# Electricity Storage Modules compliance verification

## Electricity Storage Modules type A, B, C and D according to Netcode elektriciteit

Version 2.0
Valid from 1 April 2024

Netbeheer Nederland

# Release notes

Version 1.0

Valid from 1 April 2022.

New in Version 1.1

Valid from 15 April 2023.
Paragraph 3.1 ESM type definition

- Correction of the type identification diagram.

New in Version 2.0

Valid from 1 April 2024.
Paragraph 2.2 Definitions:

- Definition of Connection capacity added

Paragraph 3.2 RFG Operational Notification Procedure

- Added that a preliminary ESMD has to be submitted at least 3 resp. 6 month before completion and final test, excluding test results and the final PGMD to be submitted within 6 months after the preliminary PGMD

Paragraph 3.7 Simulation models

- added requirements for storage unit and controller RMS and EMT simulation models

Paragraph 4.1 ESM Compliance

- Added on site testing required for ESM of 5 MW and above
- Deletion LFSM-O/U simulations for Type B when unit certificates and park controller certificates are available

# Contents

# 1. Scope

This document describes the Compliance Verification Procedure for connection of new Electricity Storage Modules according to the connection requirements set in Netcode elektriciteit, available in the Dutch language only. All references in the English language are unofficial translations of the official Dutch texts in order to be consistent with this document.

# 2. Definitions

## 2.1 Abbreviations

The following list of abbreviations gives an overview of the most common abbreviations in this document. For further explanation of terminology used, we refer to the relevant EU regulations and Netcode elektriciteit.

| Abbreviation | Description |
|---|---|
| ATO | Aansluit- en Transportovereenkomst – Connection Agreement |
| CNC | Connection Network Code |
| DSO | Distribution System Operator |
| CDSO | Closed Distribution System Operator |
| DR | Demand Response |
| EqC | Equipment Certificate |
| ESM | Electricity Storage Module |
| ESFO | Electricity Storage Facility Owner |
| ESMD | Electricity Storage Module Document |
| EON | Energisation Operational Notification |
| ION | Interim Operational Notification |
| FON | Final Operational Notification |
| LON | Limited Operational Notification |
| NC RfG | Network Code for Requirements for Grid Connection Applicable to all Generators |
| PGM | Power-Generating Module |
| GU | Generating Unit |
| SU | Storage Unit |
| PPM | Power Park Module |
| RSO | Relevant System Operator |
| SPGM | Synchronous Power Generating Module |
| TSO | Transmission System Operator |

## 2.2 Definitions

The following list of definitions gives an overview of the most common terms in this document. For further explanation of terminology used, we refer to the relevant regulations and codes. Definitions from European Network Codes:

- **Connection agreement:** a contract between the relevant system operator and either the power-generating facility owner, demand facility owner, distribution system operator or HVDC system owner, which includes the relevant site and specific technical requirements for the power-generating facility, demand facility, distribution system, distribution system connection or HVDC system; in this document, the definition of connection agreement applies mutatis mutandis to an agreement between the relevant system operator and the owner of a storage system.
- **Connection Point:** the interface at which the Power-Generating Module, demand facility, distribution system or HVDC system is connected to a transmission system, offshore network, distribution system, including closed distribution systems, or HVDC system, as identified in the connection agreement; in this document, the definition of connection point applies mutatis mutandis to a storage system;
- **Connection Capacity: the transmission capacity of the connection as stated in the Connection Agreement**
- **Energisation Operational Notification (EON)**: a notification issued by the relevant system operator to a power-generating facility owner, demand facility owner, distribution system operator or HVDC system owner prior to energisation of its internal network; in this document, the definition applies mutatis mutandis to a storage system.
- **Interim Operational Notification (ION)**: a notification issued by the relevant system operator to a power-generating facility owner, demand facility owner, distribution system operator or HVDC system owner which allows them to operate respectively a power-generating module, demand facility, distribution system or HVDC system by using the grid connection for a limited period of time and to initiate compliance tests to ensure compliance with the relevant specifications and requirements; in this document, the definition applies mutatis mutandis to a storage system.
- **Final Operational Notification (FON)**: a notification issued by the relevant system operator to a power-generating facility owner, demand facility owner, distribution system operator or HVDC system owner who complies with the relevant specifications and requirements, allowing them to operate respectively a power- generating module, demand facility, distribution system or HVDC system by using the grid connection; in this document, the definition applies mutatis mutandis to a storage system.
- **Limited Operational Notification (LON)**: a notification issued by the relevant system operator to a power- generating facility owner, demand facility owner, distribution system operator or HVDC system owner who had previously attained FON status but is temporarily subject to either a significant modification or loss of capability resulting in non-compliance with the relevant specifications and requirements; in this document, the definition applies mutatis mutandis to a storage system.
- **Installation document:** means a simple structured document containing information about a type A Power-Generating Module or a demand unit, with demand response connected below 1000V, and confirming its compliance with the specified requirements; in this document, the definition applies mutatis mutandis to a storage system.
- **Main Generating Plant:** one or more of the principal items of equipment required to convert the primary source of energy into electricity;
- **Maximum Capacity ($P_{max}$):** the maximum continuous active power which a Power-Generating Module can produce, less any demand associated solely with facilitating the operation of that Power-Generating Module and not fed into the network as specified in the connection

agreement or as agreed between the relevant system operator and the Power-Generating Facility Owner; in this document, the definition applies mutatis mutandis to a storage system

- **Power-Generating Module (PGM):** either a synchronous Power-Generating Module or a Power Park Module.
- **Synchronous Power-Generating Module (SPGM):** an indivisible set of installations which can generate electrical energy such that the frequency of the generated voltage, the generator speed and the frequency of network voltage are in a constant ratio and thus in synchronism.
- **Power Park Module (PPM):** a unit or ensemble of units generating electricity, which is either non-synchronously connected to the network or connected through power electronics, and that also has a single Connection Point to a transmission system, distribution system including closed distribution system or HVDC system.
- **Power-Generating Facility:** a facility that converts primary energy into electrical energy and which consists of one or more Power-Generating Modules connected to a network at one or more Connection Points.
- **Relevant TSO:** the TSO in whose control area a Power-Generating Module, a demand facility, a distribution system or a HVDC system is or will be connected to the network at any voltage level; in The Netherlands the relevant TSO is TenneT.
- **Relevant System Operator (RSO):** the transmission system operator or distribution system operator to whose system a Power-Generating Module, demand facility, distribution system or HVDC system is or will be connected.
- **Statement of compliance:** means a document provided by the Power-Generating Facility Owner, demand facility owner, distribution system operator or HVDC system owner to the system operator stating the current status of compliance with the relevant specifications and requirements; in this document, the definition applies mutatis mutandis to a storage system.

Other definitions and clarifications used in this document:

- **Electricity Storage Module (ESM)[1]:** means a power generating module which can inject and consume active power to and from the network.
- **Electricity storage:** means the conversion of electrical energy into a form of energy which can be stored, the storing of that energy, and the subsequent reconversion of that energy back into electrical energy.
- **Electricity Storage Facility Owner (ESFO):** a natural or legal entity owning a Electricity Storage Module.
- **Electricity Storage Facility (ESF):** means a facility that extracts electrical energy from an electric power system, stores this energy internally in some manner and injects electrical energy into an electrical power system and which consists of one or more electricity storage modules, connected to a network at one or more connection points.
- **S-ESM:** an electricity storage module connected to a network by a synchronous generator.
- **N-ESM:** an electricity storage module connected to a network by a non-synchronous generator or through power electronics.
- **Electricity Storage Module Document (ESMD):** a document provided by the Electricity Storage Facility Owner to the relevant system operator for a type B or C Electricity Storage Module which confirms that the electricity storage modules's compliance with the technical criteria set out in this Regulation has been demonstrated and provides the necessary data and statements, including a statement of compliance.

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[1] The definitions of Electricity Storage Module and Electricity storage do not refer to related definitions from the Article 2 of EU Directive (EU) 2019/944. Instead, these definitions refer to the PHASE II FINAL REPORT of Storage Expert Group established by Grid Connection European Stakeholder Committee. The final report is published in 2020 and can be found here: https://www.entsoe.eu/network_codes/cnc/expert-groups/.

- **Connected party:** either a power-generating facility owner, energy storage facility owner, demand facility owner, distribution system operator or HVDC system owner; in this document, the definition applies mutatis mutandis to a storage system.
- **Generating Unit (GU):** an individual unit of a Power Park Module converting energy into electricity, e.g. a single wind turbine or one or more inverters with solar panels.
- **Storage Unit (SU):** an individual unit of a N-ESM.

# 3. Operational Notification Procedure for New Electricity Storage Modules

## 3.1 ESM type definition

The connection requirements for an electricity storage facility are considered to be the same as those on power generation facilities unless explicitly stated otherwise in this document, as prescribed in Netcode elektriciteit, article 2.16, paragraph 3(a). An electricity storage facility consists of one or more electricity storage modules, connected to a network at one or more connection points.
An electricity storage module connected to a network by a synchronous generator (S-ESM) has to meet the same requirements as a synchronous power generating module and an electricity storage module connected to a network by a non-synchronous generator or through power electronics (N-ESM) has to meet the same requirements as a power park module (figure 1.1). In the case of electrical equipment such as synchronous compensators, flywheels and regenerative braking systems which do not fall onto the definition of a power generating module or electricity storage module, it is down to the relevant TSO to define the technical requirements that apply. [2] The definition of electricity storage modules excludes pump-storage power generating modules. The connection requirements for pump-storage power generating modules are defined separately in Commission Regulation (EU) 2016/631 (NC RfG).
In case of combined systems, where behind one connection point there is, for example, an electricity storage module and wind or solar park, the type identification and applicable requirements will be determined for a ESM separately from a PGM.

