Prequalification of Units and aggregated portfolios

Version 1.2 Valid from the 16th of August 2022

Contents

1. Introduction & Purpose

In this document, requirements, and mandatory tests for the various reserve types, i.e., FCR in DK1, FCR-N and FCR-D in DK2 as well as aFRR and mFRR are gathered and presented. The document is closely linked to the document "Ancillary services to be delivered in Denmark – Tender conditions[1]", which specifies requirements for the ancillary services in detail.

No distinction is made between consumption and production reserves; the same requirements apply to both types. However, in the requirements for and tests of units, a distinction is made between stand-alone units and aggregated portfolios comprised of several small units. The overall size of a unit determines whether it is considered a stand-alone unit or can form part of an aggregated portfolio. Thus, the market participant decides whether a unit sized below the maximum threshold for an aggregated portfolio will be tested as a stand-alone unit or as part of an aggregated portfolio. Threshold values for approving a unit as a stand-alone or as a portfolio of units, respectively, as well as matching requirements and tests are specified in the following sections describing the individual reserves.

For aggregated unit portfolios, the collection of units must be approved and prequalified for the provision of ancillary services. In other words, Energinet pre-qualifies an aggregated unit portfolio using the aggregator's aggregation tool and control system, so that tests are done to determine the practical provision and actual capacity of the overall unit. Therefore, a portfolio of units will be tested and approved based on their overall performance in relation to the applicable requirements for the ancillary service it offers. The aggregator is thus responsible for ensuring that underlying units are always aggregated, allowing them to comply with any system-related conditions for the provision of ancillary services. The overall response will also form the basis for Energinet’s regular spot checking.

Prequalification tests are done in close communication with Energinet. Energinet must be allowed to be present during tests of new units/control concepts. The service provider may carry out follow-up tests independently as agreed and subject to the submission of detailed documentation. However, Energinet will normally ask to be present during all tests. Tests in connection with prequalification for the provision of reserves are first and foremost done to determine if the unit/system can be approved for provision. If the unit/system is approved, a maximum threshold is also set for the volume of power that the unit or aggregated portfolio of units can offer in the reserve capacity market in question.

When a market participant has been approved and is permitted to make bids in a reserve capacity market, he is subsequently subject to spot checking during provision periods. The market participant must provide the quantities sold. The approved maximum capacity, which a unit can offer in a reserve capacity market, does not necessarily match the volume available in any given period. This will depend on various factors, and the market participant must be aware of this. This is particularly important when dealing with technologies with unpredictable production or consumption patterns.

In case of minor provision shortages, payment for any non-provision is deducted from the full volume. In case of major provision shortages, payment of the costs of replacement purchases and quarantine may be a possibility, cf. the tender specifications mentioned above. The lifting of a quarantine will be subject to either a renewed approval of the unit or the submission of detailed documentation proving that any faults have been remedied.

In compliance with SOGL §155, article 6 (For FCR) and §159 STK 6 (For FRR) all prequalified units must be reevaluated at minimum every 5 year. The requirement is VALID from the implementation of SOGL, the 2nd of August 2017. All units prequalified before this date, must be reevaluated at the latest the 2nd of August 2022. Reevaluation can happen

[1] Doc.no. 13/80940-90 ”Ancillary services to be delivered in Denmark – Tender conditions”. The document is available at Energinet’s website.

through activation in the market, where the demanded response is delivered. This can happen by voluntarily sending in data for a unit, or through spot checking.

2. Common requirements for delivery of frequency reserves in DK1 & DK2

Before a unit/system can join the market, it must be verified that the unit/system can provide the specific ancillary service, within the specified response time, while still observing the technical requirements of that service.

The sections below specify the technical requirements and, subsequently, required tests designed to verify the unit's ability to provide the ancillary service.

The cost of IT connections, maintenance, grid tariffs etc. for energy provisions and tests/reliability testing must be paid solely by the service provider.

3. Test of FCR in DK1

This section describes the fundamental requirements for FCR (power frequency control) and required ancillary services tests to be done before the unit can form part of/be used in the market.

3.1 FCR response requirements

FCR is used to stabilise the frequency close to the reference frequency (50 Hz) and to reduce the number of frequency dips/jumps. The service is activated for both small and large frequency deviations, as the function is activated in case of deviations from 50 Hz.

Regulation is performed as a very fast-reacting proportional control, often provided from 'running/spinning units at part load.

Units tasked with providing FCR must measure the frequency and automatically activate reserves on their own accord, as they will receive no external activation signal.

Power response to frequency fluctuations must be provided linearly to the frequency deviation in question for frequency deviations of up to ±200 mHz relative to the reference frequency, i.e. in the 49.8-49.98 Hz and 50.02-50.2 Hz ranges.

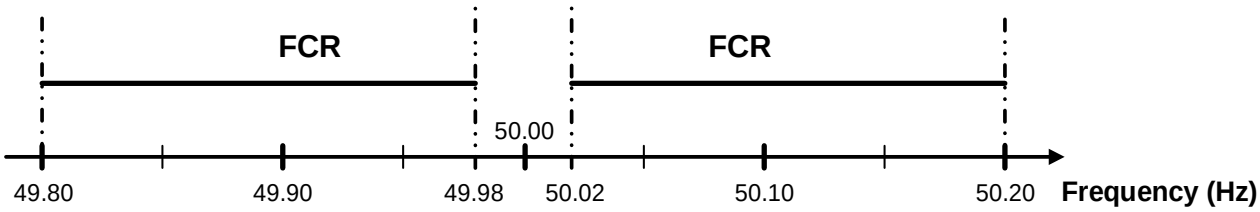


Figure 1 – FCR activation frequencies.

Units that deliver FCR must be able to maintain the power response in the frequency range of 47.5-51.5 Hz.

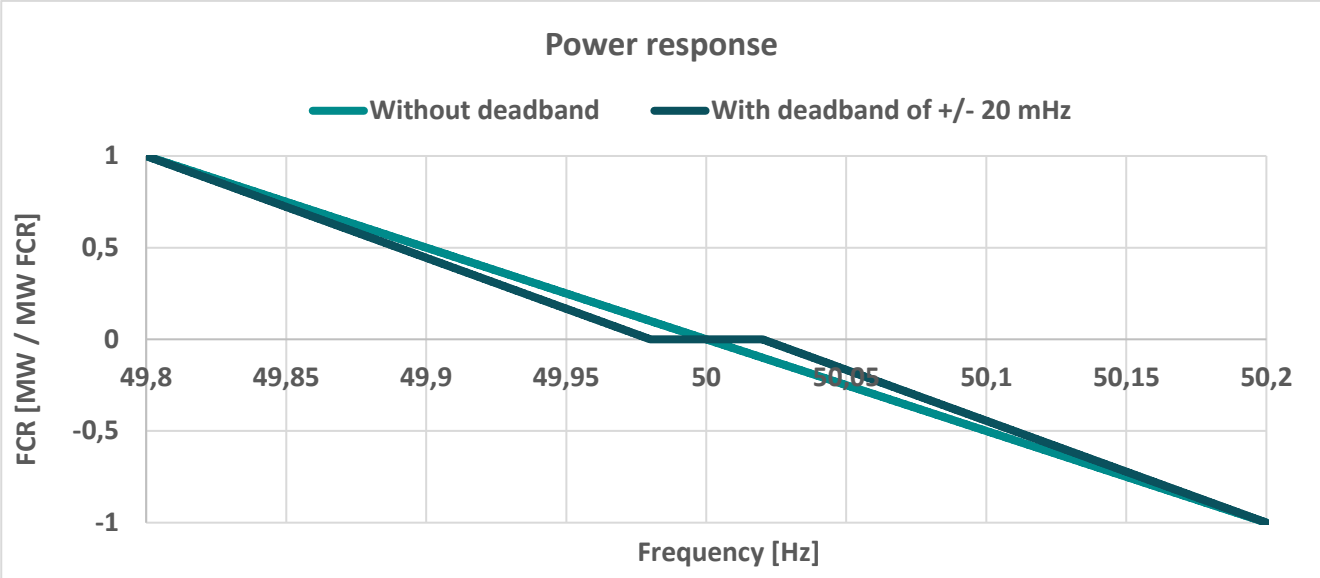


Figure 2 - Power response from FCR, with and without dead band, respectively. Both responses are acceptable.

Measuring equipment accuracy must be 10 mHz or higher. It is acceptable for a unit to have a hysteresis range of +/- 10 mHz over the frequency band. It is also acceptable for the unit to have a dead band of +/-20 mHz around 50 Hz.

FCR volume activated by a frequency deviation is linearly dependent on the frequency. For example, if the DK1 frequency deviates by -110 mHz, half the reserve is activated, as indicated in Figure 2.

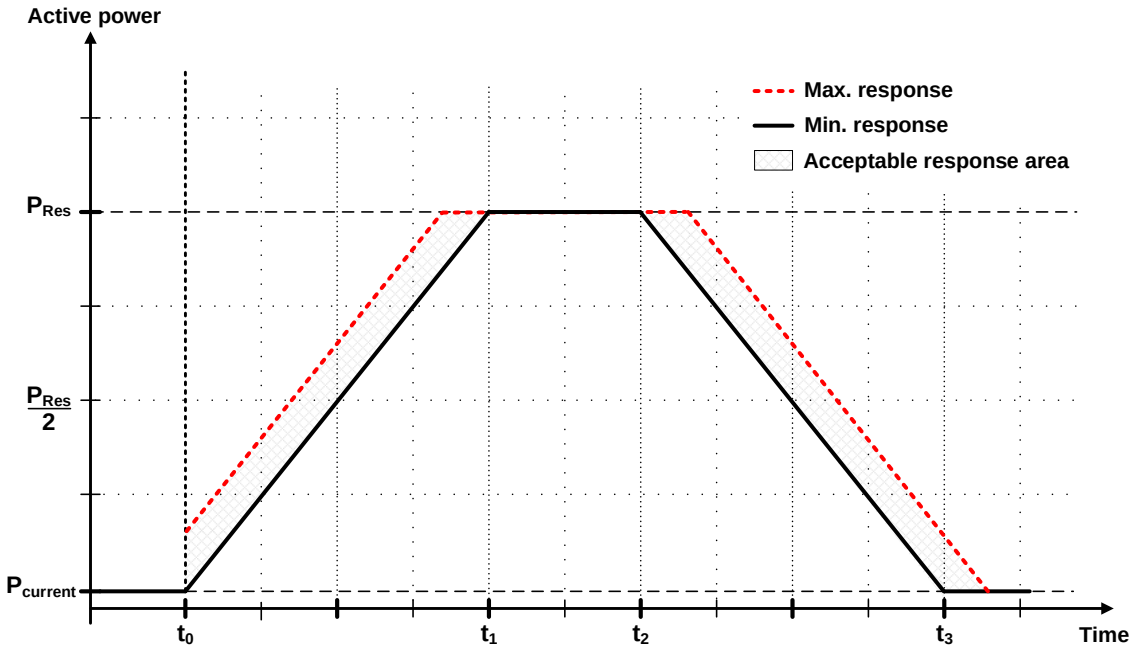


Figure 3 shows the minimum and maximum responses from activation of FCR (t0) until the reserve must be provided in full (t1). The maximum response equals a 10 mHz deviation in the frequency measurement, which is accepted based on the measuring equipment accuracy requirement. For units not equipped with ramp control, the acceptable response range may also be divided into smaller steps. A small delay of a few seconds at start-up is acceptable but the response must then return to the permissible range. In addition, minor deviations, positive as well as negative, near the permissi-

ble response range, especially near P_{res} when response is fully regulated, are also accepted. This applies to both prequalification tests of reserves and subsequent operation.

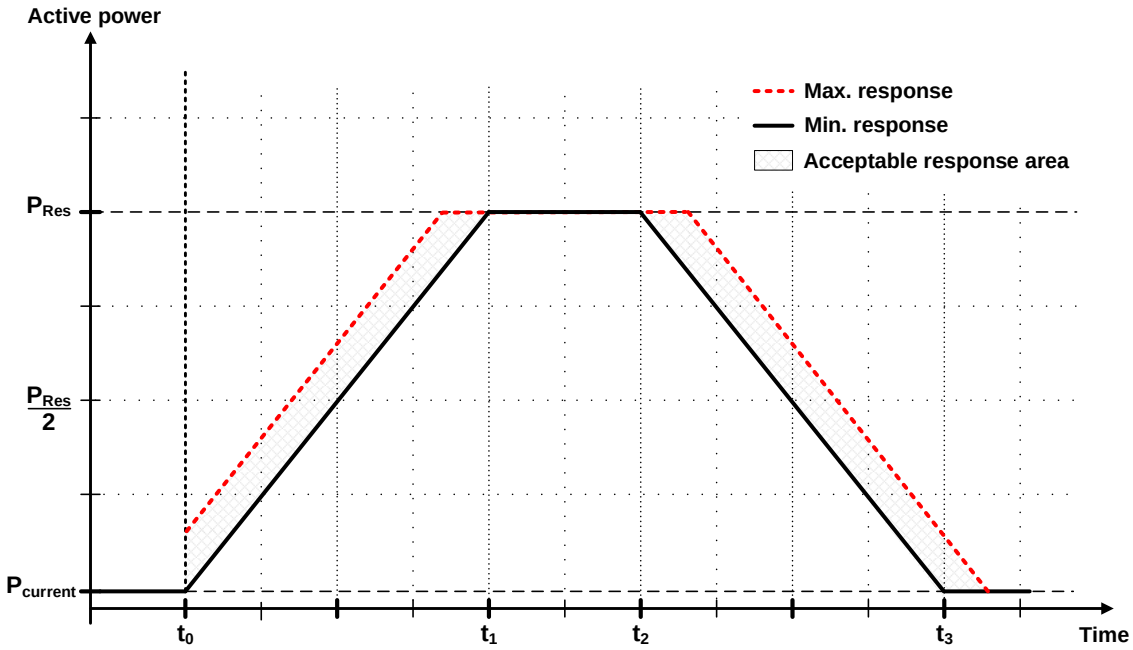


Figure 3 - Random FCR activation response sequence.

Table 1 - Time parameters for response sequence described in Figure 3.

Time parameters	Time
t_0 - t_1	< 30 s
t_1 - t_2	Frequency imbalance length, at least 15 min
t_2 - t_3	< 30 s

Table 1 - Time parameters for response sequence described in

Figure 3.

Response sequence for reserve tests, in which frequency deviations of 200 mHz are simulated, must be within the "acceptable response area". The first half of the activated reserve must be provided within 15 seconds, while the last half must be provided in full within 30 seconds. It is acceptable to perform a quicker response than shown in the figure, as long as the response is approximately linear and proportional to the frequency deviation.

Unit sensitivity must not exceed 10 mHz. This means that the unit must respond to changes of 10 mHz.

The resolution of the market participant's SCADA system must be better than or equal to 1 second, and selected signals must be able to document unit responses to frequency deviations. The service provider must save the signals for at least two weeks.

The regulation must continuous and include functions that ensure maintaining of 100% power for minimum 15 minutes, until the entire electricity grid goes into alert mode. This entails that the FCR-delivery must be taken into account, before the electricity grid goes into alert mode.

