 MW/min).

It shall be possible to specify the rate of change setpoints, which restrict the increase and decrease of active power, separately.

11.3.3.3 Frequency Control (FSM)

The grid energy storage system must be capable of changing its active power production and demand as a linear function of frequency. The grid energy storage system must be capable of switching steplessly between production and demand modes in accordance with the linear droop of frequency control (see Figure 11.2).

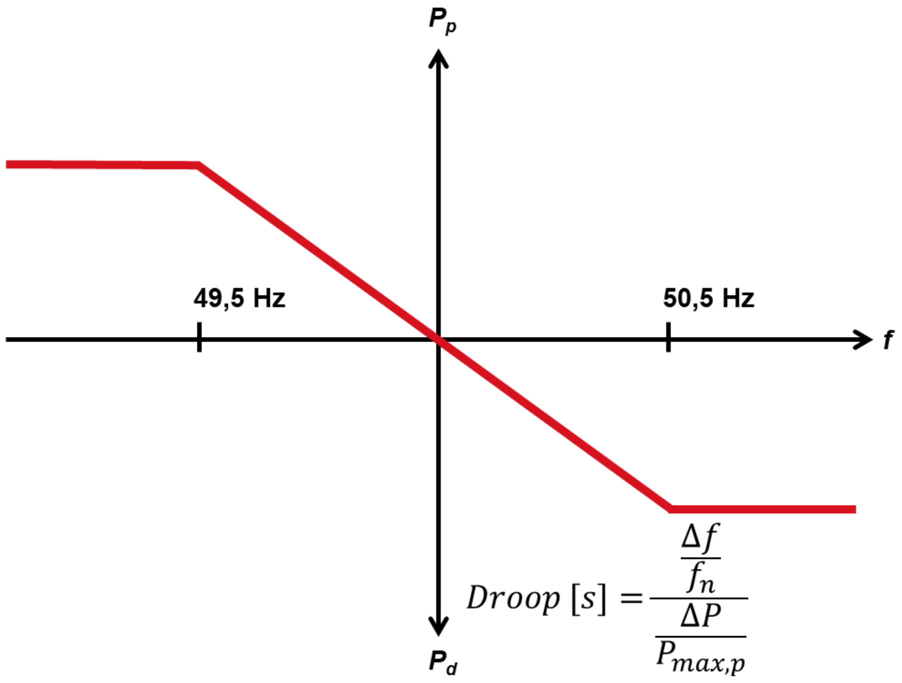

Figure 11.2. Frequency Control. The grid energy storage system must be capable of changing its active power production and demand as a linear function of frequency. The grid energy storage system must be capable of switching steplessly between production and demand modes in accordance with the linear droop. It shall be possible to adjust the droop between 2 and 12 per cent. In the figure, f is the frequency, f_n is the nominal frequency (50 Hz), P is the grid energy storage system's active power, P_p is the grid energy storage system's active power in production mode, P_d is the grid energy storage system's active power in demand mode, $P_{max,p}$ is the grid energy storage system's rated capacity.

The reference value of frequency control shall correspond to the nominal frequency of 50.00 Hz of the power system.

It shall be possible to adjust the droop of frequency control between 2 and 12 per cent in steps of a maximum of one percentage point.

It shall be possible to adjust the deadband of frequency control between 0.00 and 0.50 Hz in steps of a maximum of 0.01 Hz.

It shall be possible to specify a power range for frequency control, within which the active power generated or consumed by the grid energy storage system can be adjusted as a function of the frequency. The power range to be specified for frequency control shall correspond at minimum to the rated capacity in production mode ((0–100%) × $P_{max,p}$) of the grid energy storage system, and it shall be possible to adjust it in steps of 1 MW. It shall be possible to set the power range by combining production and demand ranges such that the limits of production and demand ranges can be set separately, i.e. it shall be possible to set an asymmetrical range.

The use and setpoints of the frequency control mode shall be agreed on separately through a commercial contract.

11.3.3.4 Limited frequency sensitive mode – underfrequency (LFSM-U)

In the active power demand mode, the grid energy storage system must be capable of reducing its active power demand as a linear function of frequency when the electricity system's frequency falls below 49.5 Hz. When the grid energy storage system achieves an operating point where no active power is transferred between the grid energy storage system and the power system, the grid energy storage system must be able to continue its operations at that level until frequency is back to a level of over 49.5 Hz (see Figure 11.4).

It shall be possible to adjust the droop of LFSM-U between 2 and 12 per cent. The recommended setpoint is 4%.

A frequency response shall be activated with an initial delay that is as short as possible, within two seconds at the most, when the electricity system's frequency falls below 49.5 Hz.

The grid energy storage system shall be capable of operating stably during LFSM-O operation, and when LFSM-O is active, its setpoint will prevail over any other active power setpoints.

Limited frequency sensitive mode – underfrequency status must always be on.