In case that an ESM provides demand response services while in consumption mode, it has to additionally meet the connection requirements as required for a demand unit providing demand response services as prescribed in Netcode electriciteit, article 2.16 paragraph 3(c).
According to EU regulation 2017/2196 (NC ER), prior to the activation of the automatic low frequency demand disconnection (LFDD) scheme, each TSO and DSO identified pursuant to Article 11(4) shall foresee that energy storage units acting as load connected to its system:

- automatically switch to generation mode within the time limit and at an active power set-point established by the TSO in the system defence plan; or
- when the energy storage unit is not capable of switching within the time limit established by the TSO in the system defence plan, automatically disconnect the energy storage unit acting as load

[2] The PHASE II FINAL REPORT of Storage Expert Group established by Grid Connection European Stakeholder Committee. https://www.entsoe.eu/network_codes/cnc/expert-groups/.

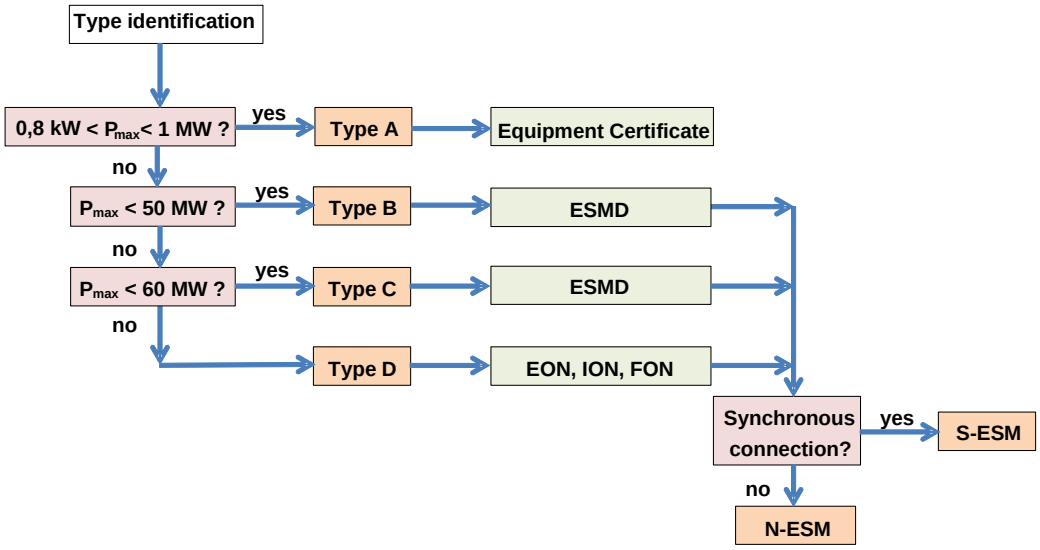



*Figure 1.1 ESM Type identification*

## 3.2 Operational Notification Procedure

This paragraph sets out the requirements for new electricity storage modules to demonstrate their compliance with the detailed technical specifications, as part of their connection process. The operational notification process sets out the steps through which demonstration of these requirements can be achieved including steady state and dynamic performance.

The significance of electricity storage modules should be based on their size and their effect on the overall system. Synchronous electricity storage modules (S-ESMs) should be classed on the machine size and include all the components of the electricity storage facility that normally run indivisibly. Non-synchronous electricity storage modules (N-ESMs) should be assessed on the aggregated capacity of all storage units, where they are collected together to form one economic unit and where they have a single connection point.

According to Netcode elektriciteit, article 2.16, clause 3a, Netcode elektriciteit chapter 3 applies mutatis mutandis to an energy storage facility, with the understanding that the energy storage module with a maximum capacity:

- greater than or equal to 0.8 kW and less than 1 MW complies with the requirements applicable to a type A power generating module;
- greater than or equal to 1 MW and less than 50 MW complies with the requirements applicable to a type B power generating module;
- greater than or equal to 50 MW and less than 60 MW complies with the requirements applicable to a type C power generating module;
- greater than or equal to 60 MW complies with the requirements applicable to a type D power generating module;

**Operational notification procedure for ESM Type A**

For each Electricity Storage Module the Electricity Storage Facility Owner (ESFO) provides an installation document to the RSO, see paragraph 3.3. Any equipment forming part of the installation is to be covered by Equipment Certificates (EqCs) issued by an authorised certifier.

**Operational notification procedure for ESM Type B, C**

An Electricity Storage Module Document (ESMD) is to be provided by the Facility Owner (ESFO) to the Relevant System Operator (RSO) for each electricity storage module, including a statement of compliance. The ESMD contains the information that demonstrates compliance with the technical criteria. It shall include test reports and simulation studies reports. The tests are described in RfG chapters 2-3 of title IV and they include use of actual measured values during testing. The simulation studies are described in RfG[3] chapters 5-6 of title IV and they demonstrate steady state and dynamic performance. The test and simulation reports shall include the test and simulation results as required to absorb and release electrical energy and as further stipulated in chapter 4 of this document.

The ESFO of an ESM type B can, instead of conducting tests, prove compliance with the relevant requirements by means of calculations, based on the, by certificates or test reports, proven properties of the applied components and/or storage units. If an ESM controller is applied, the proper functioning of the park controller in combination with the applied storage units shall be demonstrated.

Procedure

The ESMD is published on the website of Netbeheer Nederland: https://www.netbeheernederland.nl/dossiers/regulering-20/documenten.

For each electricity storage module within the Electricity Storage Facility, the Electricity Storage Facility Owner (ESFO) provides a separate independent ESMD to the relevant system operator (RSO), containing the following documents and reports:

- Evidence of an agreement on the protection and control settings relevant to the Connection Point;
- Itemised statement of compliance;
- Detailed technical data of the ESM as specified by chapter 13 of the Netcode elektriciteit;
- Equipment certificates;
- For Type C electricity storage modules, simulation models (see paragraph 3.7);
- Compliance test reports demonstrating steady-state and dynamic performance;
- Studies demonstrating steady-state and dynamic performance.

Additional information:

- Signed connection agreement (ATO);
- Protection and settings document (co-ordination with RSO substation protection, see also Netcode elektriciteit article 2.37);
- Signal exchange list (agreed between RSO and ESFO);
- Report providing the power quality compliance (according to IEC 61400-21-1:2019);
- For type C: Conformity that power quality measurements can and will be performed during the commissioning;
- Actual planning information (all relevant planning of notification process information shall be delivered by the ESFO);
- An overall testing and commissioning plan.

[3] Commission Regulation (EU) 2016/631, Requirements for Generators, https://www.entsoe.eu/network_codes/rfg/

Planning

- The ESFO requests connection for an ESM type B or C; this can be on a new connection point or on an existing connection point;
- The RSO checks the network capacity;
- The RSO sends links to ESMD and Electricity Storage Modules compliance verification document to the ESFO;
- The RSO informs the ESFO of the relevant network data; the ESFO needs this data to prepare the tests and execute the simulations;
- The ESFO hands over the detailed technical data, as specified in the ESMD;
- The ESFO hands over a protection and settings document, as specified in the ESMD, a signal exchange list and an overall testing and commissioning plan;
- The ESFO hands over the available Equipment Certificates as soon as possible;
- The ESFO hands over the results of the simulation studies as soon as possible;
- The RSO issues a notification to energise the substation and to connect the electrical storage facility for the purpose of construction and testing activities;
- The ESFO hands over the actual planning information and the overall testing and commissioning plan;
- For type C: the ESFO hands over the conformity that power quality measurements can and will be performed during the commissioning;
- Commissioning of the Storage Units of the ESM and the possible plant controller;
- Execution of required tests, as specified in chapter 4;
- Within a period of two months after energising of the substation and at least three months for ESM <5 MW and at least 6 months for ESM ≥ 5 MW before the desired completion date of the ESM, the PGFO shall submit a preliminary ESMD, accompanied with the preliminary statement of compliance, including reports of test procedures and simulation results;
- Within a period of 6 months after the preliminary ESMD, the PGFO shall submit the final ESMD, accompanied with the final statement of compliance, including reports with results of tests and simulation results
- Within a maximum of two months after receiving the statement of compliance of the Electricity Storage Facility Owner (ESFO), the RSO will respond;
- If the assessment of the statement of compliance is positive, the RSO will accept the ESMD;
- On acceptance of the complete and adequate ESMD, the RSO issues a final operational notification to the Electricity Storage Facility Owner
- If the RSO does not accept the ESMD, he will send the ESFO the reason for refusal, after which the ESFO will have the option to submit a new version of the ESMD within two months.

**Operational notification procedure for ESM type D**

For type D the process is more extensive due to their scale and potential impact on the system, the extent of the services and technical capabilities that they should be able to provide or demonstrate, and their capability to engage in more detailed testing. The tests shall be carried out on the complete ESM describing its behaviour at the Connection Point, supplemented with type tests on single Storage units if applicable or components. If a test cannot be carried out at the Connection Point, e.g., if the function does not exist at ESM control level, the on-site test shall be carried out for a representative sample of each SU type to be installed in the ESM. Alternatively, a single Storage unit shall be tested and the concerning parameters of all other individual units shall be checked.

Figure 1.2 illustrates the connection and commissioning process for a type D ESM. The steps are explained in the following paragraphs. Part of the process is the execution of tests and simulations. The relevant system operator may participate in the compliance testing.

Instead of carrying out the relevant tests or simulations, Electricity Storage Facility Owners may rely upon equipment certificates issued by an authorised certifier as part of evidence to demonstrate compliance with the relevant requirements. In such a case, the equipment certificates shall be provided to the relevant system operator, including the Non-Disclosure Agreement (NDA) if needed.

Network connection examination

In the case of grid connection of an ESM, the ESFO and the RSO must exchange data in advance. The ESFO specifies the grid connection planning to the Connection Point determined in the course of the rough planning and informs the RSO of the relevant data of the ESM. The RSO needs this "best available" data to include it in the base network model in order to execute preliminary simulations. Thereupon, the RSO informs the ESFO of the relevant network data. The ESFO needs this data to prepare the tests and simulations.