3.2 Prequalification of stand-alone units

There must be performed a test on a where a frequency signal (deviation from 50 Hz) is applied on site in the unit frequency regulator, and the input frequency and resulting system response are then logged. The market participant must be able to apply a frequency signal.

The figure below shows these tests.

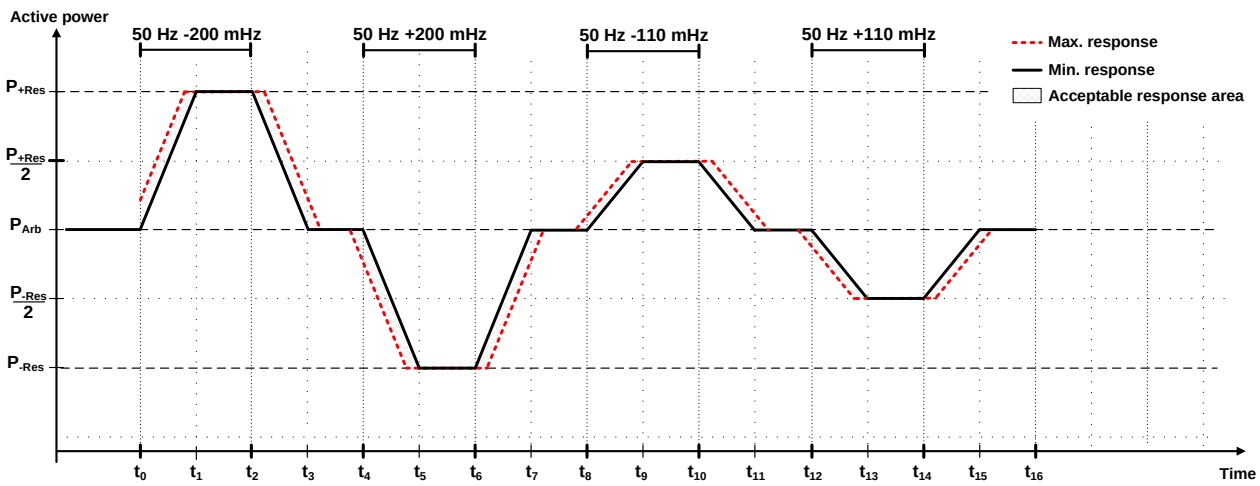


Figure 4 - Tests of minimum requirements for FCR response.

The table below specifies response times for Figure 4.

Time parameters	Time
t_0 - t_1	As specified in Figure 3
t_1 - t_2	15 min
t_2 - t_3	As specified in Figure 3
t_3 - t_4	1 min
t_4 - t_5	As specified in Figure 3
t_5 - t_6	15 min
t_6 - t_7	As specified in Figure 3
t_7 - t_8	1 min
t_8 - t_9	As specified in Figure 3
t_9 - t_{10}	5 min
t_{10} – t_{11}	As specified in

	Figure 3
$t_{11} – t_{12}$	1 min
$t_{12} – t_{13}$	As specified in Figure 3
$t_{13} – t_{14}$	5 min
$t_{14} – t_{15}$	As specified in Figure 3
$t_{15} – t_{16}$	1 min

Table 2 - Time parameters for tests described in Figure 4.

Please note that completion of the full tests specified in Figure 4 is only a requirement if the unit owner has applied to provide both upward and downward regulation. If only upward regulation is to be provided, the response to a negative frequency deviation must be verified and vice versa for only downward regulation.

Also, a sensitivity test must be done for the full regulator circuit. This test must demonstrate that the unit responds to frequency changes of 10 mHz or higher.

3.3 Units with limited energy reservoir

There are additional requirements for units or aggregated portfolios that has a Limited Energy Reservoir or LER, such as batteries. The categorisation as a LER unit/portfolio is based on if it is possible to sustain a full FCR-response for 2 concurrent hours without including charging and discharging strategies (active reservoir management).

Even though there might be batteries in an FCR-portfolio, it is only defined as a LER-portfolio if it is not possible to sustain a full FCR-response for 2 concurrent hours.

If a unit is defined as a LER-unit, the unit is only approved for 80% of the rated power **and must meet all the requirements described in section 3.3 and its subsections.**

3.3.1 Requirements for units with a limited energy reservoir (LER)

To ensure a continued and stable FCR-delivery from LER units/portfolios, additional requirements for prequalification will be requested.

1. LER units/portfolios must have an approved “active reservoir management” that ensures that the LER unit/portfolio always meets the demand of 15 minutes full FCR-delivery, including frequency deviations before the system goes into alert mode, which is described in section 3.3.2.
2. To ensure availability for the active reservoir management system, LER units/portfolios are approved for 80% of their rated power. This reduction requirement is not required, if there is a method where the active reservoir management system does not affect the LER unit/portfolios rated power.
3. LER units/portfolios that are prequalified for the first time, needs to be able to activate “reserve mode”, when the LER unit/portfolio crosses a specific state of charge (soc) – This is described in section 3.3.3
4. The LER unit must deliver parts of its energy reservoir equal to 24 minutes of full activation. In practice the reservation of the threshold values for reserve-mode and threshold values for ARM using imbalances.

3.3.2 Active reservoir management system

The purpose of the Active Reservoir Management (ARM) system is to secure the ability to regulate the energy reservoir, while the frequency is within the normal bandwidth (+/- 50 mHz) When the frequency deviation is larger than +/- 50 mHz, the ARM system must be deactivated. ARM is necessary to ensure that there are always 15 minutes of full FCR-delivery available. The ARM system is described mathematically in the following formula, where P_{ARM} is the ARM-power and P_{FCR} is the approved FCR-capacity

$$P_{ARM}[MW] \leq 0.25 \cdot P_{FCR}[MW]$$

ARM must not interfere with the linear delivery of FCR, where there is a transition period for activation and deactivating of ARM. The transition period is applied if the frequency deviation is more than +/- 50 mHz. The transition period is described by the following formula:

$$T = \begin{Bmatrix} 0 & t < t_{start} \\ \dfrac{t - t_{start}}{\Delta t_{FAT}} & t_{start} \leq t < t_{Start} + \Delta t_{FAT} \\ 1 & t \geq t_{start} + \Delta t_{FAT} \end{Bmatrix}$$

Where t_{start} is the start time for the activation of ARM and Δt_{FAT} is the length of the transition period of 5 minutes, which results in the activation speed for aFRR in DK1 and DK2. ARM with the transition period is defined with following formula:

$$P_{FCR}(t) = P_{ARM} \cdot T + (1 - T) \cdot P_{FCR}$$

Energinet recognizes the issues with predicting the energy reservoir at gate-closure-time for Intraday trading and because of that, also accept application of charge/discharging through standing imbalances. Applying standing imbalances is not allowed until the energy reservoir is past a threshold defined by following formulas:

$$ARM_{Threshold\ min} = P_{FCR}[\mathrm{MW}] \cdot \frac{0.4[h]}{C[MWh]}$$

$$ARM_{Threshold\ max} = 1 - P_{FCR}[\mathrm{MW}] \cdot \frac{0.4[h]}{C[MWh]}$$

Where P_{FCR} is the FCR-delivery, $t_{min\ Ler}$ is the 15-minute requirement, and C is the energy reservoir in MWh. The 0.4 hours (24 minutes) is the energy reservation according to section 3.3.1. ARM based on imbalances are deactivated either if the frequency deviation exceeds |50| mHz or the energy reservoir again exceeds the threshold. No matter how, the deactivation happens through the transition period described above.

3.3.3 Reserve Mode

Reserve mode is an operation condition that the LER-unit/portfolio switches to when the energy reservoir exceeds the SOC_{max} and SOC_{min} (State of charge) thresholds. In the reserve mode, the unit reacts to frequency deviations in relation to the average of the past 5 minutes.

$$SOC_{min} = \frac{P_{FCR} \cdot \Delta t_{fat}}{C}$$

$$SOC_{max} = 1 - SOC_{min}$$

Where P_{FCR} is the FCR-delivery in MW, Δt_{fat} is the AFRR response time (5 minutes) in the unit of hours, and C is the energy reservoir in MWh. The switch to reserve mode must happen over a smooth (linear) transition, equivalent to the method from ARM. Also, a corresponding but opposite direction transition, when the energy reservoir is again outside the SOC_{max} and SOC_{min} thresholds. The transition period is defined mathematically as:

Normal operation → Reserve mode Reserve mode → Normal operation

$$T = \begin{cases} 0 & t < t_{start} \\ \frac{t - t_{start}}{\Delta t_{FAT}} & t_{start} \leq t < t_{Start} + \Delta t_{FAT} \\ 1 & t \geq t_{start} + \Delta t_{FAT} \end{cases} \quad T = \begin{cases} 0 & t < t_{restore} \\ \frac{t - t_{restore}}{\Delta t_{FAT}} & t_{restore} \leq t < t_{restore} + \Delta t_{FAT} \\ 1 & t \geq t_{restore} + \Delta t_{FAT} \end{cases}$$

Where the t_{start} and $t_{restore}$ are the starting time for the transition for normal operation to reserve mode and back again. During the transition period one responds to a weighed combination of the absolute frequency deviation (Δf). And the reserve mode frequency ($\Delta f_{reaction}$). Mathematically the weighed frequency is expressed as:

$$f_{reaction}(t) = \Delta f_{RESM} \cdot T + (1 - T) \cdot \Delta f$$

In the reserve mode the FCR unit/portfolio delivers according to the current frequency deviation, subtracted from the average of the frequency deviation for running time according to the AFRR response time (Δt_{fat}) described as:

$$\Delta f_{RESM} = \Delta f - \frac{1}{\Delta t_{fat}} \sum_{i=1}^{\Delta t_{fat}} \Delta f$$

For all the time dependent formulas, the operators SCADA time resolution must be used, and it must be better or equal to 1 second.

3.4 Prequalification of aggregated portfolios

For aggregated unit portfolios, the collection of units must be approved and prequalified for the provision of ancillary services. In other words, Energinet pre-qualifies an aggregated unit portfolio using the aggregator's aggregation tool and control system, so that tests are done to determine the practical provision and actual capacity. Therefore, a portfolio of units will be tested and approved based on its overall performance in relation to the applicable requirements for the ancillary service it offers. The aggregated portfolio will be approved based on the same conditions as described above for stand-alone units. During tests of aggregated portfolios, Energinet would also like to see the response from a stand-alone unit as well. The aggregator is charged with ensuring that underlying units are always aggregated, allowing them to comply with any system-related conditions for the provision of ancillary services. The overall response will also form the basis for spot checking.

3.4.1 Approval of aggregation concept

For aggregated portfolios, the market participant must submit a description of the aggregation concept, including a description of the communication mode selected. This description must state how requirements and specifications are complied with. The description must be approved by Energinet before the market participant can join the market with the concept selected.

3.4.2 Maximum power for aggregated portfolios

The maximum pool approvable as an aggregated portfolio totals 3 MW for FCR. Prequalification of an aggregated portfolio for FCR exceeding 3 MW requires separate tests of each portfolio. For example, in case of an aggregated volume for FCR of 5 MW, this can be divided into a 3 MW and a 2 MW portfolio, respectively, and requires prequalification of both. The portfolios may then subsequently be pooled when offering the reserve in the market.

When adding additional units to an aggregated pool, Energinet will allow the addition of up to 3 MW of the same technology within the same price area to the existing portfolio of units, without new actual tests of the portfolio or the unit. A total addition of 3 MW to the portfolio requires new tests to be done. The aggregator must in accordance with 'Main agreement on the supply of ancillary services' keep an updated list of ancillary service units, that the aggregator over-

sees. Documentation must contain information about MW, type, placement, and potential consumption pattern over a given period.

3.4.3 Frequency meters for aggregated portfolios

For aggregated units, the ancillary service is provided through an aggregator and balance responsible party. Energinet looks at the overall volume of power sold by the aggregator, and this entails that only one frequency meter is required. This meter then sends the signal to the units in charge of the delivery. If using a central frequency meter, there is a requirement of an alternative method, in case of meter error, disconnection or similar. This could be a backup frequency meter, placed somewhere else, which creates redundancy in case of power outage or similar. The backup procedure for the central frequency meter is described and approved along with the other deliverances for prequalification. The aggregator is allowed to use several decentral frequency meters.

Energinet reserves the right to make any future changes necessary to ensure compliance with the additional joint properties for FCR, cf. SO GL article. 154 (2)

3.4.4 Storage of data for aggregated portfolios

For aggregated units, the ancillary service is provided through an aggregator and balance responsible party. Energinet looks at the overall volume of power sold by the balance responsible party, and this means that the storage of data to document service provision may be done at the aggregated level. Energinet's sole focus is to ensure that the actual provision can be verified and not from where actual provision has taken place. This means that the aggregator must comply with the applicable rules for storage of, for example, frequency data, but only at an aggregated level. The aggregator may store and submit data for spot checking from separate units if they want.

3.5 Audit of provisions

Only units and systems that have undergone a functional test can participate in the FCR market. When a unit/system has been approved and begins to provide ancillary services, regular inspections/audits will be carried out to determine whether the unit/system provides the ancillary services in the agreed/approved quality and quantity.

The market participant must provide the quantities sold. In case of minor provision shortages, payment for any non-provision is deducted from the full volume. In case of major provision shortages, payment of the costs of replacement purchases and quarantine may be a possibility, cf. the tender specifications mentioned above. The lifting of a quarantine will be subject to either a renewed approval of the unit or the submission of detailed documentation proving that any faults have been remedied. Please note that the approved maximum capacity, which a unit can offer in a reserve capacity market, does not necessarily match the volume available in any given period.

3.6 Prognosis & baseline

To achieve a sufficient delivery security for reserves from fluctuating production technologies and demand response, Energinet requires a prognosis for the available capacity at the time of submission of bids for the reserve (the day before operation). To be able to estimate and control if a given response has been carried out, a reference power is necessary to know on a given unit. This reference power is also called baseline. For conventional plants this can be determined as the schedule. For units with fluctuating production and for demand response, the baseline can be difficult to determine. Examples on baseline calculations for different types of units are available in Appendix 9.2. Furthermore, suggestions, advice, and expectations for the baseline calculations from non-conventional units are given.

Energinet will request a concept description and results from the developed calculation when a unit or a portfolio of units are prequalified to deliver ancillary services. The calculations must also be prequalified.

4. Test of FCR-D in DK2

This section describes the fundamental requirements for FCR-D (frequency-controlled disturbance reserves) and required ancillary services tests to be done before the unit can form part of/be used in the market.

4.1 Prior to market participation

Before a unit/system can join the market, it must be verified that the unit/system can provide the specific ancillary service, within the specified response time, while still maintaining the technical requirements of that service.

The sections below specify the technical requirements followed by required tests designed to verify the unit's ability to deliver.

The cost of IT connections, maintenance, grid tariffs etc. for energy provisions and tests/reliability testing must be paid solely by the service provider.

4.1.1 FCR-D response requirements

FCR-D is used to reduce frequency dips/-jumps. The service is activated in case of large frequency deviations, as this function is activated at frequencies below 49.9 Hz or larger than 50.1 Hz.

Regulation is performed as a very fast-reacting proportional control, often provided from 'running/spinning' units at part load.

Units tasked with providing FCR-D must measure the frequency and automatically activate reserves on their own accord, as they will receive no external activation signal.