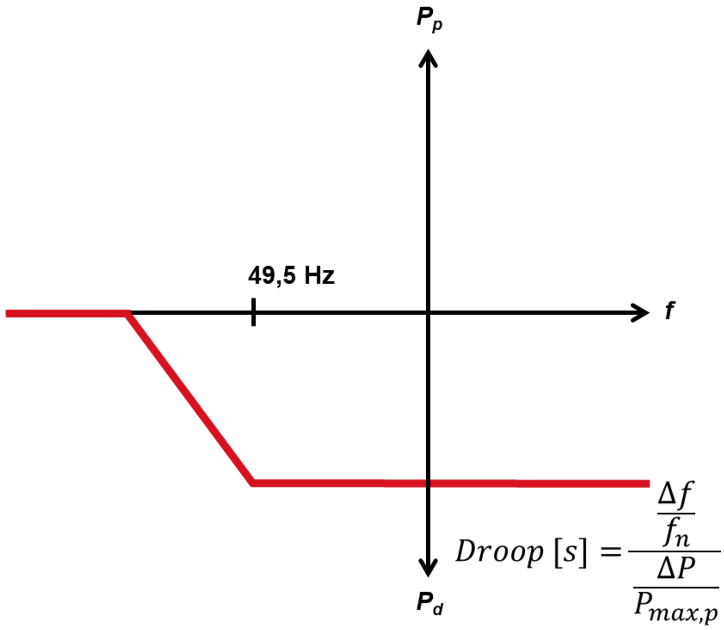

Figure 11.3. Limited frequency sensitive mode — underfrequency – (LFSM-U). In the active power demand mode, the grid energy storage system must be capable of reducing its active power demand as a linear function of frequency when the electricity system's frequency falls below 49.5 Hz. When the grid energy storage system achieves an operating point where no active power is transferred between the grid energy storage system and the power system, the grid energy storage system must be able to continue its operations at that level until frequency is back to a level of over 49.5 Hz. It shall be possible to adjust the droop between 2 and 12 per cent. In the figure, f is the frequency, f_n is the nominal frequency (50 Hz), P is the grid energy storage system's active power, P_p is the grid energy storage system's active power in production mode, P_d is the grid energy storage system's active power in demand mode, $P_{max,p}$ is the grid energy storage system's rated capacity.

11.3.4 Changes between the modes of active power control and frequency control

A change in the mode of active power control and frequency control shall not cause a major sudden variation in the active power or reactive power generated by the grid energy storage system.

It shall be possible to change, prevent and allow the modes of operation and setpoints of the active power control and frequency control of the grid energy storage system. The control of the modes of operation and setpoints shall work in the same way regardless of whether the grid energy storage system is controlled locally or remotely.

11.3.5 Accuracy and sensitivity of control

The accuracy of the active power control shall be at least 1 MW or ± 5% of the rated capacity in production mode (the greater value is chosen)

The sensitivity of frequency control shall be at least 10 mHz, and the response time shall be no more than 2 s.

The accuracy and sensitivity of the active grid energy storage system's power and frequency control shall be verified as part of commissioning testing.

12 Reactive power capacity of grid energy storage systems

12.1 Reactive power capacity of type B grid energy storage systems

The relevant network operator sets the reactive power capacity requirement for type B grid energy storage systems. However, the requirement shall not exceed the reactive power capacity requirement specified for type C and D grid energy storage systems.

12.2 Reactive power capacity of type C and D grid energy storage systems

12.2.1 Reactive Power capacity requirement

The grid energy storage system shall be able to generate and consume reactive power (Q), within the operating range limited by its maximum rated capacity in production mode and demand mode, at a reactive power capacity corresponding to the system's operating point at a power factor of 0.95 of the rated power in production mode. The reactive power capacity range is shown in Figure 12.1a).

As illustrated in Figure 12.1b), the reactive power measured at the connection point shall be:

- 0–0.33 [$Q/ P_{max,p}$] input, when the voltage at the connection point is 0.90–1.00 pu.
- 0–0.33 [$Q/ P_{max,p}$] output, when the voltage at the connection point is 1.00–1.05 pu.

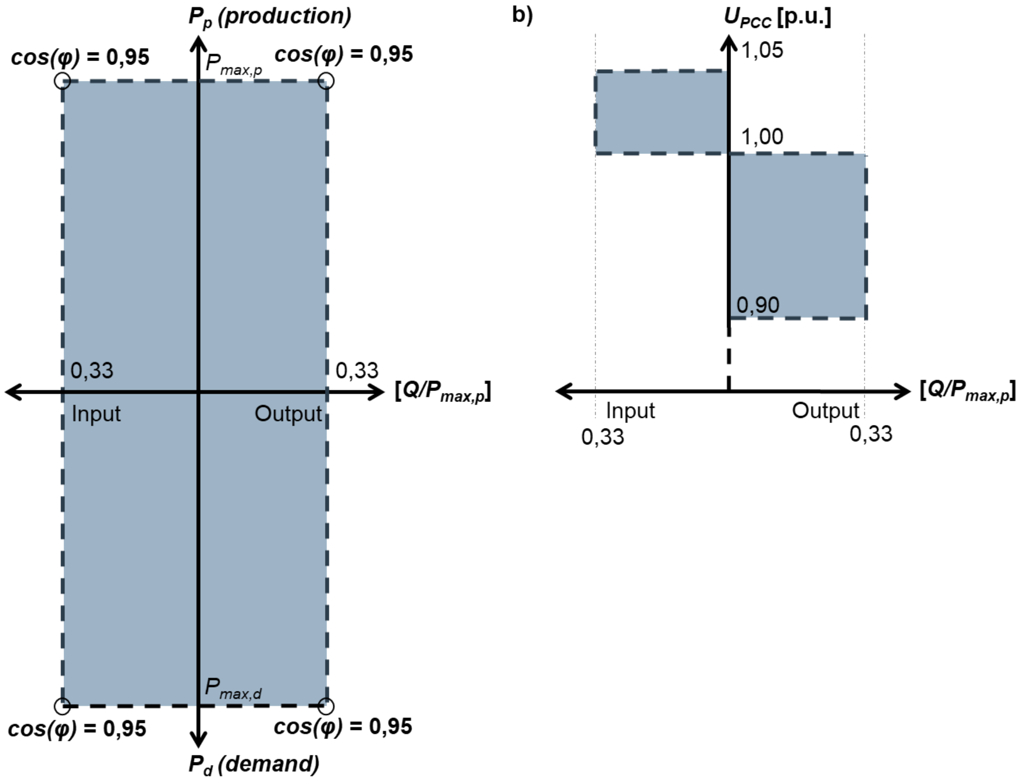

Figure 12.1. Reactive power capacity requirements for type C and D grid energy storage systems as the function of active power and the voltage at the connection point. In the figure, a voltage of 1.0 pu corresponds to the normal operating voltage specified by the relevant network operator.

12.2.2 Supplementary reactive power capacity

With regard to reactive power capability, the relevant network operator may specify supplementary reactive power to be provided if the connection point of a grid energy storage system is neither located at the high-voltage terminals of the step-up transformer to the voltage level of the connection point nor at the alternator terminals of the grid energy storage system, if no step-up transformer exists.

This supplementary reactive power shall compensate the reactive power demand of the high-voltage line or cable and shall automatically adapt so that the reactive power available at the connection point is as specified in Section 12.2.1.

