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

Draft 2017

Prequalification Working Group, FCP project

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THIS IS A DOCUMENT DESCRIBING THE NEW TECHNICAL REQUIREMENTS FOR FCR IN THE NORDIC SYNCHRONOUS SYSTEM.

THE REQUIREMENTS ARE SO FAR DRAFT REQUIREMENTS AND ARE THUS NOT REQUIREMENTS TO BE FULFILLED FOR CURRENT NORDIC FCR MARKET.

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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 *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 prequalification shall be performed before a provider can deliver FCR-N (Frequency Containment Reserve for Normal operation) and FCR-D (Frequency Containment Reserve for Disturbances) products, 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 are described in this document. The prequalification process 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, 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 regulation, in the range of 49.9 – 49.5 Hz
- FCR-D downwards regulation, 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] System Operation Guideline (SO GL), part IV LFC&R, version 4 May 2016

[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.

2. The prequalification process

This section describes the prequalification for the first time and the regular reassessment of the prequalification.

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.

Providers who aggregate many small units shall, besides the formal application to the reserve connecting TSO, also provide a description on how the aggregation system works.

2.2. Reassessment of the prequalification

As stated in the SO GL the prequalification process shall include at least a reassessment in case of requirements or equipment change and a periodical reassessment within the time frame of at least five years. For the Nordic countries, a reassessment will be required every fifth year. FCR providers with entities that are due for reassessment are to report these to the reserve connecting TSO at least six months prior to expiration of the 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 is described in Subsection 4.6.

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

Aggregated entities are reassessed as a whole entity. If new resources are added to an aggregated entity the new resources can be prequalified separately and then merged with the existing entity.

2.3. Prequalification application

The FCR provider shall perform the required tests and gather the required documentation and shall send this information to the reserve connecting TSO on the requested format (Appendix 1 in Supporting document). 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 description of limitations for FCR activation 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

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

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

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

Generation based resources

- General description of the providing unit/units
- Generator: Rated apparent power [MVA], Inertia constant H [MWs/MVA]
- Turbine: Rated power [MW], Inertia constant H [MWs/MVA]
- Hydro units: Water starting time constant T_w [s], rated head [m]
- Turbine governor: Type, and settings

Load based resources

- General description of the providing unit/units
- Information on the type of the load
- Technical description of the controller, including controller settings

Energy storage based resources

- General description of the providing unit/units
- 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

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.

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 also state the validity of qualification and when reassessment is due.

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 destabilize the power system or cause any other type of problem in the system.

Since the governor control characteristic of generation based resources is different for a power feedback arrangement compared to a valve position feedback arrangement, the test and evaluation procedure has to be slightly different for providing entities with power feedback. The requirements are the same irrespective of the providing entity, i.e. generating entities and load entities should be tested in a similar way to ensure the fulfilment of the performance and stability requirements, respectively.

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.

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.

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 stationary linear 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. As indicated by the dashed line in the figure, the resources are also allowed to continue to linearly increase their activation beyond frequencies of 49.9 Hz and 50.1 Hz. In such a case the behaviour must be accordingly reported in the prequalification documentation.

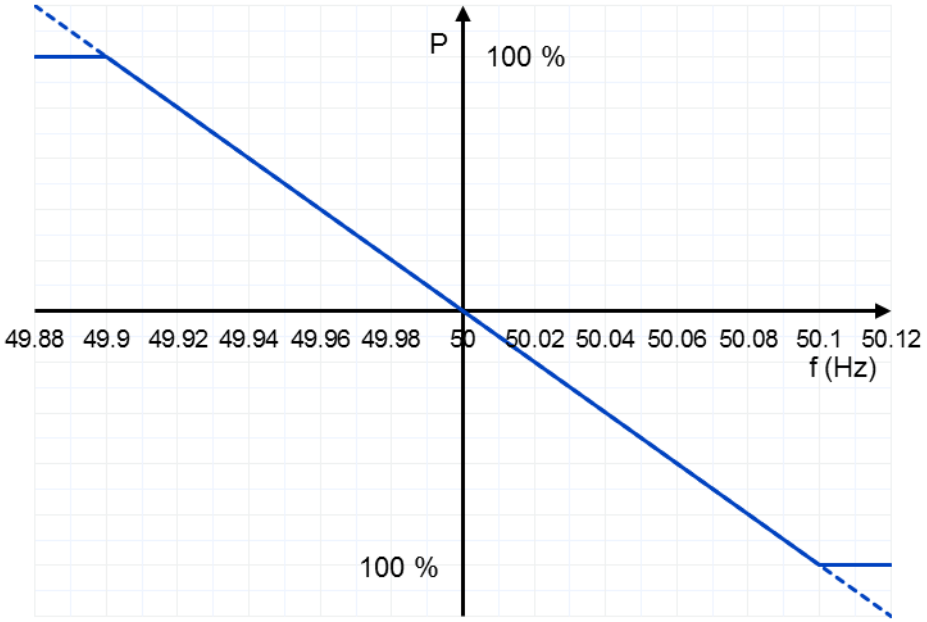

Figure 1: Activation of continuously controlled FCR-N.