Power response to frequency fluctuations must be provided at frequency deviations of up to ±500 mHz relative to the reference frequency, i.e. in the range 49.5 - 49.9 Hz and 50.1-50.5 Hz.

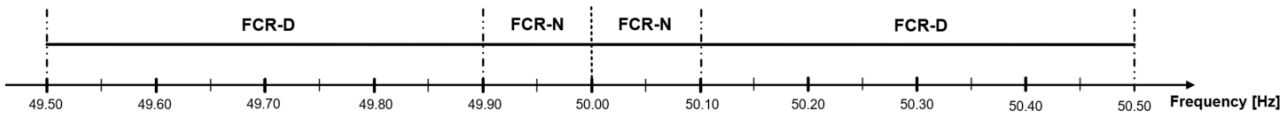


Figure 5 - Activation frequencies for FCR-D (FCR-N, respectively).

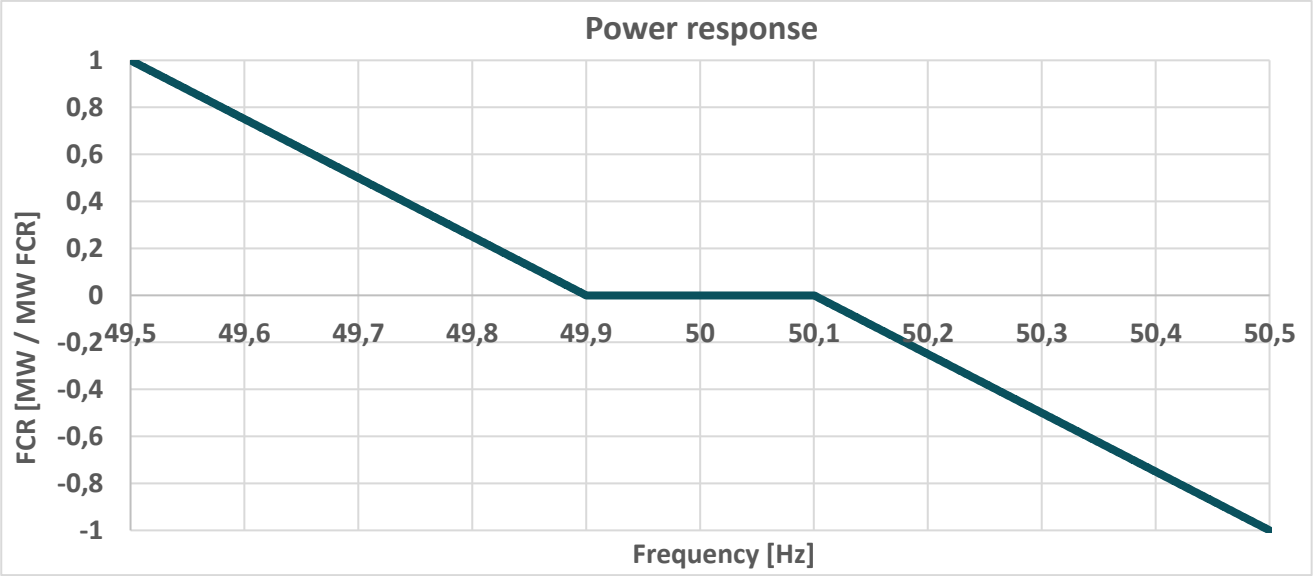


Figure 6 - Power response from FCR-D

Measuring equipment accuracy must be 10 mHz or higher. It is acceptable for a unit to have a hysteresis range of +/- 10 mHz in the entire frequency band.

FCR-D volumes activated by a frequency deviation are linearly dependent on the frequency. For example, if the DK2 frequency differs -300 mHz, half the reserve is activated.

The below figure shows the minimum response from the activation of FCR-D (t0) to the time when the reserve must be fully provided (t2). The maximum response equals a 10 mHz deviation in the frequency measurement, which is accepted based on the measuring equipment accuracy requirement. For units not equipped with ramp control, the acceptable response range may also be divided into smaller steps. A small delay of a few seconds at start-up is acceptable but the response must then return to the permissible range. In addition, minor deviations, positive as well as negative, near the permissible response range, especially near P_{res} when response is fully regulated, are also accepted. This applies to both prequalification tests of reserves and subsequent operation.

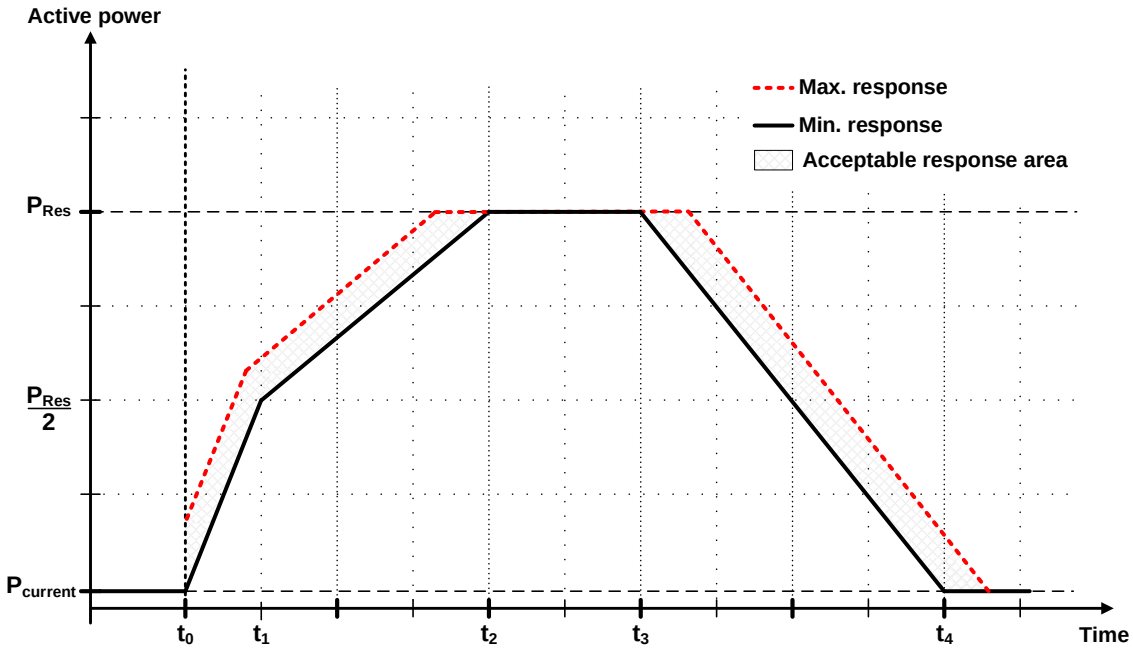


Figure 7 - Random FCR-D activation response sequence.

Table 3 specifies the response times of Figure 7. In case of an activation in the opposite direction, the activation will be symmetric with the activation above.

Table 3 Time parameters for response sequence described in Figure 7

Time parameters	Time
t_0 - t_1	< 5 s
t_1 - t_2	< 25 s
t_2 - t_3	Frequency imbalance length, at minimum 15 min
t_3 - t_4	< 30 s

Response sequences for reserve tests must be within the "acceptable response area". The first half of the activated reserve must be provided within 5 seconds, while the last half must be provided in full within 30 seconds. It is acceptable to perform a quicker response than shown in the figure, if the response is proportional with the frequency deviation.

Unit sensitivity must not exceed 10 mHz. This means that the unit must respond to changes of 10 mHz.

Also, a sensitivity test must be done for the full regulator circuit. This test must demonstrate that the unit responds to frequency changes of 10 mHz or higher.

The resolution of the market participant's SCADA system must be better than or equal to 1 second, and selected signals must be able to document unit responses to frequency deviations. The service provider must save the signals for at least one week.

The regulation must continuous and include functions that ensure maintaining of 100% power for minimum 15 minutes.

4.2 Prequalification of stand-alone units

The unit must be tested, where a frequency signal (deviation from 50 Hz) is applied on site in the unit frequency regulator, and the input frequency and resulting system response are then logged. The market participant must be able to apply a frequency signal.

The figure below shows these tests.

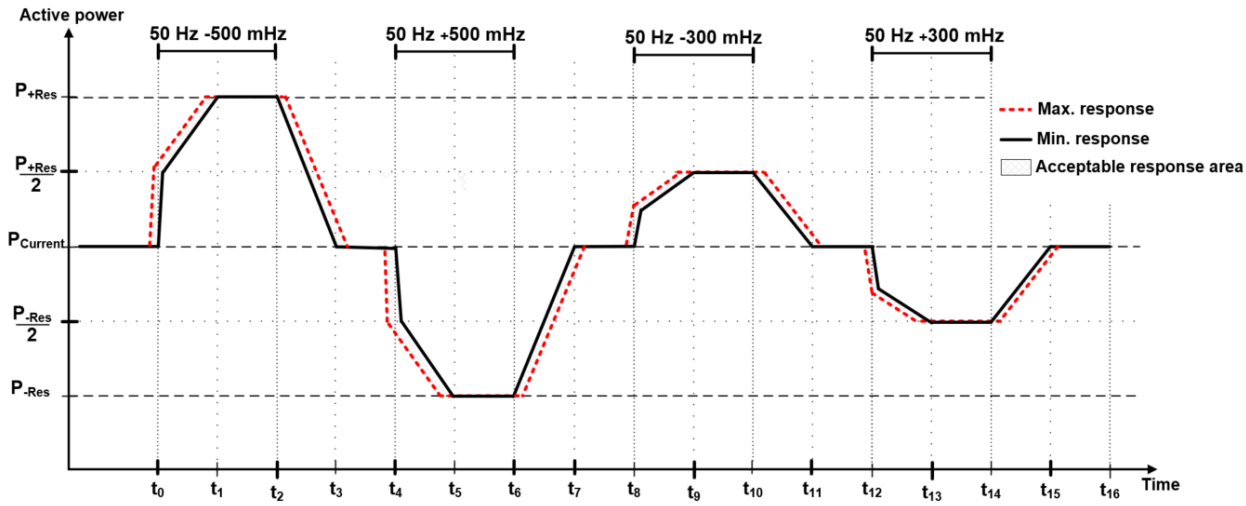


Figure 8 - Tests of minimum requirements for response for FCR-D.

The table below specifies response times for Figure 8.

Time parameters	Time
t_0 - t_1	As specified in Figure 7
t_1 - t_2	15 min
t_2 - t_3	As specified in Figure 7
t_3 - t_4	1 min
t_4 - t_5	As specified in Figure 7
t_5 - t_6	15 min
t_6 - t_7	As specified in Figure 7
t_7 - t_8	1 min
t_8 - t_9	As specified in Figure 7
t_9 - t_{10}	5 min
t_{10} - t_{11}	As specified in Figure 7
t_{11} - t_{12}	1 min
t_{12} - t_{13}	As specified in Figure 7
t_{13} - t_{14}	5 min
t_{14} - t_{15}	As specified in Figure 7
t_{15} - t_{16}	1 min

Table 4 - Time parameters for tests described in Figure 8.

Please note that completion of the full test specified in Figure 8 is only a requirement if the unit owner has applied to provide both upward and downward regulation. Figure 9 and Figure 10 represents the tests for unit owners only providing upward or downward regulation. Response times can be seen in Table 5.

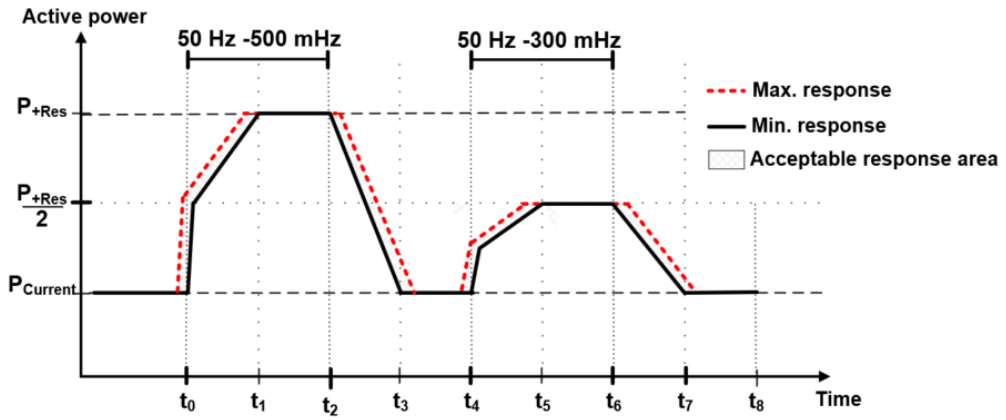


Figure 9 - Tests of minimum requirements for response for FCR-D upward regulation.

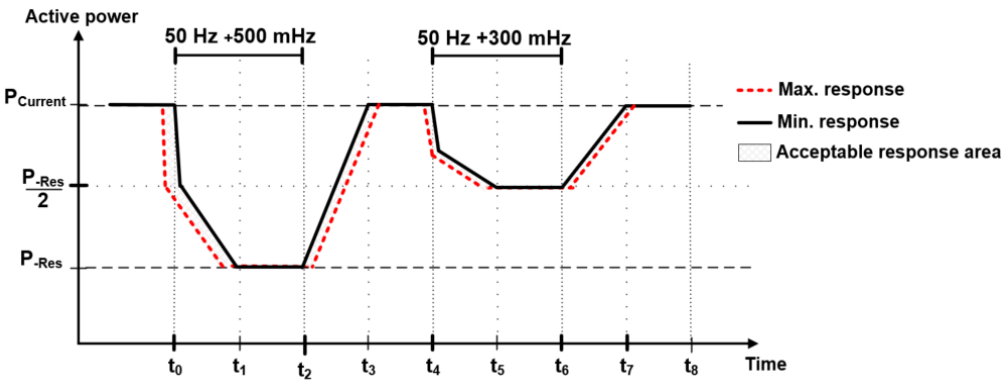


Figure 10 - Tests of minimum requirements for response for FCR-D downward regulation.

Time parameters	Time
t_0 - t_1	As specified in Figure 7
t_1 - t_2	15 min
t_2 - t_3	As specified in Figure 7
t_3 - t_4	1 min
t_4 - t_5	As specified in Figure 7
t_5 - t_6	5 min
t_6 - t_7	As specified in Figure 7
t_7 - t_8	1 min

Table 5 - Time parameters for tests described in Figure 9 and Figure 10.

4.3 Prequalification of aggregated portfolios

For aggregated unit portfolios, the collection of units must be approved and prequalified for the provision of ancillary services. In other words, Energinet pre-qualifies an aggregated unit portfolio using the aggregator's aggregation tool

and control system, so that tests are done to determine the practical provision and actual capacity. Therefore, a portfolio of units will be tested and approved based on its overall performance in relation to the applicable requirements for the ancillary service it offers. The aggregated portfolio will be approved based on the same conditions as described above for stand-alone units. During tests of aggregated portfolios, Energinet would also like to see the response from a stand-alone unit as well. The aggregator is charged with ensuring that underlying units are always aggregated, allowing them to comply with any system-related conditions for the provision of ancillary services. The overall response will also form the basis for spot checking.