12.2.3 Components utilised to achieve the reactive power capacity requirement

Reactive power capacity does not need to be reserved in grid energy storage systems only, but it can be reserved in one or more separate adjustable reactive power compensation devices, which have been connected to the power system to the connection point of the grid energy storage system or beyond it to be part of the other grid energy storage system equipment.

The functioning of components utilised so as to achieve the reactive power capacity requirement shall be co-ordinated with the functioning of the other grid energy storage system components that control voltage, in such a manner that the voltage control requirements and reactive power control requirements laid down for the grid energy storage system in Section 13 are fulfilled.

The testing, documentation and simulation requirements of devices used so as to fulfil the reactive power capacity requirement of the grid energy storage system shall be agreed upon separately with the relevant network operator in Stage 1 of the compliance process of the Specifications.

12.2.4 Reactive power capacity calculation

The grid energy storage system owner shall deliver a calculation of the reactive power capacity of the grid energy storage system at the connection point to the relevant network operator. The calculation shall be delivered at stage 1 of the compliance process. The calculation shall demonstrate the capability of the grid energy storage system to generate and consume reactive power at the voltage levels specified for the connection point and at the active power output levels specified for grid energy storage systems in Table 12.1. The setpoint values used in the reactive power limiters shall be specified in the reactive power capacity calculation document.

If the step-up transformer of the grid energy storage system is equipped with an on-load tap-changer, the calculation shall be provided for not only the middle position of the on-load tap-changer but also for the automatic settings of the on-load tap-changer of the step-up transformer.

In addition to the reactive power capacity specified for the grid energy storage system in the calculation, the reactive power capacity calculation shall present the input data used in the calculation, such as the voltage ranges and reactive power capacities of the grid energy storage system’s units.

The reactive power capacity calculation shall take into account, where necessary, the grid energy storage system and any other grid energy storage system components that generate and consume reactive power. The frequency value used in the calculation shall be 50 Hz.

Operating point 0.85 pu is momentary at the voltage levels of the connection point, and at this operating point the grid energy storage system shall be able to operate for a minimum of 10 seconds.

Table 12.1. Operating points used in the reactive power capacity calculation.

Connection point’s voltage [pu]	0.85*	0.90	1.00	1.10
Power level 1	Rated capacity at production mode $P_{max,p}$			
Power level 2	$P=0.50*P_{max,p}$			
Power level 3	$P=0.50*P_{max,d}$			
Power level 4	Rated capacity at demand mode $P_{max,d}$			
*Operating point 0.85 pu is momentary, at this operating point reactive power shall be produced for a minimum of 10 seconds				

If the actual components of the grid energy storage system are different from those planned, the reactive power capacity calculation shall be updated correspondingly and delivered to the relevant network operator.

The reactive power capacity of the grid energy storage system at the connection point, specified in the calculation, shall be verified during commissioning in accordance with the principles described in Section 14.

12.2.5 Restriction of reactive power capacity

When operating outside the limit values specified in Section 12.2.1, the reactive power production capacity of the grid energy storage system shall be in accordance with that indicated in the reactive power capacity calculation, and it must not be limited by means of software.

The protection related to the operation of current limiters (or equivalent equipment) used in the grid energy storage system shall be co-ordinated so that the available reactive power capacity can be utilised efficiently without the risk of the grid energy storage system disconnecting from the power system.

13 Voltage control and reactive power control of a grid energy storage system

13.1 Voltage control and reactive power control of a type B grid energy storage system

The grid energy storage system shall be able to operate at a power factor of 1.0 measured at the connection point, or alternatively the grid energy storage system shall be able to support the voltage of the connection point by means of its reactive power capacity, as follows:

- The grid energy storage system generates reactive power to the power system when the voltage of the connection point decreases.
- The grid energy storage system consumes reactive power from the power system when the voltage of the connection point increases.

13.2 Voltage control and reactive power control of a type C grid energy storage system

13.2.1 Functionalities of voltage control and reactive power control

The grid energy storage system shall be capable of automatic reactive power control and voltage control. The control shall be carried out so that the control operates continuously and so that the changes in reactive power at the connection point as a result of the control take place steplessly.

Voltage control and reactive power control shall enable the utilisation of the reactive power capacity of the grid energy storage system in the manner described in Section 12. The functioning of the control shall not be disturbed by changes in the voltage and frequency of the power system or by momentary voltage disturbances.

The voltage control and reactive power control of the grid energy storage system shall have the following operating modes:

1) constant voltage control
2) constant reactive power control, and
3) constant power factor control

The primary method of voltage control and reactive power control is constant voltage control at the connection point. The control range shall correspond to the actual reactive power capacity of the grid energy storage system. The reactive power capacity shall not be artificially limited. The basic operation of limiters implemented in order to guarantee the electrical strength of the grid energy storage system components shall be described as part of the grid energy storage system documentation to be delivered.

The voltage control functions and reactive power control functions shall be able to keep the reactive power production of the grid energy storage system within the reference value of the control function. The accuracy of the voltage control functions and reactive power control functions shall be verified during the commissioning testing. The response of the control functions to stepwise changes and to continuous variation in the voltage of the power system shall be stable, and the control functions to be carried out as a result of the changes shall not lead to repeated or poorly damping oscillations in the reactive power or active power of the grid energy storage system.

13.2.2 Constant voltage control

The grid energy storage system shall be able to operate at constant voltage control so that the control can be used, considering the slope, for controlling directly the voltage of the connection point.

It shall be possible to adjust the constant voltage control setpoint within the continuous operating range limit values specified for the voltage of the connection point in steps no greater than 0.01 pu. Defining a deadband for voltage control shall not be allowed.

The slope of voltage control shall be linear, and it shall be possible to set the slope within a range of 2–7 per cent in steps no greater than 0.5 percentage points. The reference value can be set as positive or negative depending on the implementation of the voltage control of the grid energy storage system.

With the grid energy storage system connected to the network, when the stepwise change in the voltage of the connection point or the change in the setpoint of the automatic voltage regulator is less than 0.05 pu, the response of constant voltage control shall be as follows:

1) the rise time of the reactive power response from 0 to 90 per cent of the measured total change in reactive power shall be 0.2–1.0 seconds,

2) the exceeding verified in the step response shall not be more than 15 per cent of the measured total change in reactive power,

3) the response shall settle to its target level within 5 seconds from the stepwise excitation,

4) When steady-state stability is achieved, the actual value of reactive power shall deviate by no more than ±5% of the reactive power target value, up to a maximum of ±1 Mvar.