Resources that are relay controlled shall activate their FCR-N contribution based on a monotonic piecewise linear power-frequency characteristic, e.g. a step function, see Figure 2.

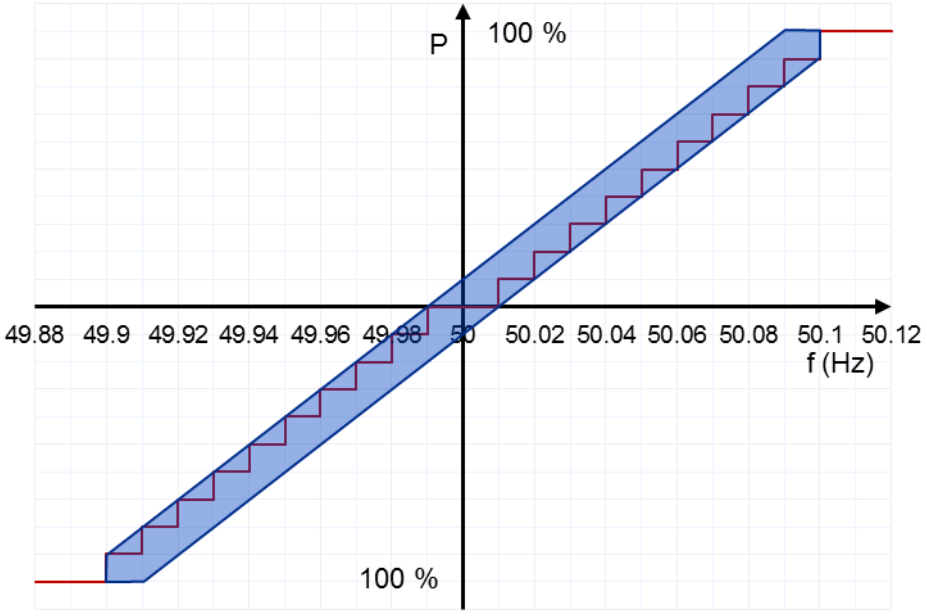

Figure 2: Activation of relay controlled FCR-N resources.

Relay controlled FCR-N resources have to activate their contribution within the blue area in Figure 2, which means that the number of steps has to be at least 10. The red line in the figure indicates one possible activation scheme that fulfils the requirement.

3.1.2. FCR-N dynamic performance requirement

The dynamic performance requirement is such that a curve defined by the FCR-vectors, described in Subsection 3.3 in the Supporting document, 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 300 s.

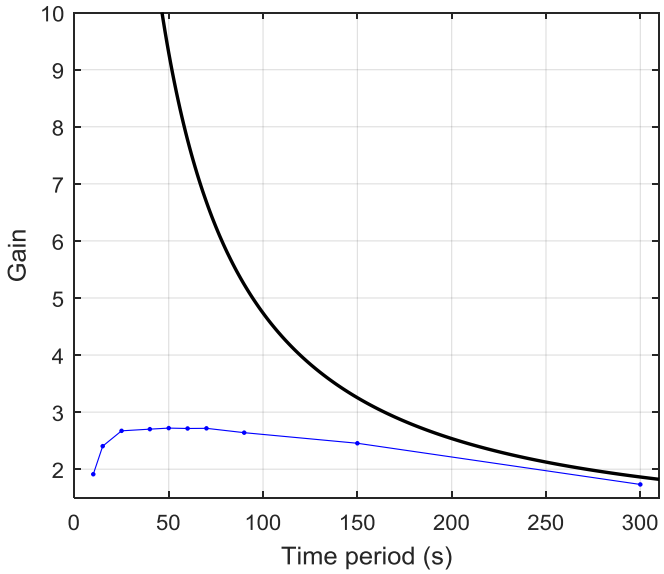

Figure 3: FCR-N dynamic performance requirement (black) together with an example response (blue).

3.1.3. 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 FCR-vectors together with a representation of the power system) does not encircle the Nyquist point (-1, 0) and does not enter the black stability margin circle, around the Nyquist point, as shown in Figure 4.

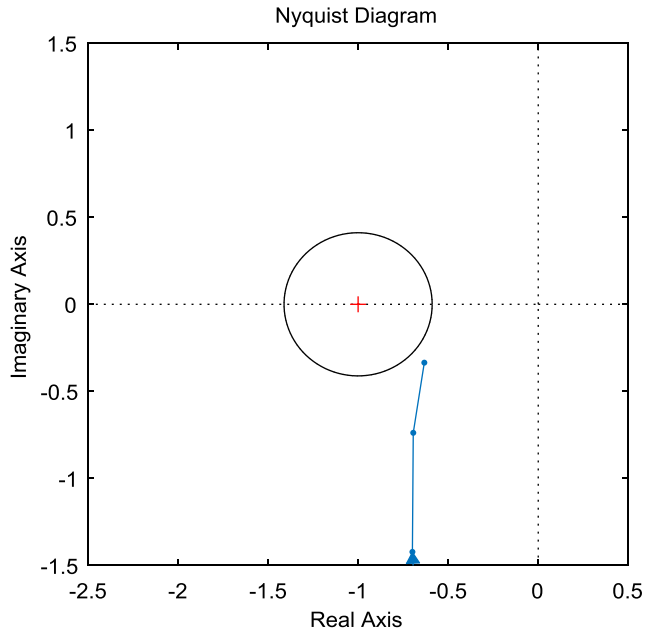

Figure 4: FCR-N stability requirement (black) together with an example response (blue).