- *Energisation operational notification (EON)*
  An EON entitles the facility owner to energise their equipment using their connection but not to generate and is subject to the agreement with the RSO of protection and control settings.
- *Interim operational notification (ION)*
  An ION entitles the facility owner to operate their Electricity Storage Module and to generate for a limited period of time – which is to be specified by the RSO but will be no more than 24 months. Issue of an ION is subject to completion of the data and study review as specified/requested by the RSO including simulation models and studies demonstrating steady state and dynamic performance and details of the intended compliance tests. Tests may be substituted by the provision of Equipment Certificates (EqCs). Simulations can be based on validated equipment models provided by the EqCs. See RfG Article 35.
- *Final operational notification (FON)*
  A FON signifies the completion of the operational notification process and allows the Electricity Storage Facility Owner to operate an Electricity Storage Module using their grid connection.
- *Limited Operational Notification (LON)*
  A type D electricity storage module holding a FON must inform the RSO with whom they hold a connection agreement in the case that their equipment is affected by a temporary loss of capability, is subject to significant modification affecting performance, or is affected by equipment failure affecting performance, in each case where this is expected to last for more than 3 months.

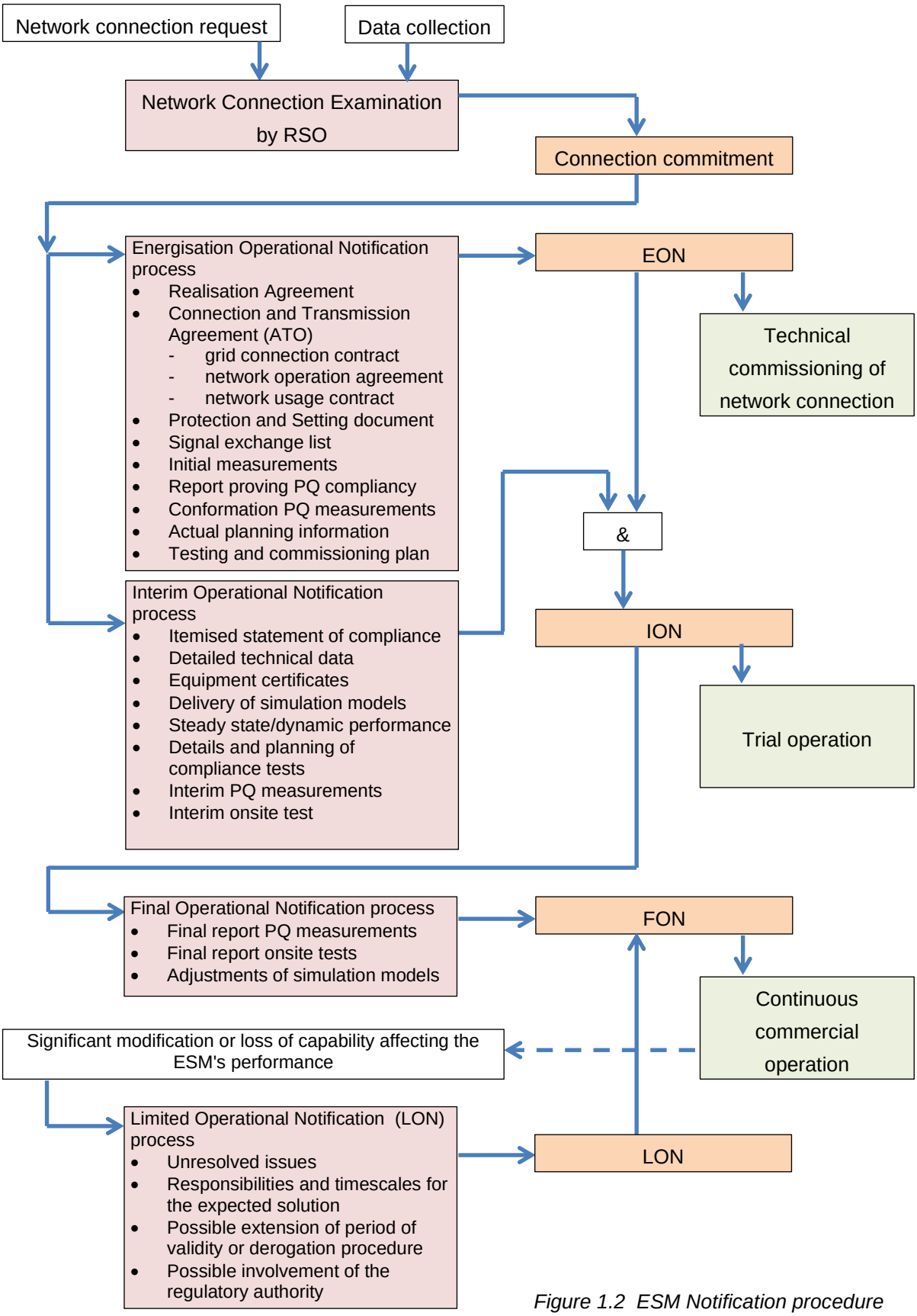



*Figure 1.2 ESM Notification procedure*

*Energisation operational notification (EON)*

An EON entitles the facility owner to energise their equipment using their connection but not to generate and is subject to the agreement with the RSO of protection and control settings.

Procedure

The Electricity Storage Facility Owner (ESFO) shall submit a Statement of Compliance to the RSO for issuing an EON. This Statement of Compliance refers to the following documents and reports, all approved by the RSO:

- Realisation Agreement;
- Signed Connection Agreement (ATO: Aansluit- en transportovereenkomst):
    - grid connection contract;
    - network operation agreement;
    - network usage contract;
- Protection and settings document;
- Signal exchange list;
- Initial measurements (power quality) (measurements to be performed after EON is granted and a measuring device shall be in operation one week before energisation of a connection);
- Report providing the power quality compliance;
- Confirmation that power quality measurements can and will be performed during the commissioning;
- Actual planning information;
- Overall testing and commissioning plan, including:
    - Planning of personnel;
    - Contact details of responsible commissioning manager and authorised personnel;
    - Planning of active- and reactive power exchanged till first Storage unit.

Planning

- At least 16 months before the date of granting the EON, the ESFO requests the necessary information for the harmonic analysis, after which the RSO makes the required information available to the ESFO as quickly as possible;
- A period of minimum 10 months before the date of granting the EON shall be scheduled for review, discussion and approval by the RSO of the report regarding the power quality compliancy;
- Within a maximum of four weeks after receiving the Statement of Compliance of the Electricity Storage Facility Owner (ESFO), the RSO will respond. If the assessment of the Statement of Compliance is positive an EON will be granted by the RSO;
- The ESFO shall have an EON at least one month before the energization of the connection.

*Interim operational notification (ION)*

ION entitles the facility owner to operate their Electricity Storage Module and to generate for a limited period of time – which is to be specified by the RSO but will be no more than 24 months (an extension of this period may be granted if a request for derogation is made to the RSO before the expiry of that period in accordance with the derogation procedure laid down in RfG article 60). Issue of an ION is subject to completion of the data and study review as specified/requested by the RSO including simulation models and studies demonstrating steady state and dynamic performance as described by RfG chapters 5-7 of title IV, and details of the intended compliance tests as described by RfG chapters 2-4 of title IV. After receiving the ION the compliance tests can be executed. Tests may to some extend be substituted by the provision of EqCs. Simulations can be based on validated equipment models provided by the EqCs.

Procedure
The Electricity Storage Facility Owner (ESFO) shall submit a statement of compliance to the RSO for issuing an ION. This statement of compliance refers to the following documents and report, all approved by the RSO:

- An EON;
- Itemised Statement of Compliance;
- Detailed technical data on the Storage units and the Electricity Storage Module;
- Equipment certificates in respect of Electricity Storage Modules, where they are relied upon as part of the evidence of compliance;
- Simulation models, as required by the RSO;
- Simulation studies demonstrating the expected steady-state and dynamic performance as required by RfG Chapter 5, 6 or 7 of Title IV;
- Details and planning of compliance tests in accordance with RfG Chapters 2, 3 and 4 of Title IV and approved by the RSO;
- Confirmed parameter settings of active power control and voltage control as stated in the connection agreement;
- Interim power quality measurements (measurements to be performed after ION is granted and before interim operation starts);
- Interim voltage test procedure.

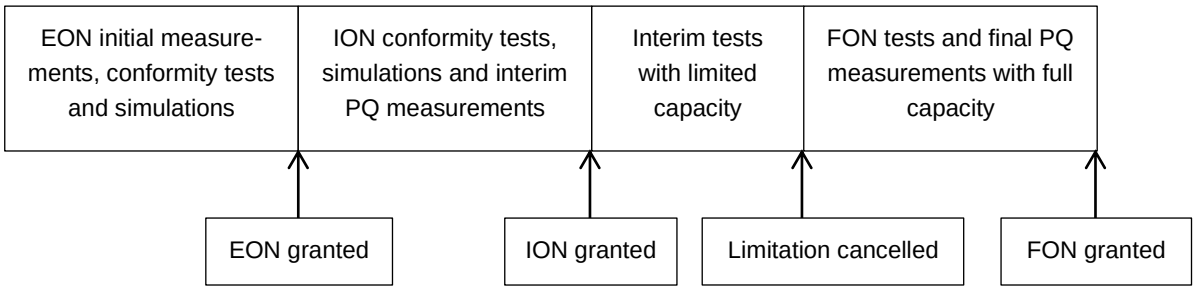
Planning

- Within a maximum of four weeks after receiving the statement of compliance of the Electricity Storage Facility Owner (ESFO), the RSO will respond. If the assessment of compliance is positive an ION will be granted by the RSO;
- The ESFO shall have an ION at least one month before taking the first Storage Unit in operation;
- After receiving the ION the compliance tests can be executed.

*Final operational notification (FON)*
A FON signifies the completion of the operational notification process and allows the Electricity Storage Facility Owner to operate an Electricity Storage Module using their grid connection.
To progress a FON the facility owner has to have an ION. Completion of the FON is subject to completion of any outstanding requirements set out in the ION and must include submission, by the facility owner, of an itemized statement of compliance and an update of the technical data, studies and models provided as part of the ION but now also validated and using actual values found through testing.

