European Network of
Transmission System Operators
for Electricity

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# Technical Requirements for Frequency Containment Reserve Provision in the Nordic Synchronous Area

17 March 2021

**Version for the pilot phase**

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## Contents





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# 1. Introduction

These *Technical Requirements for Frequency Containment Reserve Provision in the Nordic Synchronous Area* specify formal technical requirements for Frequency Containment Reserve (FCR) providers as well as requirements for compliance verification and information exchange. The requirements are based on SO GL[1], with proper adjustments to be suitable for the Nordic conditions. The requirements have been developed in cooperation between the Nordic TSOs: Energinet, Fingrid, Statnett and Svenska kraftnät.

The *Supporting Document on Technical Requirements for Frequency Containment Reserve Provision in the Nordic Synchronous Area* contains material to support the interpretation of these technical requirements.

In order to participate in the FCR markets, it is necessary for FCR providing units and FCR providing groups, jointly referred to as FCR providing entities[2], to be prequalified. The prequalification process ensures that FCR providers have the ability to deliver the specified product required by the TSO and that all necessary technical requirements are fulfilled. The TSOs provide an IT tool that performs the necessary calculations and evaluates compliance from the test results with the technical requirements. The prequalification shall be performed before a provider can deliver the products FCR-N (Frequency Containment Reserve for Normal operation) and FCR-D (Frequency Containment Reserve for Disturbances), and shall consist of documentation showing that the provider can deliver the specified product as agreed with the TSO. The technical requirements, the specific documentation required and the process for prequalification testing are described in this document. The process to validate the requirements includes:

1) Verification of the properties of the FCR providing entity.
2) Accomplishment of prequalification tests.
3) Setting up telemetry data to be sent to the reserve connecting TSO in real-time if requested, and data logging for off-line validation purposes.

Three FCR products are defined and can be provided independently:

- FCR-N, in the range of 49.9 – 50.1 Hz
- FCR-D upwards, in the range of 49.9 – 49.5 Hz
- FCR-D downwards, in the range of 50.1 – 50.5 Hz

Each product can be provided either as a linear function of frequency deviation or as an approximation of a linear function.

Each product offered must comply with the requirements specified in this document.

The requirements addressed in this document apply to FCR providing entities providing FCR-N and/or FCR-D services.

[1] COMMISSION REGULATION (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation.
[2] Since most of the requirements specified in this document refer to both FCR providing groups and FCR providing units, the term *FCR providing entity* has been introduced to cover both FCR providing units and FCR providing groups, in the text.



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# 2. The prequalification process

This section describes how a first-time prequalification process is handled and the regular reassessment of the prequalification. The prequalification process is implemented locally at each TSO. Information about the practicalities can be obtained from the reserve connecting TSO.

## 2.1. The prequalification process for the first time

The prequalification process starts with a notification of the tests from the potential FCR provider to the reserve connecting TSO. After successful completion of the tests, a formal application has to be submitted. The application shall contain all information required by the TSO, and listed in this document. Within 8 weeks the TSO shall confirm if the application is complete or request additional information from the provider. Additional information shall be provided within 4 weeks, otherwise the application is deemed withdrawn. When the application is complete, the TSO shall within 3 months either prequalify or deny the FCR providing entity to provide the service. The test results included in an application must not be older than 1 year.

In case compliance with certain requirements of this document has already been verified against the reserve connecting TSO, it will be recognised in the prequalification.

## 2.2. Reassessment of the prequalification

The prequalification shall be re-assessed:

- once every five years,
- in case the requirements or the equipment have changed, and
- in case of modernisation of the equipment related to FCR activation.

To maintain continuous validity of the prequalification, the FCR provider is responsible for initiating the reassessment process well in advance of the expiration of the previous prequalification. The reassessment requires new testing and complementary documentation to the extent necessary to verify the capacity, the performance and the stability. The extent of the reassessment tests are described in Subsection 4.6.

In case of any change that has a significant impact on the FCR provision for an already prequalified entity, a full prequalification is required. Such a change could be a new turbine governor or changed turbine governor settings.

## 2.3. Prequalification application

The FCR provider shall perform the required tests, gather the required documentation and send this information to the reserve connecting TSO in the requested format. The respective TSO will specify how, and to where, the application should be sent.

**The application shall contain, as a minimum, the following documentation:**

1) Formal application cover letter – including the reason for the application (first time, 5 year periodic reassessment, or substantial change)
2) General description of the providing entity
    - Including block diagram of the controller
    - Including description of limitations for FCR capability, if applicable
3) Test report and test data with respect to performance and stability, in a format specified in Subsection 5.2.1, for (when applicable)



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- FCR-N
- FCR-D upwards
- FCR-D downwards

4) Documentation of the real-time telemetry data performance and accuracy as requested
5) Documentation of the data logging system performance and accuracy as requested

**In addition, the application shall contain, as a minimum, the following documentation:**

Generation based resources

- Generator: Rated apparent power [MVA]
- Turbine: Rated power [MW]
- Hydro units: Water starting time constant $T_w$ [s], rated head [m]
- Turbine governor: Type, settings and block diagram[3]

Load based resources

- Information on the type of the load
- Technical description of the controller, including controller settings

Energy storage based resources

- Rated apparent power [MVA]
- Rated energy capacity of the energy storage [MWh]
- Energy storage upper and lower limits [MWh]
- Technical description of the controller, including controller settings
- Description of energy management, if applicable

For other types of resources, corresponding data describing the properties of the entity have to be documented. The specification of such data has to be agreed with the reserve connecting TSO.

For aggregated resources, a high level technical description of the aggregation system shall be included. For entities without a predefined setpoint, a description of the method for forecasting available FCR capacity and of the method for calculating the baseline shall be included.

## 2.4. Approval

Upon approval, the FCR provider shall receive a notification from the reserve connecting TSO that the FCR providing entity is qualified to provide the stated FCR products. The notification shall state the qualified FCR capacities at the tested operating points. The notification shall also state the validity of qualification and when reassessment is due. The validity period of 5 years starts from the day of approval.

[3] Block diagram can be excluded if it cannot be obtained with a reasonable effort



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# 3. Technical requirements for the FCR-products

Each FCR providing entity has to meet a number of technical requirements. The purpose of these technical requirements is to guarantee that the resources taking part in frequency control:

- have sufficient stationary and dynamic performance, and
- do not destabilise the power system.

The requirements are the same irrespective of the providing entity, i.e. generating entities, load entities and energy storage should be tested in a similar way to ensure the fulfilment of the performance and stability requirements, respectively.

The maximal provision per single point of failure is limited to 5% of the nominal reference incident in the Nordic power system. Currently the limit for FCR-N and FCR-D is 73 $MW$ ($= 1450\ MW \cdot 0.05$). When providing both reserves the combined limit is 100 MW.

FCR providers shall have the ability to deactivate their FCR contribution by means of remote control in case the entity is not at all times locally monitored. Voltage control using frequency-voltage droop is allowed.

## 3.1. FCR-N

In this subsection the stationary performance requirements, the dynamic performance requirements, and the stability requirement for FCR-N are outlined.

### 3.1.1. FCR-N stationary performance requirements

FCR-N activation has to be such that at frequencies over 50.0 Hz power generation facilities decrease their power production and loads increase their power consumption. Vice versa, at frequencies below 50.0 Hz power generation facilities shall increase their power production and loads shall decrease their power consumption.

In stationary state, at a frequency of 50.0 Hz, 0% of the FCR-N capacity shall be activated and at frequencies equal or below 49.9 Hz, 100% of the FCR-N upward capacity shall be activated. Respectively, at frequencies equal or above 50.1 Hz, 100% of the FCR-N downward capacity shall be activated. The activation within the interval 49.9 to 50.1 Hz must be proportional to the frequency deviation. FCR-N shall remain activated as long as the frequency deviation persists[4].

For resources that are able to continuously modify their power exchange, the FCR-N contribution from each FCR providing entity shall be designed to be as linear as possible with respect to the frequency deviation from the nominal frequency (50 Hz), within a frequency range from 49.9 Hz to 50.1 Hz, see Figure 1. FCR-N shall be saturated at 49.9 Hz and 50.1 Hz.

Resources that cannot be continuously controlled, such as relay controlled resources, shall activate their FCR-N contribution based on a monotonic piecewise linear power-frequency characteristic within the blue area of Figure 1.

[4] In accordance with SO GL article 156.7-9



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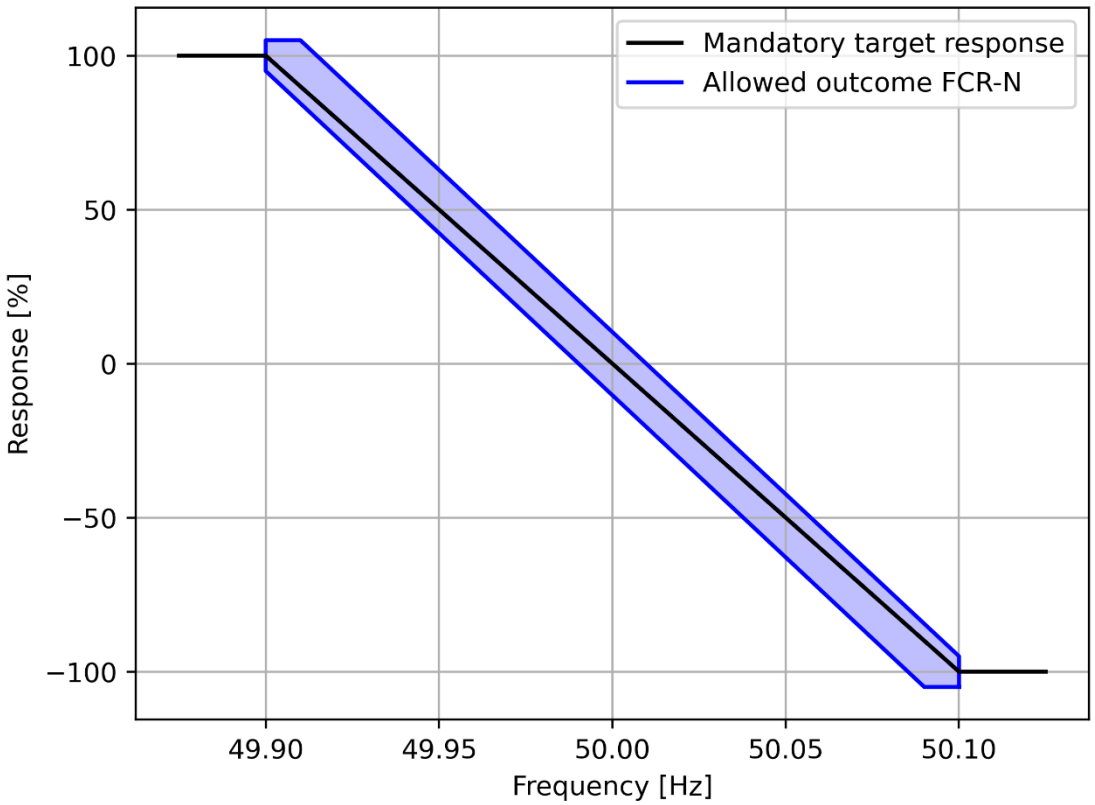


**Figure 1. Activation of linear and piecewise linear FCR-N resources. The black line indicates the mandatory target response. The controller shall be designed to minimise the deviation from the target response. The blue area defines the allowed outcome of the deviations, due to e.g. non-linear effects or step sizes for relay connected loads. The coordinates of the corners are provided in Table 1 below.**

FCR-N resources have to activate their contribution within the blue area in Figure 1[5]. For stepwise activated resources this means that the number of steps has to be at least 10. The black line in the figure indicates the mandatory target response for the controller. The controller shall aim to be as close and centred as possible to the target response. Deviations from the target response are allowed if caused by uncertainties in the response, natural variations in production/consumption, or due to fixed step sizes of the resources connected to the relay.