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 products; one product for upwards regulation to be activated at 49.9 Hz and lower frequencies, and one product for downwards regulation to be activated at 50.1 Hz and higher frequencies.

Resources providing FCR-D must not have any saturation limit on the frequency controller measurement inputs.

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 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.

For resources that are able to continuously control their power, the FCR-D contribution shall be designed to be activated linearly 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 blue 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. For existing controllers where it is difficult to implement FCR activation according to the blue lines, the activation can also be according to the green dotted line in Figure 5 (the activation may continue below 49.5 Hz and above 50.5 Hz).

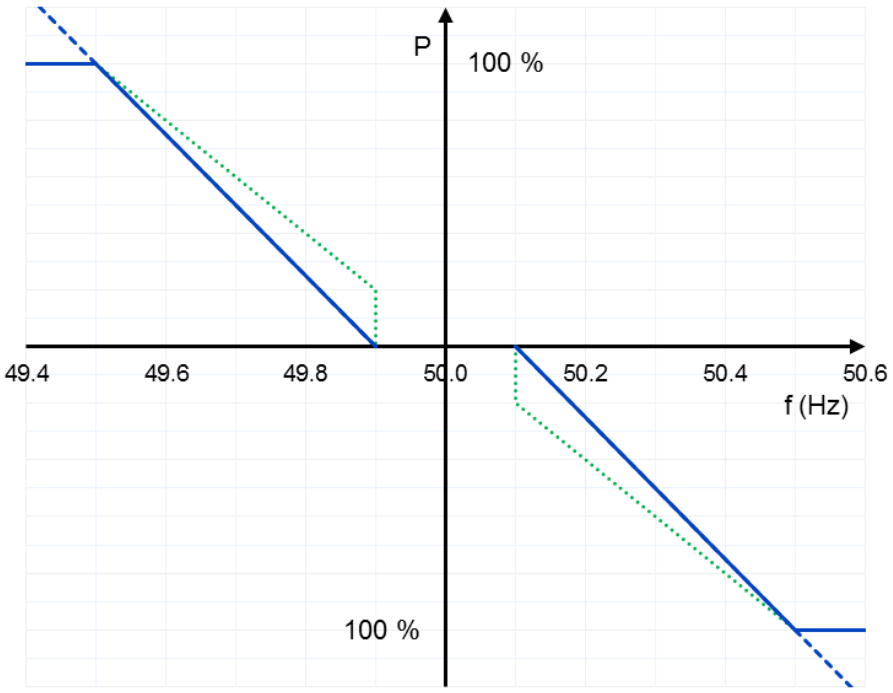

Figure 5: Activation of continuously controlled FCR-D.

Resources that are relay controlled shall activate their FCR-D contribution based on a monotonic piecewise linear power-frequency characteristic, e.g. a step function, see Figure 6.

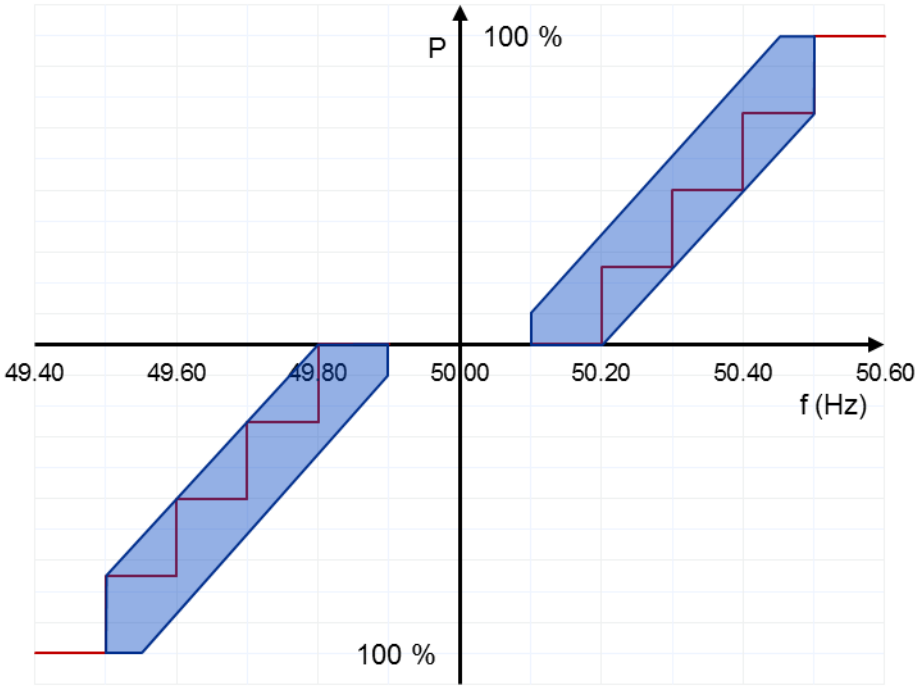

Figure 6: Activation of relay controlled FCR-D resources.