In case of an N-ESM, the Interim Operational Notification (ION) gives the right to produce with a limited amount of Storage units simultaneously in operation in such a way that the maximum actual output of the N-ESM does not exceed 20% of the final maximum capacity of the N-ESM.

- If the Electricity Storage Facility Owner (ESFO) has completed all the interim tests and measurements with the first Storage Units to reasonable satisfaction of the RSO, the mentioned power output limitation is cancelled.
- Following successful completion of this test each additional Storage Unit should be included in the voltage control scheme as soon as it is technically possible (unless the RSO agrees otherwise).
- The interim tests can be skipped in case the expected building-time between 20% of full capacity and full capacity is less than one week. In that case the FON-tests will be applied only. In case the mentioned building-time appeared to be more than one week the interim tests can still be ordered by the relevant RSO.




In general, the ESFO must have a FON no later than four months after reaching the full installed ESM capacity. FON-tests in particular require a minimum output power of 60 % of the maximum capacity.

Part of the FON should be an agreement between RSO and facility owner, how compliance will be monitored over the life time of the storage module, taking into account possible changes in controller software, hardware and also changes in the Connection Point characteristics like short circuit power and frequency impedance characteristics. This agreement will be initiated by the RSO and can be assured by a continuous compliance monitoring.

Procedure:
The Electricity Storage Facility Owner (ESFO) shall submit a statement of compliance to the RSO for issuing a FON. This statement of compliance refers to the following documents and reports:

- An ION;
- Final report on power quality measurements approved by the RSO;
- Final report full on-site tests approved by the RSO;
- Simulation models, validated against test results (as built);
- Motivation and/or re-simulations approved by the RSO, as result of as built values.

Planning

- Within a maximum of four weeks after receiving the statement of compliance of the Electricity Storage Facility Owner (ESFO), the RSO will respond. If the assessment of compliance is positive a FON will be granted by the RSO;
- The ESFO shall ensure that he has a FON no later than four months after reaching full installed ESM capacity.

*Limited Operational Notification (LON)*
A type D ESM/ESFO holding a FON must inform the RSO with whom they hold a connection agreement immediately in the case that their equipment is affected by a temporary loss of capability, is subject to significant modification affecting performance, or is affected by equipment failure affecting performance. A LON shall be granted in each case where this is expected to last for more than 3 months (RfG Article 37(2)). Issue of a LON by the RSO should be subject to identification of the means and timescales by which the non-compliance will be resolved and can last for a maximum of 12 months without requiring a further derogation. A further expansion of the period of validity of the LON may be granted upon a request for a derogation made by the RSO before the expiry of that period, in accordance with the derogation described in RfG Title V.

Consequences in case a notification cannot be granted in time

In order to maintain system stability the RSO is entitled to:

- Refuse energizing of the connection in case an EON cannot be granted a minimum of one month before energization of the connection;
- Refuse generating mode in case an ION cannot be granted a minimum of one month before connection of the first Storage unit;
- Order to limit generating mode to 20% of the Maximum Capacity of the N-ESM and S-ESM in case all the interim tests and measurements, mentioned in the ION paragraph have not been completed to reasonable satisfaction of the RSO;
- Order to stop generating mode in case a FON cannot be granted a minimum of four months after reaching full commissioned Electricity Storage Module capacity and the ION has been expired.

## Operational notification procedure for electricity storage modules that additionally provide demand response services to system operators

Demand response services provided to system operators can be remotely or autonomously controlled. If remotely controlled, the demand response can be on active power control, on reactive power control or on transmission constraint management. If autonomously controlled, the demand response can be on system frequency control or on very fast active power control. As required by Netcode elektriciteit, article 2.16, clause 3(c), the relevant articles of NC DCC and of Netcode elektriciteit, paragraph 4.2 apply mutatis mutandis to Electricity Storage Modules that provide demand response.

NC DCC Article 2 defines the following:

16. demand response active power control: demand within a demand facility or closed distribution system that is available for modulation by the relevant system operator or relevant TSO, which results in an active power modification;
17. demand response reactive power control: reactive power or reactive power compensation devices in a demand facility or closed distribution system that are available for modulation by the relevant system operator or relevant TSO;
18. demand response transmission constraint management: demand within a demand facility or closed distribution system that is available for modulation by the relevant system operator or relevant TSO to manage transmission constraints within the system;
20. demand response system frequency control: demand within a demand facility or closed distribution system that is available for reduction or increase in response to frequency fluctuations, made by an autonomous response from the demand facility or closed distribution system to diminish these fluctuations;
21. demand response very fast active power control: demand within a demand facility or closed distribution system that can be modulated very fast in response to a frequency deviation, which results in a very fast active power modification

Each electricity storage module that provides demand response, to which one or more requirements in NC DCC Title III (articles 27-30) apply mutatis mutandis, according to Netcode electriciteit, article 2.16, shall confirm to the RSOs its ability to satisfy these following an operational notification procedure. The operational notification procedure shall be distinguished between the electricity storage modules connected at a voltage level

- of or below 1000 V
- above 1000 V.

The operational notification procedure for an electricity storage module connected at a voltage level of or below 1000 V shall comprise an installation document.

The operational notification procedure for an electricity storage module providing demand services connected at a voltage level above 1000 V shall be included in ESMD ( "DCC compliance verification by testing and simulating" document requires that this procedure shall comprise a demand response unit document, DRUD. For electricity storage module type B and C, it will be part of ESMD). The ESMD shall include a statement of compliance which contains the information in NC DCC Articles 36 to 47. Based on the ESMD, the relevant system operator shall issue a FON to the electricity storage facility owner.

## 3.3 Type A documents

The operational notification procedure for connection of each new type A electricity storage module consists of submitting an installation document. The contents of the installation document are specified by the RSO. The contents are:

- the location at which the connection is made;
- the EAN code
- the date of the connection;
- manufacturer and type-identification;
- the Maximum Capacity of the installation in kW;
- Maximum electricity storage capacity (kWh);
- reference to equipment certificates issued by an authorised certifier used for equipment that is in the site installation;
- as regards equipment used, for which an equipment certificate has not been received, information shall be provided as directed by the relevant system operator;
- the contact details of the Electricity Storage Facility Owner and the installer and their signatures.
- in the case that the ESM provides demand response service:
    - the maximum capacity of the demand response installation in kW;
    - the type of demand response services;
    - the demand unit certificate and the equipment certificate as relevant for the demand response service, or if not available, equivalent information;
    - the contact details of the electricity storage facility owner or the third party aggregating the electricity storage modules.

The installation document refers to equipment certificates. The Electricity Storage Facility Owner may rely upon equipment certificates. The equipment certificates describe the extent to which the relevant requirements are met.

## 3.4 Type B – D main documents

For ESM type D and, as applicable, for types B and C, the Electricity Storage Facility Owner (ESFO) shall hand over to the RSO:

- Results and details of physical tests
- Results and details of simulations
- Technical data
- Statement of compliance

- Actual planning of:
    - Energisation, First Storage Unit (in case of a N-ESM), 20% of the Maximum Capacity of the N-ESM, and full capacity
    - In case of type B or C ESM: Delivery of statement of compliance ESMD
    - In case of type D ESM: Delivery of statement of compliance EON, ION and FON
    - Delivery of documents on compliancy tests and simulations
    - Onsite tests

In case of type B or C ESM: From RSO to Electricity Storage Facility Owner (ESFO)

- Reviews of simulations and test results (ESMD)
- Declaration of acceptance of the ESMD (RfG Article 32(3)).

In case of type D ESM: From the RSO to Electricity Storage Facility Owner (ESFO)

- Reviews of simulations and test results
- Energization operational notification (EON)
- Interim operational notification (ION)
- Final operational notification (FON).

## 3.5 Type B – D technical data

The relevant system operator will request that the Electricity Storage Facility Owner provides all detailed technical data of the Electricity Storage Module with relevance to the grid connection as specified by the relevant system operator, as described in chapter 13 of the Netcode elektriciteit.

## 3.6 Type B – D test reports

Type tests may be performed either by an independent test institute, by the ESFO or by the manufacturer. If the type tests are performed by the ESFO or the manufacturer, they need to be witnessed and approved by an independent test institute.

In case of a type test, a report (hereafter called ‘Storage unit test report’) shall cover information from type tests according to FGW TG3-2018 Rv. 25, as well as information on additional tests and information, if required by the RSO. In detail the ‘Storage unit test report' shall include:

- Reactive power capability including PQ and PV diagrams based on measurements;
- Report on fault-ride-through capability according to the requirements including measurements;
- Report on fast fault current injection tests for an N-ESM Storage unit;
- Test reports for operation during:
    - Over and under frequency (RfG article 13(1) and Netcode elektriciteit article 3.13 sub 1)
    - Over and under voltage according to Netcode elektriciteit 3.15, sub 9 (ESM with voltage higher than 1 kV and lower than 110 kV), RfG article 16(2) and Netcode elektriciteit 3.28, sub 1 (ESM type D).
- Power quality conformity test measurements:
    - Nederlandse praktijkrichtlijn NPR-IEC/TR 61000-3-6:2008 (en) Electromagnetic compatibility (EMC) – Part 3-6: Limits – Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems;

- IEC TR 61000-2-6:1995 Electromagnetic compatibility (EMC) - Part 2: Environment - Section 6: Assessment of the emission levels in the power supply of industrial plants as regards low-frequency conducted disturbances;
- Nederlandse praktijkrichtlijn NPR-IEC/TR 61000-3-7:2008 (en) Electromagnetic compatibility (EMC) – Part 3-7: Limits – Assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems;
- NEN-EN-IEC 61400-21-1:2019 (en) Wind energy generation systems – Part 21-1: Measurement and assessment of electrical characteristics – Wind turbines, paragraph 8.2: Power quality aspects;
- NPR-IEC/TR 61400-21-3:2019 (en) Wind energy generation systems - Measurement and assessment of electrical characteristics - Wind turbine harmonic model and its application.