4.3.1 Approval of aggregation concept

For aggregated portfolios, the market participant must submit a description of the aggregation concept, including a description of the communication mode selected. This description must state how requirements and specifications are complied with. The description must be approved by Energinet before the market participant can join the market with the concept selected.

4.3.2 Maximum power for aggregated portfolios

The maximum pool which can be approved as an aggregated portfolio, is 3 MW for FCR-D. Prequalification of an aggregated portfolio for FCR-D exceeding 3 MW requires tests for each portfolio. For example, in case of an aggregated volume for FCR-D of 5 MW this can be divided into a 3 MW and a 2 MW portfolio, respectively, and requires prequalification of both. The portfolios may then subsequently be pooled when offering the reserve in the market.

When adding additional units to an aggregated pool, Energinet will allow the addition of up to 3 MW of the same technology within the same price area to the existing portfolio of units, without new actual tests of the portfolio or the unit. A total addition of 3 MW to the portfolio requires new tests to be done. The aggregator must in accordance with" Main agreement on the supply of ancillary services", keep an updated list of ancillary service units, that the aggregator oversees. Documentation must contain information about MW, type, placement, and potential consumption pattern over a given period.

4.3.3 Frequency meters for aggregated portfolios

For aggregated units, the ancillary service is provided through an aggregator and balance responsible party. Energinet looks at the overall volume of power sold by the aggregator, and this means that there must only be one frequency meter, which then distributes the signal to the units providing the service. If using a central frequency meter, there is a requirement of an alternative method, in case of meter error, disconnection or similar. This could be a backup frequency meter, placed somewhere else, which creates redundancy in case of power outage or similar. The backup procedure for the central frequency meter is described and approved along with the other deliverances for prequalification. The aggregator may choose to use several meters.

4.3.4 Storage of data for aggregated portfolios

For aggregated units, the ancillary service is provided through an aggregator and balance responsible party. Energinet looks at the overall volume of power sold by the balance responsible party, and this means that the storage of data to document service provision may be done at the aggregated level. Energinet's sole focus is to ensure that the actual provision can be verified and not from where actual provision has taken place. This means that the aggregator must comply with the applicable rules for storage of, for example, frequency data, but only at an aggregated level. The aggregator may store and submit data for spot checking from separate units if they want.

4.4 Audit of provisions

Only units and systems that have undergone a functional test can participate in the FCR-D market. When a unit/system has been approved and begins to provide ancillary services, regular inspections/audits will be carried out to determine whether the unit/system provides the ancillary services in the agreed/approved quality and quantity.

The market participant must provide the quantities sold. In case of minor provision shortages, payment for any non-provision is deducted from the full volume. In case of major provision shortages, payment of the costs of replacement purchases and quarantine may be a possibility, cf. the tender specifications mentioned above. The lifting of a quarantine will be subject to either a renewed approval of the unit or the submission of detailed documentation proving that any faults have been remedied. Please note that the approved maximum capacity, which a unit can offer in a reserve capacity market, does not necessarily match the volume available in any given period.

4.5 Prognosis & baseline

To achieve a sufficient delivery security for reserves from fluctuating production technologies and demand response Energinet requires a prognosis for the available capacity at the time of submission of bids for the reserve (the day before operation). To be able to estimate and control if a given response has been carried out, a reference power is necessary to know on a given unit. This reference power is also called baseline. For conventional plants this can be determined as the schedule. For units with fluctuating production and for demand response, the baseline can be difficult to determine. Examples on baseline calculations for different types of units are available in Appendix 9.2. Furthermore, suggestions, advice, and expectations for the baseline calculations from non-conventional unit are given.

Energinet will request a concept description and results from the developed calculation when a unit or a portfolio of units are prequalified to deliver ancillary services. The calculations must also be prequalified.

5. Test of FCR-N in DK2

This section describes the fundamental requirements for FCR-N (frequency-controlled normal operation reserves) and required ancillary services tests to be done before the unit can form part of/be used in the market.

5.1 Prior to market participation

Before a unit/system can join the market, it must be verified that the unit/system can provide the specific ancillary service, within the specified response time, while still maintaining the technical requirements of that service.

The sections below specify the technical requirements followed by required tests designed to verify the unit's ability to deliver.

The cost of information technology (IT) connections, maintenance, grid tariffs etc. for energy provisions and tests/reliability testing must be paid solely by the service provider.

5.1.1 FCR-N response requirements

FCR-N is used to stabilise the frequency close to the reference frequency (50 Hz) and to reduce the number of frequency dips/jumps. The service is activated for both small and large frequency deviations, as the function is activated in case of deviations from 50 Hz.

Regulation is performed as a fast-reacting proportional control, often provided from 'running/spinning' units at part load.

Units tasked with providing FCR-N must measure the frequency and automatically activate reserves on their own accord, as they will receive no external activation signal.

Power response to frequency fluctuations must be provided at frequency deviations of up to ±100 mHz relative to the reference frequency, i.e. in the range 49.9 - 50.1 Hz.

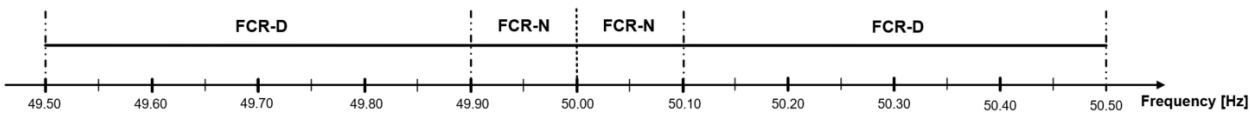


Figure 11 - Activation frequencies for FCR-N.

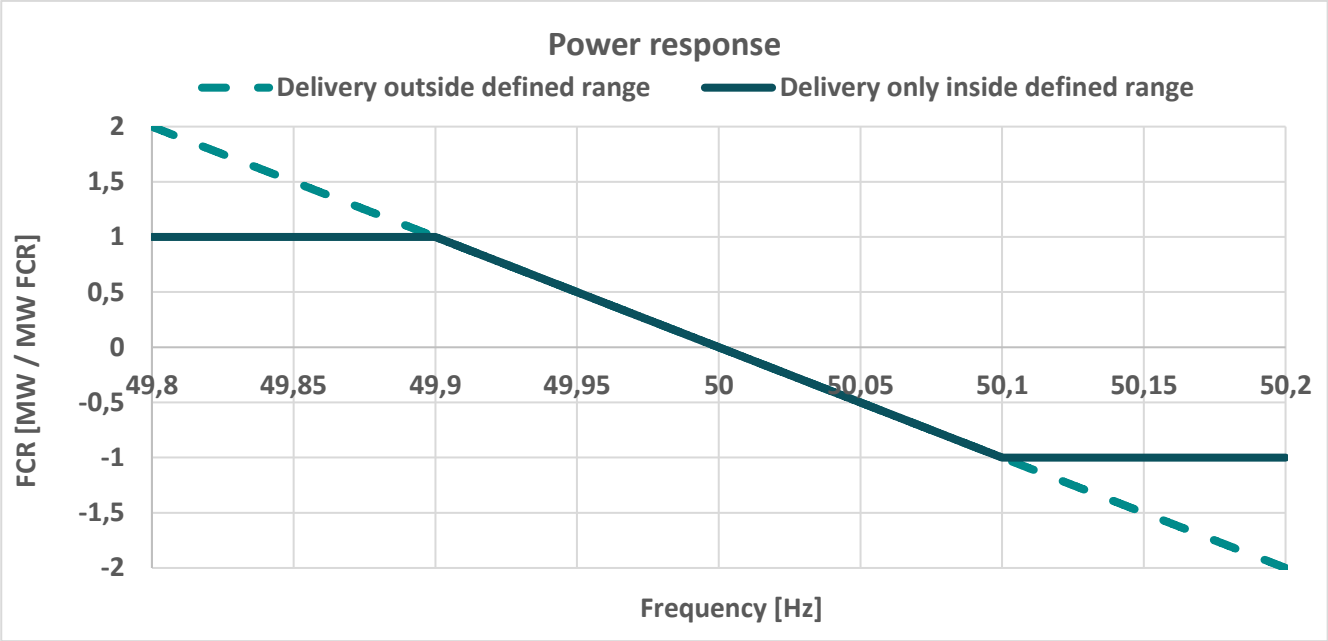


Figure 12 - Power response from FCR-N for continued provision outside and inside the band, respectively.

Measuring equipment accuracy must be 10 mHz or higher. It is acceptable for a unit to have a hysteresis range of +/- 10 mHz over the frequency band.

FCR-N volumes activated by a frequency deviation are linearly dependent on the frequency. For example, if the DK2 frequency differs -50 mHz, half the reserve is activated.

The below figure shows the minimum and maximum responses from the activation of FCR-N (t0) until the time when the reserve must be fully provided (t1). The maximum response equals the existence of a 10 mHz deviation in the frequency measurement, which is accepted based on the measuring equipment accuracy requirement. For units not equipped with ramp control, the acceptable response range may also be divided into smaller steps. A small delay of a few seconds at start-up is acceptable but the response must then return to the permissible range. In addition, minor deviations, positive as well as negative, near the permissible response range, especially near P_{res} when response is fully regulated, are also accepted. This applies to both prequalification tests of reserves and subsequent operation.

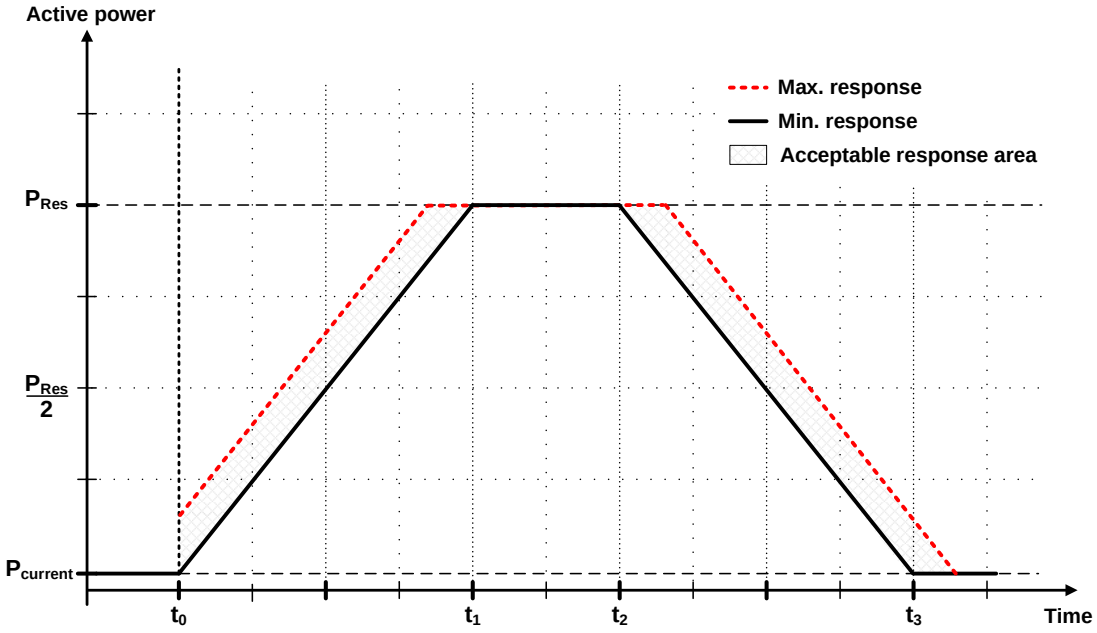


Figure 13 - Random FCR (FNR) activation response sequency in DK2.

Table 6 - Time parameters for tests described in Figure 12 and Figure 13.

Time parameters	Time
t_0 - t_1	150 s
t_1 - t_2	Frequency imbalance length, at least 15 min
t_2 - t_3	150 s

Response sequences for reserve tests must be within the "acceptable response area". It is acceptable to perform a quicker response than shown in the figure, as long as the response is approximately linear and proportional to the frequency deviation.

Unit sensitivity must not exceed 10 mHz. This means that the unit must respond to changes of 10 mHz.

The resolution of the market participant's SCADA system must be better than 1 second, and selected signals must be able to document the units' responses to frequency deviations. The service provider must save the signals for at least one week. Regulation must continious and include functions that ensure maintenance of 100% power during the contracted period.

5.2 Prequalification of stand-alone units

The unit must do a test procedure, where a frequency signal (deviation from 50 Hz) is applied on site in the unit frequency regulator, and the input frequency and resulting system response are then logged. The market participant must be able to apply a frequency signal.

The figure below shows these tests.

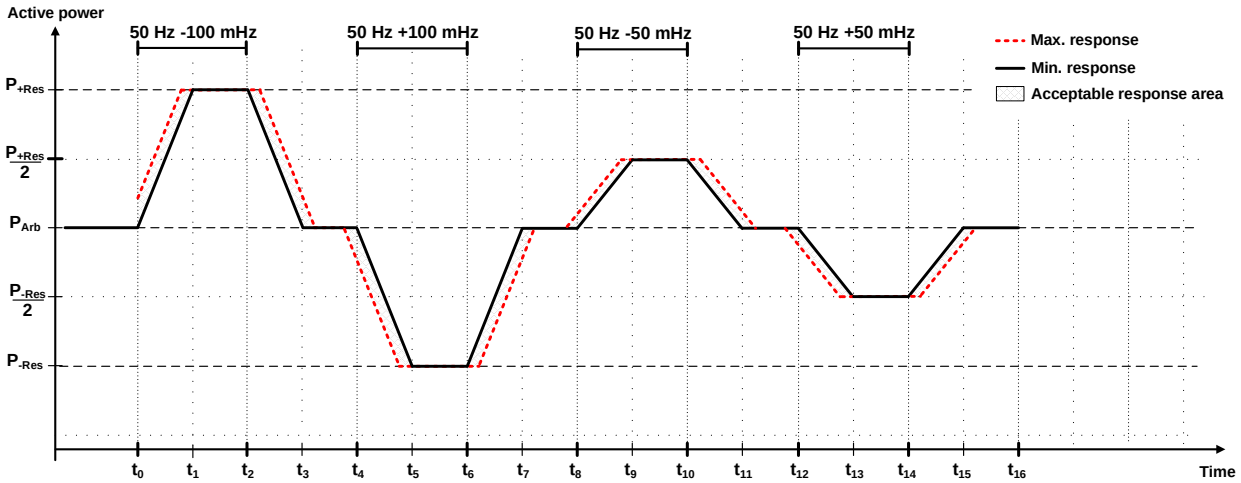


Figure 14 - Tests of minimum requirements for response for FCR-N.

The table below specifies response times for Figure 14.

Time parameters	Time
t_0 - t_1	As specified in Figure 13
t_1 - t_2	15 min
t_2 - t_3	As specified in Figure 13
t_3 - t_4	1 min
t_4 - t_5	As specified in Figure 13
t_5 - t_6	15 min
t_6 - t_7	As specified in Figure 13
t_7 - t_8	1 min
t_8 - t_9	As specified in Figure 13
t_9 - t_{10}	5 min
$t_{10} – t_{11}$	As specified in Figure 13
$t_{11} – t_{12}$	1 min
$t_{12} – t_{13}$	As specified in Figure 13
$t_{13} – t_{14}$	5 min
$t_{14} – t_{15}$	As specified in Figure 13
$t_{15} – t_{16}$	1 min

Table 7 - Time parameters for tests described in Figure 14.