Relay controlled FCR-D resources have to contribute within the blue area in Figure 6, which requires at least 4 steps in each direction. The red line in the figure indicates one possible activation scheme that fulfils the requirement.

3.2.2. FCR-D dynamic performance requirement

The FCR-D dynamic performance is described by the FCR-D capacity of the FCR-D providing entity. To calculate the FCR-D capacity, a frequency ramp (Figure 7) and step tests are used. The FCR-D capacity is calculated as

$$C_{\mathrm{FCR-D}} = \mathbf{min}\left(\frac{\Delta P_{5s}}{0.93},\ \Delta P_{ss},\ \frac{E_{\mathrm{supplied}}}{1.8s}\right) \tag{3.1}$$

where

ΔP_{5s} is the activated power 5 seconds after the start of the ramp

ΔP_{ss} is the steady state FCR-D activation when the entity is subjected to a frequency input step from 49.9 Hz to 49.5 Hz or from 50.1 Hz to 50.5 Hz, for FCR-D upwards and downwards respectively

E_{supplied} is the activated energy from the start of the ramp to 5 seconds after the start of the ramp, that is

$$E_{\mathrm{supplied}} = \int_{t}^{t+5s} \Delta P(t)dt \tag{3.2}$$

when the entity is subjected to a frequency input ramp from 49.9 Hz to 49.0 Hz with a slope of -0.30 Hz/s for FCR-D upwards (see Figure 7 for illustration). For FCR-D downwards, the ramp is from 50.1 Hz to 51.0 Hz with a slope of 0.30 Hz/s.

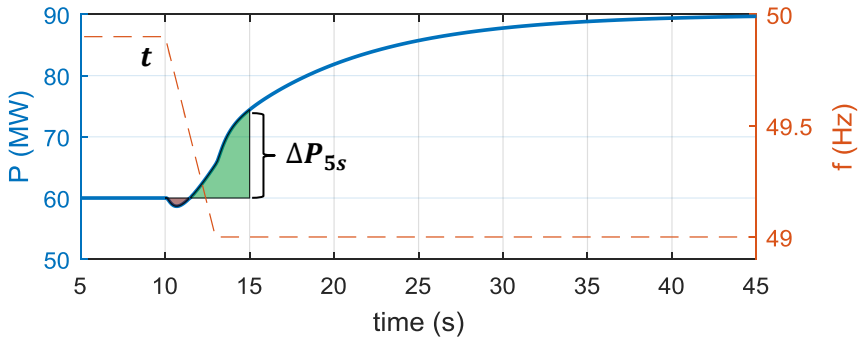

Figure 7: Calculation of FCR-D upwards capacity.

3.2.3. FCR-D stability requirement

FCR-D providing entities with continuous control need to fulfil the same stability requirement as the FCR-N providing entity. The stability requirement is fulfilled if the Nyquist curve (curve defined by FCR-vectors together with a representation of the power system) does not encircle the Nyquist point (-1, 0) and does not enter the black stability margin circle, around the Nyquist point, as illustrated in Figure 4.

3.3. Special considerations on FCR-D activation

On FCR providing entities where FCR-D activation can be considered to cause harm like wear and tear, schemes where FCR-D is activated only when the absolute value of the frequency derivative exceeds a certain threshold value, can be implemented. This derivative threshold may be active only when the absolute value of the frequency deviation is smaller than 0.2 Hz. That is, FCR-D must be activated once the frequency goes below 49.8 Hz or above 50.2 Hz, irrespective of the frequency derivative.

If derivative based trigger is used, it shall be set to 0.06 Hz/s and FCR-D shall be activated also within the range of 49.8-49.9 Hz and 50.1-50.2 Hz respectively, if the threshold value for the absolute value of the derivative is exceeded. This derivative based activation has to be tested with an input frequency ramp with

a slope of 0.06 Hz/s to the frequency measurement device. FCR-D has to be activated at the latest 200 ms after the start of the test ramp.

Alternatively, a 200 ms long transition delay may be used (FCR-D is activated once the frequency has been outside the frequency range 49.9 to 50.1 Hz, for 200 ms). This shall also be tested using the ramp test.

3.4. Activation capability of FCR providing entities

With respect to FCR capacity, it is the responsibility of the FCR provider to ensure that the contracted capacity can be activated. If a provider for some reason is not capable of fulfilling its obligations, the provider must immediately inform the reserve connecting TSO.

An FCR providing entity is considered to have limited activation capability, if the entity is only able to have its FCR contribution fully activated for a time period, that is shorter than the contractually agreed delivery period[3] (for example due to limited energy reservoirs). The limitations shall be specified in the application documentation. Such entity must be able to fully activate its FCR contribution for at least a time period in the interval 15 to 30 minutes[4]. In such case additional reporting is required, see Subsection 5.1. The precise value in the 15-30 minutes interval will be decided by the reserve connecting TSOs in a harmonized way.