13.2.2.1 Constant voltage control performance calculation

The grid energy storage system owner shall provide the relevant network operator with a calculation of the performance of the automatic voltage regulator of the grid energy storage system. The calculation shall be delivered at stage 1 of the compliance process. The calculation shall demonstrate the performance of the automatic voltage regulator of the grid energy storage system when the regulator’s setpoint is changed in the following manner:

- The slope of the grid energy storage system is set to 2%, and the voltage control setpoint of the grid energy storage system is changed as follows: 1.00 pu, 1.01 pu, 1.00 pu, 0.99 pu, 1.00 pu, 1.02 pu, 1.00 pu, 0.98 pu and 1.00 pu.

- The slope of the grid energy storage system is set to 4%, and the voltage control setpoint of the grid energy storage system is changed as follows: 1.00 pu, 1.01 pu, 1.00 pu, 0.99 pu, 1.00 pu, 1.02 pu, 1.00 pu, 0.98 pu and 1.00 pu.

A description of the model used in the calculation, including the parameters used in the calculation and the block diagram presentations of the control systems, shall be delivered as part of the calculation to the relevant network operator.

13.2.3 Constant reactive power control

The grid energy storage system shall be able to operate at constant reactive power control so that the control can be used for controlling directly the reactive power fed to the connection point and the reactive power taken from the connection point.

The reactive power measurement accuracy for constant reactive power control, measured at the connection point, shall be at least 1 MVar (tolerance: ±0.5 Mvar). The setting range of the reference value shall correspond to the actual reactive power capacity of the grid energy storage system.

The constant reactive power control shall achieve its target value within 10 seconds of a change in the reactive power setpoint of the grid energy storage system.

13.2.4 Constant power factor control

The grid energy storage system shall be able to operate at constant power factor control so that the control can be used for controlling directly the power factor of the connection point, i.e. the reactive power fed to the connection point and the reactive power taken from the connection point as a function of the active power generated or consumed by the grid energy storage system.

It shall be possible to set the reference value of constant power factor control for the power factor in maximum steps of 0.01 between 0.95ind–0.95cap or in a broader range.

The voltage measurement accuracy for constant power factor control, measured at the connection point, shall be at least 0.01 (tolerance: ±0.005).

The constant power factor control shall achieve its target value within 10 seconds of a sudden change in the active power of the grid energy storage system.

13.2.5 Changes in the modes and reference values of voltage control and reactive power control

Any transitions in the mode and operating point of the control shall take place without sudden significant changes (no more than 5 per cent of the rated capacity in production mode) or repeated, significant oscillations in the active power and reactive power generated or consumed by the grid energy storage system. The mode transition shall take place within a predetermined period of time after the mode transition is requested from the grid energy storage system.

The control of the modes of operation and setpoints of the automatic voltage regulator shall work in the same way regardless of whether the grid energy storage system is controlled locally or remotely.

13.2.6 Protection and limiters related to the functioning of voltage control

When the voltage of the connection point of the grid energy storage system is high, the functioning of the limiters shall control, in as direct and delay-free manner as possible, the functioning of the voltage control in order to avoid intense overvoltages.

13.2.7 Other components contributing to voltage control and reactive power control

If separate compensation devices implemented as part of the grid energy storage system are utilised in order to achieve the reactive power capacity requirement, the functioning of such devices shall be co-ordinated with the functioning of the controllers of the grid energy storage system so as to fulfil the other requirements laid down in Section 13. Moreover, the need to co-ordinate the functioning of the devices with the other components contributing to the control of voltage in the power system shall be agreed upon separately with the relevant network operator.

13.3 Voltage control and reactive power control of a type D grid energy storage system

Grid energy storage systems belonging to power class D shall meet all of the requirements concerning type C grid energy storage systems. Furthermore, type D grid energy storage systems shall be subject to additional requirements concerning the impact of voltage control and reactive power control on electromechanical oscillations.

When tuning the setpoint for voltage control and reactive power control, the potential impact of the functioning of the relevant controller on the dynamics of the power system shall be taken into account. The analysis of the response of voltage control and reactive power control shall be carried out in close co-operation between the grid energy storage system owner, the relevant network operator and Fingrid in order to be able to specify the impact of the grid energy storage system on the transmission capacity of the power system so that it supports the functioning of the power system as well as possible.

If the response of the normal control functions of the grid energy storage system to electromechanical oscillations deteriorates the transmission capacity of the power system irrespective of the implementation and set values of the controls, the impact of the response of the control of the grid energy storage system on the oscillations shall be improved by means of additional control functions, such as functionalities corresponding to power system stabiliser (PSS) or power oscillation damping (POD).

The details related to the control settings shall be documented comprehensively and delivered as part of the data to be provided.

The functioning of the control shall be verified during the commissioning testing.

14 Commissioning testing of grid energy storage systems

14.1 Shared requirements for the commissioning testing of grid energy storage systems of type B–D

It is the responsibility of the grid energy storage system owner to verify that the operation of the grid energy storage system meets the specified requirements. The grid energy storage system owner is responsible for the costs related to the compliance process. Compliance with the Specifications shall primarily be verified by means of tests carried out in conjunction with the commissioning of the grid energy storage system.

The relevant network operator and/or a representative of Fingrid may participate in the compliance testing either on site or remotely from the network control centre of the relevant network operator. For that purpose, the grid energy storage system owner shall provide the monitoring equipment necessary to record all relevant test signals and measurements as well as ensure that the necessary representatives of the grid energy storage system owner are available on site for the entire testing period. Signals specified by the relevant network operator or Fingrid shall be provided if, for selected tests, the network operator or Fingrid wishes to use its own equipment to record performance. The relevant network operator and Fingrid shall decide on their participation at their discretion.

14.2 Commissioning testing of type B grid energy storage systems

The grid energy storage system owner shall deliver minutes of commissioning testing to the relevant network operator. The minutes shall comprise the documentation of the variables validated by means of measurements and the time of the measurements.