The coordinates for the corners of the blue area in Figure 1 are provided in Table 1 below. The coordinates are given counter-clockwise starting from the minimum activation at 49.9 Hz. The full requirement is calculated via linear interpolation of the provided coordinates.

[5] For entities using controllers commonly not utilising power feedback the response may be allowed some deviations outside the blue area. This applies where the choice of controller is motivated on a technical basis and the derivative of the response is limited (locally linear), e.g. that the entity will always provide a response even for small changes in frequency.



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**Table 1. Coordinates of the corners in Figure 1.
Counter-clockwise starting from the minimum activation at 49.9 Hz.**

| Frequency [Hz] | Response [%] |
|---|---|
| 49.90 | 95 |
| 49.90 | 105 |
| 49.91 | 105 |
| 50.10 | -95 |
| 50.10 | -105 |
| 50.09 | -105 |
| 49.90 | 95 |

### 3.1.2. FCR-N dynamic performance requirement

The dynamic performance requirement is defined for the step response of an FCR-N providing entity. The step response is measured for four stepwise changes in frequency, with a magnitude of 100 mHz, see test sequence in Figure 10. The following three requirements shall be fulfilled for all four steps:

1. $|\Delta P_{60s}| \geq 0.63 \cdot |\Delta P_{ss}|$
2. $|\Delta P_{180s}| \geq 0.95 \cdot |\Delta P_{ss}|$
3. $|E_{60s}| \geq 24\ s \cdot |\Delta P_{ss}|$

In the equations above,

$\Delta P_{60s}$ (MW) is the activated power 60 seconds after applying the step signal

$\Delta P_{180s}$ (MW) is the activated power 180 seconds after applying the step signal

$\Delta P_{ss}$ (MW) is the steady state FCR-N activation, i.e. the value where the power stabilizes as shown in Section 4.7 of the Supporting Document.

$E_{60s}$ (MWs) is the activated energy 60 seconds after applying the step signal

$$E_{60s} = \int_{t}^{t+60s} \Delta P(t)dt \tag{3.1}$$

Figure 2 illustrates an example of the calculation of the performance requirements for one of the steps in the test sequence, shown in Figure 10.



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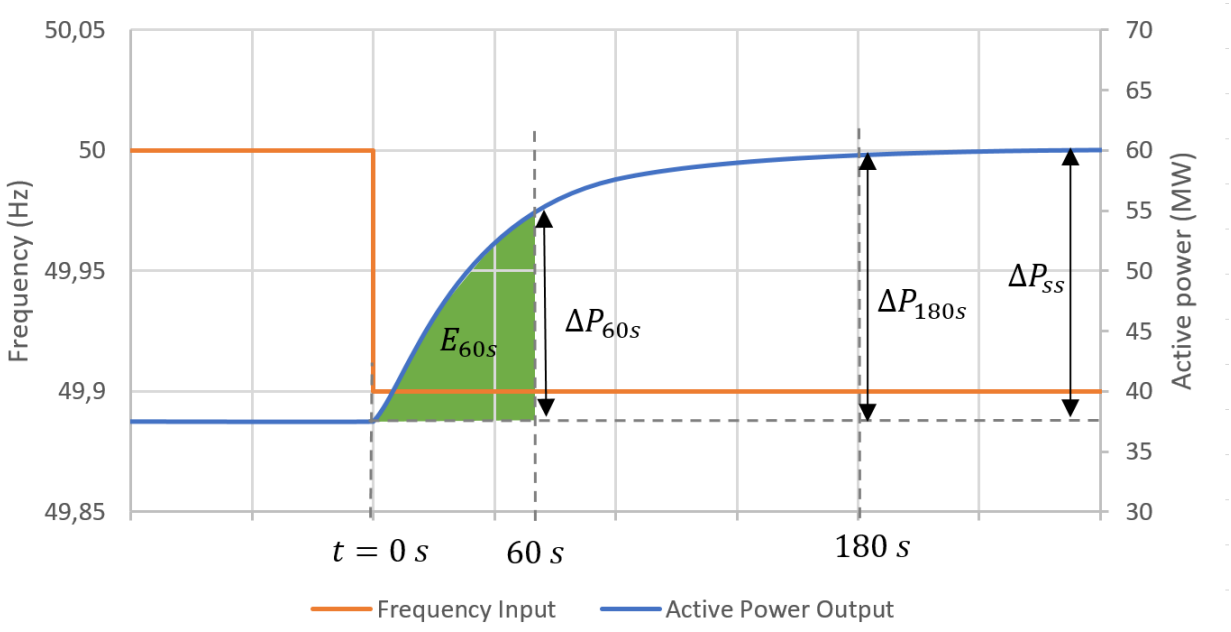


**Figure 2. Example response, blue, from input frequency, orange, according to FCR-N step test from 50 to 49.9 Hz**

In addition, the dynamic performance is evaluated based on transfer function values of the FCR providing entity obtained from sine in sine out tests. The requirement is such that a curve defined by the transfer function values, together with a representation of the power system, shall remain below a pre-defined performance requirement curve, as illustrated in Figure 3. The requirement applies to time periods from 10 s to 70 s (including interpolated values between the tested period times).

In mathematical form the requirement is expressed as

$$\left|\frac{\mathrm{G_{avg}(s)}}{1-\mathrm{F}(s)\mathrm{G_{avg}(s)}}\right| < \left|\frac{1}{D(s)}\right| \qquad (3.2)$$

where s is the Laplace operator, $F(s)$ is the transfer function of the FCR providing entity, $G_{avg}(s)$ is the transfer function of the power system and $D(s)$ is a transfer function describing the disturbance profile that FCR-N shall balance. See Subsection 4.1 in the Supporting document for information on derivation of the transfer functions.



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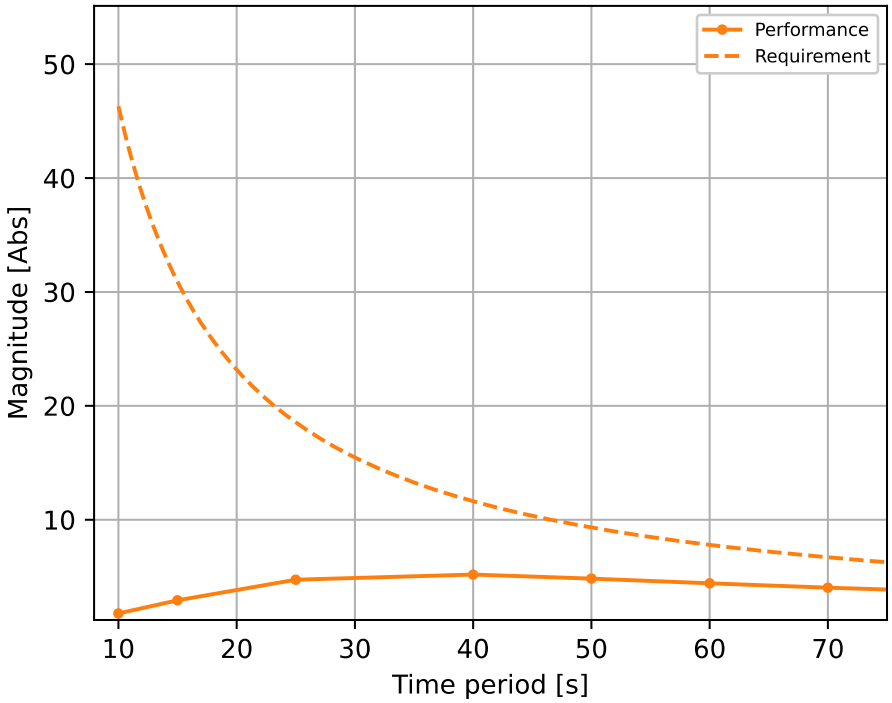


**Figure 3. FCR-N dynamic performance requirement (dashed line) together with an example response (solid line). The example response fulfils the performance requirement as the solid line is below the dashed line.**

### 3.1.3. FCR-N deactivation performance

Deactivation is defined as decreasing the FCR response when the frequency deviation decreases. FCR-N providing entities shall fulfil the requirements stated in section 3.1.2.

### 3.1.4. FCR-N stability requirement

The power system, with the FCR providing entities, is required to be stable and have sufficient stability margins in order to guarantee stable system operation. This is achieved when the Nyquist-curve (defined by the transfer function values of the FCR providing entity and the power system) does not encircle the Nyquist point (-1, 0) and does not enter the blue stability margin circle around the Nyquist point, as shown in Figure 4.

In mathematical form the requirement is expressed as

$$|1 - F(s)G_{min}(s)| > \left|\frac{1}{M_s}\right| = \frac{1}{2.31} \qquad (3.3)$$

where s is the Laplace operator, $F(s)$ is the transfer function of the FCR providing entity, $G_{min}(s)$ is the transfer function of the power system and $M_s$ is the maximum sensitivity. See Subsection 4.1 in the Supporting document for information on derivation of the transfer functions.



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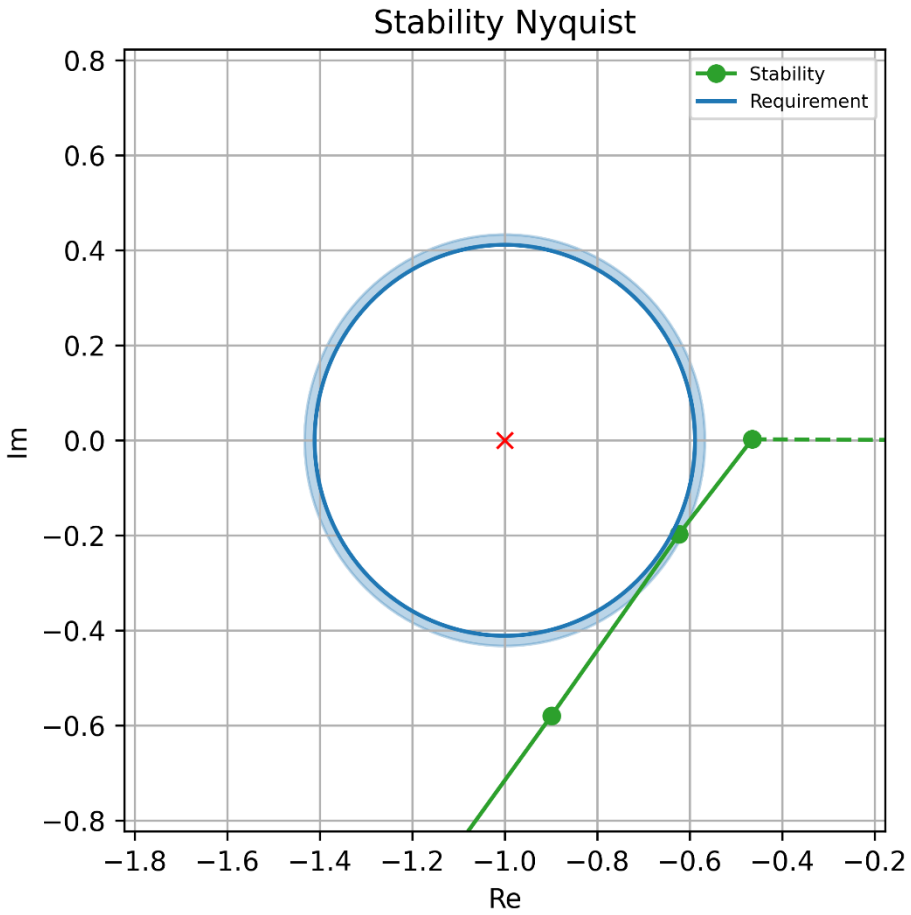


**Figure 4. FCR-N stability requirement (blue) together with an example response (green). The example response fulfils the stability requirement since it does not enter the blue circle or encircle the red cross.**

## 3.2. FCR-D

In this section the stationary performance requirements, the dynamic performance requirement, and the stability requirement for FCR-D are outlined.