[3] The contractually agreed delivery period is the amount of time, for which the FCR provider has got acceptance of it's bids and thereby a capacity obligation. The smallest delivery period is presently 1 hour (the “bidding hour”).
[4] According to SO GL

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.

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 that is impossible or causes significant incremental costs or inconvenience, compared to the value of using an external source, an internal governor test source may be used, after approval by the reserve connecting TSO, provided that the internal source is appropriate for the purpose of the testing, e.g. with respect to accurately representing the frequency measurement loop. Test setup and equipment used for the tests are described in the Supporting document.

Between different tests, waiting time long enough for the power response to stabilize shall be applied. For example, after a sine test with a certain time period, the simulated frequency signal shall be set to 50.0 Hz and the next signal can be applied only after the power response has stabilized.

4.1. Operational test conditions

Since the tests cannot be performed for all possible operational situations, the test conditions are limited to the following 4 extreme operational conditions, and corresponding controller parameter sets. For FCR providing entities including generation, the tests are to be performed on a controller level. For other types of FCR providing entities other reasonable limitations to extreme operational conditions have to be made.

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

In addition, entities may also be tested at other conditions applicable for the specific entity.

FCR providing entities, where the setpoint does not have any influence on the FCR response, can be tested at only one setpoint value.

4.2. Ambient test conditions

The testing aims at verifying that the entity tested fulfills the technical requirements specified in Section 3 during foreseeable operational conditions. All operational conditions at the time for the testing must therefore be within normal operational limits, as close to the foreseeable operational conditions as reasonably possible. The operational conditions at the time for the test must not be optimized for the purpose of the testing.

For FCR providing entities not including generation, tests must be performed in such a way that the behaviour of the entity is verified for all different operational conditions applicable to the specific unit or group.

The FCR capacity may vary with parameters and conditions, which were not subject to variations during the tests, such as head of a hydro unit. For such conditions a calculated value of the actual capacity is accepted, after approval of the methodology and parameter values used, by the reserve connecting TSO.

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 for the values mentioned in this section, with the exception that time-stamps don't have to be synchronised to CET and a running number of seconds may be used instead of a full time-stamp. 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 1 or Table 2.
- [Test_set] = The test set which was used e.g. Test-set1

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

- **Continuously logged during the tests**
    - Instantaneous active power in MW with a resolution of 0.01 MW and an accuracy of 0.5% of the rated power of the providing entity, or better. The value shall be such, that it covers all active power changes as a result of the FCR activation.
    - Measured grid frequency in Hz, with a resolution of 1 mHz and an accuracy of 10 mHz or better.
    - Applied frequency signal, with a resolution of 1mHz and an accuracy of 10 mHz or better.
    - 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
- For batteries
  - Charge level

- **Provided per test set**[5]
  - 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

  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. For generation based entities different setpoints (max/min) have to be tested. 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 performance requirements, and the sine tests, to verify the dynamic performance and stability.

4.4.1. FCR-N step response sequence test

The step response sequence consists of two major steps in the input signal to determine the capacity and a minor step to clear the effect of the backlash, see Figure 8, where the applied frequency is shown. The active power response has to be stabilized after each frequency step change before the next frequency step change is applied.

[5] 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

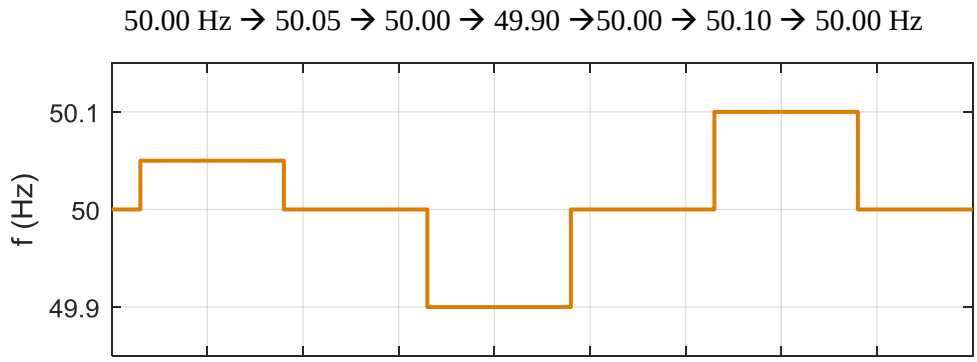

Figure 8 FCR-N step response sequence to be performed for each setpoint and parameter set.

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 300 s, as shown in Table 1 below. For time periods of 10 s to 70 s at least 5 periods with stabilized response shall be registered. For time periods of 90 s - 300 s at least 3 periods with stabilized response shall be registered. The applied frequency with the superimposed sinusoidal signal is illustrated in Figure 9 together with an example of the resulting power output.