It is the responsibility of the grid energy storage system owner to verify by commissioning testing that the following characteristics of a type B grid energy storage system conform to the Specifications:

1) Impact of the starting and stopping of the grid energy storage system on the voltage level at the connection point
    - The test shall verify that starting or stopping the grid energy storage system does not cause quality deviations in the network of the relevant network operator.
2) Rated capacity of the grid energy storage system
    - The test shall verify that the grid energy storage system's rated capacity in production mode and demand mode conforms to the connection agreement.
3) Reactive power capacity of grid energy storage systems
    - The test shall verify the reactive power capacity of the grid energy storage system at its rated capacity in production mode and demand mode at the highest possible inductive and capacitive reactive power.

4) Functioning of voltage control or reactive power control

- The test shall verify that voltage control or reactive power control functions appropriately. If necessary, the relevant network operator shall provide additional instructions for the test.

5) Limited frequency sensitive mode — overfrequency – (LFSM-O)

- The grid energy storage system's capability to continuously modulate active power to contribute to frequency control in case of a large increase of frequency in the system shall be demonstrated. The steady-state parameters of regulations, such as droop and deadband, and dynamic parameters, including frequency step change response shall be verified.

- The test shall be carried out by simulating frequency steps and ramps big enough to trigger an active power change of at least 10% per cent of the rated capacity in production mode, taking into account the droop settings and the deadband.
The test can be performed by introducing an interfering signal of +0.7 Hz in the frequency measurement and using a droop of 4% and a deadband of 0.00 Hz. The test shall be carried out in both the production mode and the demand mode.

- The test shall be deemed successful if the requirements set out in Section 11.1.2 are fulfilled and no undamped power oscillations occur after the step change response.

Instead of the relevant test, the grid energy storage system owner may use equipment certificates issued by an authorised certifier to demonstrate compliance with the relevant requirement. In such a case, the equipment certificates shall be provided to the relevant network operator. As a rule, equipment certificates cannot be relied upon to demonstrate the cooperation of the grid energy storage system as a whole and of all of its auxiliary equipment. Consequently, equipment certificates shall not be accepted as a primary means of verifying compliance, and their use must be agreed on separately with the relevant network operator and Fingrid.

14.3 Commissioning testing of type C grid energy storage systems

14.3.1 Commissioning test plans, measurements and data exchange

The commissioning testing shall be carried out in co-operation between the grid energy storage system owner, the relevant network operator, and Fingrid. Fingrid’s representatives have the right to participate in all commissioning testing.

The grid energy storage system owner shall draw up a commissioning plan for the grid energy storage system. The plan shall cover the testing of the functionalities at least in the scope described in this section. The grid energy storage system owner shall deliver the commissioning test plan, preliminary commissioning instructions and a description of the practical arrangements of the tests. The description of the practical arrangements shall cover at least the measurement arrangements, responsible persons, and preliminary schedule. The documents shall be delivered to the relevant network operator no later than 2 months before the planned start of the commissioning testing.

In conjunction with the drawing up and delivery of the commissioning test plans, the grid energy storage system owner shall arrange a meeting between the grid energy storage system owner, the relevant network operator, and Fingrid. The meeting shall take place no later than two months before the commissioning testing. In the meeting, the grid energy storage system owner shall agree on the final commissioning test plan and on the schedule and practical arrangements of the commissioning testing with the relevant network operator and Fingrid. If the above-mentioned parties agree that a meeting will not be held, the data exchange concerning the issues to be agreed shall be arranged in some other way. Each of the above-mentioned parties shall appoint at least one contact person for the commissioning testing.

As the transmission system operator, Fingrid has the right to cancel or change the schedule of the commissioning testing if the execution of the tests at the planned time is not possible due to the operation situation of the power system. The relevant network operator has a corresponding right with regard to the operation situation of its own electricity network. The cancellation or schedule change may be caused by factors such as circumstances related to the operation of the grid energy storage system or the operation situation of the local electricity network and national power system. If the timing of the commissioning testing needs to be changed, the grid energy storage system owner shall agree on a new schedule with the relevant network operator and Fingrid.

At least the below variables shall be measured and recorded in all commissioning testing at a minimum recording frequency of 50 Hz:

- active power of the grid energy storage system,
- reactive power of the grid energy storage system,
- voltage at the connection point,
- frequency at the connection point.

Moreover, the setpoint of the variable adjusted in the commissioning testing and the changes of the setpoint shall be recorded.

The commissioning testing shall be planned so that the correspondence of the actual operation of the grid energy storage system and the dynamic modelling data can be demonstrated by means of calculations.

14.3.2 Substituting the commissioning testing

Instead of the relevant test, the grid energy storage system owner may use equipment certificates issued by an authorised certifier to demonstrate compliance with the relevant requirement. In such a case, the equipment certificates shall be provided to the relevant network operator. As a rule, equipment certificates cannot be relied upon to demonstrate the cooperation of the grid energy storage system as a whole and of all its auxiliary equipment. Consequently, equipment certificates shall not be accepted as a primary means of verifying compliance, and their use must be agreed on separately with Fingrid and the relevant network operator.

If the commissioning testing cannot be performed, for example, due to the operational situation of the power system, the grid energy storage system owner shall agree separately with Fingrid and the relevant network operator on substituting the commissioning testing. Fingrid shall determine whether any commissioning testing can be substituted with one of the following methods:

1) equipment certificates issued by an authorised certifier, certificates issued by accredited laboratories, or equivalent detailed test reports,
2) continuous monitoring,
3) simulation examinations carried out by utilising verified calculation models.

14.3.3 Documentation and acceptance of commissioning testing

It is the responsibility of the grid energy storage system owner to document the commissioning testing and its results in the commissioning report. The grid energy storage system owner shall deliver the commissioning report as an electronic document and the results of the commissioning testing in numerical format to the relevant network operator in the scope specified under Section 15.1.5.

The grid energy storage system owner shall agree separately with the relevant network operator on the timing of tests of grid energy storage system projects which proceed in stages, described in Section 6.3.