Please note that completion of the full test specified in Figure 14 is only a requirement if the unit owner has applied to provide both upward and downward regulation.

5.3 Prequalification of aggregated portfolios

For aggregated unit portfolios, the collection of units must be approved and prequalified for the provision of ancillary services. In other words, Energinet pre-qualifies an aggregated unit portfolio using the aggregator's aggregation tool and control system, so that tests are done to determine the practical provision and actual capacity. Therefore, a portfo-

lio of units will be tested and approved based on its overall performance in relation to the applicable requirements for the ancillary service it offers. The aggregated portfolio will be approved based on the same conditions as described above for stand-alone units. During tests of aggregated portfolios, Energinet would also like to see the response from a stand-alone unit as well. The aggregator is charged with ensuring that underlying units are always aggregated, allowing them to comply with any system-related conditions for the provision of ancillary services. The overall response will also form the basis for spot checking.

5.3.1 Approval of aggregation concept

For aggregated portfolios, the market participant must submit a description of the aggregation concept, including a description of the communication mode selected. This description must state how requirements and specifications are complied with. The description must be approved by Energinet before the market participant can join the market with the concept selected.

5.3.2 Maximum power for aggregated portfolios

The maximum pool, which can be approved as an aggregated portfolio, is 3 MW for FCR-N. Prequalification of an aggregated portfolio for FCR-N exceeding 3 MW requires tests for each portfolio. For example, in case of an aggregated volume for FCR-N of 5 MW, this can be divided into a 3 MW and a 2 MW portfolio, respectively, and requires prequalification of both. The portfolios may then subsequently be pooled when offering the reserve in the market.

When adding additional units to an aggregated pool, Energinet will allow the addition of up to 3 MW of the same technology within the same price area to the existing portfolio of units, without new actual tests of the portfolio or the unit. A total addition of 3 MW to the portfolio requires new tests to be done. The aggregator must in accordance with" Main agreement on the supply of ancillary services", keep an updated list of ancillary service units, that the aggregator oversees. Documentation must contain information about MW, type, placement and potential consumption pattern over a given period.

5.3.3 Frequency meters for aggregated portfolios

For aggregated units, the ancillary service is provided through an aggregator and balance responsible party. Energinet looks at the overall volume of power sold by the aggregator, and this means that there must only be one frequency meter, which then distributes the signal to the units providing the service. If using a central frequency meter, there is a requirement of an alternative method, in case of meter error, disconnection or similar. This could be a backup frequency meter, placed somewhere else, which creates redundancy in case of power outage or similar. The backup procedure for the central frequency meter is described and approved along with the other deliverances for prequalification. The aggregator may choose to use several meters.

5.3.4 Storage of data for aggregated portfolios

For aggregated units, the ancillary service is provided through an aggregator and balance responsible party. Energinet looks at the overall volume of power sold by the balance responsible party, and this means that the storage of data to document service provision may be done at the aggregated level. Energinet's sole focus is to ensure that the actual provision can be verified and not from where actual provision has taken place. This means that the aggregator must comply with the applicable rules for storage of, for example, frequency data, but only at an aggregated level. The aggregator may store and submit data for spot checking from separate units if they want.

5.4 Audit of provisions

Only units and systems that have undergone a functional test can participate in the FCR-D market. When a unit/system has been approved and begins to provide ancillary services, regular inspections/audits will be carried out to determine whether the unit/system provides the ancillary services in the agreed/approved quality and quantity.

The market participant must provide the quantities sold. In case of minor provision shortages, payment for any non-provision is deducted from the full volume. In case of major provision shortages, payment of the costs of replacement purchases and quarantine may be a possibility, cf. the tender specifications mentioned above. The lifting of a quarantine will be subject to either a renewed approval of the unit or the submission of detailed documentation proving that any faults have been remedied. Please note that the approved maximum capacity, which a unit can offer in a reserve capacity market, does not necessarily match the volume available in any given period.

5.5 Prognosis & baseline

To achieve a sufficient delivery security for reserves from fluctuating production technologies and demand response Energinet requires a prognosis for the available capacity at the time of submission of bids for the reserve (the day before operation). To be able to estimate and control if a given response has been carried out, a reference power is necessary to know on a given unit. This reference power is also called baseline. For conventional plants this can be determined as the schedule. For units with fluctuating production and for demand response, the baseline can be difficult to determine. Examples on baseline calculations for different types of units are available in Appendix 9.2. Furthermore, suggestions, advice, and expectations for the baseline calculations from non-conventional unit are given.

Energinet will request a concept description and results from the developed calculation when a unit or a portfolio of units are prequalified to deliver ancillary services. The calculations must also be prequalified.

6. Test of FFR in DK2

This section describes the fundamental requirements for FFR (fast frequency reserve) and required ancillary services tests to be done before the unit can form part of/be used in the market.

6.1 Prior to market participation

Before a unit/system can join the market, it must be verified that the unit/system can provide the specific ancillary service, within the specified response time, while still observing the technical requirements of that service.

The sections below specify the technical requirements followed by required tests designed to verify the unit's ability to deliver.

The cost of information-technological (IT) connections, maintenance, grid tariffs etc. for energy provisions and tests/reliability testing must be paid solely by the service provider.

6.1.1 FFR response requirements

FFR is used to stabilise the frequency, in case major outages occur in low inertia situations, and to reduce frequency dips/jumps to avoid exceeding the threshold of a deviation greater than 1 Hz. The service is only activated for large frequency deviations, as the function is activated in case of deviations of 300 mHz or more from 50 Hz.

This is a fast-reacting active power response regulation, which is activated when the frequency exceeds the chosen threshold. Regulation will be provided from 'running/spinning' units at part load, disconnectable load or inverter-based technologies.

Units tasked with providing FFR must measure the frequency and automatically activate reserves on their own accord, as they will receive no external activation signal.

Three combinations of activation level and full activation time are possible, and these are equally effective in meeting system FFR response demands. The table below presents the three options.

Alternative	Activation level [Hz]	Maximum full activation time [s]
A	49.7	1.3
B	49.6	1.0
C	49.5	0.7

Table 8 - Possible thresholds, A, B and C, for FFR activation level and respective maximum activation times.

Under-frequency situations have proven very critical compared to over-frequency situations. Therefore, FFR is only purchased for under-frequency situations.

Measuring equipment accuracy must be 10 mHz or lower. A unit can have a hysteresis range of +/- 10 mHz within the frequency range.

The FFR volume activated by a frequency deviation is governed by a step function and therefore not linearly dependent on the frequency. This means that if, for example, the frequency in DK2 deviates, exceeding the threshold, the entire reserve is activated.

The figure below shows minimum and maximum responses from the time of FFR activation (t0) to the time when the reserve must be fully provided (t1). The maximum response corresponds to a permissible overshoot of 35% of the reserve. A small delay of a few seconds in response start-up is **not** allowed; (t0) is the time when measurements show that the frequency crosses the activation level value.

In addition to the option to choose between different activation levels in relation to the frequency threshold, it is also possible to choose between a short and a long FFR activation period of minimum 5 or 30 seconds, respectively. Independently of the choice of activation level with respective maximum activation time, the activation period can be freely chosen.

For short periods, FFR response deactivation cannot exceed a 20% per second gradient. For step-by-step deactivation, steps must not exceed 20%.

Alternative	FFR provision period [s]	Deactivation requirements [s]
1	5 s	Gradient spanning minimum 5 s or steps of maximum 20% spanning 5 s
2	30 s	No requirements

Table 9 - Possible FFR provision periods, 1 and 2, and respective deactivation requirements.

Following response deactivation, the unit must, at a minimum, hold approximately the same set point for 10 seconds.

Following an activation, the providing unit may change set point, for example if there is a need to recharge or another type of rebound effect. The new set point must equal the load set point prior to activation less 25% of activated FFR power. It is permissible to hold this set point until 15 minutes after the time of activation, after which the FFR unit must be re-established and ready for another activation.

Any tests must be carried out as detailed as in the figure below. The FFR provider simulates a frequency deviation of a scale that triggers an FFR response. Activation level, activation time, duration, and deactivation time to be tested must be selected and Energinet must be informed prior to any test.

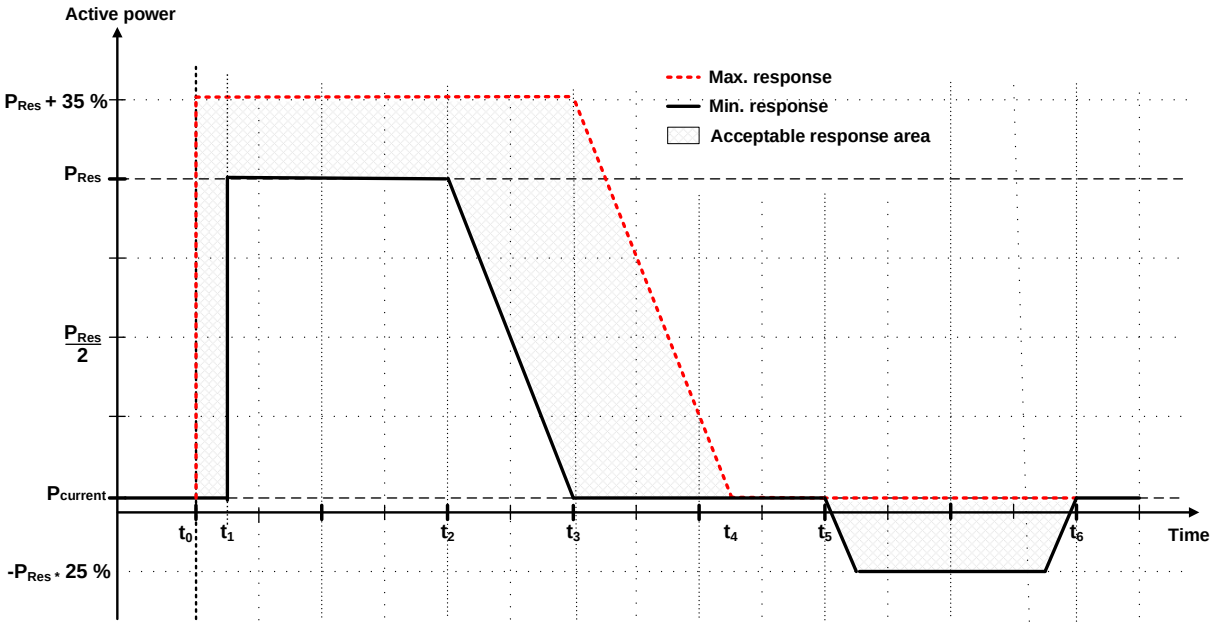


Figure 15 - Test of minimum FFR activation requirements for DK2.

The table below specifies the response times of Figure 15.

Time parameters;	Time
t_0 - t_1	0.7 s / 1.0 s / 1.3 s, (alternatives C, B, or A, respectively)
t_1 - t_2	Minimum 5 s / 30 s, (alternatives 1 or 2, respectively)
t_2 - t_3	Minimum 5 s at t_1 – t_2 in 5 seconds, otherwise no requirements
t_3 - t_4	Unlimited, subject to compliance with t_6
t_4 - t_5	Minimum 10 s at t_1 -t_2 in 5 seconds, otherwise no requirements
t_6	Maximum 15 minutes after t_0

Table 10 - Time parameters for response sequences described in Figure 15.

Response sequences for reserve tests must be within the "acceptable response area".
Unit sensitivity must not exceed 10 mHz. This means that the unit must respond to changes of 10 mHz.

The resolution of the market participant's SCADA system must be at least 0,1 second, and selected signals must be able to document the unit's responses to frequency deviations. The service provider must save the signals for at least one week. The regulation must be active at all times and include functions that ensure maintenance of 100% power during the contracted period.

6.2 Prequalification of stand-alone units

The unit must do a test procedure, where a frequency signal (deviation from 50 Hz) is applied on site in the unit frequency regulator, and the input frequency and resulting system response are then logged. The market participant must be able to apply a frequency signal.

6.3 Prequalification of aggregated portfolios

For aggregated unit portfolios, the collection of units must be approved and prequalified for the provision of ancillary services. In other words, Energinet pre-qualifies an aggregated unit portfolio using the aggregator's aggregation tool and control system, so that tests are done to determine the practical provision and actual capacity. Therefore, a portfolio of units will be tested and approved based on its overall performance in relation to the applicable requirements for the ancillary service it offers. The aggregated portfolio will be approved based on the same conditions as described above for stand-alone units. During tests of aggregated portfolios, Energinet would also like to see the response from a stand-alone unit as well. The aggregator is charged with ensuring that underlying units are always aggregated, allowing them to comply with any system-related conditions for the provision of ancillary services. The overall response will also form the basis for spot checking.

6.3.1 Approval of aggregation concept

For aggregated portfolios, the market participant must submit a description of the aggregation concept, including a description of the communication mode selected. This description must state how requirements and specifications are complied with. The description must be approved by Energinet before the market participant can join the market with the concept selected.

6.3.2 Maximum power for aggregated portfolios

The maximum pool, which can be approved as an aggregated portfolio, is 3 MW for FFR. Prequalification of an aggregated portfolio for FFR exceeding 3 MW requires tests for each portfolio. For example, in case of an aggregated volume for FFR of 5 MW, this can be divided into a 3 MW and a 2 MW portfolio, respectively, and requires prequalification of both. The portfolios may then subsequently be pooled when offering the reserve in the market.

When adding additional units to an aggregated pool, Energinet will allow the addition of up to 3 MW of the same technology within the same price area to the existing portfolio of units, without new actual tests of the portfolio or the unit. A total addition of 3 MW to the portfolio requires new tests to be done. The aggregator must in accordance with" Main agreement on the supply of ancillary services", keep an updated list of ancillary service units, that the aggregator oversees. Documentation must contain information about MW, type, placement and potential consumption pattern over a given period.

6.3.3 Frequency meters for aggregated portfolios

For aggregated units, the ancillary service is provided through an aggregator and balance responsible party. Energinet looks at the overall volume of power sold by the aggregator, and this means that there must only be one frequency meter, which then distributes the signal to the units providing the service. If using a central frequency meter, there is a requirement of an alternative method, in case of meter error, disconnection or similar. This could be a backup frequency meter, placed somewhere else, which creates redundancy in case of power outage or similar. The backup procedure for the central frequency meter is described and approved along with the other deliverances for prequalification. The aggregator may choose to use several meters.

6.3.4 Storage of data for aggregated portfolios

For aggregated units, the ancillary service is provided through an aggregator and balance responsible party. Energinet looks at the overall volume of power sold by the balance responsible party, and this means that the storage of data to document service provision may be done at the aggregated level. Energinet's sole focus is to ensure that the actual provision can be verified and not from where actual provision has taken place. This means that the aggregator must comply with the applicable rules for storage of, for example, frequency data, but only at an aggregated level. The aggregator may store and submit data for spot checking from separate units, if they want.

6.4 Audit of provisions

Only units and systems that have undergone a functional test can participate in the FCR-D market. When a unit/system has been approved and begins to provide ancillary services, regular inspections/audits will be carried out to determine whether the unit/system provides the ancillary services in the agreed/approved quality and quantity.