Table 1: Time periods (s) for FCR-N sine tests

10	15	25	40	50	60	70	90	150	300

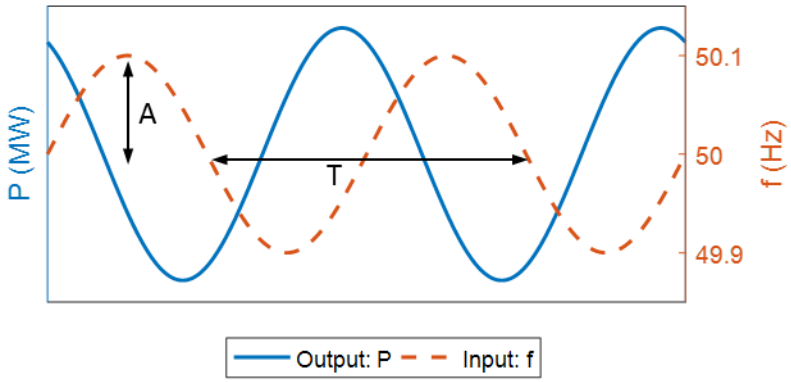

Figure 9 The applied frequency (f) with the superimposed sinusoidal signal (amplitude A, time period T) and the corresponding power output (P).

By inserting the test results into Supporting document Appendix 3, graphs corresponding to **Feil! Fant ikke referansekilden.** and Figure 4 can be derived.

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 for each parameter set where FCR-D is to be provided. For generation based entities different setpoints (max/min) have to be tested. The tests to be conducted are the below described step response and sine tests, in addition to the ramp test specified in Subsection 3.2.2.

4.5.1. FCR-D upwards – step response sequence test

The step response sequence consists of two major steps, where the applied frequency is shown in Figure 10. A sequence with at least two step changes has to be applied to verify compliance with the stationary performance requirements. For each step performed the next step shall not be performed until the active power response has stabilized.

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

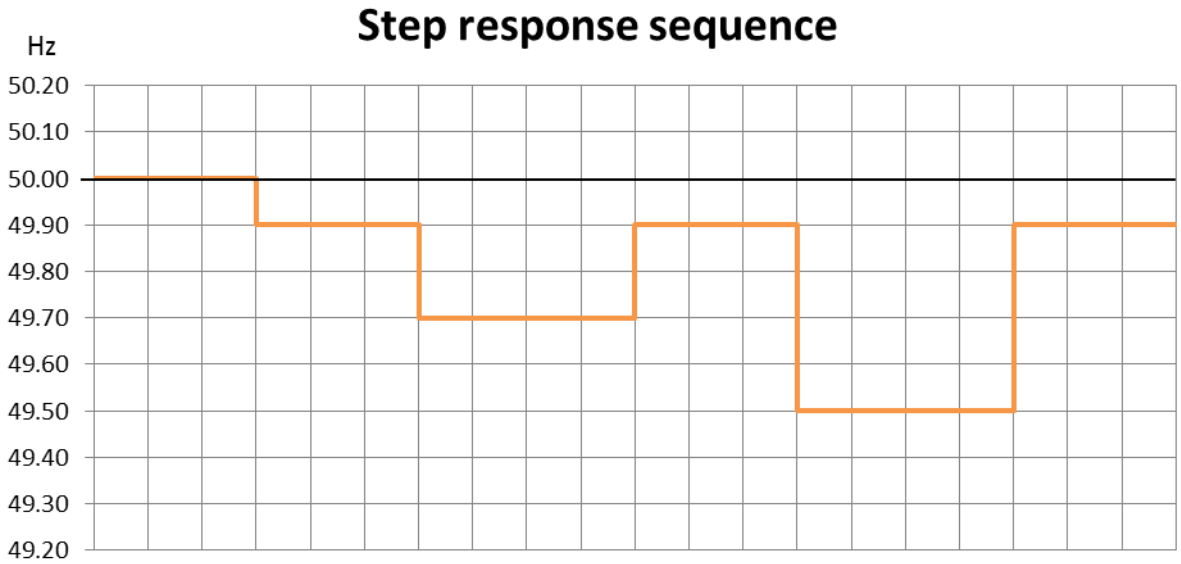

Figure 10 FCR-D upwards regulation step response sequence.

4.5.2. FCR-D upwards – ramp response test

The ramp response test is to be performed according to Figure 11. It consists of a small step to 49.90 Hz followed by a ramp to 49.00 Hz with the ramp rate specified in Subsection 3.2.2. The test is finished when the response has stabilised at 49.00 Hz.