It is the responsibility of the relevant network operator to confirm the fulfilment of the compliance obligation related to the requirements in terms of the commissioning testing based on the following four sectors:

1) The preparation, planning and data exchange of the tests have been carried out in accordance with the Specifications.
2) The tests have been carried out in accordance with the scope of the Specifications.
3) The operation of the grid energy storage system verified by the tests is in accordance with the Specifications and with the data provided on the grid energy storage system.
4) A commissioning report and measurement data in numerical format have been delivered of the tests related to the Specifications in accordance with the Specifications (Section 15.1.5).

14.3.4 Functions to be verified in commissioning testing

The commissioning testing shall verify the following functions:

1) Limited frequency sensitive mode — overfrequency – (LFSM-O)

- The grid energy storage system's technical capability to continuously modulate active power to contribute to frequency control in case of a large increase of frequency in the system shall be demonstrated. The steady-state parameters of regulations, such as droop and deadband, and dynamic parameters, including frequency step change response shall be verified.
- The test shall be carried out by simulating frequency steps and ramps big enough to trigger an active power change of at least 10% per cent of the rated capacity in production mode, taking into account the droop settings and the deadband. The test can be performed by introducing an interfering signal of +0.7 Hz in the frequency measurement and using a droop of 4% and a deadband of 0.00 Hz. The test shall be carried out in both the production mode and the demand mode.
- The test shall be deemed successful if the requirements set out in Section 11.1.2 are fulfilled and no undamped power oscillations occur after the step change response.

2) Limited frequency sensitive mode — underfrequency – (LFSM-U)

- The grid energy storage system's technical capability to continuously modulate active power to contribute to frequency control in case of a large drop of frequency in the system shall be demonstrated.
- The test shall be carried out by simulating frequency steps and ramps big enough to trigger an active power change of at least 10% per cent of the rated capacity in production mode, taking into account the droop settings and the deadband. The test can be performed by introducing an interfering signal of –0.7 Hz in the frequency measurement and using a droop of 4% and a deadband of 0.00 Hz. The test shall be carried out in both the production mode and the demand mode.
- The test shall be deemed successful if the requirements set out in Section 11.3.3.4 are fulfilled and no undamped power oscillations occur after the step change response.

3) Frequency sensitive mode

- The grid energy storage system's technical capability to continuously modulate active power as a function of frequency within the range limited by the maximum active power in production and demand modes shall be demonstrated. The steady-state parameters of regulations, such as droop and deadband and dynamic parameters, including robustness through frequency step change response and large, fast frequency deviations shall be verified. The control range of frequency control shall be at least ±10% of the grid energy storage system’s rated capacity in production mode. The test shall be carried out in both the production mode and the demand mode.

- The test shall be carried out on the basis of network frequency measurement and by simulating frequency steps and ramps big enough to trigger the whole active power frequency response range. Taking into account the settings of droop and deadband, as well as the capability to increase or decrease active power output from the respective operating point.
  The rate of change of the active power setpoint shall be set to the highest permissible value for the duration of the test.
  When performing the test, all interfering signals shall be reset to zero before introducing a new interfering signal. The test can be carried out in both the production mode and the demand mode using the following procedure:

  - The response of frequency control shall be measured for no less than 10 minutes on the basis of normal network frequency measurement.
  - Using two different droop values, such as 4% and 6%, an interfering signal of +0.1 Hz shall be introduced by means of both steps and ramps.
  - Using two different droop values, such as 4% and 6%, an interfering signal of +0.5 Hz shall be introduced by means of both steps and ramps.
  - Using two different droop values, such as 4% and 6%, an interfering signal of –0.1 Hz shall be introduced by means of both steps and ramps.
  - Using two different droop values, such as 4% and 6%, an interfering signal of –0.5 Hz shall be introduced by means of both steps and ramps.
  - The deadband shall be set to ±10 mHz and the response of frequency control shall be measured for no less than 5 minutes on the basis of normal network frequency measurement.
  - The deadband shall be set to ±100 mHz. An interfering signal of +50 mHz and –50 mHz shall be introduced, followed by an interfering signal of +150 mHz and –150 mHz.
  - The droop shall be set to the minimum and maximum value of the droop setpoint range. The deadband shall be set to the minimum and maximum value of the deadband setpoint range.

- The test shall be deemed successful if the requirements set out in Sections 11.3.3.3 and 11.3.5 are fulfilled and no undamped power oscillations occur after the step change response.

4) Rate of change of active power

- The test shall demonstrate the technical capability of the grid energy storage system to modulate active power within the operating range and at the rate of change defined in Section 11.3.3.2.
  The test shall be conducted using two different values for the rate of change of active power in both the production mode and demand mode: $0.1 \times P_{max}$/min and $1.0 \times P_{max}$/min.
  The test can be performed by gradually increasing the active power of the grid

energy storage system to its maximum in demand mode and, afterwards, gradually increasing the active power of the grid energy storage system to its maximum in production mode. Once complete, the test shall be repeated in the opposite order.

- The test shall be deemed successful if the requirements set out in Section 11.3.3.2 are fulfilled and no undamped power oscillations occur during or after the power change.

5) Constant voltage control

- The test shall demonstrate the technical capability of the grid energy storage system to regulate voltage and to function in accordance with the requirements set out in Sections 13.2.2 and 13.2.5 when the grid energy storage system is connected to the network.

- The test shall consist of voltage control step response tests performed with the grid energy storage system connected to the network. The tests shall demonstrate the performance of voltage control and the ability to set the required setpoint and slope.
  The test can be performed using the following procedures:

  - The slope of voltage control is set to 2%, and the voltage control setpoint of the grid energy storage system is changed as follows: 1.00 pu, 1.01 pu, 1.00 pu, 0.99 pu, 1.00 pu, 1.02 pu, 1.00 pu, 0.98 pu and 1.00 pu.

  - The slope of voltage control is set to 4%, and the voltage control setpoint of the grid energy storage system is changed as follows: 1.00 pu, 1.01 pu, 1.00 pu, 0.99 pu, 1.00 pu, 1.02 pu, 1.00 pu, 0.98 pu and 1.00 pu.