The market participant must provide the quantities sold. In case of minor provision shortages, payment for any non-provision is deducted from the full volume. In case of major provision shortages, payment of the costs of replacement purchases and quarantine may be a possibility, cf. the tender specifications mentioned above. The lifting of a quarantine will be subject to either a renewed approval of the unit or the submission of detailed documentation proving that any faults have been remedied. Please note that the approved maximum capacity, which a unit can offer in a reserve capacity market, does not necessarily match the volume available in any given period.

6.5 Prognosis & baseline

To achieve a sufficient delivery security for reserves from fluctuating production technologies and demand response Energinet requires a prognosis for the available capacity at the time of submission of bids for the reserve (the day before operation). To be able to estimate and control if a given response has been carried out, a reference power is necessary to know on a given unit. This reference power is also called baseline. For conventional plants this can be determined as the schedule. For units with fluctuating production and for demand response, the baseline can be difficult to determine. Examples on baseline calculations for different types of units are available in Appendix 9.2. Furthermore, suggestions, advice, and expectations for the baseline calculations from non-conventional unit are given.

Energinet will request a concept description and results from the developed calculation when a unit or a portfolio of units are prequalified to deliver ancillary services. The calculations must also be prequalified.

7. Test of mFRR/manual reserves in DK1 and DK2

This section describes the fundamental requirements for mFRR (manual reserves) and required ancillary services tests to be done before the unit/system can form part of/be used in the market.

Prequalification has earlier only been necessary for units that are part of the capacity market. They have not been necessary for voluntary bids. During transition to a common Nordic, and later common European marked (MARI & PICASSO), the energy activation markets for mFRR and aFRR requires voluntary bids to be prequalified as well. The required responses are described in this document for mFRR and aFRR reserves. Because of this, prequalification of the voluntary bids is also required.

7.1 Prior to market participation

Before a unit/system can join the market, it must be verified that the unit/system can provide the specific ancillary service, within the specified response time, while still observing the technical requirements of that service.

The sections below specify the technical requirements followed by required tests designed to verify the unit's ability to deliver. Each production or consumption unit providing manual reserves must have an IT connection to Energinet's control centre. The control centre must at a minimum present the following online:

- status of production or consumption unit out of/in operation
- metered data for production or consumption unit's
    - net production or consumption in the Point of Connection
    - Balance responsible party net production

Requirements and point of delivery for notifications and measurement data is to be agreed with Energinet.

The cost of IT connections, maintenance, grid tariffs etc. for energy provisions and tests/reliability testing must be paid solely by the service provider.

7.1.1 mFRR response requirements

mFRR is a manual upward and downward regulating reserve, which is used, for example, to relieve primary (FCR, FCR-N and FCR-D) and secondary (aFRR) reserves. mFRR is activated by Energinet’s control centre by the activation of market bids, for example after the automatic reserves have stabilised and restored the frequency to the reference frequency (50 Hz) in connection with a frequency deviation.

The figure below shows minimum responses for units that provide mFRR in DK1 and DK2. Minor deviations, positive as well as negative, near the permissible response range near P_{res} when response is fully regulated, are accepted. This applies to both prequalification tests of reserves and subsequent operation.

The ramps illustrated in the figure are the maximum allowed ramping speed equal to 20 % of the nominal capacity of the unit or system of units pr. minute. It means that an activation of the total nominal capacity of a unit or system of units are not allowed to ramp faster than five minutes. The minimum allowed ramping speed is 15 minutes equal to 6,67 % per minute of the volume of the activation.

The maximum ramping speed is applied regardless of when the activation is started, also exactly in between t_0 and t_1 where the allowed response area visually allows a step response.

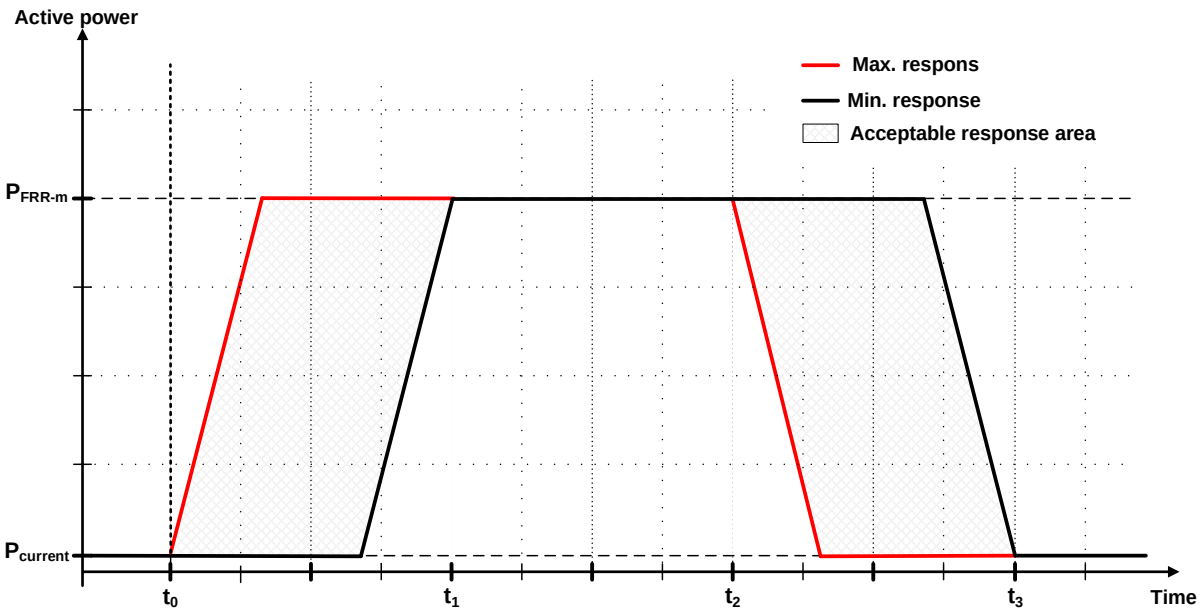


Figure 16 - Random mFRR activation response sequence.

The table below specifies response times for Figure 16.

Time parameters	Time
t_0 - t_1	< 15 min
t_1 - t_2	Unlimited
t_2 - t_3	< 15 min

Table 11 - Time parameters for response sequence described in Figure 16.

The large response area allowed is permissible because activation occurs through the submission of operational schedules/consumption schedules which reflect the unit's response. Please note, however, that bids must be fully activated within 15 minutes.

Times specified for response sequences apply to both upward and downward regulation.

7.2 Prequalification of stand-alone units

The unit must use the test procedure specified in the below figure, where the balance responsible party submits an operational schedule for the test procedure, after which the unit is activated according to this schedule. Power response from the unit is logged. If a unit is expected to only operate with one set point for upward and downward regulation (P_{+Res} og P_{-Res}), respectively, the test may be stopped at t_7 in Figure 17.

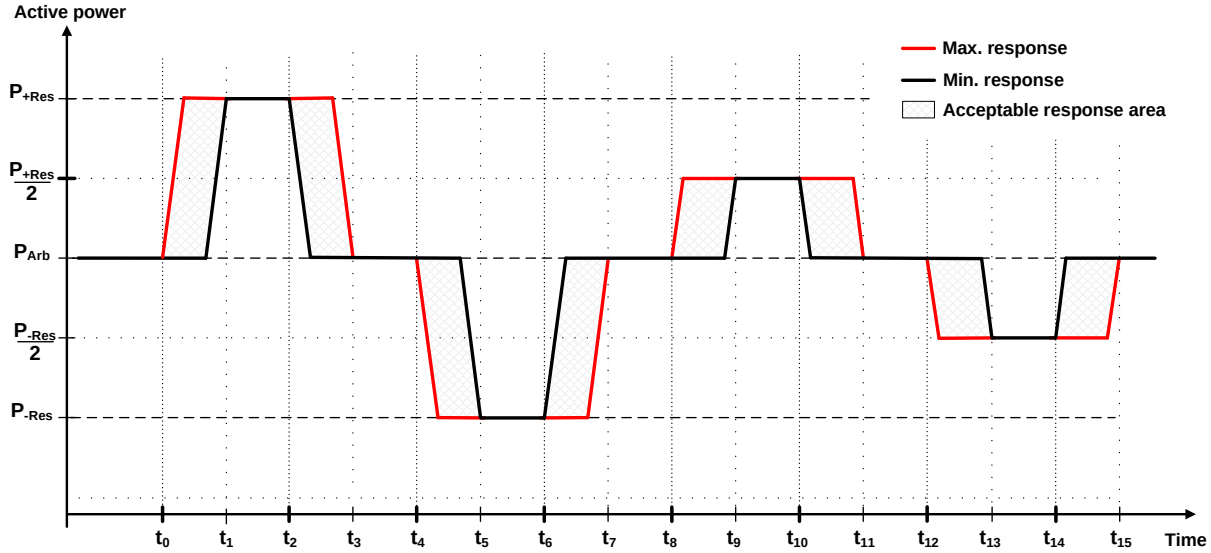


Figure 17 - Tests of minimum requirements for response for mFRR at both upward and downward regulation.

The table below specifies response times for Figure 17.

Time parameters	Time
t_0 - t_1	*As specified in Figure 16*
t_1 - t_2	30 min
t_2 - t_3	*As specified in Figure 16*
t_3 - t_4	1 min
t_4 - t_5	*As specified in Figure 16*
t_5 - t_6	30 min
t_6 - t_7	*As specified in Figure 16*
t_7 - t_8	1 min
t_8 - t_9	*As specified in Figure 16*
t_9 - t_{10}	5 min
t_{10} – t_{11}	*As specified in Figure 16*
t_{11} – t_{12}	1 min
t_{12} – t_{13}	*As specified in Figure 16*
t_{13} – t_{14}	5 min
t_{14} – t_{15}	*As specified in Figure 16*

Table 12 - Time parameters for tests described in Figure 17.

Please note that completion of the full test specified in Figure 17 is only a requirement if the unit owner has applied to provide both upward and downward regulation at full and part load.

At full load, for both upward and downward regulation of consumption and production units, tests will show results similar to those shown in Figure 18 and Figure 19 below. If a unit is expected to only operate with one set point for upward and downward regulation (P_{+Res} og P_{-Res}), respectively, the test may be stopped at t_3 in Figure 18 and Figure 19, respectively.

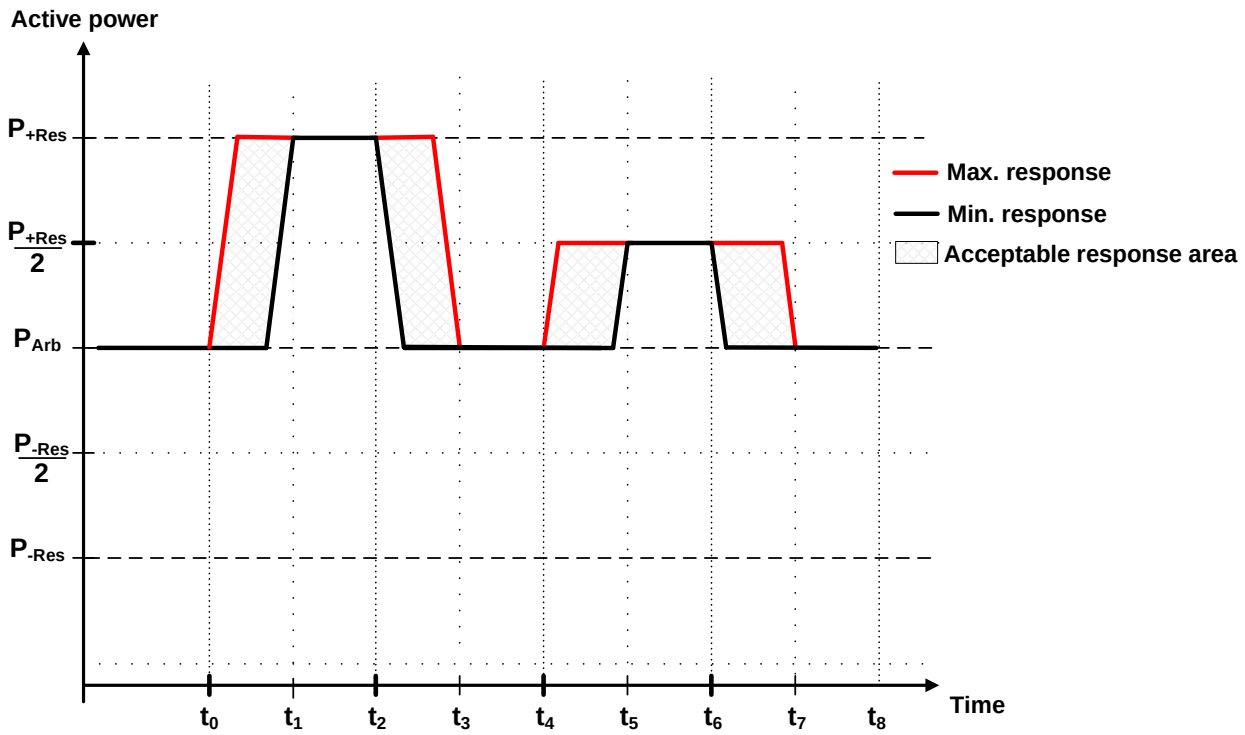


Figure 18 - Tests of minimum requirements for response for mFRR at upward regulation.

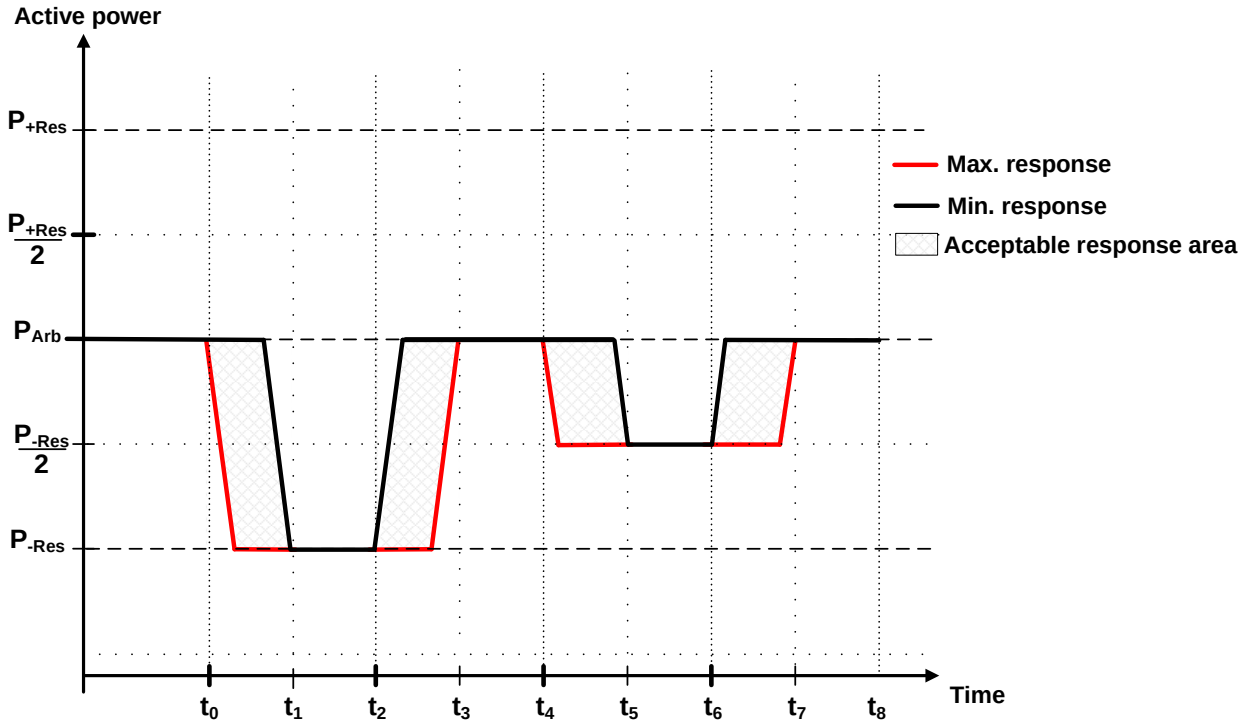


Figure 19 - Tests of minimum requirements for response for mFRR at downward regulation.