50.00 Hz → 49.80 → 49.90 → 49.00 Hz

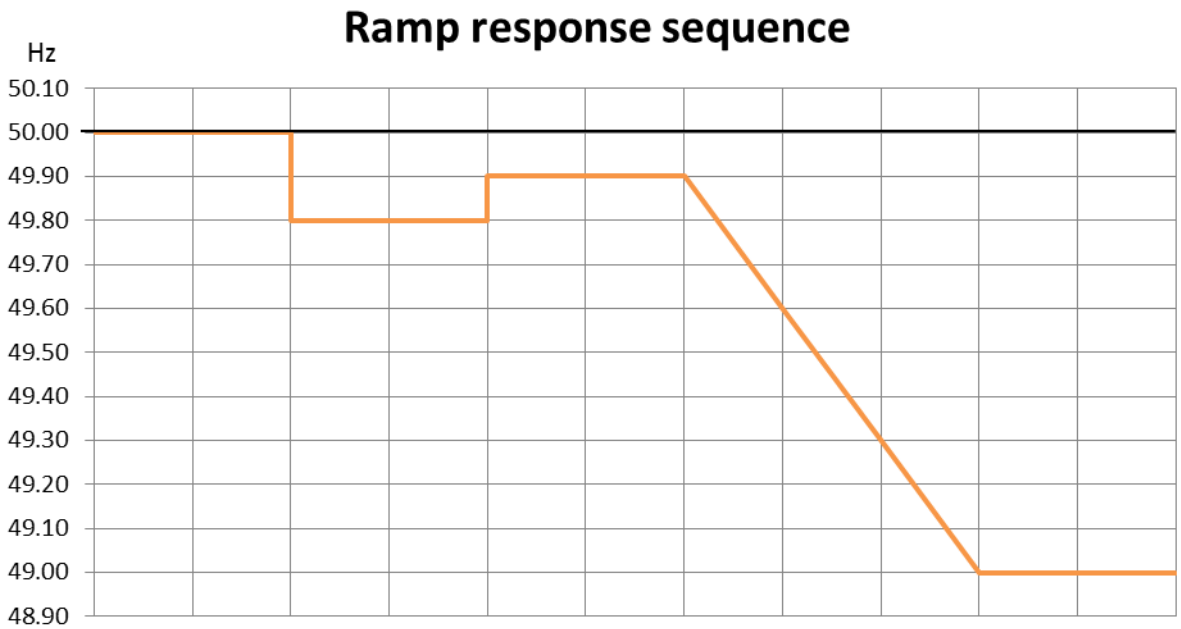

Figure 11 FCR-D upwards regulation ramp response sequence.

4.5.3. FCR-D downwards – step response sequence test

The step response sequence test consists of two major steps, where the applied frequency is shown in Figure 12. A sequence with at least two step changes has to be applied to verify compliance with the stationary performance requirements. For each step performed the next step shall not be performed until the active power response has stabilized.

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

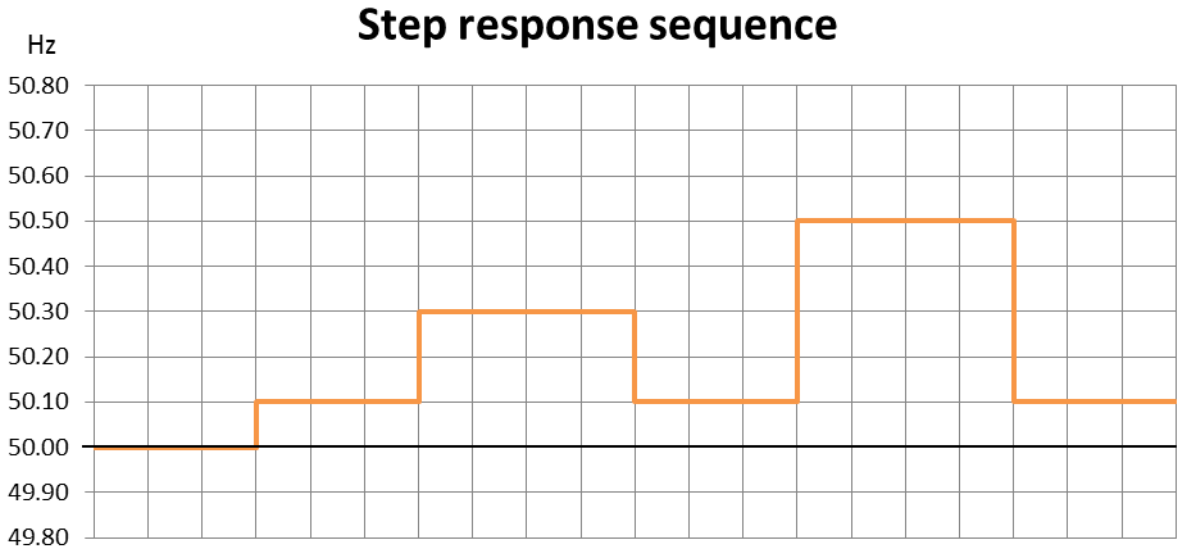

Figure 12 FCR-D downwards regulation step response sequence.

4.5.4. FCR-D downwards – ramp response test

The ramp response test is to be performed according to Figure 13. It consists of a small step to 50.10 Hz followed by a ramp to 51.00 Hz with the ramp rate specified in Subsection 3.2.2. The test is finished when the response has stabilised at 51.00 Hz.