FCR-D is divided into two separate products; one product for upwards regulation to be activated for frequencies lower than 49.9 Hz, and one product for downwards regulation to be activated for frequencies higher than 50.1 Hz.

It is not allowed to have a saturation limit on the frequency measurement input to the controller, i.e. for upwards regulation there is no lower limit for the frequency input and for downwards regulation there is no upper limit for the frequency input. Special considerations shall be made for units with LFSM, see subsection 3.2.6.

### 3.2.1. FCR-D stationary performance requirements

FCR-D activation has to be such that, at frequencies over 50.1 Hz, power generation facilities decrease their power production and loads increase their power consumption. Vice versa, at frequencies below 49.9 Hz, power generation facilities shall increase their power production and loads shall decrease their power consumption.

At a frequency of 49.9 Hz, 0% of the FCR-D capacity shall be activated and at frequencies below or equal to 49.5 Hz, 100% of the upward capacity shall be activated. Respectively, at a frequency of 50.1 Hz, 0% of



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the FCR-D capacity shall be activated and at frequencies above or equal to 50.5 Hz, 100% of the downward capacity shall be activated. FCR-D shall remain activated as long as the frequency deviation persists[6]. For FCR providing entities with a limited energy reservoir (LER), see also subsection 3.4.

For resources that are able to continuously control their power, the FCR-D contribution shall be designed to be activated as linear as possible in a frequency range from 49.9 Hz to 49.5 Hz and in a frequency range from 50.1 Hz to 50.5 Hz, for upwards and downwards regulation respectively. The stationary activation requirement is shown in Figure 5. As indicated by the black dashed line in the figure, the resources are also allowed to continue to linearly increase their activation beyond the frequencies of 49.5 Hz and 50.5 Hz, respectively. In such a case the behaviour must be accordingly reported in the prequalification documentation.

Resources that cannot be continuously controlled, such as relay connected resources, shall activate their FCR-D contribution based on a monotonic piecewise linear power-frequency characteristic within the blue area of Figure 5.

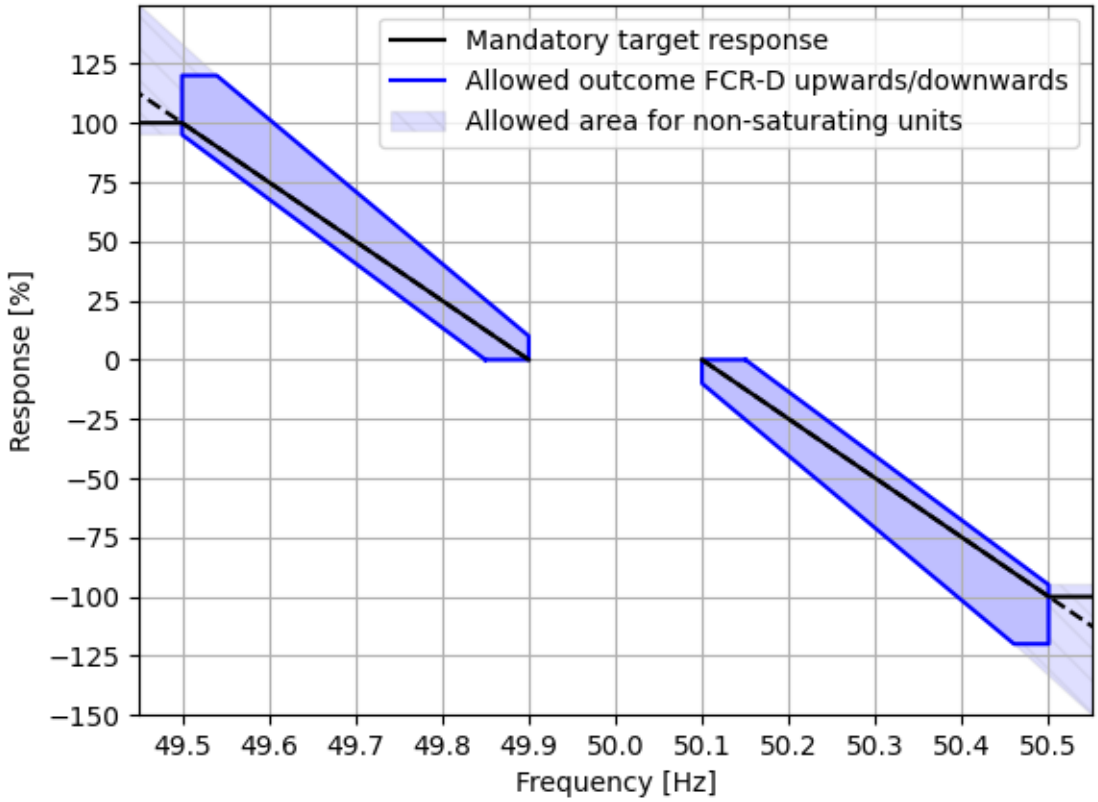


**Figure 5. Activation of linear and piecewise linear FCR-D resources. The black line indicates the mandatory target response. The controller shall be designed to minimise the deviation from the target response. The blue area defines the allowed outcome of the deviations, due to e.g. non-linear effects or step sizes for relay connected loads. The coordinates of the corners are provided in Table 2 below.**

FCR-D resources have to contribute within the blue area in Figure 5.[7] For stepwise activated resources this means that the number of steps has to be at least 4, for each direction. The black line in the figure indicates

[6] In accordance with SO GL article 156.7-8

[7] For entities using controllers commonly not utilising power feedback the response may be allowed some deviations outside the blue area. This applies where the choice of controller is motivated on a technical basis and the derivative of the response is limited (locally linear), e.g. that the entity will always provide a response even for small changes in frequency.



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the mandatory target response for the controller. The controller shall aim to be as close and centred as possible to the target response Deviations from the target response are allowed if caused by uncertainties in the response, natural variations in production/consumption, or due to step sizes of the resources connected to the relay.

The coordinates for the corners of the blue areas in Figure 5 are provided in Table 2 below. The coordinates are given counter-clockwise starting from the minimum activation at 49.9 Hz and 50.1 Hz respectively. The full requirement is calculated via linear interpolation of the provided coordinates. Any uncertain response at 49.9 Hz and 50.1 Hz respectively will not be counted as available capacity, see subsection 4.7 of the Supporting document.

**Table 2. Coordinates of the corners in Figure 5. Counter-clockwise starting from the minimum activation at 49.9 Hz and 50.1 Hz respectively. Left FCR-D upwards regulation, right FCR-D downwards regulation.**

| Frequency [Hz] | Response [%] |
|---|---|
| 49.90 | 0.0 |
| 49.85 | 0.0 |
| 49.50 | 95 |
| 49.50 | 120 |
| 49.54 | 120 |
| 49.90 | 10.0 |
| 49.90 | 0.0 |

| Frequency [Hz] | Response [%] |
|---|---|
| 50.10 | 0.0 |
| 50.15 | 0.0 |
| 50.50 | -95 |
| 50.50 | -120 |
| 50.46 | -120 |
| 50.10 | 10.0 |
| 50.10 | 0.0 |

### 3.2.2. FCR-D dynamic performance requirement

The FCR-D dynamic performance requirement is evaluated based on the activated power and energy, when the entity is subjected to a frequency input ramp from 49.9 Hz to 49.0 Hz with a slope of -0.24 Hz/s for FCR-D upwards (see Figure 6 for illustration). For FCR-D downwards, the ramp is from 50.1 Hz to 51.0 Hz with a slope of 0.24 Hz/s.

The requirements are:

1. $\left|\Delta P_{7.,5\mathrm{s}}\right| \geq 0.93 \cdot |\Delta P_{ss}|$
2. $|E_{7.5\mathrm{s}}| \geq 3.7s \cdot |\Delta P_{ss}|$

where

$\Delta P_{7.5\mathrm{s}}$ (MW) is the activated power 7.5 seconds after the start of the ramp

$\Delta P_{\mathrm{ss}}$ (MW) is the steady state FCR-D activation when the entity is subjected to a frequency input change from 49.9 Hz to 49.5 Hz or from 50.1 Hz to 50.5 Hz, for FCR-D upwards and downwards respectively (see subsection 4.5.1 and 4.5.3 for the tests).

$E_{7.5\mathrm{s}}$ (MWs) is the activated energy from the start of the ramp to 7.5 seconds after the start of the ramp, that is

$$E_{7.5\mathrm{s}} = \int_{t}^{t+7.5s} \Delta P(t)dt \qquad (3.4)$$



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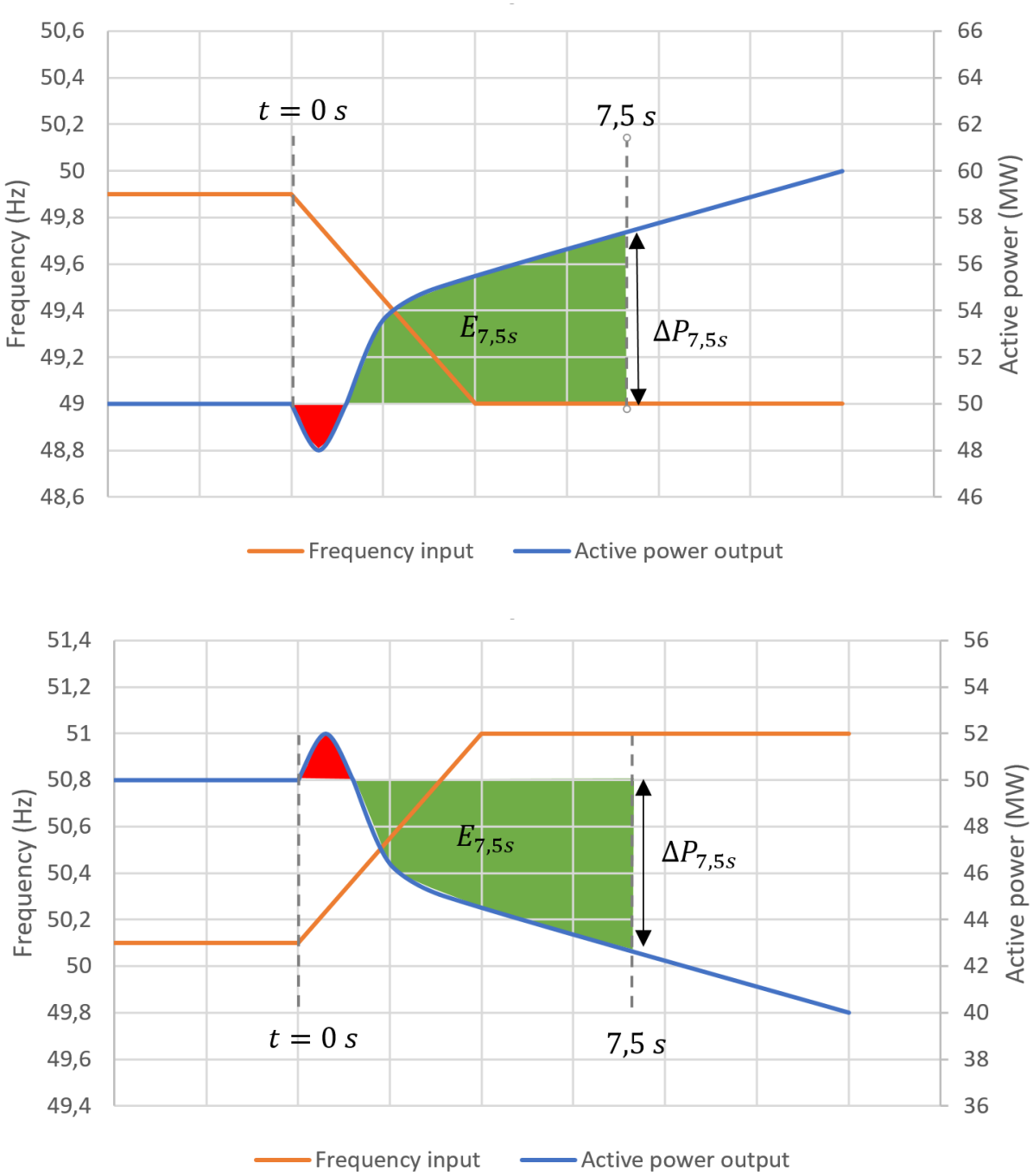