- The test shall be deemed successful if the requirements set out in Sections 13.2.2 and 13.2.5 are fulfilled and, following the step change response tests, the grid energy storage system is able to reach a stable operating point free of poorly damped reactive or active power oscillations.

6) Constant reactive power control

- The test shall demonstrate the technical capability of the grid energy storage system to regulate reactive power and to function in accordance with the requirements set out in sections 13.2.3 and 13.2.5 when the grid energy storage system is connected to the network.

- The test shall include stepwise changes in reactive power when the grid energy storage system is connected to the network. The tests shall demonstrate the performance of reactive power control and the ability to set the required setpoint. The test can be performed by making changes in the constant reactive power control setpoint of the grid energy storage system, for example, in steps of 1 Mvar.

- The test shall be deemed successful if the requirements set out in sections 13.2.3 and 13.2.5 are fulfilled and, following the stepwise change in reactive power, the grid energy storage system is able to reach a stable operating point free of poorly damped reactive or active power oscillations.

7) Constant power factor control

- The test shall demonstrate the technical capability of the grid energy storage system to regulate the power factor measured from the connection point in accordance with the requirements set out in sections 13.2.4 and 13.2.5 when the grid energy storage system is connected to the network.

- The test shall consist of stepwise changes in reactive power, achieved by adjusting the power factor, with the grid energy storage system connected to the network. The tests shall demonstrate the performance of power factor control and the ability to set the required setpoint.
The test can be performed by making changes in the power factor control setpoint of the grid energy storage system (for example, in steps of 0.01).

- The test shall be deemed successful if the requirements set out in Sections 13.2.4 and 13.2.5 are fulfilled and, following the stepwise change in reactive power, the grid energy storage system is able to reach a stable operating point free of poorly damped reactive or active power oscillations.

8) Reactive power capacity test and restriction of active power

- The test shall demonstrate the capability of the grid energy storage system to generate and consume reactive power in accordance with the requirements set out in Section 12.2, and the test shall verify the results of the reactive power calculation. Additionally, the test shall verify the functioning of the system's active power restriction and the accuracy of its active power control.

- Before conducting the test, the grid energy storage system owner and the relevant network operator shall agree on the permissible voltage and reactive power ranges. The reactive power capacity test shall be restricted to within the range permitted by the normal operating voltage range of the network.

- The test shall be performed at the maximum inductive and maximum capacitive reactive power of the grid energy storage system, with the grid energy storage system generating or consuming active power at four different operating points for the required operating time:

    - At more than 60% of rated capacity in production mode: no less than 30 minutes,

    - at 30...50% of rated capacity in production mode: no less than 30 minutes, and

    - at more than 60% of rated capacity in demand mode: no less than 30 minutes,

    - at 30...50% of rated capacity in demand mode: no less than 30 minutes.

- The test can be performed by making gradual changes in the voltage control setpoint of the grid energy storage system until both the inductive and capacitive limit is reached, at each active power level.

- The test shall be deemed successful if the requirements set out in Sections 11.3.3.1, 11.3.5 and 12.2 are fulfilled.

9) Starting and stopping

- The test shall demonstrate that starting and stopping the grid energy storage system does not cause quality deviations in the network of the relevant network operator.

- The test shall be deemed successful if the requirements set out in Section 11.3.2.2 as well as the requirements for electricity quality specified by the relevant network operator are fulfilled.

10) Fault-ride-through capability

- The test shall demonstrate the fault-ride-through capability of the grid energy storage system in accordance with the requirements set out in Section 10.3.2 (type C) or 10.5.2 (type D). The procedure for the fault-ride-through test shall be determined by Fingrid on a case-by-case basis. If a fault-ride-through test is not conducted, the functioning of the grid energy storage system in a local fault shall be demonstrated through simulation calculations and continuous monitoring when the system is in operation.

14.4 Commissioning testing of type D grid energy storage systems

The commissioning testing requirements for type D Commissioning testing of type C grid energy storage systems are the same as for type C Commissioning testing of type C grid energy storage systems (Section 14.3). If the voltage control functions of a type D grid energy storage system influence electromechanical oscillations in a manner that reduces the transmission capacity of the power system, the grid energy storage system owner and Fingrid shall separately agree on the verification of the additional control functions set out in Section 13.3.

15 Modelling requirements applicable to grid energy storage systems

15.1 Modelling requirements of type C and D grid energy storage systems

15.1.1 General simulation model requirements

The simulation models to be supplied on grid energy storage systems shall reproduce the main functionalities and characteristics of the grid energy storage system realistically.

The simulation models shall be delivered either as a model compatible with the calculation software specified by Fingrid or as detailed block diagram level descriptions, with the set values. The models may be substituted with block diagram models and parameter listings generated with other calculation software, provided that the models are compliant with publicly documented standards (IEC or IEEE).

15.1.2 Aggregation of grid energy storage system for the simulation model

The power flow simulation models, fault current simulation models and dynamics simulation models of each grid energy storage system shall be delivered as an entity compiled into a single equivalent grid energy storage system. The model shall cover the grid energy storage system and the transformers needed to connect the grid energy storage system to the power system. The aggregation requirement does not apply to the simulation models of Section 15.1.6 for the simulation of electromagnetic transients.

15.1.3 Requirements concerning power flow and fault current simulation

The power flow simulation model and fault current simulation model shall reproduce, within the voltage and frequency operating range conforming to the Specifications, the impact of the grid energy storage system on the following issues:

1) power flow of the power system, considering potential dependences, for example, between the production power and the voltage of the connection point,

2) voltage profile of the power system, considering the different modes and constraints of voltage control and reactive power as well as potential compensation equipment,

3) fault currents.

15.1.4 Requirements concerning the dynamics simulation of grid energy storage systems

The model intended for dynamics simulation shall reproduce the operation of the grid energy storage system within the voltage and frequency operating range in accordance with the Specifications, taking into account the response and impact of the grid energy storage system on the following issues:

1) changes in the voltage amplitude and in its phase angle in conjunction with electromechanical transients,

2) electromechanical oscillations related to angle stability at frequencies 0.2–2 Hz following small and large signal disturbances,

3) high-speed (10 ms – 10 s) transients related to voltage stability. These shall take into account the operation of the grid energy storage system in conjunction with momentary voltage disturbances, and the dependence of the recovery of active power and the reactive power capacity on voltage.