Time parameters	Time
$t_0 – t_1$	As specified in Figure 16
$t_1 – t_2$	30 min
$t_2 – t_3$	As specified in Figure 16
$t_3 – t_4$	15 min
$t_4 – t_5$	As specified in Figure 16
$t_5 – t_6$	30 min
$t_6 – t_7$	As specified in Figure 16

Table 13 - Time parameters for tests described in Figure 18 and Figure 19.

7.3 Prequalification of delivery of local flexibility

Delivery of local flexibility to Energinet in relation to handling of local flexibles in the transmission grid requires prequalification. The requirements are identical to the requirements for mFRR reserves as described above.

For an aggregated portfolio of smaller units are on/off regulation of units with an appropriate delay, to mimic a ramp allowed.

Furthermore a “geo-tag” is added to the mFFR energy bid, which is the transformer station in the transmission grid, that the unit is connected to (this is found in collaboration with Energinet).

7.4 Prequalification of aggregated portfolios

For aggregated unit portfolios, the collection of units must be approved and prequalified for the provision of ancillary services. In other words, Energinet pre-qualifies an aggregated unit portfolio using the aggregator's aggregation tool and control system, so that tests are done to determine the practical provision and actual capacity. Therefore, a portfolio of units will be tested and approved based on its overall performance in relation to the applicable requirements for the ancillary service it offers. The aggregated portfolio will be approved based on the same conditions as described above for stand-alone units. During tests of aggregated portfolios, Energinet would also like to see the response from a stand-alone unit as well. The aggregator is charged with ensuring that underlying units are always aggregated, allowing them to comply with any system-related conditions for the provision of ancillary services. The overall response will also form the basis for spot checking.

7.4.1 Approval of aggregation concept

For aggregated portfolios, the market participant must submit a description of the aggregation concept, including a description of the communication mode selected. This description must state how requirements and specifications are complied with. The description must be approved by Energinet before the market participant can join the market with the concept selected.

7.4.2 Maximum power for aggregated portfolios

The maximum pool, which can be approved as an aggregated portfolio, is 10 MW for mFRR. Prequalification of an aggregated portfolio for mFRR exceeding 3 MW requires tests for each portfolio. For example, in case of an aggregated volume for mFRR of 18 MW, this can be divided into a 10 MW and an 8 MW portfolio, respectively, and requires prequalification of both. The portfolios may then subsequently be pooled when offering the reserve in the market.

When adding additional units to an aggregated pool, Energinet will allow the addition of up to 3 MW of the same technology within the same price area to the existing portfolio of units, without new actual tests of the portfolio or the unit. A total addition of 3 MW to the portfolio requires new tests to be done. The aggregator must in accordance with" Main agreement on the supply of ancillary services", keep an updated list of ancillary service units, that the aggregator oversees. Documentation must contain information about MW, type, placement and potential consumption pattern over a given period.

7.4.3 Online measurements

For aggregated units, the ancillary service is provided through an aggregator and balance responsible party. Energinet looks at the total volume of power sold by the aggregator, and this means that only one online measurement is required for the aggregated volume when providing mFRR. The aggregator may choose to use several meters however, one online measurement per unit is required for units of 1.5 MW or more. Only one online measurement is required for aggregated units with unit sizes of less than 1.5 MW in a portfolio, cf. SO GL article 158 (1) (e).

7.4.4 Settlement meters

The set-up for the provision of ancillary services from aggregated units is a deciding factor in settlement meter requirements. Set-up options include an aggregator with own balance responsibility or an aggregator collaborating with a balance responsible party. Due to the many set-up options, reference is made to market regulation D1 for details on settlement meter requirements.

7.5 Audit of provisions

Only units and systems that have undergone a functional test can participate in the FCR-D market. When a unit/system has been approved and begins to provide ancillary services, regular inspections/audits will be carried out to determine whether the unit/system provides the ancillary services in the agreed/approved quality and quantity.

The market participant must provide the quantities sold. In case of minor provision shortages, payment for any non-provision is deducted from the full volume. In case of major provision shortages, payment of the costs of replacement purchases and quarantine may be a possibility, cf. the tender specifications mentioned above. The lifting of a quarantine will be subject to either a renewed approval of the unit or the submission of detailed documentation proving that any faults have been remedied. Please note that the approved maximum capacity, which a unit can offer in a reserve capacity market, does not necessarily match the volume available in any given period.

7.6 Prognosis & baseline

To achieve a sufficient delivery security for reserves from fluctuating production technologies and demand response Energinet requires a prognosis for the available capacity at the time of submission of bids for the reserve (the day before operation). To be able to estimate and control if a given response has been carried out, a reference power is necessary to know on a given unit. This reference power is also called baseline. For conventional plants this can be determined as the schedule. For units with fluctuating production and for demand response, the baseline can be difficult to determine. Examples on baseline calculations for different types of units are available in Appendix 9.2. Furthermore, suggestions, advice, and expectations for the baseline calculations from non-conventional unit are given.

Energinet will request a concept description and results from the developed calculation when a unit or a portfolio of units are prequalified to deliver ancillary services. The calculations must also be prequalified.

8. Test of aFRR in DK1 and DK2

This section describes the fundamental requirements for aFRR (secondary reserves, LFC) and required ancillary services tests to be done before the unit/system can form part of/be used in the market.

There are two sets of requirements for aFRR, dependent on whether the unit/portfolio is in DK1 or DK2. In the future the requirements for DK1 will be as they currently are for DK2.

8.1 aFRR response requirements

The aFRR response times are different for DK1 and DK2.

- DK1: Full activation must be achieved within 15 minutes
- DK2: Full activation must be achieved within 5 minutes

The balance responsible party determines whether aFRR capacity is provided from a single unit or from an aggregated unit portfolio.

Energinet only has one communication line per balance responsible party. If a balance responsible party only offers one unit for use in this market, Energinet will allow direct communication from Energinet's SCADA system to this unit. If the balance responsible party’s portfolio comprises several units that will submit capacity bids separately or in an aggregated capacity bid, Energinet will only assign one communication line, in this case to the balance responsible party's SCADA system. The balance responsible party is then responsible for further communication to its units.

The Energinet LFC function set point value will be a "continuous" signal with a refresh interval of 4 to 10 seconds. Reserved capacity is activated using a proportionate distribution that reflects the result of the capacity auction.

Managing provisions in daily operation relies on balance responsible parties operating according to the submitted schedules. The activation signal is an additional signal of the power schedule. If capacity is composed of both production and consumption, 5-minute power schedules must be submitted for both production and consumption.

8.2 Approval of concept

The balance responsible party must submit a description of the system that will receive and execute activations. This description must explain how requirements stated in this document are met. The description must be approved by Energinet before the balance responsible party can be allowed to participate in the capability contracts, capacity and automatic balancing markets. Please see the Appendix section for an example of balancing controller configuration.

8.2.1 Communication test

A signal test must be carried out between Energinet and the balance responsible party and between the balance responsible party and at least one unit. Documentation of a successful signal test must be submitted before the functional test is performed.

The approval procedure comprises both signal and activation tests that document the functionality of the balance responsible party's system. The balance responsible party's capacity and energy offerings are based on portfolio provisions, necessitating ongoing follow-up during normal operation as an important part of the assessment of whether the balance responsible party meets conditions.

8.2.2 Functional test DK2

Energinet sends a step-wise signal to the balance responsible party. The functional test is based on three different types of responses:

- FAT-test: Full activation within 5 minutes, hereafter steady-state operation and finally deactivation in 5 minutes.
- Spike-test: Signal with full activation for 5 minutes, and then a drop to no delivery.
- Step-test: Signal with partial activation and deactivation.

The three tests can be completed at different times, or in conjunction, where the resting periods can be shorter or longer than shown on the figure. The response from the aFRR delivering unit must be within the accepted area as shown in green in Figure 20.

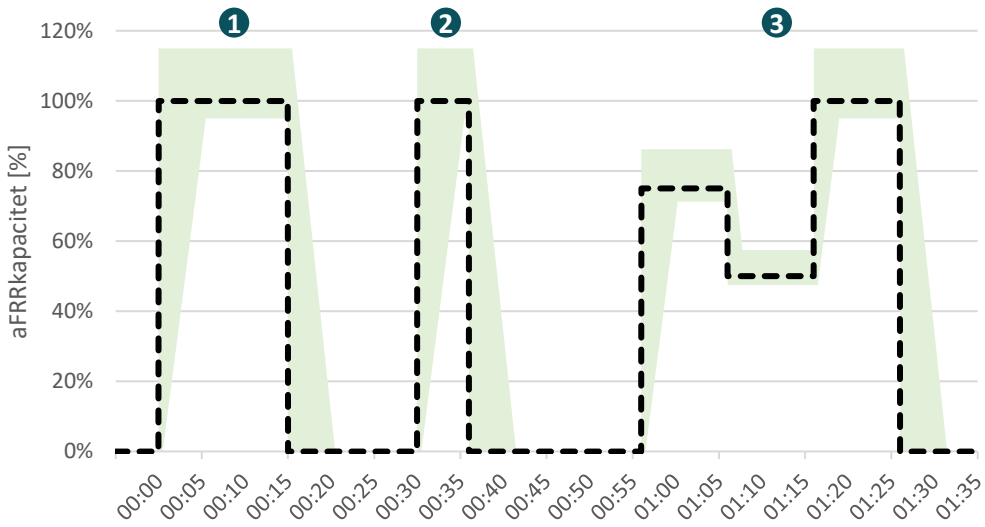


Figure 20 Test of the minimal requirement for the response for aFRR upregulation.

Table 14 Time parameters for test described in Figure 20.

T1	00:00	00:05	00:15	00:20	00:30	00:36	00:41	00:55	01:00	01:05	01:10	01:15	01:20	01:25
T2	00:05	00:15	00:20	00:30	00:36	00:41	00:55	01:00	01:05	01:10	01:15	01:20	01:25	01:30
ΔT	00:05	00:10	00:05	00:10	00:06	00:05	00:14	00:05	00:05	00:05	00:05	00:05	00:05	00:05
Signal	100%	100%	0%	0%	100%	0%	0%	75%	75%	50%	50%	100%	100%	0%

The minimum response is based on a 30 second delay, as well as linear ramps with a maximum under delivery of 95%. The max response is based on a step-based delivery and an over-delivery of 15%.

8.2.3 Functional test DK1

Energinet sends a step-based activation signal to the balance responsible actor. The response from the unit or the aggregated portfolio, must be within the area between “Test Step/Ramp” and “Minimum response” as seen in Figure 21. Minimum response at the test with a gradient corresponding to the “delay”, from the receival of the set point change and until the response is measured, with a maximum of 135 seconds for DK1.

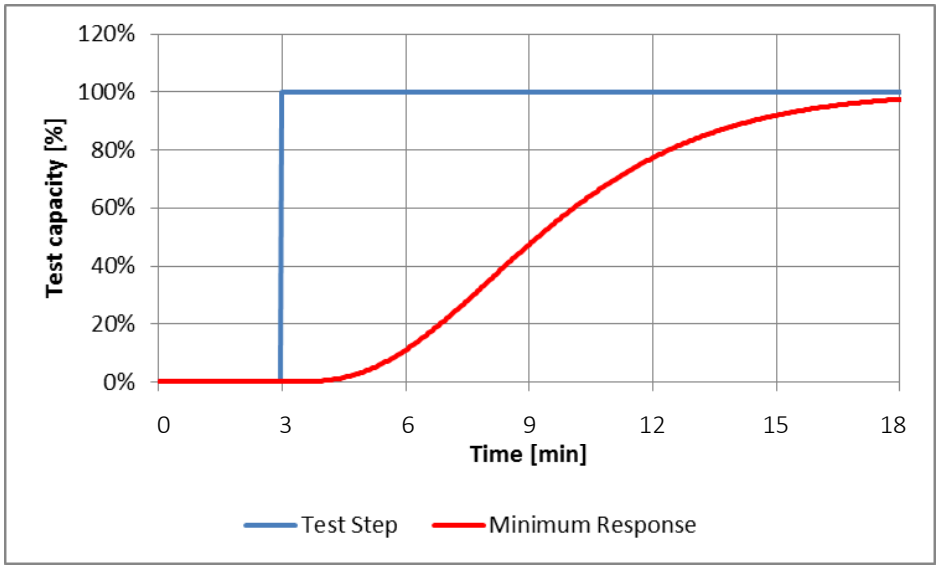


Figure 21 – Example of the required response, when the unit/portfolio is tested up towards a stepwise setpoint change in DK1, where 90% of the full activation must be reached 12 minutes after the starting signal.

The resolution for the market participant's SCADA -system must be better or equal to 10 seconds and chosen signals must be able to be document the response of the unit based on Energinet's regulation signal. The participant must store the signals for a minimum of two weeks.

8.2.4 Configuration of PBR control system

Input power is calculated based on the activation signal. This calculation is based on an expected response corresponding to a delayed response to an activation signal. In terms of balancing control set-up, the respective balance responsible party decides whether to distribute response equally between participating units or not. If a market participant wants Energinet to use an online value, this is possible.

8.2.5 Signal list

aFRR is an automatic power regulation function that reacts to an online regulation signal sent by Energinet to the units via the balance responsible party.

To provide this reserve, a new function must be built into the control systems of the unit. The function ensures that the units regulate up and down in response to an online regulation signal from Energinet. The online regulation signal is an addition/a correction to the units' existing power regulation signal.

The regulation reference is the providers' power schedules.

The online regulation signal sent by Energinet must be distributed by the balance responsible party to the units participating in aFRR regulation so that the combined reaction matches the regulation signal sent by Energinet.

From the unit to Energinet, only an online availability signal is required, which indicates that the unit is actively responding to the regulating signal from Energinet.

The units can consider online calculation of availability of up and down regulation (MW), regulating gradients (MW/minute), as well as time constants (seconds) and online send these inputs to the production balance responsibility party, who gathers the partial results into a combined result, which is then sent to Energinet. Alternatively, Energinet will use the ramps and time gradients from the prequalification test, as the input to the online signal.

Signals must be exchanged via an IEC 60870-6 TASE.2-connection, IEC 60870-5-104 or IEC 61-850 connection.