**Figure 6. Calculation of FCR-D upwards capacity and FCR-D downwards capacity. The green area indicates positive energy contribution while the red area indicates negative energy contribution.**

If the FCR providing entity fulfils the performance requirement, capacity is based on steady state power. If the FCR providing entity does not fulfil the performance requirement, it can still be prequalified for the part of the capacity that meets the above stated requirements. Then the FCR-D capacity, $C_{\mathrm{FCR-D}}$, is calculated as the minimum of the three requirements for power activation performance, stationary performance and energy activation performance:



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$$C_{\mathrm{FCR-D}} = \mathbf{min}\left(\left|\frac{\Delta P_{7.5\mathrm{s}}}{0.93}\right|,\ |\Delta P_{\mathrm{ss}}|,\ \left|\frac{E_{7.5\mathrm{s}}}{3.7\mathrm{s}}\right|\right) \quad (3.5)$$

In case of disturbances smaller than full activation and/or continuously changing frequency deviations, the performance of the FCR-D response should behave in a similar way.

### 3.2.3. FCR-D deactivation performance

Deactivation is defined as decreasing the FCR response when the frequency deviation decreases. FCR-D providing entities shall fulfil the same requirements for deactivation as stated for activation in section 3.2.2.

Entities utilising parameter switching in accordance with section 3.2.5 shall when using *high performance* parameters fulfil the same requirements for deactivation as stated for activation in section 3.2.2. When using the *high stability* parameters the response shall fulfil the same requirements for deactivation as stated for activation of FCR-N in section 3.1.2.

A limited amount of capacity may be procured from entities not being able to deactivate in accordance with the above stated requirements. Such entities will be allowed a grace period of 15 minutes where they are not required to deactivate and/or be able to perform a second activation, counted from the start of the allowed recovery. The TSOs shall set a suitable quota for the maximal procured volume from such entities to ensure that the objectives of these technical requirements are not endangered.

### 3.2.4. FCR-D stability requirement

FCR-D providing entities must fulfil a stability requirement that ensures sufficient margin towards instability. The stability requirement is fulfilled if the Nyquist curve (curve defined by transfer function values of the FCR providing entity and the power system) does not encircle the Nyquist point (-1, 0) and does not enter the blue stability margin circle, around the Nyquist point, as illustrated in Figure 7. Equation 3.3 expresses the requirement in mathematical form. Note that the transfer function of the power system, $G_{min}(s)$, is different for FCR-D and FCR-N. See Subsection 4.1 in the Supporting document for information on derivation of the transfer functions.



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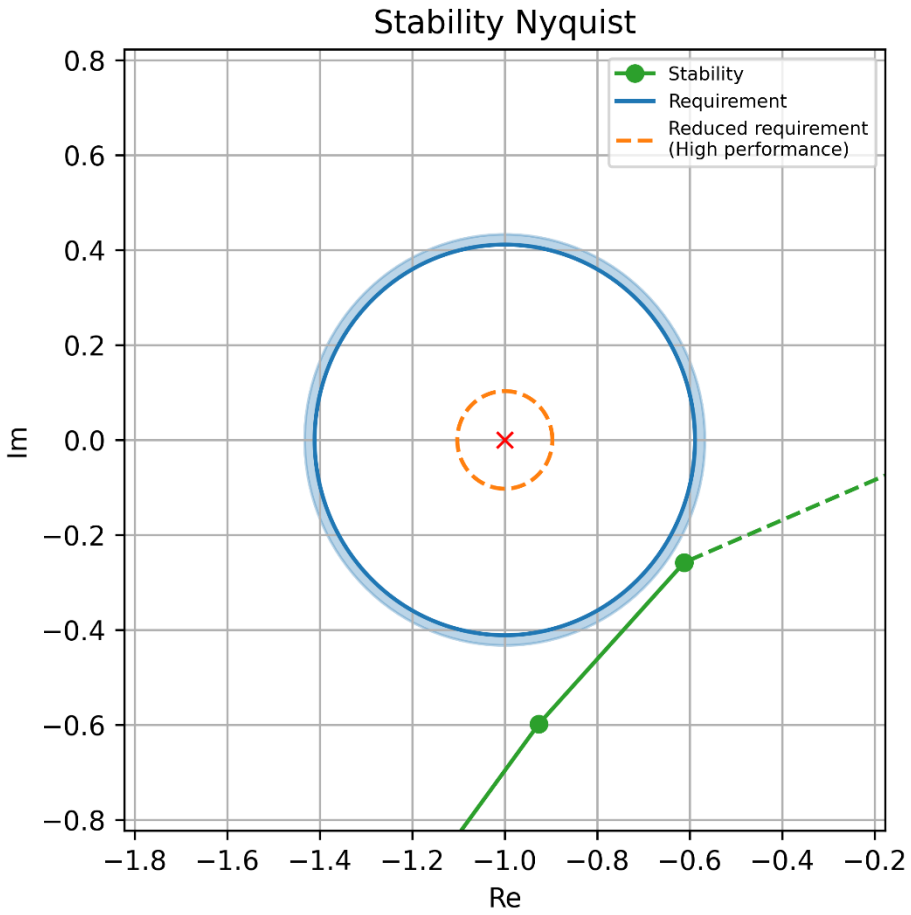


**Figure 7. FCR-D stability requirement (blue) together with an example response (green). The example response fulfils the stability requirement since it does not enter the blue circle or encircle the red cross. The orange circle indicates the reduced stability requirement for entities utilising high performance parameters in accordance with subsection 3.2.5**

### 3.2.5. FCR-D with separate high performance and high stability parameters

This section describes an alternative parameter configuration for entities that have difficulties to comply with both performance and stability requirements at the same time. Instead of using one set of FCR-D parameters that fulfils all requirements, the provider may choose to use a combination of a *high performance* parameter set and a *high stability* parameter set. The high performance parameters are used to achieve good performance during a large frequency disturbance. They are active for a limited time, after which the entity switches to the high stability parameters to ensure stable operation.

When using the high performance parameters, the entity is allowed to have a reduced stability margin, which in turn allows for a faster response. The stability margin, i.e. the radius of the stability margin circle around the Nyquist point, may be reduced maximally to a fourth of the general requirement when applying the high performance parameters. The high stability parameters set must comply with the general stability requirement in section 3.2.4. The dynamic performance (for activation and deactivation) of the high stability parameters shall fulfil at least the performance requirements for FCR-N, see section 3.1.2.



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The following rules apply for using the high performance parameters:

- The entity may activate the high performance parameters at 49.8 Hz or lower for FCR-D upwards and at 50.2 Hz or higher for FCR-D downwards.
- Regardless of the frequency, the entity must deactivate the high performance parameters when 15-30 seconds have passed from the activation instant, and switch to the high stability parameters.
- After deactivation, the high performance parameters must be blocked from reactivating for 5 minutes. The block shall apply separately for FCR-D upwards and FCR-D downwards.

### 3.2.6. FCR-D and LFSM

FCR-D providing entities shall continue to use the FCR-D parameters also when the frequency goes below 49.5 Hz or above 50.5 Hz. Entities that are required to have Limited Frequency Sensitivity Mode (LFSM) through grid connection requirements shall not activate different parameters for LFSM provision and shall have no frequency saturation, if the same controller is used for both FCR-D and LFSM.

If independent controllers are used for FCR-D and LFSM the FCR-D controller input is allowed to have frequency saturation at 49.5 Hz and 50.5 Hz respectively. The LFSM controller is recommended to utilise the same parameters as the FCR-D controller.

## 3.3. Providing both FCR-N and FCR-D

An entity providing both FCR-N and FCR-D shall comply with the following requirements:

- The power setpoint must allow activation of both contracted FCR-N and FCR-D according to their individual prequalification.
- In steady state, an entity providing both FCR-N and FCR-D shall activate the sum of FCR-N and FCR-D at any frequency deviation, see Figure 8. For entities with one controller that switches the control parameters between the products, this implies that the droop setting must be the same in both parameter sets.



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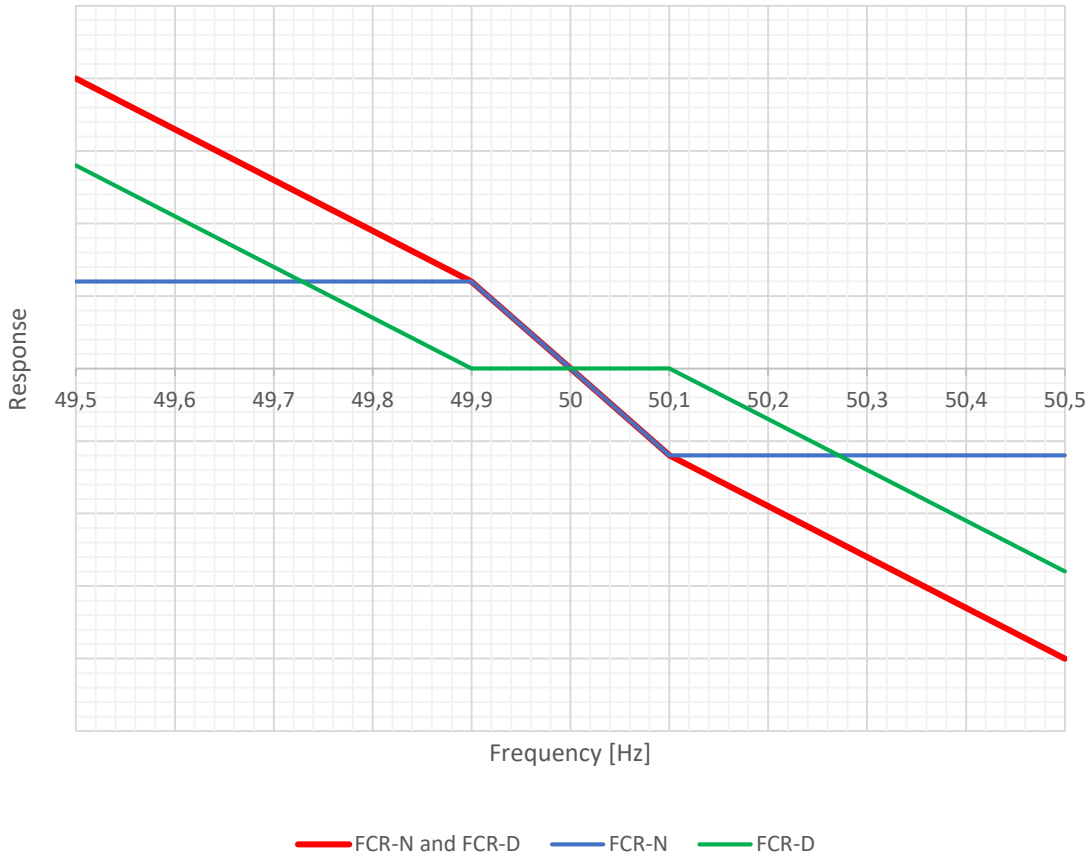


**Figure 8. Steady state active power activation as a function of frequency, droop profile of FCR-N (blue), FCR-D (green) and both combined (red).**

- If the entity switches the control parameters, it must switch from FCR-N parameters to FCR-D parameters when the frequency crosses 49.9 Hz or 50.1 Hz without intentional delay. For switching back from FCR-D to FCR-N there can be a delay after the frequency has returned within the 49.9-50.1 Hz band. The delay may be up to 30 s, recommended value is 15 s.
- The switching of the parameters can be done in an arbitrary way, given that the behaviour complies with all other requirements. The TSO has the right to ask for additional testing and/or simulations, if there is reason to believe that the controller configuration and/or parameter settings have any unforeseen dynamic that is disadvantageous for the power system stability.