15.1.5 Requirements concerning the verification and documentation of the modelling data

The data to be delivered for the modelling calculation shall be verified by comparing the modelling data, using the modelling results obtained, to the results of the commissioning testing of the grid energy storage system. The verification obligation of modelling data applies to grid energy storage systems in the scope presented in Tables 15.1 and 15.2.

The data to be delivered for the modelling calculation shall be documented. The documentation shall be delivered as electronic documents to the relevant network operator. The documents to be submitted shall be clear and unambiguous in terms of their layout and structure. The documentation shall cover the following main issues:

1) The components of the grid energy storage system and the electricity network that connects the components
2) A block diagram of active power control and frequency control and the associated parameters
3) A block diagram of voltage control and reactive power control and the associated parameters
4) A block diagram of any other additional grid energy storage system control functions or components and their function if these are relevant in terms of the Specifications
5) Instructions for the use and maintenance of the simulation model
6) Results of verification of modelling data:
    a) report of the verification of the model,
    b) comparison of the modelling results and the results of the commissioning testing in the scope presented in Table 15.1,
    c) measurement results of the commissioning testing in numerical format in the scope presented in Table 15.2 in so far as Table 15.1 obliges verification,
    d) account of potential differences between the modelling results and the results of the commissioning testing.

Table 15.1. Verification obligation of modelling data on grid energy storage systems by type.

Item to be verified	Type C	Type D
Step response of voltage control of the grid energy storage system using two different slope values (both the increase and decrease in voltage)	X	X
Reactive power capacity of the grid energy storage system and the functioning of limiters that restrict the capacity	X	X
Operation of additional control functions, such as POD (Section 13.3)		X
Fault-ride-through test [1]	X	X

[1] To be agreed on a case-by-case basis. If a fault-ride-through test for the grid energy storage system is not carried out, the functioning of the grid energy storage system in a local fault shall be demonstrated by means of simulation calculations.

Table 15.2. Measurement data on commissioning testing to be delivered in numerical format, to which measurement data the results calculated using the modelling data is compared.

Item to be verified	U_{PCC}	P_{PCC}	Q_{PCC}	Signals
Step response of voltage control of the grid energy storage system using two different slope values (both the increase and decrease in voltage)	X	X	X	Voltage setpoint
Reactive power capacity of the grid energy storage system and the functioning of limiters that restrict the capacity	X	X	X	Voltage setpoint
Operation of additional control functions, such as POD (Section 13.3)	X	X	X	To be agreed on a case-by-case basis.
Fault-ride-through test	To be agreed on a case-by-case basis. If a fault-ride-through test for the grid energy storage system is not carried out, the functioning of the grid energy storage system in a local fault shall be demonstrated by means of simulation calculations.			
U_{PCC} Connection point's voltage level P_{PCC} Active power of the grid energy storage system measured at the connection point Q_{PCC} Reactive power of the grid energy storage system measured at the connection point				

15.1.6 Specific study requirements

If conducting the specific studies requires utilising calculation programs applicable to electromagnetic transients, the simulation models of the grid energy storage system used in the simulation shall be delivered to Fingrid as part of the final report of the specific study. The said simulation model shall be updated after the commissioning testing and delivered to Fingrid as part of the final documentation of the grid energy storage system.

15.1.7 Requirements for the simulation models of compensation devices

The simulation models for compensation devices related to the grid energy storage system project shall be agreed upon separately with Fingrid.

16 Appendix A: Compliance process monitoring tables for type D grid energy storage systems

16.1 Stage 1 (Planning)

	Data to be delivered	Data delivered	Data approved	Status of data exchange related to the Specifications	Comments
1	General data			Approved	
2	Technical data			Approved	
3	Operating voltage and frequency range			Approved	
4	Fault-ride-through capability (incl. fault-ride-through calculation)			Approved	
5	Active power control and frequency control			Approved	
6	House load and changes in production power			Approved	
7	Reactive power capacity (incl. reactive power capacity calculation)			Approved	
8	Voltage and reactive power control (incl. voltage control step response calculation)			Approved	
9	Protection settings of the power generating facility and impact on power quality			Approved	
10	Data required for dynamic modelling			Approved	
11	Real-time measurement data and instrumentation			Approved	
12	Specific study requirements			Approved	
13	Grid energy storage system project's schedule and commissioning			Approved	
14	Statement of compliance			Approved	
Status of stage 1			Approved		

16.2 Stage 2 (Commissioning and compliance)

	Data to be delivered	Data delivered	Data approved	Status of data exchange related to the Specifications	Comments
1	Further specifications to the data presented in stage 1			In progress	
2	Data related to commissioning tests			In progress	
3	Results of commissioning tests			In progress	
4	Verified modelling data			In progress	
5	Final controller setting values			In progress	
6	Final protection setting values			In progress	
7	Statement of compliance			In progress	
Status of stage 2			In progress		

16.3 Stage 2: Comprehensive commissioning testing – grid energy storage system

Commissioning test		Availability of functionality has been verified	Operation in accordance with the Specifications has been verified	Status	Comments
1	Limited frequency sensitive mode — overfrequency – (LFSM-O)			Unverified	
2	Limited frequency sensitive mode — underfrequency – (LFSM-U)			Unverified	
3	Frequency sensitive mode			Unverified	
4	Rate of change of active power			Unverified	
5	Constant voltage control			Unverified	
6	Constant reactive power control			Unverified	
7	Constant power factor control			Unverified	
8	Reactive power capacity test and restriction of active power			Unverified	
9	Starting and stopping			Unverified	
10	Fault-ride-through capability			Unverified	
Status of Stage 2 commissioning tests			Unverified		

16.4 Stage 3 (Review and approval):

SJV2019 subset	Action started	Action performed in an accepted manner	Status	Comments
Energisation operational notification (EON)			Approved	
Stage 1			Approved	
Interim operational notification (ION)			Approved	
Stage 2			Approved	
Stage 3			Approved	
Final operational notification (FON)			Approved	
Compliance verification		Approved		