50.00 Hz → 50.20 → 50.10 → 51.00 Hz

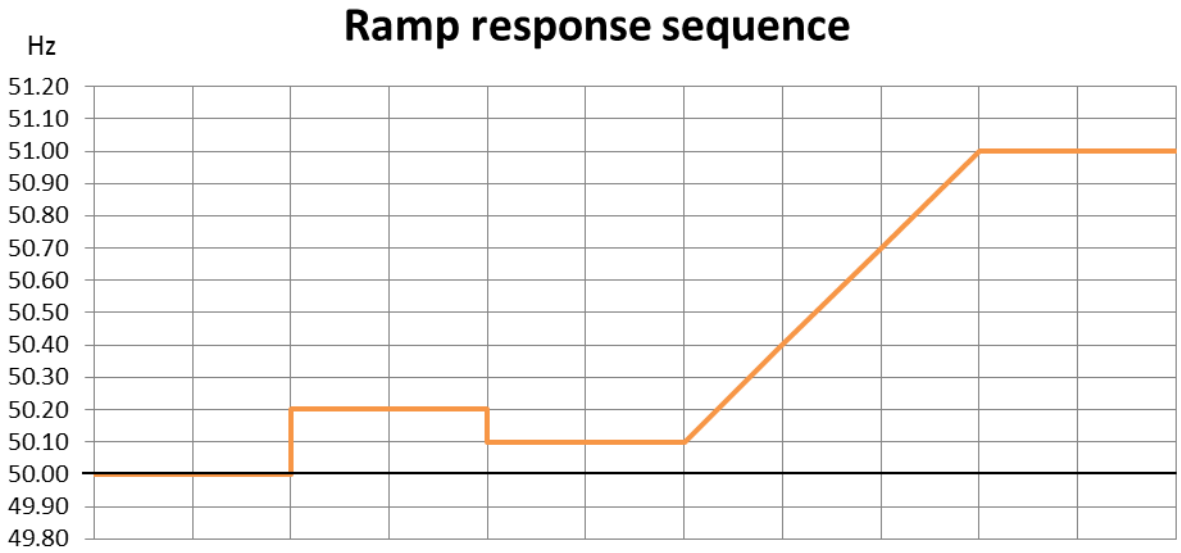

Figure 13 FCR-D downwards regulation ramp response sequence.

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 2 below. At least 5 periods with stabilized response shall be registered. The applied frequency with the superimposed sinusoidal signal is illustrated in Figure 9 together with the resulting power output.

For entities with multiple controller parameter sets, FCR-D parameters shall be continuously active during FCR-D sine tests.

Table 2: Time periods (s) for FCR-D sine tests

10	15	25	40	50

By inserting the test results into Supporting document Appendix 6, graphs corresponding to Figure 4 can be derived.

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, 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.

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 consists of the tests in Subsection 4.5.1 and Subsection 4.5.2, for entities providing FCR-D upwards.

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

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. Templates for test reports are provided as Appendix 4 and 7 of the Supporting document.

In addition to the test report, a set of 24 hour logged data, with active frequency control, according to Subsection 5.2, should be submitted to the TSO.

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. Also, the requirements for data to be logged by the reserve provider and delivered to the TSO upon request are outlined.

5.1. Real-time telemetry

Each FCR provider shall deliver the following real-time telemetry for each of its FCR providing entities to the reserve connecting TSO:

- 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 activation capability additional real-time telemetry is to be provided as follows:

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

The maintained FCR-N/D capacity includes both contracted and non-contracted capacity. The real-time telemetry shall be delivered with a time resolution better than or equal to 10 seconds[6]. The required accuracy for measured values is 0.5% of rated power with a resolution of 0.01 MW. 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 data below 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 (when requested by the TSO) the format specified in Subsection 5.2.1 applies.

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

[6] If this time resolution requirement turns out to be extremely hard to fulfil, the provider can request an exception from the connecting TSO, according to Section 6.

- Instantaneous active power [MW]. The value shall be such that it covers active power changes as a result of the reserve activation.
- $P_{\max}$ [MW]
- $P_{\min}$ [MW]
- Grid frequency [Hz]
- Controller setpoint
- Control Mode, alphanumeric identifier indicating which prequalified controller parameter set is active

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

- 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 containment (size), if applicable [MWh]
- In limitation flag (Boolean indicator) per product [1/0]
- Ambient temperature [°C] (thermal units)
- Cooling water temperature [°C] (thermal units)

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. Required resolution for power values are at least 0.01 MW with an accuracy of 0.5% of rated power. The resolution of the frequency must be at least 1 mHz and an accuracy of 10 mHz or better.

The data shall be time-stamped and time shall 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. A template file is available in the prequalification package provided by the reserve connecting TSO, see Appendix 8 in the Supporting document.

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

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
- [InLimFcrn] = Boolean indicator if the entity is in limitation or not based on current reservoir, with respect to FCR-N, one or zero, e.g 1
- [InLimFcrdDo] = Boolean indicator if the entity is in limitation or not based on current reservoir, with respect to FCR-D downward, one or zero, e.g 1
- [InLimFcrdUp] = Boolean indicator if the entity is in limitation or not based on current reservoir, with respect to FCR-D upward, one or zero, e.g 1
- [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

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 request, from the reserve connecting TSO, 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.