It is recommended that the controller structure is implemented such that all three FCR products are individually controllable, i.e. delivered from separate controllers for each product.

## 3.4. FCR providing entities with limited energy reservoirs

An FCR providing entity with an energy reservoir that limits its capability to provide FCR shall activate its FCR for as long as the frequency deviation persists, unless its energy reservoir is exhausted in either the positive or negative direction.

The FCR provider shall in the application document the limitations of the energy reservoir in accordance with instructions from the reserve connecting TSO. The application shall also describe the implementation of any energy management solution, including the recovery process, to be approved by the TSO. Use of energy management functions shall not interfere with the ability to provide FCR.



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### 3.4.1. FCR-N

FCR-N provision from an FCR providing entity with limited energy reservoirs (LER) shall be continuously available during the whole contractually agreed delivery period, currently increments of 1 hour. Recharging and discharging of FCR-N is mainly handled by natural frequency deviations, as FCR-N is a symmetric product.

### 3.4.2. FCR-D

FCR-D provision from an FCR providing entity with limited energy reservoirs (LER) shall be continuously available in normal state. As of triggering of alert state[8] and during the alert state, each FCR-D providing entity with limited energy reservoirs shall be able to fully activate FCR continuously for a time period of 15 minutes[9].

Recharging of FCR-D (upwards) is only allowed if the frequency has remained above 49.9 Hz for $T$ seconds. Discharging of FCR-D (downwards) is only allowed if the frequency has remained below 50.1 Hz for $T$ seconds. The delay $T$ shall be randomly selected by the providing entity from a uniform distribution $U(15\ s,\ 45\ s)$ and be updated for each activation. FCR providing entities without the ability to implement a randomised delay are allowed to use a static delay of 60 s.

FCR-D providing entities with partially or fully depleted energy reservoirs shall restore full nominal capacity within 120 minutes of the allowed start of recovery. The recovery process shall be initiated and completed as soon as possible. For entities recharging via the power grid, the maximal recharge rate is limited to 34% of procured capacity. In case of a new disturbance during the recovery process an FCR providing entity shall be able to stop the recovery and start activation of the reserve with the available energy.

[8] Conditions for triggering of alert state are defined in SO GL article 18.2(c). Alert state trigger time is defined to be 5 minutes in accordance with SO GL article 127.
[9] In accordance with SO GL article 156.10.



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## 3.5. Provision from aggregated resources

**Note:** The Nordic TSOs are currently discussing requirements for aggregated resources to ensure suitable performance and stability. The requirements will be added to this section once a proposal has been developed. The following paragraphs contain an outline of the current thinking.

It can be expected that providers using aggregated groups desire some flexibility within the group, e.g. that they may want to add or remove resources after initial prequalification or that not all resources in the group are able to participate in provision all the time. A framework has been developed for discussing the different scenarios regarding flexibility of groups that can be expected to occur. The framework defines dynamic prequalification and dynamic operation. Dynamic prequalification means that an initial set of units has been prequalified normally and checked for fulfilment of the technical requirements per the usual process. Afterwards the provider is allowed to extend the group with additional resources without performing a full new prequalification of the whole group. Thus, the original prequalification within some limits will remain valid and extended to the new resources, hence the nomenclature *dynamic prequalification*.

Dynamic operation on the other hand means that the whole group does not need to participate in provision at all times, i.e. the provider is allowed to choose a subset of the prequalified group to use during delivery. This flexibility constitutes *dynamic operation*.

The two concepts may be combined. The combinations are illustrated in Figure 9 and explained in Table 3 below.

**Table 3. Explanation of the different dynamic scenarios.**

| | Operation static | Operation dynamic |
|---|---|---|
| **Prequalification static** | The group is tested the same as if it were a single unit | The whole group is tested at the same time, but the subgroup of members participating is changed during operation. |
| **Prequalification dynamic** | Resources enter and/or leave the group, but during operation the whole group participates | Resources enter and/or leave the group, the subgroup of members participating is changed during operation |



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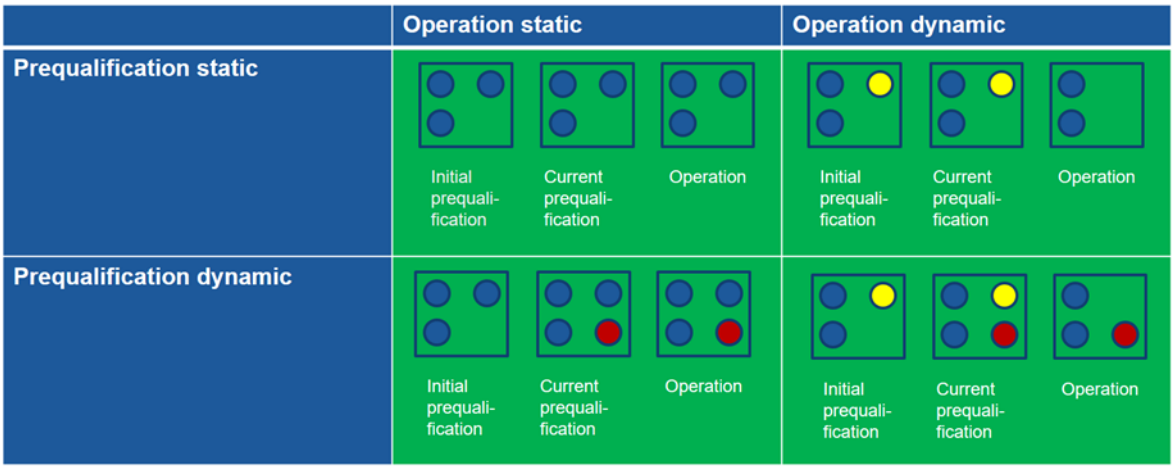


**Figure 9. Illustration of classification of static and dynamic operation and prequalification respectively. Blue circle indicates a resource that participated in the original prequalification and now participates during operation. Yellow circle denotes a resource that participated during original prequalification but currently does not participate during operation. Red circle corresponds to a resource that was added after initial prequalification and now participates during operation**

The TSOs have agreed to the following principles regarding flexibility of aggregated resources:

- The TSOs shall *aim* to allow the flexibility that is possible without endangering the general purpose and intent of the technical requirements.
- The response shall still be required to be within the technical requirements even if some flexibility is allowed with regard to testing.
- During initial testing the group should be tested according to normal procedures. Periodic reassessment shall be made according to normal procedures.
- The provider shall apply for the kind of flexibility that is desired (dynamic prequalification and/or dynamic operation).
- The provider shall in the application describe how they will ensure compliance under the desired flexibility. The description shall be assessed and approved by the reserve connecting TSO.
- If approved, the provider may then add additional units to the group and/or operate dynamically within the general limits for dynamic behaviour as stated in the technical requirements. Further changes outside of the stated limits will require a new prequalification.

The TSO shall in the decision, when applicable to ensure that compliance is always met in operation, set additional or stricter limits on how, and to what extent, the flexibility can be used for that specific group, and how the compliance shall be tested. For example, if a battery is needed to achieve compliance the TSO shall require the battery to always be in operation when the group is providing FCR.

## 3.6. Provision from centrally controlled FCR providing entities

An entity is defined to be centrally controlled if during operation it is dependent on a centralised function. Examples of such functions are central frequency measurements and central control systems not located together with the providing entity, by e.g. using (third party) communication links. An entity that is not dependent on centralised functions is denoted as locally controlled. An entity may be regarded as locally

controlled even if it is dependent on central functions prior to the operation phase and actual provision, e.g. for scheduling of the resource. It is in such cases required that any centralised signals are sent well in advance of the contractually agreed delivery period and that the provider is able to verify that the entity has received the signal prior to provision.

Local control shall always be implemented whenever feasible from a technical point of view. The reserve connecting TSO may allow central control if local control would incur unreasonable cost. It is the provider's responsibility to contact the TSO to determine if the control configuration is acceptable and if it is regarded as local or central.

Central frequency measurements may only be used to control resources in the same LFC (Load-Frequency Control) area[10] in which the measurements were made.

The maximal provision per central controller is limited to 5% of the nominal reference incident in the Nordic power system. Currently the limit for FCR-N and FCR-D is 73 $MW$ ($= 1450\ MW \cdot 0.05$). When providing both reserves the combined limit is 100 MW.

The implemented solution shall be designed to guarantee an availability of the central functions of at least X % (TBD)[11]. The solution shall be robust against unavailability of the central functions, and hence the provider shall implement one of the following methods:

- Redundancy for the central functions, to be evaluated and approved by the reserve connecting TSO
- Alternatively, a local fall-back solution. The reserve connecting TSO may allow the local fall-back to be slightly less accurate than otherwise stated by the requirements, if motivated on a technical basis.
- Single point of failures shall be allowed if deemed unfeasible to avert by redundancy or local fall-back, if the availability requirement can still be met.

## 3.7. Requirements on the measurement system

An FCR providing entity shall be able to respond to relatively small variations in the measured quantities. The measurement system shall fulfil the requirements on accuracy, resolution and sample rate stated in this section. The active power measurement shall be such, that it covers all active power changes as a result of the FCR activation.

### 3.7.1. Accuracy

The measurement accuracy for active power and frequency shall achieve the values stated in Table 4, or better. The value shall include the total inaccuracy of instrument (measurement) transformer, measurement transducer and any other equipment in the measurement system.

[10] Currently LFC areas correspond to bidding zones in the Nordics.
[11] The Nordic TSOs are currently working to define the value.



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**Table 4. Accuracy of measurement system.**

| Measured quantity | Category | Rated power[12] | Accuracy |
|---|---|---|---|
| Active power | 1 | $< 2$ MW | $\pm 5\%$ |
| | 2 | $2 - 10$ MW | $\pm 1\%$ |
| | 3 | $> 10$ MW | $\pm 0{,}5\ \%$ |
| Grid frequency | N/A | N/A | $\pm 10$ mHz |
| Applied frequency | N/A | N/A | $\pm 10$ mHz |

The active power accuracy shall be achieved when full active power is being measured. When the active power is lower than the rated power a slightly worse accuracy is accepted. For example, an active power inaccuracy of less than 0,5% can be achieved by using e.g. a current transformer of class 0,2S and voltage transformer of class 0,2. The remaining inaccuracy for transducer and other equipment then becomes approximately 0,1%.