The Storage unit test report also applies to other active components, such as flexible alternating current (FACTS) devices, if these components actively contribute by means of control functions to:

- The fault-ride-through performance at the Connection Point;
- Short and long term operation during over and under frequency as well as over and under voltage.

The ESFO shall submit simulation studies in the form of a report to demonstrate compliance. In all cases the simulation studies must utilise models applicable to the S-ESM or N-ESM with proposed or actual parameter settings. Reports should be submitted in Dutch or English with all diagrams and graphs plotted clearly with legible axes and scaling provided to ensure any variations in plotted values is clear. In all cases the simulation studies must be presented as function of time to demonstrate compliance with all applicable requirements.

## 3.7 Type B – D simulation model

Before granting the EON, the ESFO and the RSO must exchange data in advance. The RSO needs this "best available" data to include it in the base network model in order to execute preliminary simulations. Before granting the ION, the simulation (software) models shall be delivered by the ESFO. Before granting the FON, the simulation models shall be updated with as-built data and validated with test results.

To perform grid stability calculations, information according Netcode elektriciteit article 13.1 and 13.2 shall be delivered for EON/ION, as a result of that:

- For type B ESM:
  - the simulation model should be adequate to simulate the load flow and short-circuit behaviour and the LFSM-O function as referred to in RfG articles 51(2) and 54(2);
  - the simulation model is validated against the compliance test for LFSM-O response;
  - the type of ESM models and reports that need to be delivered for each model will be specified by the relevant RSO.
- For types C or D ESM:
  - Full detail simulation model of the ESM up to the Connection Point, including individual Storage units, transformers, inter-array cabling (in case of a N-ESM), step-up transformer(s), high voltage cables, reactive power compensation equipment (if any), FACTS (if any), and ESM controllers and other active component;
  - For S-ESM:

        - Dynamic simulation models of exciter, governor, power system stabiliser and any other limiters or controls shall be described by means of generic terms and parameters given by IEC and IEEE series
    - For N-ESM:
        - Full detail simulation model of Storage unit and N-ESM controller and any other active component for load flow, short-circuit, harmonic (up to the 50$^{th}$ harmonic order) (only for type D) and dynamic simulations including manual and model controller settings to be applied shall be supplied;
        - Aggregation of Electricity Storage Facility for the simulation model:
            - the power flow simulation models, fault current simulation models and dynamics simulation models of each Electricity Storage Facility shall be delivered as an entity compiled into a minimum number of single equivalent generators;
            - the model shall cover – alongside the equivalent generators – the transformers needed to connect the generators and the Electricity Storage Facility to the power system;
            - this aggregation level should be adequate for the optimal use of the dynamic simulation models for Storage unit controller and ESM controller;
            - the aggregated model shall be described by means of generic terms and parameters given by IEC 61400-27 series;
    - All models shall be delivered in latest versions of both PSS/E and PowerFactory format;
    - Report on validation of simulation models shall be supplied.
    - More specifically, the type of ESM models of type C and D and reports that need to be delivered for each model are shown in the table below. Detail requirements can be found in Annexes: Requirements for RMS Simulation models in the PGM Compliance Verification Document.

| **Models** | **Storage Unit (SU) and controller model** | **Documents/Reports** |
|---|---|---|
| Full detail PowerFactory simulation model (of ESM) | User defined SU and ESM controller model | The dynamic study should be delivered based on this model |
| Full detail PSS/E simulation model (of ESM) | User defined SU and ESM controller model | Benchmarking report of the PSS/E model based on the results of the full detail Powerfactory model for certain study cases (to be agreed with the ESFO) |
| Aggregated PowerFactory simulation model (of ESM) | Generic SU and ESM controller model (IEC models). | Benchmarking report of the Powerfactory aggregated model based on the results of the full detail Powerfactory model for certain study cases (to be agreed with the ESFO) |

| | | |
|---|---|---|
| Aggregated PSS/E simulation model (of ESM) | Generic SU and ESM controller model (WECC models)[4]. | Benchmarking report of the PSS/E aggregated model based on the results of the full detail Powerfactory model for certain study cases (to be agreed with the ESFO) |

Validation of the simulation models is a responsibility of the ESFO. Validation can be done by the ESFO himself or by an external expert (manufacturer, consultant). Model validation of wind energy generation systems is the draft for IEC 61400-27-2. Model validation of other energy driven systems is expected to follow the same procedure.

- For type D ESM: electromagnetic transient (EMT) models should also be delivered. Detail requirements can be found in Annex: Requirements for EMT Simulation models in the PGM Compliance Verification Document.

Evaluation criteria

- Models are delivered as described in this paragraph;
- Models will be checked related to data consistency and correct working in the RSO-grid model context.

[4] Western Electricity Coordinating Council. These generic models are reduced-order, positive-sequence models suitable for transmission planning studies; the link: https://www.wecc.org/Pages/home.aspx

# 4. Grid connection of electricity storage modules

## 4.1 ESM compliance

The compliance monitoring requirements for generators and the demand connections are described in detail in the respective compliance verification documents[5]:

1. "RfG compliance verification by testing and simulating" (RfG CVD) according to the articles following Title IV Compliance specified in EU Regulation 2016/631 (NC RfG)
2. "DCC compliance verification by testing and simulating" (DCC CVD) according to articles following Title IV Compliance specified in EU Regulation 2016/1388 (NC DCC)

As the electricity storage modules operate in generation as mode well as in consumption mode, the selected set of the compliance monitoring requrements explained in aforementioned compliance verification documents that is relevant for ESMs, according to Netcode electriciteit (article 2.16), will be applied here (table 1 and table 2).

*Table 1. The list of compliance monitoring requirements for electricity storage systems*

| Sub-paragraph in RfG CVD | Requirement | S-ESM | | | | N-ESM | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | A | B | C | D |
| 4.2.1 | LFSM-O | x | x | x | x | x | x | x | x |
| | LFSM-U-Storage | x | x | x | x | x | x | x | x |
| 4.2.3 | FSM | | | x | x | | | x | x |
| 4.2.4 | Frequency restoration | | | x | x | | | x | x |
| 4.2.5 | Black start capability | | | x | x | | | | |
| 4.2.6 | Tripping to houseload | | | x | x | | | | |
| 4.2.7 | Frequency range and Voltage range | x | x | x | x | x | x | x | x |
| 4.2.8 | Reactive power capability | | x | x | x | | x | x | x |
| 4.2.9 | Active power controllability | | | | | | | x | x |
| 4.2.10 | Voltage control mode | | | | | | | x | x |
| 4.2.11 | Reactive power control mode | | | | | | | x | x |
| 4.2.12 | Power factor control mode | | | | | | | x | x |
| 4.2.13 | Island operation | | | x | x | | | x | x |
| 4.2.14 | FRT (profiles different B/C and D) | | x | x | x | | x | x | x |
| 4.2.15 | Reconnecting after disconnection | | x | x | x | | x | x | x |
| 4.2.16 | Post fault active power recovery | | x | x | x | | x | x | x |
| 4.2.17 | Power Oscillation Damping Control (POD) | | | | x | | | x | x |
| 4.2.18 | Fast fault current injection | | | | | | x | x | x |
| 4.2.19 | Synthetic inertia | | | | | | | x | x |
| 4.2.20 | Power quality: voltage fluctuations, harmonics | | | | | | | | x |
| 4.2.21 | Insulation coordination | | | | | | | | x |

[5] https://www.netbeheernederland.nl/dossiers/regulering-20/documenten

The following table summarises the requirements against which testing and simulation are to be carried out as described in the RfG code.

| RfG article | Requirement | S-ESM / N-ESM | Testing | | | | Simulations | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Article | Type B | Type C | Type D | Article | Type B | Type C | Type D |
| 13.1 | Frequency range | N-ESM | 1) | x | x | x | | | | |
| 13.2 | LFSM-O | S-ESM | 44.2 | x | x | x | 51.2 | x | x | x |
| 13.2 | LFSM-O | N-ESM | 47.3 | x | x | x | 54.2 | x | x | x |
| CVD ESM | LFSM-U-Storage | S-ESM | para. 4.2.1 | x | x | x | para. 4.2.1 | x | x | x |
| CVD ESM | LFSM-U-Storage | N-ESM | para. 4.2.1 | x | x | x | para. 4.2.1 | x | x | x |
| 15.2.d | FSM | S-ESM | 45.3 | | x | x | 52.3 | | x | x |
| 15.2.d | FSM | N-ESM | 48.4 | | x | x | 55.3 | | x | x |
| 15.2.e | Frequency restoration | S-ESM | 45.4 | | x | x | | | | |
| 15.2.e | Frequency restoration | N-ESM | 48.5 | | x | x | | | | |
| 15.5.a | Black-start capability | S-ESM | 45.5 | | x | x | 1) | | x | x |
| 15.5.c | Tripping to houseload | S-ESM | 45.6 | | x | x | | | | |
| 16.2 | Voltage range | S-ESM | 1) | | | x | | | | |
| 16.2 | Voltage range | N-ESM | 1) | x | x | x | | | | |
| 18.2.b/c | Reactive power capability | S-ESM | 45.7 | x | x | x | 52.5 | x | x | x |
| 21.3.b/c | Reactive power capability | N-ESM | 48.6 | x | x | x | 55.6 | x | x | x |
| 15.2.a | Active power controllability | N-ESM | 48.2 | | x | x | | | | |
| 21.3.d | Voltage control mode (V1-mode and V2-mode) | N-ESM | 48.7 | | x | x | | | | |
| 21.3.d | Reactive power control mode | N-ESM | 48.8 | | x | x | | | | |
| 21.3.d | Power factor control mode | N-ESM | 48.9 | | x | x | | | | |
| 15.5.b | Island operation | S-ESM | | | | | 52.4 | | x | x |
| 15.5.b | Island operation | N-ESM | | | | | 55.4 | | x | x |
| 14.3.a | Fault-Ride-Through type B | S-ESM | | | | | 51.3 | x | | |
| 14.3.a | Fault-Ride-Through type C | S-ESM | | | | | 51.3 | | x | |
| 14.3.a | Fault-Ride-Through type B | N-ESM | 1) | x | | | 54.4 | x | | |
| 14.3.a | Fault-Ride-Through type C | N-ESM | 1) | | x | | 54.4 | | x | |
| 16.3.a | Fault-Ride-Through type D | S-ESM | 1) | | | x | 53.3 | | | x |
| 16.3 | Fault-Ride-Through type D | N-ESM | 1) | | | x | 56.3 | | | x |
| 14.4 | Reconnecting after disconnection | S-ESM | 1) | x | x | x | | | | |
| 14.4 | Reconnecting after disconnection | N-ESM | 1) | x | x | x | | | | |
| 17.3 | Post fault active power recovery | S-ESM | | | | | 51.4 | x | x | x |
| 20.3 | Post fault active power recovery | N-ESM | | | | | 54.5 | x | x | x |
| 19.2 | Power Oscillation Damping Control | S-ESM | | | | | 53.2 | | | x |
| 21.3.f | Power Oscillation Damping Control | N-ESM | | | | | 55.7 | | x | x |
| 20.2.b | Fast fault current injection | N-ESM | 1) | x | x | x | 54.3 | x | x | x |
| 21.2.a | Synthetic inertia | N-ESM | | | | | 55.5 | | x | x |
| NC 2.15 | Power quality: rapid voltage change, flicker emissions, harmonics | N-ESM | 1) | | | x | 1) | | | x |
| NC 2.13 | Insulation coordination | S-ESM | | | | | 1) | | | x |
| NC 2.13 | Insulation coordination | N-ESM | | | | | 1) | | | x |