### 3.7.2. Resolution

The measurement resolution for active power and frequency shall achieve the values stated in Table 5, or better. The resolution is limited by e.g. the amount of bits in the measurement system. For a 16-bit system $2^{16} = 65536$ number of levels is possible to report. If the measured interval corresponds to 0-100% the resolution becomes 100/65536 = 0,0015%.

**Table 5. Resolution of the measurement system.**

| Measured quantity | Resolution |
|---|---|
| Active power | 0,01 MW or 0,025%[13] |
| Grid frequency | 1 mHz |
| Applied frequency | 1 mHz |

### 3.7.3. Sampling rate

The sampling rate shall be high enough to achieve the above stated requirement for measurement accuracy and measurement resolution, and to supply the controller with a suitable update interval. The sampling rate shall be at least the same as the logged data interval values stated in subsection 4.3 and 5.2 respectively.

[12] Rated power of the resource being measured.
[13] For new installations it is recommended to use a 16-bit transducer and thus have a resolution of 0,0015%.



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# 4. Tests and calculations for compliance and capacity verification

This section describes how the compulsory tests are to be performed. The tests are made to verify the compliance with the stationary and dynamic performance requirements and to the stability requirements, separately for FCR-N, FCR-D upwards, and FCR-D downwards. The compliance with these requirements shall be verified using a dedicated tool provided and certified by the TSO.

During the tests, the frequency input signal is replaced by a synthetic signal, while the entity is still synchronized to the grid. The synthetic signal is applied by the provider.

Reliable test equipment, suitable for the purpose of the testing, must be used. Test signals shall preferably be generated using an external signal source (signal generator) connected to the frequency measurement device. If an internal signal is used, the impact of the frequency measurement must be accounted for. Test setup and equipment used for the tests are described in the Supporting document.

## 4.1. Operational test conditions

Since the tests cannot be performed for all possible operational situations, the required test conditions are limited to the following 4 operational conditions, and corresponding controller parameter sets.

1) *Maximum active power setpoint* where the entity will provide FCR, and *maximum droop*, and corresponding controller parameter sets, where the entity will provide FCR
2) *Maximum active power setpoint* where the entity will provide FCR, and *minimum droop*, and corresponding controller parameter sets, where the entity will provide FCR
3) *Minimum active power setpoint* where the entity will provide FCR, and *maximum droop*, and corresponding controller parameter sets, where the entity will provide FCR
4) *Minimum active power setpoint* where the entity will provide FCR, and *minimum droop*, and corresponding controller parameter sets, where the entity will provide FCR

Providers are allowed to include additional testing at other operational conditions in the prequalification, for example if it is not suitable to perform linear interpolation of the capacity using only the above stated operational conditions, in accordance with subsection 4.7 of the Supporting document.

If the above stated conditions are not applicable or representative for the FCR providing entity, the test conditions shall be agreed with the TSO prior to performing the tests. For example, FCR providing entities, where the setpoint does not have any influence on the FCR response, can be tested at only one setpoint. Other exemptions can be given where relevant, see section 3 of the Supporting document.

## 4.2. Ambient test conditions

The testing aims at verifying that the entity tested fulfils the technical requirements specified in Section 3 under foreseeable operational conditions. For FCR providing entities, tests must be performed in such a way that the results are representative of all foreseeable operational conditions. The operational conditions at the time for the test must not be optimized for the purpose of the testing.

The FCR capacity may vary with parameters and conditions, which were not subjected to variations during the tests, such as head of a hydro unit. For such conditions a calculated value of the actual capacity is accepted. A description of the method for calculation and parameters used shall be provided upon request by the reserve connecting TSO.

Hydro units with a joint penstock can be tested individually. Effect of the joint penstock can be shown by simulations or calculations. A description of the method for simulations or calculations shall be provided upon request by the reserve connecting TSO.



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## 4.3. Test data to be logged

Data logged during tests shall be provided to the reserve connecting TSO, and should as a minimum include the below listed quantities, which are to be provided in the format described in Subsection 5.2.1. The logged test data shall preferably be time-stamped and with accuracy synchronised to CET, alternatively a running number of seconds may be used. A separate file for each test is to be prepared and named according to the scheme below:

[DateTime]_[Resource]_[Test]_[Test_set].csv

Where:

- [DateTime] = The day and time of the day the test is performed in format YYYYMMDDThhmm e.g. 20160310T1210
- [Resource] = Identifier for the resource agreed with the reserve connecting TSO e.g. FCPG1
- [Test] = The test performed named according to one of the following "FCR-N_step", "FCR-N_sine_[TimePeriod]", "FCR-D_down_step", "FCR-D_down_ramp", "FCR-D_up_step", "FCR-D_up_ramp" and "FCR-D_sine_[TimePeriod]"
- [TimePeriod] = One of the time periods specified in Table 6 or Table 7. Time periods (s) for FCR-D sine tests.
- [Test_set] = The test set[14] which was used e.g. Test-set1

The sampling rate for data logging during the tests shall be at least 10 Hz for FCR-D and at least 5 Hz for FCR-N.[15]

**Continuously logged during the tests**

- Instantaneous active power in [MW], Measured grid frequency in [Hz], Applied frequency in [Hz]. The resolution and accuracy shall be as stated in subsection 3.7.
- Status ID indicating which controller parameter set is active, if it can be automatically changed during the test.

In addition, it is recommended that important states affecting the FCR response are also logged. Such data includes but is not limited to:

- For hydro units
    - Controller output signal
    - Guide vane opening
    - Runner blade angle (Kaplan units)
    - Upstream water level above sea level [m]
    - Downstream water level above sea level [m]
- For thermal units
    - Controller output signal
    - Turbine control valve opening

[14] A test set is a group of different tests performed at a certain setpoint of the entity with a certain controller parameter set and consists of all the tests that need to be performed at that setpoint with those controller parameters

[15] In cases where the data logging requirement during test is prohibitive, the reserve connecting TSO may grant an exception to use a sampling rate for data logging of at least 1 Hz. This exception only applies in cases where the higher data rate is not needed for the evaluation, i.e. the response is fast, stable and with low noise levels.



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- For batteries
    - Charge level
- For entities without a predefined setpoint
    - Calculated baseline

**Provided per test set**

- $P_{max}$ in [MW]
- $P_{min}$ in [MW]
- Active power setpoint of FCR providing entity [MW]
- Controller parameter set
- Expected FCR capacity in [MW]
- Dead band for frequency control [Hz]

Conditions that have an impact on the FCR response, such as

- Ambient temperature [°C] (thermal units)
- Cooling water temperature [°C] (thermal units)

## 4.4. Tests to be performed to verify compliance with the requirements for FCR-N

In order to verify compliance with the requirements for FCR-N, the provider of the service shall perform the following tests for each controller parameter set, where FCR-N is to be provided. Parameters that are scaled linearly with the droop are not seen as different parameter sets. The tests to be conducted are the below described step response tests, to determine the FCR-N capacity and to verify the compliance with the stationary and dynamic performance requirements, and the sine tests, to verify stability and dynamic performance. Sine tests only need to be performed at the most challenging operating point in terms of stability. The choice of the operating point must be motivated by prior knowledge and approved by the TSO. For entities with non-continuous response a linearity test also has to be performed.

### 4.4.1. FCR-N step response sequence test

The step response sequence consists of 100 mHz steps in the input signal to determine the capacity and 50 mHz steps to clear the effect of the backlash, see Figure 10, where the applied frequency is shown. The active power response has to be clearly stabilized after each frequency step change before the next frequency step change is applied.



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50.00 Hz → 50.05 Hz → 50.00 Hz → 49.90 Hz →50.00 → 50.10 Hz → 50.00 Hz

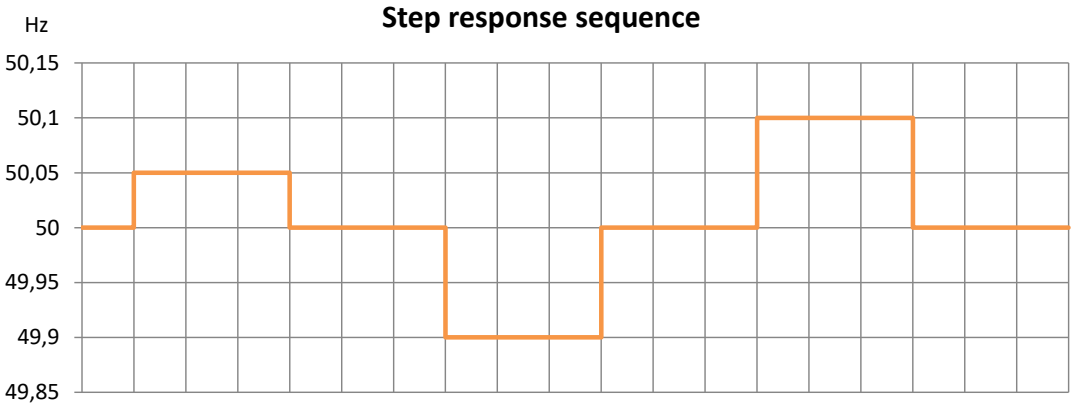


**Figure 10. FCR-N step response sequence to be performed for each setpoint and parameter set.**

### 4.4.2. FCR-N sine tests

Sine tests shall be performed with a frequency amplitude of 100 mHz. The applied nominal 50 Hz frequency signal is to be superimposed with a sinusoidal test signal with different time periods ranging from 10 s to 70 s, as shown in Table 6 below. For each time period at least 5 periods with stabilized response shall be registered. If the response already crosses the real axis (Im=0) in the Nyquist plane on the right side of the stability requirement circle for tested time periods, the testing of time periods less than or equal to 40 seconds can be omitted. The applied frequency with the superimposed sinusoidal signal is illustrated in Figure 11 together with an example of the resulting power output.

**Table 6. Time periods (s) for FCR-N sine tests**

| 10 | 15 | 25 | 40 | 50 | 60 | 70 |
|---|---|---|---|---|---|---|

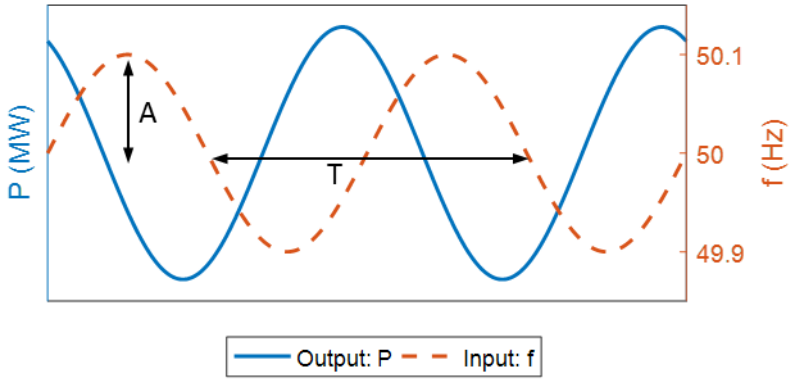


**Figure 11. The applied frequency (f) with the superimposed sinusoidal signal (amplitude A, time period T) and the corresponding power output (P).**



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### 4.4.3. FCR-N linearity test

For entities with a non-continuous response, a linearity test shall be performed to verify compliance with the requirement for linearity as outlined in Figure 1. The test consists of a sequence of ramps illustrated in Figure 12:

50.0 Hz → 49.9 Hz → 50.0 Hz → 50.0 Hz → 50.1 Hz → 50.0 Hz

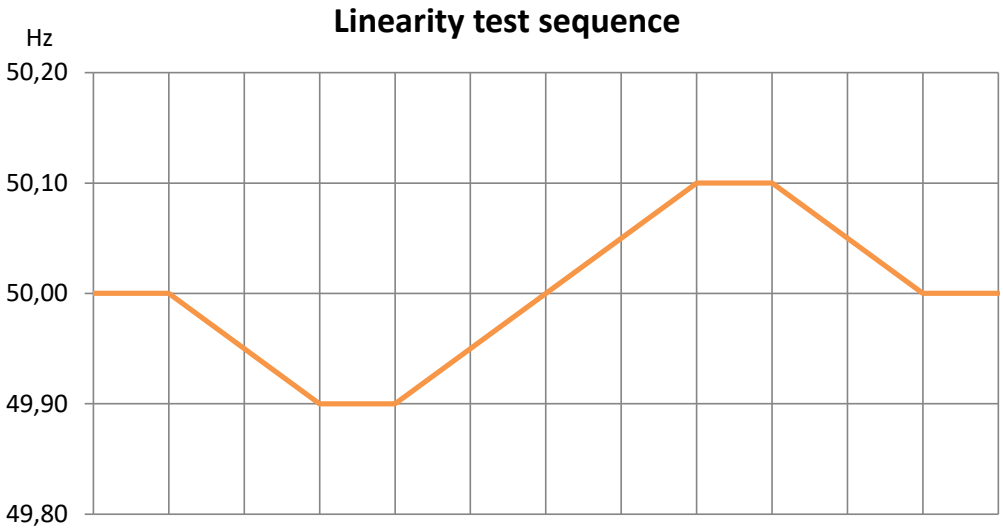


**Figure 12. FCR-N linearity test sequence to be performed for minimum and maximum capacity.**

I.e. both activation and deactivation shall be tested in the upwards and downwards direction respectively. The ramp rate shall be at least 0.5 mHz/s, i.e. a full activation from 50.0 Hz to 49.9 Hz shall be made within maximum 200 seconds. A faster ramp rate may be chosen, up to 2 mHz/s, i.e. 50 seconds for full activation.

## 4.5. Tests to be performed to verify compliance with the requirements for FCR-D

In order to verify compliance with the requirements for FCR-D, the provider of the service shall perform the following tests. If there are several different FCR-D parameter sets, all of them shall be tested. Parameters that are scaled linearly with the droop are not seen as different parameter sets. An entity can be prequalified for FCR-D upwards, FCR-D downwards or both. The tests to be conducted are the below described stationary performance, ramp response and sine tests. Sine tests only need to be performed at the most challenging operating point in terms of stability. The choice of the operating point must be motivated by prior knowledge and approved by the TSO. For entities with non-continuous response a linearity test also has to be performed.

### 4.5.1. FCR-D upwards stationary performance test

The stationary performance test sequence is performed to verify compliance with the stationary performance requirement in subsection 3.2.1, and the requirements for combined delivery of FCR-N and FCR-D in subsection 3.3 where applicable. The test consists of a sequence of ramps. The ramp rate shall be at least 2 mHz/s, i.e. a full activation from 50.0 Hz to 49.5 Hz shall be made within maximum 250 seconds. A faster ramp rate may be chosen, up to 10 mHz/s, i.e. 50 seconds for full activation. The test is similar to the ramp sequence in Subsection 4.5.2, but shall be performed with a slower ramp rate. The test consists of a sequence of ramps illustrated in Figure 13.



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50.00 Hz → 49.50 Hz → 49.70 Hz → 49.90 Hz → 49.70 Hz → 49.50 Hz → 49.70 Hz → 49.90 Hz

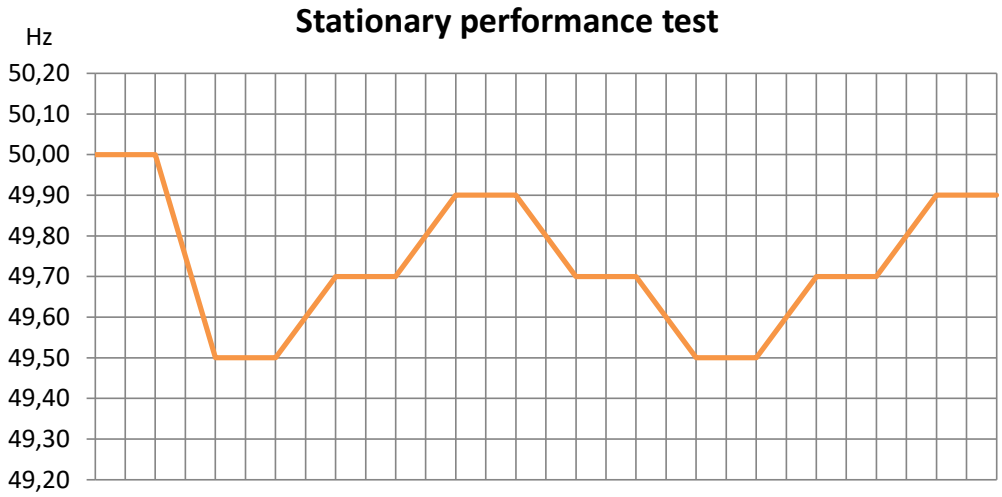


**Figure 13. FCR-D upwards stationary performance test sequence.**

### 4.5.2. FCR-D upwards ramp response test

The ramp response test is to be performed according to Figure 14. It consists of two stepwise changes followed by a ramp from 49.90 Hz to 49.00 Hz with a ramp rate of -0.24 Hz/s. The activation sequence is finished when the response has stabilised at 49.00 Hz. Deactivation response shall then be tested by performing the same ramp in the opposite direction, i.e. from 49.00 Hz to 49.90 Hz.

50.00 Hz → 49.80 Hz → 49.90 Hz → 49.00 Hz → 49.90 Hz

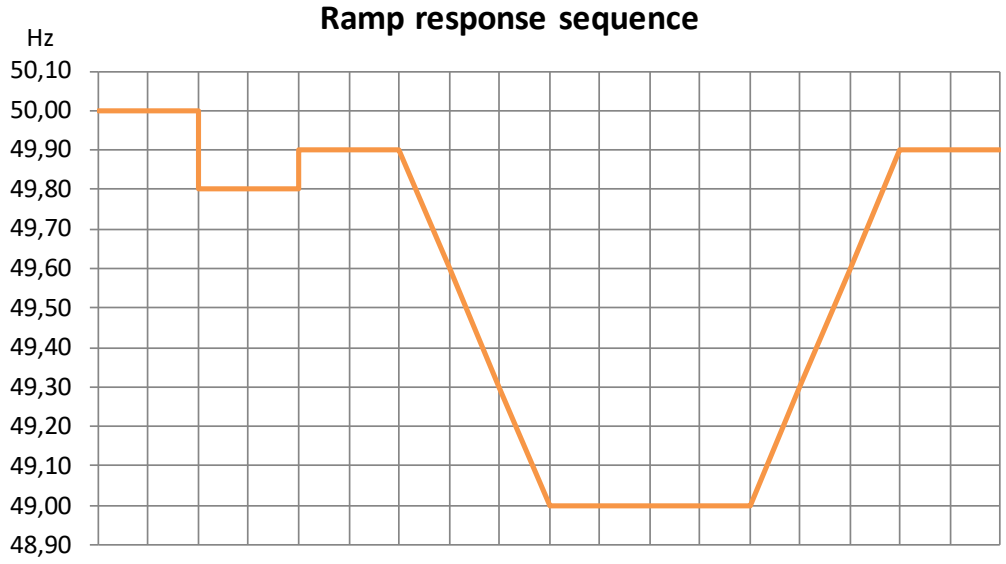


**Figure 14. FCR-D upwards regulation ramp response sequence.**

### 4.5.3. FCR-D downwards stationary performance test

The stationary performance test sequence is performed to verify compliance with the stationary performance requirement in subsection 3.2.1, and the requirements for combined delivery of FCR-N and



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FCR-D in subsection 3.3 where applicable. The test consists of a sequence of ramps. The ramp rate shall be at least 2 mHz/s, i.e. a full activation from 50.0 Hz to 50.5 Hz shall be made within maximum 250 seconds. A faster ramp rate may be chosen, up to 10 mHz/s, i.e. 50 seconds for full activation. The test is similar to the ramp sequence in Subsection 4.5.4, but shall be performed with a slower ramp rate. The test consists of a sequence of ramps illustrated in Figure 15.

50.00 Hz → 50.50 Hz → 50.30 Hz → 50.10 Hz → 50.30 Hz → 50.50 Hz → 50.30 Hz → 50.10 Hz

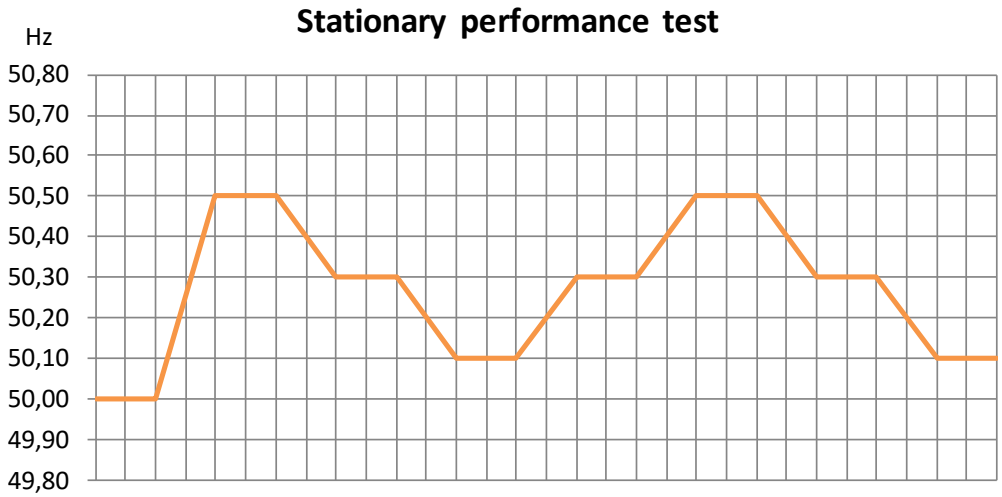


**Figure 15. FCR-D downwards stationary performance test sequence.**

### 4.5.4. FCR-D downwards – ramp response test

The ramp response test is to be performed according to Figure 16. It consists of two stepwise changes followed by a ramp from 50.10 Hz to 51.00 Hz with a ramp rate of 0.24 Hz/s. The activation sequence is finished when the response has stabilised at 51.00 Hz. Deactivation response shall then be tested by performing the same ramp in the opposite direction, i.e. from 51.00 Hz to 50.10 Hz.