1) additionally required by RSO

The detail description of tests and/or simulations needed for the requirements listed in Table 1 can be found in Chapter 4 of the document "RfG compliance verification by testing and simulating". Note that the compliance monitoring requirements for S-ESM are equivalent to the respective requirements for SPGM and that the compliance monitoring requirements for N-ESM are equivalent to the respective requirements for PPM. The LFSM-U-Storage requirement and related test and simulation is partially explained in this document (Chapter 4.2).

In the case of an ESM complying with the requirements applicable to a type B power generating module the following simplifications may be applied:

- Tests at site are not mandatory for ESM with Pmax below 5MW. The tests at site that are mandatory for a ESM with Pmax of 5 MW and above are:
    - LFSM-O and LFSM-U-Storage
    - Reactive power capability
    - Reconnection after disconnection
- Regarding fault-ride-through,fast fault current injection and post fault active power recovery: storage units are type tested on these requirements; if for these requirements unit certificates are available for all storage units in the ESM, simulations to prove compliance with these requirements will not be required by the RSO.
- Regarding LFSM-O and LFSM-U: storage units and ESM (park) controller are type tested on these requirements; if for these requirements unit certificates are available for all storage units and the (park) controller in the ESM, simulations to prove compliance with LFSM-O and LFSM-U requirements will not be required by the RSO.

In the case of an ESM complying with the requirements applicable to a type B power generating module of which each Storage Unit is only controlled by an individual Storage Unit controller and not by a park controller, a number of simplifications may be applied:

- Regarding reactive power capability, if for this requirement certificates are available for all storage units and other dynamically active components in the ESM, these may be used together with load flow based network calculations to prove the ESM reactive power capability at the connection point; in that case the on-site test for ESM with Pmax ≥ 5MW will not be required by the RSO;
- Regarding LFSM-O: storage units are type tested on these requirements; if for these requirements unit certificates are available for all storage units in an N-ESM, simulations to prove compliance with these requirements will not be required by the RSO.

The following table summarises the requirements against which testing and simulation are to be carried out as described in the DCC code.

*Table 2. Additional list of compliance monitoring requirements applicable to the electricity storage systems that can provide demand response*

| **Sub-paragraph in DCC Compliance Verification Document** | **NC DCC requirement** | **Requirement to be fulfilled** | **Test/ Simulation** |
|---|---|---|---|
| 4.2.11 | 28.2 | Demand modification | Test |
| 4.2.13 | 30 | Very fast active power control | Sim |

The detail technical description of all tests and simulations needed for the requirements from Table 2 can be found in Chapter 4 of the document "DCC compliance verification by testing and simulating".

In addition to the requirements mentioned in Table 1 and Table 2, the new electricity storage modules shall demonstrate the compliance to the requirements prescribed in Article 2.16 sub 3 (b), sub 3 (c), sub 3 (d), sub 3 (e) of the Netcode electriciteit.

## 4.2 Compliance testing and simulation for ESM

### 4.2.1 Requirement: LFSM-U-Storage

Applicable to:

| S-ESM | N-ESM | Type A | Type B | Type C | Type D |
|---|---|---|---|---|---|

Netcode elektriciteit article: 2.16, sub 3(b)

The function of LFSM-U-Storage is described as follows. In the case of electricity storage modules, active power frequency response to an underfrequency event shall be provided in consumption mode (charging) and in generating mode (discharging). The consumption mode is regarded as a point of operation with negative active power. In consumption mode the active power consumption is reduced with decreasing frequency according to the indicative figure 1.3 at a frequency threshold and with a droop setting specified by the relevant TSO. Depending on the depth of the underfrequency event a change to generating mode up to the maximum capacity will happen. Figure 1.3 illustrates the relationship between active power output and frequency, for an operating point in consumption mode (charging; $P_{pre}$ is negative active power at 50 Hz) and for an operating point in generating mode (discharging; $P_{pre}$ is positive active power at 50 Hz).

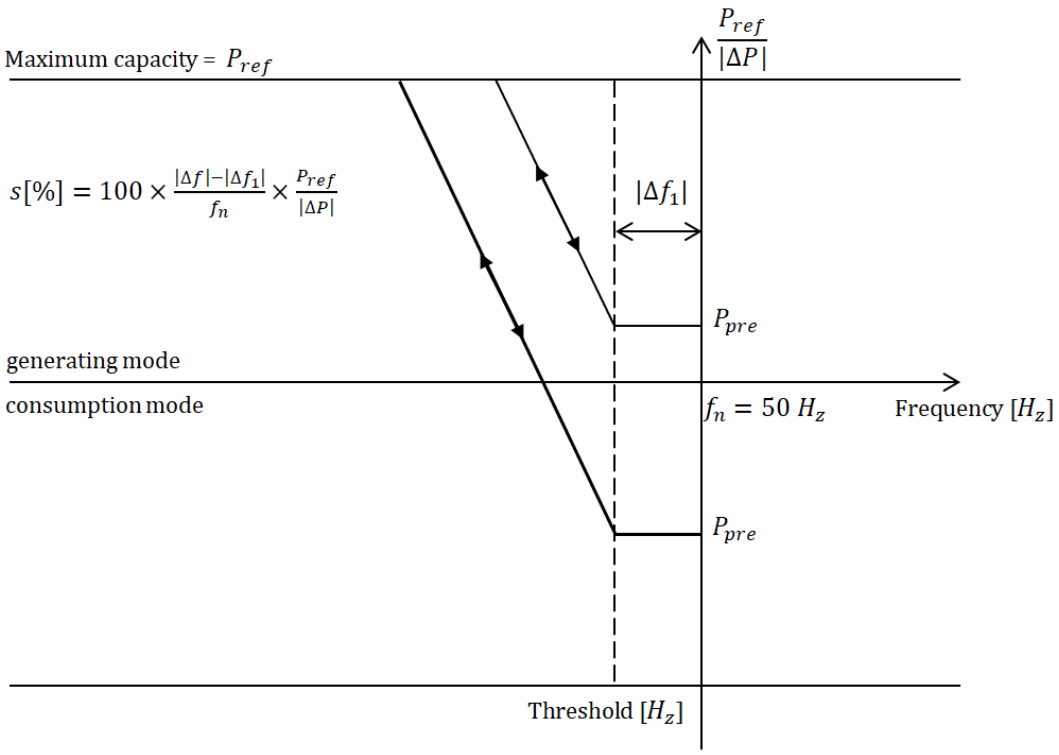



*Figure 1.3 Active power frequency response to an underfrequency event*

s : LFSM-U-Storage frequency droop [%]

$f_n$ : nominal frequency: 50 Hz

$f_1$ : LFSM-U-Storage frequency threshold: 49.8 Hz

$\Delta f$ : frequency deviation in the network [Hz]

$\Delta f_1$ : frequency deviation threshold: $\Delta f_1 = f_1 - f_n$

$P_{ref}$ : the reference active power to which ΔP is related and is equal to Pmax

$\Delta P/P_{ref}$ : change in active power output from the electricity storage module [%] as a proportion of $P_{ref}$

$P_{pre}$ : a value of active power injection or absorption of ESM at nominal frequency.

At underfrequencies where Δf is below $\Delta f_1$, the ESM has to provide a positive active power output change according to the droop s. The available power includes the state of charge of the storage.

According to Netcode elektriciteit, article 2.16, clause 3a, Netcode elektriciteit chapter 3 applies mutatis mutandis to an energy storage facility, with the understanding that the energy storage facility with a maximum capacity:

- greater than or equal to 0.8 kW and less than 1 MW complies with the requirements applicable to a type A power generating module;
- greater than or equal to 1 MW and less than 50 MW complies with the requirements applicable to a type B power generating module;

- greater than or equal to 50 MW and less than 60 MW complies with the requirements applicable to a type C power generating module;
- greater than or equal to 60 MW complies with the requirements applicable to a type D power generating module;

Additionally, according to Netcode elektriciteit, article 2.16, clause 3b, the electricity storage facility shall have the ability to automatically switch from consumption mode to generation mode as referred to in Article 15(3)(a) of Regulation (EU) 2017/2196 (NC ER), as well as the ability to automatically disconnect as referred to in Article 15(3)(b) of Regulation (EU) 2017/2196 (NC ER).

Additionally, according to Netcode elektriciteit, article 2.16, clause 3c, the relevant articles of Regulation (EU) 2016/1388 (NC DCC) and Netcode elektriciteit section 4.2 shall apply mutatis mutandis if the energy storage facility provides demand response to a system operator.