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50.00 Hz → 50.20 Hz → 50.10 Hz → 51.00 Hz → 50.10 Hz

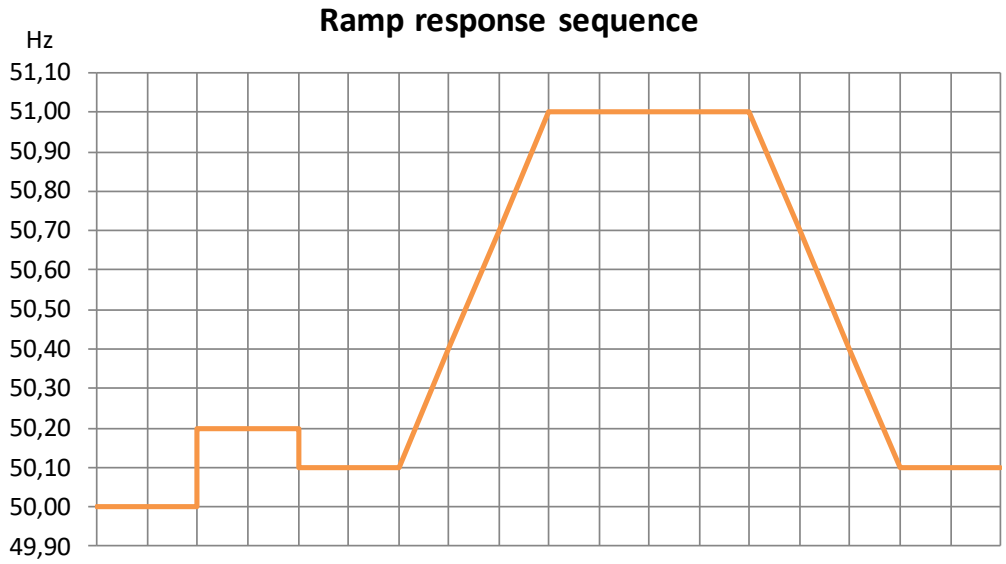


**Figure 16. FCR-D downwards ramp response sequence.**

### 4.5.5. FCR-D sine tests

The sine tests shall be performed with a frequency amplitude of 100 mHz. The applied nominal 50 Hz frequency signal is to be superimposed with a sinusoidal test signal with different time periods ranging from 10 s to 50 s, as shown in Table 7 below. At least 5 periods with stabilized response shall be registered. If the response already crosses the real axis (Im=0) in the Nyquist plane on the right side of the stability requirement circle for tested time periods, the testing of shorter time periods can be omitted. The applied frequency with the superimposed sinusoidal signal is illustrated in Figure 11 together with the resulting power output.

**Table 7. Time periods (s) for FCR-D sine tests**

| | | | | |
|---|---|---|---|---|
| 10 | 15 | 25 | 40 | 50 |

For entities with multiple controller parameter sets, FCR-D parameters shall be continuously active during FCR-D sine tests. For sine testing the baseline shall be shifted to 49.7 Hz or 50.3 Hz, for FCR-D upwards and downwards respectively. Alternatively, a baseline of 50.0 Hz can be used for entities with the same parameters for both FCR-D upwards and downwards and/or FCR-N or otherwise agreed with the reserve connecting TSO. Entities providing FCR-D with separate parameters for high performance and high stability, per subsection 3.2.5, shall perform separate sine testing for each parameter set, with parameter switching disabled. For entities that provide FCR-D with the same parameter set as FCR-N, only the FCR-N sine tests (see Section 4.4.2 ) need to be performed.

## 4.6. Reassessment tests

Reassessment tests are to be done under the conditions stated in Subsection 4.1 and Subsection 4.2 unless stated otherwise. If a full prequalification procedure was performed less than 5 years ago, and no changes to the entity have occurred that can be expected to affect the fulfilment of the requirements, a simplified reassessment according to Subsections 4.6.1 and 4.6.2 can be performed. If such simplified reassessment test results are in line with the most recent full prequalification test results, the FCR providing entity should be considered prequalified for another period of 5 years.



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### 4.6.1. Reassessment for FCR-N providing entities

The reassessment for FCR-N consists of the test in Subsection 4.4.1.

If the calculated capacities from the step tests are not in line with previous test results, a full prequalification procedure is to be performed.

### 4.6.2. Reassessment for FCR-D providing entities

The reassessment for FCR-D upwards consists of the tests in Subsection 4.5.1 and Subsection 4.5.2.

The reassessment for FCR-D downwards consists of the tests in Subsection 4.5.3 and Subsection 4.5.4.

If the calculated capacities from the step tests are not in line with previous test results, a full prequalification procedure is to be performed.

## 4.7. Test reports

For each providing entity tested, an overall test report shall be put together that summarizes the outcome of the tests. The test report shall be accompanied by the logged data specified for each product tested.

In addition to the test report, a set of one (1) hour of logged data, in accordance with Subsection 5.2, shall be submitted to the TSO. The test shall include active frequency control with at least FCR-N active, recommended to be activated on maximal capacity, if applicable.



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# 5. Requirements on real-time telemetry and data logging

The requirements for telemetry delivered to the reserve connecting TSO in real-time are outlined in this section. The requirements for data to be logged by the reserve provider and delivered to the TSO upon request are also outlined.

## 5.1. Real-time telemetry

Each TSO may require FCR providers to deliver the following real-time telemetry, with an update interval defined by the TSO, for each of their FCR providing entities:

- Instantaneous active power [MW]. The value shall be such that it covers active power changes as a result of the reserve activation.
- Activated FCR capacity [MW],
- Maintained FCR-N capacity [MW],
- Maintained FCR-D capacity [MW], for upwards regulation
- Maintained FCR-D capacity [MW], for downwards regulation

For entities with a limited energy reservoir additional real-time telemetry is to be provided as follows:

- Maintained FCR-N capacity with limited energy reservoir [MW],
- Maintained FCR-N capacity with limited energy reservoir endurance [minutes]
- Maintained FCR-D capacity with limited energy reservoir [MW], for upwards regulation
- Maintained FCR-D capacity with limited energy reservoir endurance [minutes], for upwards regulation
- Maintained FCR-D capacity with limited energy reservoir [MW], for downwards regulation
- Maintained FCR-D capacity with limited energy reservoir endurance [minutes], for downwards regulation

The maintained FCR-N and FCR-D capacity includes both contracted and non-contracted capacity. The resolution and accuracy shall be as specified in subsection 3.7, or better. Calculations are to be performed on an entity level by the provider and to be reported to the reserve connecting TSO. Calculation of the maintained capacities and activated capacity are described in the Supporting document Section 5.

## 5.2. Data logging

Each FCR provider shall store the logged data for each of its FCR providing entities for at least 14 days, data may be stored in any format suitable for the provider. When data is to be delivered to the reserve connecting TSO (i.e. when requested by the TSO) the format specified in Subsection 5.2.1 applies.

Each FCR provider shall log:

- Instantaneous active power [MW]. The value shall be such that it covers active power changes as a result of the reserve activation.
- Grid frequency [Hz]

In addition, it is recommended that important states affecting the FCR response are also logged, such as

- Maintained FCR-N capacity [MW]
- Maintained FCR-D capacity [MW], for upwards regulation



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- Maintained FCR-D capacity [MW], for downwards regulation
- $P_{\max}$ [MW]
- $P_{\min}$ [MW]
- Controller setpoint
- Control Mode (where relevant), alphanumeric identifier indicating which prequalified controller parameter set is active
- Controller output signal [in a format suitable for the specific controller]
- Guide vane opening [% of full operational range or degrees]
- Runner blade angle (Kaplan units) [% of full operational range or degrees]
- Upstream water level, meters above sea level [m]
- Downstream water level, meters above sea level [m]
- Reservoir energy level / state of charge, if applicable [%]
- Ambient temperature [°C] (thermal units)
- Cooling water temperature [°C] (thermal units)
- Calculated baseline [MW] (For entities without a predefined setpoint)

Guidelines for calculating the capacities are specified in the Supporting document. The data shall be recorded with a time resolution less than or equal to 1 second. The measurement resolution and accuracy shall be as specified in subsection 3.7, or better.

The data shall be time-stamped, and time shall with high accuracy be synchronized to CET. The data shall be made available in csv-format for the TSO within five working days from request in the file format specified in Subsection 5.2.1.

### 5.2.1. File format for logged data delivery

The file format for data delivery is the European standard csv-file, character encoding in ASCII where values are delimited by semicolon (;), decimal separator is comma (,) and record delimiter is carriage return (↲ ASCII/CRLF=0x0D 0x0A). Date and time formats are in accordance to ISO 8601 and are specified below.

Naming format for the file is [Date]_[Area]_[Resource]_[Interval].csv

Where:

- [Date] = The day data is extracted in format YYYYMMDD e.g. 20160310
- [Area] = The bidding area where the resource is located e.g. SE1, FI, NO5, DK2
- [Resource] = Identifier for the resource agreed with reserve connecting TSO e.g. FCPG1
- [Interval] = The time interval for which data is delivered in format YYYYMMDDThhmm-YYYYMMDDThhmm e.g. 20160101T0000-20160114T2359

Data records are provided in the following format: [DateTime];[record1];[record2];…;[recordX].

- [DateTime] = Date and time in format YYYYMMDDThhmmss.nnn where n are decimal fractions of a second e.g. 20160330T093702.012



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The data records to be provided are listed below, together with their record headers and data types. If the data record is non-applicable it should be left blank. Capacities are calculated as described in the Supporting document.

- [FcrnCap] = double with three decimals of maintained FCR-N capacity in MW e.g. 20,100
- [FcrdCapUp] = double with three decimals of maintained FCR-D upwards capacity in MW e.g. 67,500
- [FcrdCapDo] = double with three decimals of maintained FCR-D downwards capacity in MW e.g. 67,500
- [InsAcPow] = double with three decimals of instantaneous active power in MW e.g. 120,532
- [Pmax] = double with three decimals of current maximum power level in MW, output (generation) outtake (consumption) e.g. 120,532
- [Pmin] = double with three decimals of current minimum power level in MW output (generation) outtake (consumption) e.g. 0,832
- [GridFreq] = double with three decimals of measured frequency in Hz e.g. 49,320
- [ContSetP] = double with three decimals of controller set point in MW, e.g. 67,500
- [ContOutSig] = double with three decimals of the control signal output from the controller e.g. 0,300
- [ContMode] = alphanumeric identifier of the control mode in use e.g. FCRN4
- [GuideVane] = double with three decimals of the guide vane opening, only applies to hydro, as a percentage of full operational range or in degrees e.g. 17,500
- [BladeAng] = double with three decimals of the runner blade angle in a Kaplan unit, as a percentage of full operational range or in degrees e.g. 5,301
- [UppWatLev] = double with three decimals of the current upper water level, only applies to hydro, in meters e.g. 16,500
- [LowWatLev] = double with three decimals of the current lower water level, only applies to hydro, in meters e.g. 4,500
- [ResSize] = double with three decimals of the current calculated energy reservoir level in MWh, e.g 1,505
- [AmbTemp] = double with three decimals of the current ambient temperature, applies to where temperature has an impact e.g. thermal, in degrees Celsius e.g. -5,120
- [CoolTemp] = double with three decimals of the cooling fluid temperature, applies to where temperature has an impact e.g. thermal, in degrees Celsius e.g. 4,120
- [CalcBaseline] = double with three decimals of the calculated baseline, applies to units without predefined setpoint, in MW, e.g. 8,100



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# 6. Validity and exceptions

These technical requirements for frequency containment reserve provision in the Nordic synchronous area are valid from YYYY-MM-DD.

If a specific requirement turns out to be difficult to fulfil, due to technical or significant economic reasons, the FCR provider may from the reserve connecting TSO request an exception from the specific requirement. The reserve connecting TSO may approve such an exception, if such an exception has no impact on the FCR provision from that specific FCR providing entity, and no significant impact on the stability of the interconnected power system.

Any dispute between a reserve provider and the connecting TSO should be forwarded to the national regulator, for a recommendation to the TSO involved on how to handle the dispute.



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# 7. Revision history

*to be added*



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