Additionally, according to Netcode elektriciteit, article 2.16, clause 3f, the droop setting for LFSM-U of Electricity Storage Modules larger than 0.8kW shall be set to 1%.

Requirements to be verified

(i) As described in the defence plan[6] according to NC ER, article 15, clause 3, the Electricity Storage Modules larger that 0.8kW that are at nominal frequency in consumption mode ($P_{pre}$ is negative) shall be capable of activating the provision of active power frequency response at decreasing frequency as follows:
   - the frequency threshold shall be 49.8 Hz;
   - the droop setting shall be 1%;
   - after switching to generation mode, regulation of the supplied active power is continued according to the droop of 1 %, and
   - conversely when returning to the nominal frequency.

   Electricity Storage Module that is not technically capable to comply with the previous point shall, in case of being at nominal frequency in the consumption mode, with decreasing frequency:
   - disconnect from the grid at the frequency value of 49.7 Hz within 10 seconds;
   - immediately disconnect from the grid at the frequency value of 49.3 Hz;
   - upon returning to the nominal frequency, consumption mode may be resumed possibly after the approval of the relevant system operator.

   The above requirement (i) does not refer to a specific provision from the Netcode Electriciteit, but is based on article 15, clause 3 of the NC ER and will be laid down in the ATO.

[6] Systeembeschermings- en herstelplan https://tennet-drupal.s3.eu-central-1.amazonaws.com/default/2023-12/Systeembeschermings-%20en%20herstelplan%20V6_update%202023.pdf

The detail technical description of all tests and simulations needed for the requirements concerning LFSM-U-Storage for electricity storage module that are at nominal frequency in consumption mode will be explained in the parts LFSM-U-Storage tests and LFSM-U-Storage simulations of this chapter.

(ii) As described in the defence plan according to Netcode elektriciteit, article 2.16, clause 3a, the Electricity Storage Modules of type C and type D that are at nominal frequency in generation mode ($P_{pre}$ is positive) shall be capable of activating the provision of active power frequency response at decreasing frequency from a frequency threshold and with a droop as follows:
- the frequency threshold shall be 49,8 Hz;
- the droop setting shall be 5% (a lower droop is also allowed, preferably the same as in part (i))[7];

The detail technical description of all tests and simulations that apply for LFSM-U for ESMs that are at nominal frequency in generation mode can be found in Chapter 4, paragraph 4.2.2. ("Requirement: LFSM-U") of the document "RfG compliance verification by testing and simulating" as well as in the parts LFSM-U-Storage tests and LFSM-U-Storage simulations of this chapter.

(iii) the activation of active power frequency response by the Electricity Storage Module shall not be unduly delayed. In the event of any delay greater than two seconds, the Electricity Storage Facility Owner shall justify it to the relevant TSO;
(iv) in LFSM-U-Storage the Electricity Storage Module shall be capable of providing a power increase up to its maximum capacity;
(v) stable operation of the Electricity Storage Module during LFSM-U-Storage operation shall be ensured;

As defined in IGD on Limited Frequency Sensitive Mode[8], the duration of a response to reach a set value is defined by the response time (figure 1.4). The response time (Tresp) is defined as the time from the step inception (e.g. a step in frequency) until the response (e.g. change of active power) reaches the tolerance range of its set value first. It includes an initial delay (Tid), which covers the period between step inception and the beginning of the response.

The response time for an active power change for LFSM-U-Storage is recommended to be as fast as technically feasible and as described below[9]:
- for S-ESM: less or equal to 8 s for an active power setpoint change of 1 pu of capacity excluding the time for switching from consumption to generation or vice versa.

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[7] The addition in brackets, concerning the allowed lower droop, does not refer to a specific provision from the Netcode elektriciteit, but it is done to support the technical feasibility of the requirements in part (i) and part (ii). There are efforts to implement related amendment at national level as well.

[8] Implementation Guidance Document (IGD) on Limited frequency sensitive mode (https://eepublicdownloads.entsoe.eu/clean-documents/Network%20codes%20documents/NC%20RfG/IGD_LFSM-O-U_final.pdf)

[9] The response times for electricity storage modules are, because of their technical capabilities, recommended to be shorter that those recommended for PPMs and SPGMs in the IGD on Limited frequency sensitive mode.

- for N-ESM: less or equal to 1 s for an active power setpoint change of 1 pu of capacity excluding the time for switching from consumption to generation or vice versa.
- switching from consumption to generation and vice versa should be as fast as technically feasible.

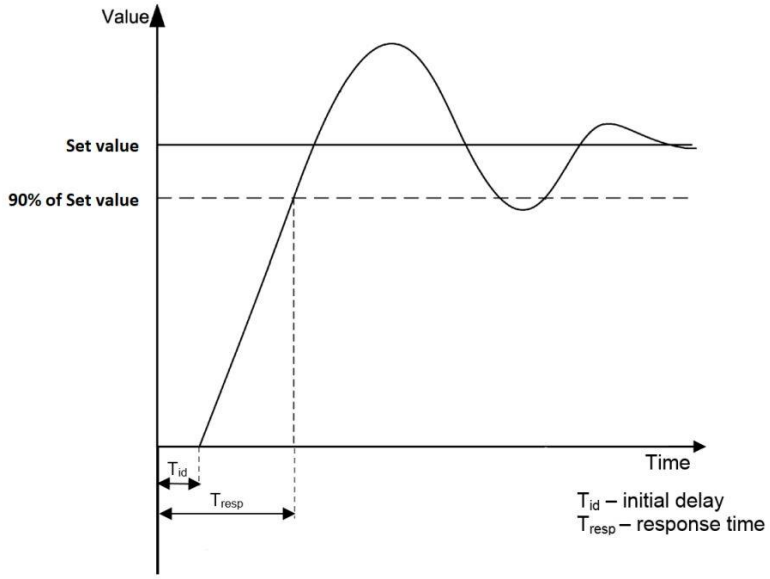


*Figure 1.4 The response time and initial delay*

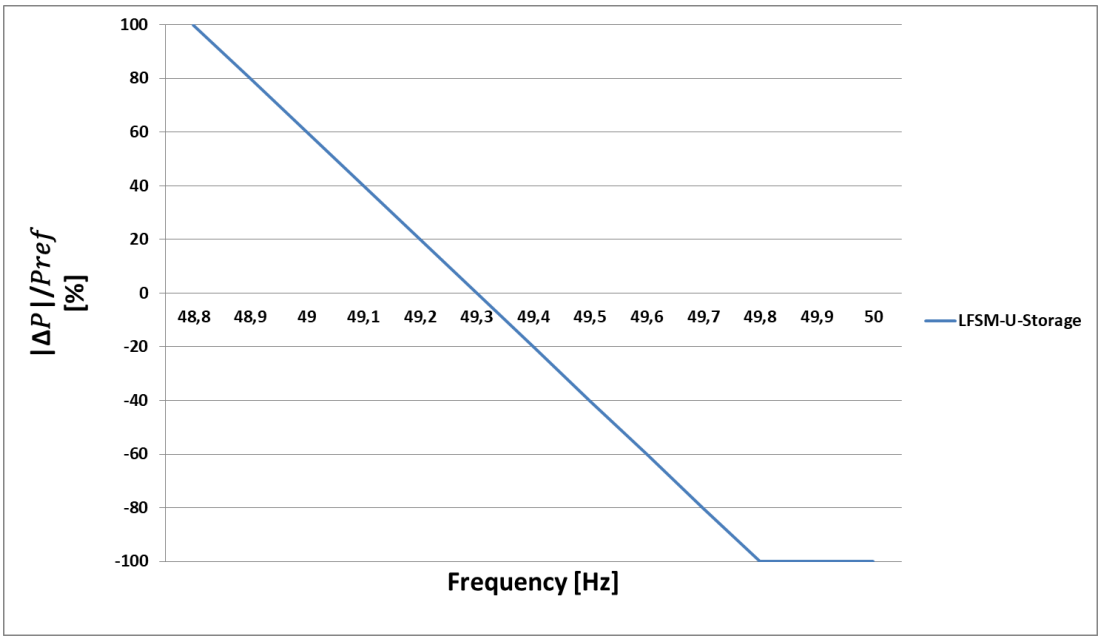


*Figure 1.5 Active power frequency response capability of Electricity Storage Modules in LFSM-U-Storage with the droop of 1%.*

Objective

- The Electricity Storage Facility Owner (ESFO) shall demonstrate the Electricity Storage Module's technical capability to continuously modulate active power to contribute to frequency

control in case of any large drop of frequency in the system;

- The steady-state parameters of regulations (such as droop and the power-frequency control threshold value) and dynamic parameters, including frequency step change response shall be verified.

### LFSM-U-Storage tests

The default response

The ESM must be in operation and connected with the network. The state of charge shall be sufficient for carrying out the test.
The LFSM-U-Storage activates below a frequency threshold of 49.8 Hz. The droop shall be set to 1%. At 1% droop, a frequency change of -300 mHz below the frequency threshold should cause a change of active power equal to +60% of $P_{ref}$ at the start of the test.
For the performance of the test, the FSM shall be deactivated, so that the provision of primary and secondary control power shall be deactivated.
Operating point: the ESM active power is set equal to the maximum capacity in consumption mode.
A frequency step response test will be carried out according to the following sequences:

| **Starting frequency (Hz)** | **To frequency (Hz)** | **Graph points** | **Power change** | **Output power** |
|---|---|---|---|---|
| 50.0 | 49.8 | (0) -> (1) | 0% | -100% |
| 49.8 | 49.5 | (1) -> (2) | +60% | -40% |
| 49.5 | 49.3 | (2) -> (3) | +40% | 0% |
| 49.3 | 49.1 | (3) -> (4) | +40% | +40% |
| 49.1 | 48.8 | (4) -> (5) | +60% | +100% |

The "graph points" refer to figure 1.6. The power change is in % of $P_{ref}$.
After each frequency step:

- the initial delay time is as short as possible;
- the maximum response time: 8 s (S-ESM); 0.5 s (N-ESM) (1 s for systems that are not technically capable for the response time of 0.5 s);
- hold until conditions stabilise;
- the ESM shall maintain the new operating point for 2 minutes.

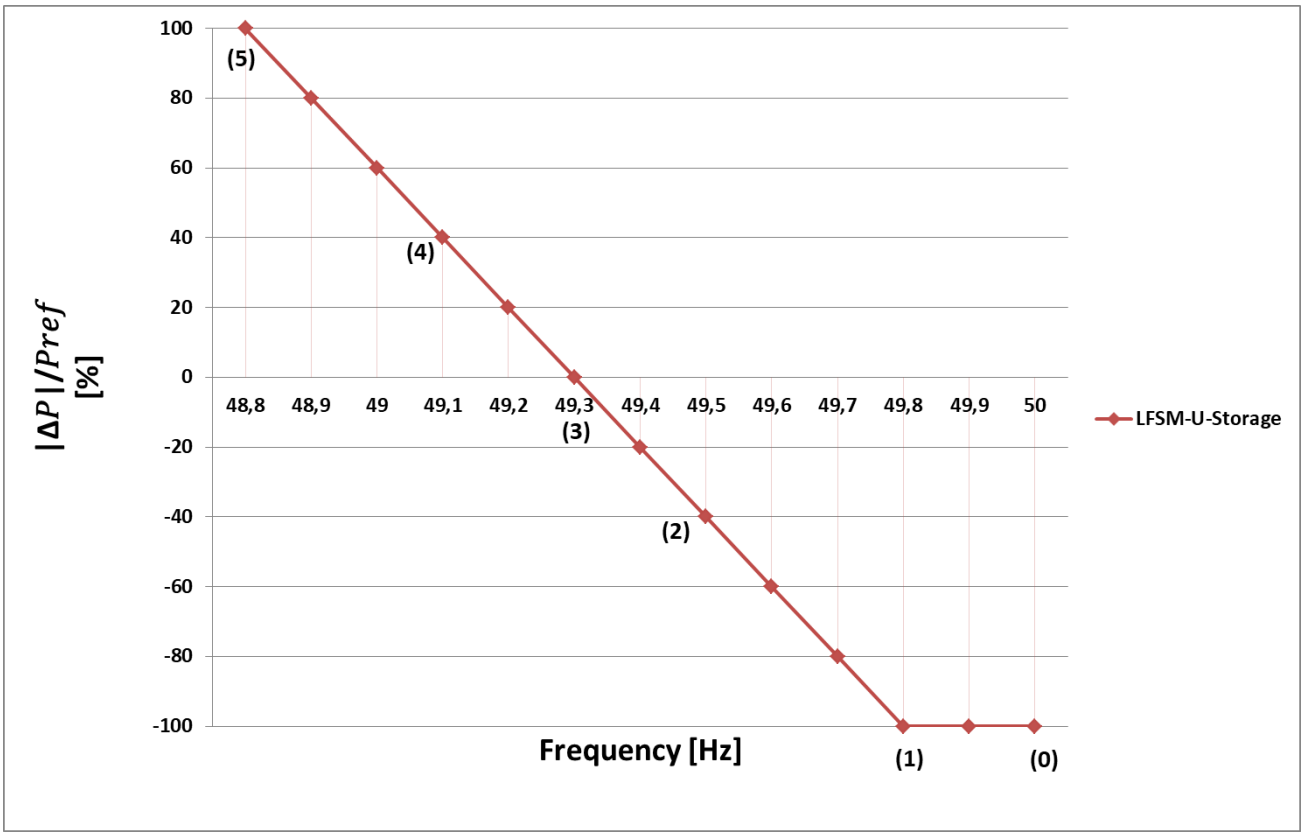


*Figure 1.6 LFSM-U-Storage test points corresponding to 1% droop*

Documentation/measurements

- The simulated frequency, P, Q, V shall be measured as function of the time at the Connection Point; all will be recorded on the same time scale;
- Applied settings of ESM and SU controller including frequency droop setting;
- A measuring error of max. +/- 5% of the measured value will be accepted.

Test evaluation criteria

The test shall be deemed successful if the following conditions are fulfilled:

- The ESM has not tripped as a consequence of the test during or after the test
- The frequency threshold is 49.8 Hz
- The active power response to a frequency drop at or below 49.8 Hz is according to the droop setting
- The initial delay time is as short as possible;
- The response time is maximum 8 s (S-ESM) or 0.5 s (N-ESM) (1 s for systems that are not technically capable for the response time of 0.5 s) for an active power setpoint change of 1 pu of capacity while not switching from consumption to generation or vice versa.
- The ESM maintains each new operating point for a time that is technical feasible, with a minimum of 2 minutes.
- Undamped oscillations do not occur after the step change response.

The alternative response

The ESM must be in operation and connected with the network. The state of charge shall be sufficient for carrying out the test. For the performance of the test, the FSM shall be deactivated, so that the provision of primary and secondary control power shall be deactivated.
During the test, the frequency is gradually decreased from 50 Hz to 49.3 Hz with 0.2 Hz/min:
1. At the frequency value of 49.7 Hz the ESM shall be automatically disconnected from the network within the period of 10 s.
2. At the frequency value of 49.3 Hz the ESM shall be immediately disconnected from the network.

Documentation/measurements

- The simulated frequency, P, Q, V shall be measured as function of the time at the Connection Point; all will be recorded on the same time scale;
- Applied settings of ESM and SU controller
- A measuring error of max. +/- 5% of the measured value will be accepted.

Test evaluation criteria
The test shall be deemed successful if the following conditions are fulfilled:

- The ESM has not tripped as a consequence of the test during or after the test
- The frequency threshold is 49.7 Hz
- ESM shall automatically disconnect within 10 seconds from the network from the moment upon reaching the frequency threshold value of 49.7 Hz.
- ESM shall immediately disconnect from the network from the moment upon reaching the frequency value of 49.3 Hz.
- The initial delay time is as short as possible;
- Undamped oscillations do not occur after the step change response.
- The response time is maximum 8 s (S-ESM) or 0.5 s (N-ESM) (1 s for systems that are not technically capable for the response time of 0.5 s) for an active power setpoint change of 1 pu of capacity while not switching from consumption to generation or vice versa.
- The ESM maintains new operating point for a time that is technical feasible, with a minimum of 2 minutes.

### LFSM-U-Storage simulations

The default response

The simulation will be carried out by simulating frequency steps and frequency ramps which are sufficiently large to increase the active power output to the ESM's Maximum Capacity.
The LFSM-U-Storage activates below a frequency threshold of 49.8 Hz. The droop setting is: 1%.

- The simulations shall cover the tests for the ESM and prove the validity of the simulation model

- The simulations will be carried out for the same operating point as was used in the test
- A frequency step simulation will be carried out:
    - Starting at 50.0 Hz injection of a frequency step of -200 mHz at the ESM's control input;
    - followed by injection of a frequency step of -300 mHz at the ESM's control input, causing the ESM's active power output to change by +60% of $P_{ref}$;
    - followed by injection of a frequency step of -200 mHz at the ESM's control input, causing the ESM's active power output to change by +40% of $P_{ref}$;
    - followed by injection of a frequency step of -200 mHz at the ESM's control input, causing the ESM's active power output to change by +40% of $P_{ref}$;
    - followed by injection of a frequency step of -300 mHz at the ESM's control input, causing the ESM's active power output to change by +60% of $P_{ref}$;

- A frequency ramp simulation will be carried out:
    - Starting at 50.0 Hz injection of a frequency ramp from 0 mHz to -200 mHz at -0.2 Hz per minute at the ESM's control input;
    - followed by injection of a frequency ramp from 0 mHz to -300 mHz at -0.2 Hz per minute at the ESM's control input, causing the ESM's active power consumption to decrease by 60%;
    - followed by injection of a frequency ramp from 0 mHz to -200 mHz at -0.2 Hz per minute at the ESM's control input, causing the ESM's active power consumption to decrease by 40%;
    - followed by injection of a frequency ramp from 0 mHz to -200 mHz at -0.2 Hz per minute at the ESM's control input, causing the ESM's active power generation to increase by 40%;
    - followed by injection of a frequency ramp from 0 mHz to -300 mHz at -0.2 Hz per minute at the ESM's control input, causing the ESM's active power generation to increase by 60%;

Simulation evaluation criteria

The simulation shall be deemed successful if the following conditions are fulfilled:

- The frequency threshold is 49.8 Hz
- The droop is 1%
- The ESM active power response to frequency drop at or below 49.8 Hz is according to the droop setting until the Maximum Capacity has been reached
- The initial delay time is as short as possible;
- The response time is maximum 8 s (S-ESM) or 0.5 s (N-ESM) (1 s for systems that are not technically capable for a response time of 0.5 s) for an active power setpoint change of 1 pu of capacity while not switching from consumption to generation or vice versa.
- The simulation model of the N-ESM and S-ESM is validated against the compliance test for LFSM-U-Storage response by expert judgement
- Undamped oscillations do not occur after the step change response.

The alternative response

The simulations shall cover the tests required for ESM (the corresponding alternative response) and prove the validity of the simulation model.
The simulations will be carried out for the same operating point as was used in the test.

Simulation evaluation criteria
The simulation shall be deemed successful if the following conditions are fulfilled:

- The frequency threshold is 49.7 Hz
- ESM shall automatically disconnect within 10 seconds from the network from the moment upon reaching the frequency threshold value of 49.7 Hz.
- ESM shall immediately disconnect from the network from the moment upon reaching the frequency value of 49.3 Hz.
- The initial delay time is as short as possible;
- Undamped oscillations do not occur after the step change response.
- The response time is maximum 8 s (S-ESM) or 0.5 s (N-ESM) (1 s for systems that are not technically capable for a response time of 0.5 s) for an active power setpoint change of 1 pu of capacity while not switching from consumption to generation or vice versa.
- The simulation model of the N-ESM and S-ESM is validated against the compliance test for LFSM-U-Storage response by expert judgement