TASE 2:

ICCP INPUT

MXU MW RESERVE UP
MXD MW RESERVE DOWN
RTU RAMP UP
RTD RAMP DOWN
DEV DEVIATION EXPECTED
(unbalance which the BRP for production expects to regulate)
TCU TIME CONSTANT UP
TCD TIME CONSTANT DOWN
AUTO INDICATION
(status signal indicating that the unit is available for aFRR regulation)

ICCP OUTPUT

EBAS SETPOINT EXPECTED
EXPV REGULATION EXPECTED
LFCS LFC REGULATION CONTROL (ON/OFF, INDICATION)

Signals are sent every four seconds.

In case of breakdowns, the balance responsible party sends the TASE.2 signal 'AUTO INDICATION' to Energinet. At the same time, the balance operator is informed via telephone and e-mail.

IEC 60870-5-104 and IEC 61-850:

Participant to Energinet

Requirement	*WATCHDOG*	*Indication*	*Status signal that indicates that the unit is available for LFC regulation.*
Optional	*MW RESERVE UP*	*Measurement*	*Available up regulation, maximum the contract amount*
Optional	*MW RESERVE DOWN*	*Measurement*	*Available down regulation, maximum the contract amount*
Optional	*RAMP UP*	*Measurement*	*MW/minut. How fast can the unit ramp up*
Optional	*RAMP DOWN*	*Measurement*	*MW/minut. How fast can the unit ramp down.*
Optional	*TIME CONSTANT UP*	*Measurement*	*The seconds delay compared to the signal from Energinet.*
Optional	*TIME CONSTANT DOWN*	*Measurement*	*The seconds delay compared to the signal from Energinet.*

Optional	*DEVIATION EXPECTED*	*Measurement*	Unbalance which the BRP for production expects to regulate
Energinet to participant:			
Require-ment	SETPOINT EXPECTED	Measurement Feedback	*Energinets is expecting aFRR delivery from the particpant*
Require-ment	*SETPOINT EXPECTED*	*Setpoint*	*The setpoint signal from Energinet. Is sent as one signal, with +/-.*

Table 15 – Signal list

8.2.6 Maximum power for aggregated portfolios

The maximum pool approvable as an aggregated portfolio totals 10 MW for aFRR. Prequalification of an aggregated portfolio for aFRR exceeding 10 MW requires separate tests of each portfolio. For example, in case of an aggregated volume for aFRR of 18 MW, this can be divided into a 10 MW and an 8 MW portfolio, respectively, and requires prequalification of both. The portfolios may then subsequently be pooled when offering the reserve in the market.

On prequalification of a portfolio, the total response of the system is shown for the portfolio, and signal exchange between the system and a single unit is tested. When adding unit(s) to an existing pool of units or an aggregated portfolio, only the unit(s) added requires approval and not the overall system.

When adding additional units to an aggregated pool, Energinet will allow the addition of up to 10 MW of the same technology within the same price area to the existing portfolio of units without new actual tests of the portfolio or the unit. A total addition of more than 10 MW to the portfolio requires new tests to be done. The aggregator must in accordance with “Main agreement on the supply of ancillary services”, keep an updated list of the ancillary service units, that are part of the portfolios. The documentation must include information about MW, type, placement, and potential consumption pattern over a given period.

8.2.7 Online measurements

For aggregated units, the ancillary service is provided through an aggregator and balance responsible party. Energinet looks at the total volume of power sold by the aggregator, and this means that only one online measurement is required for the aggregated volume when providing aFRR. The aggregator may choose to use several meters. However, one online measurement per unit is required for units of 1.5 MW or more. Only one online measurement is required for aggregated units with unit sizes of less than 1.5 MW in a portfolio, cf. SO GL article 158 (1) (e).

8.2.8 Settlement meters

The set-up for the provision of ancillary services from aggregated units is a deciding factor in settlement meter requirements. Set-up options include an aggregator with own balance responsibility or an aggregator collaborating with a balance responsible party. Due to the many set-up options, reference is made to market regulation D1 for details on settlement meter requirements.

8.3 Audit of provisions

Only units/systems that have undergone a functional test can participate in the aFRR market. When a unit/system has been approved and begins to provide ancillary services, regular inspections/audits will be carried out to determine whether the unit/system provides the ancillary services in the agreed/approved quality and quantity.

The market participant must provide the quantities sold. In case of minor provision shortages, payment for any non-provision is deducted from the full volume. In case of major provision shortages, payment of the costs of replacement purchases and quarantine may be a possibility, cf. the tender specifications mentioned above. The lifting of a quarant ine will be subject to either a renewed approval of the unit or the submission of detailed documentation proving that any faults have been remedied. Please note that the approved maximum capacity, which a unit can offer in a reserve capacity market, does not necessarily match the volume available in any given period.

8.4 Prognosis & baseline

To be able to estimate and control if a given response have been carried out, a reference power is necessary to know on a given unit. This reference power is also called baseline. For conventional plants this can be determined as the schedule. At units with fluctuating production and for demand response, the baseline can be difficult to determine. Examples on baseline calculations for different types of units are available in Appendix 9.2. Furthermore, suggestions, advice, and expectations for the baseline calculations from non-conventional unit are given.

Energinet will request a concept description and results from the developed calculation when a unit or a portfolio of units are prequalified to deliver ancillary services. The calculations must also be prequalified.

9. Appendix

9.1 Example of aFRR balancing controller configuration

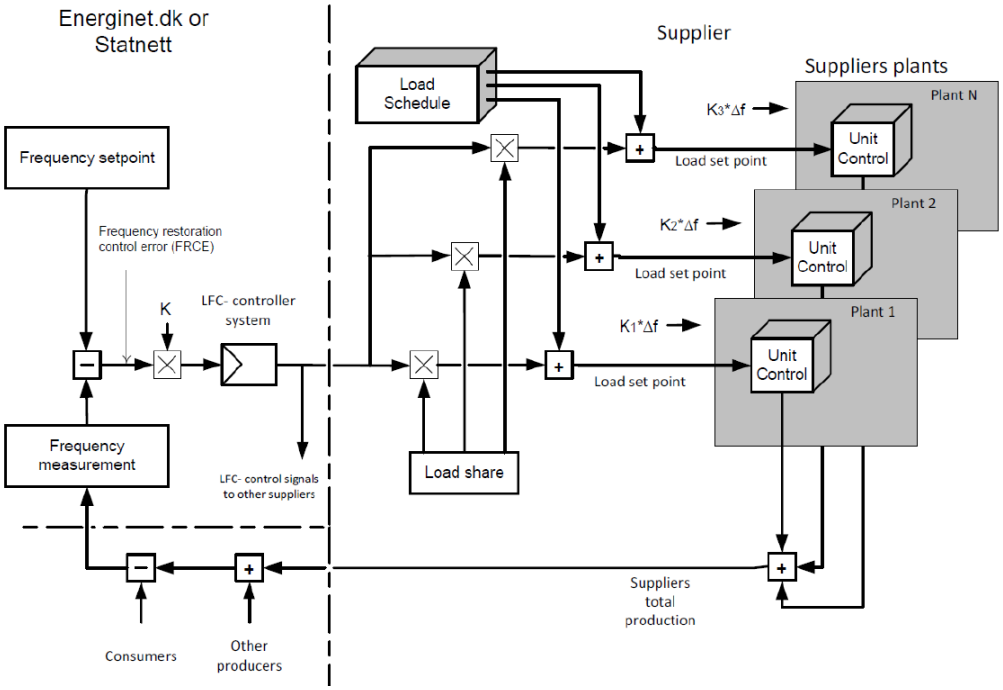


Figure 22 - aFRR balancing controller principle drawing for DK2, where the BRP does not have a provider imbalance controller. The power input calculation is based on the activation signal, using an expected response equivalent to a delayed response to the activation signal.

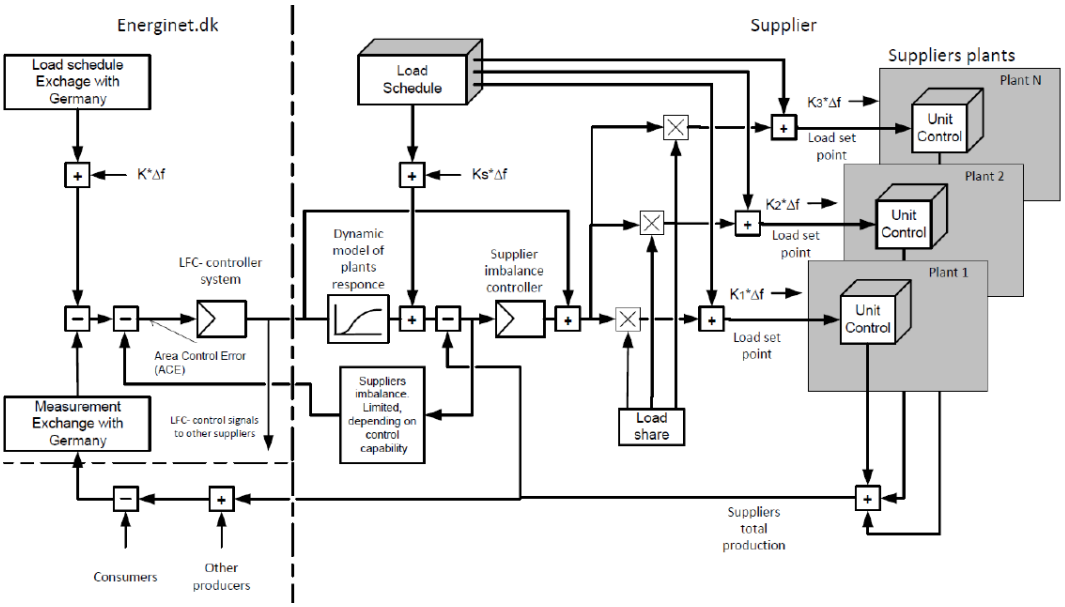


Figure 23 - aFRR balancing controller principle drawing for DK1, where the BRP has a provider imbalance controller. The power input calculation is based on the activation signal, using an expected response equivalent to a delayed response to the activation signal.

9.2 Prognosis & Baseline

To create an electricity system with as large a flexibility as possible, Energinet allows all types of production and or consumption to deliver reserves. Energinet strives towards 100% technology neutrality in the purchase of reserves, as well as even conditions and competition. Reserves must deliver security of supply, and the import part that the reserve is delivered, and that there is always electricity available. When Energinet purchases reserves, it is done in a way that no technology is preferred over another, if the purchased product is delivered, when the need arises. Energinet is looking into a future where the capacity from non-fluctuating production sources is dropping. This entails that we in the future can experience situations, where the current conventional actors providing ancillary service, are not available or are available but in a reduced capacity.

There are significant differences between conventional units and fluctuation production as well as flexible consumption, regarding deliver ancillary services. The most important differences are security of delivery and the reference power, also called the baseline.

- How can a wind turbine park or an electric vehicle-portfolio guarantee at the time of bidding for the reserve (the day before) that the capacity for the sold period id available.
- What would a wind turbine park or an electric vehicle-portfolio have produced or consumed of active power, without active regulation because of participation in one or more ancillary service markets.

Conventional power plants have a predefined operational power schedule as their reference. This schedule makes up the plant's set baseline which should always be available if the power plant does not experience any outages. This operational schedule is determined by factors such as the electricity price on the day-ahead market and the heating requirements of Danish dispatchable generation units such as central and local power plants. For wind turbines and solar cells, the reference primarily depends on the weather at the time of operation as marginal generation costs are very low. For demand-side response units, there may be a myriad of dependencies.

Energinet has requirements for the calculation of available capacity that is bid into the reserve-markets, as well a requirement for a calculation of a baseline. A uniform calculation of available capacity and baseline for renewable production sources and consumption allows participation in the reserve markets on equal footing with conventional units.

<u>The calculation of available capacity is considered as an "ex ante" prognosis and the baseline an "ex-post" prognosis.</u>

9.2.1 Requirement for prognosis & baseline¨

Fractiles in production prognosis for fluctuating renewable energy and flexible consumption are used as an indicator for security of delivery. This reflects a probabilistic calculation, according to the prognosis calculated probability what the actual production or consumption is. The calculated probabilities for a series of given values form a statistical distribution. When bidding the expected production or consumption into the day ahead market, a value around the median for the prognosis is used. This is the 50% fractile, where the prognosis expects there to be 50% probability for the actual production or consumption Is higher or even, and likewise 50% probability that it is lower. Since the prognosis calculated probabilities often end up with a normal distribution or similar, the value for the 50% fractile will be the value the prognosis with greatest probability estimates to be the actual production or consumption. This makes it the best estimate of the actual production or consumption at the given time.

By bidding into the day ahead market, where imbalances are allowed and can be corrected by the market participant through the intra-day market, or they can be left to Energinet to handle in the regulating power market. The median value is a decent starting point for bidding the expected production or consumption, since it is seen as the prognosis best guess. For the reserve markets, a 50% probability is not seen as a sufficient security of delivery. In the capacity market, the participant is paid for the capacity, where it is essential that the capacity is actual available with large security for the operational hour.

Requirements for the prognosis at the time of bidding for reserves (Ex-ante)

Energinet have requires for that there must at maximum bid in capacity corresponding to the 10% fractile with delivery of capacity reserves from fluctuating renewables and flexible consumption. This means, that the participant's prognosis, which must be approved by Energinet, evaluates that the probability is 10% that the sold capacity is not available. This entails that there is a 90% chance that the sold capacity or more is available. This is when the prognosis is assumed to be correct.

The probability is then also 10%, that the entire sold capacity is not available. If this were to happen, it does not entail that the sold capacity is not available at all, however just that a part of the total capacity is not available. The available part will with great likely be close to the sold capacity. Because of this Energinet uses the 10% fraction and the e.g., 5% or 1% fractions. Energinet will continuously evaluate the determined fraction based on experience.

If a market participant repeatedly, in good faith, does not deliver the sold reserve-capacity, then the participant will be excluded from participating in the market, until an approved prognosis can be approved by Energinet. If a participant can not deliver the sold capacity because of a bid based on a capacity lower than the 10% fractile, the participant will be excluded instantly for an undetermined time. This will happen as part of Energinet's regular monitoring. If a participant, in good faith, is not able to deliver the sold capacity, the payment will be repaid after the rules for the different ancillary service productions according to the "Ancillary services to be delivered in Denmark – Tender conditions".

To be able to determine an available capacity for the coming operational day, and a baseline, a substantial amount of data is required for the operation of the unit or portfolio of units. For comparable units, data from other units can also be applied. Before Energinet can approve a prognosis, a validation of prognosis precision is required, which is based on historical operation data. A minimum of three months of data is required.

When implementing the same approved prognosis or supplier of a prognosis for a new comparable unit added to a portfolio, this prognosis can be seen as type approved and does not need to be approved again. If a different operational experience, the participant can apply for dispensation for the requirement of the three months operational data from Energinet.

When Energinet has approved the prognosis method and the prognosis precision, the responsibility for correct and the ability to deliver is the market participants responsibility. This is the same it is for other technologies as well. It is therefore the participants responsibility to secure that there is only bid capacities that are expected to be available.

Requirements for the baseline in the operational moment (Ex-post)

For fluctuating production and flexible consumption, there is also a requirement for a calculation of a baseline or reference power. This is to compare the actual production/consumption with the possible production/consumption, if a

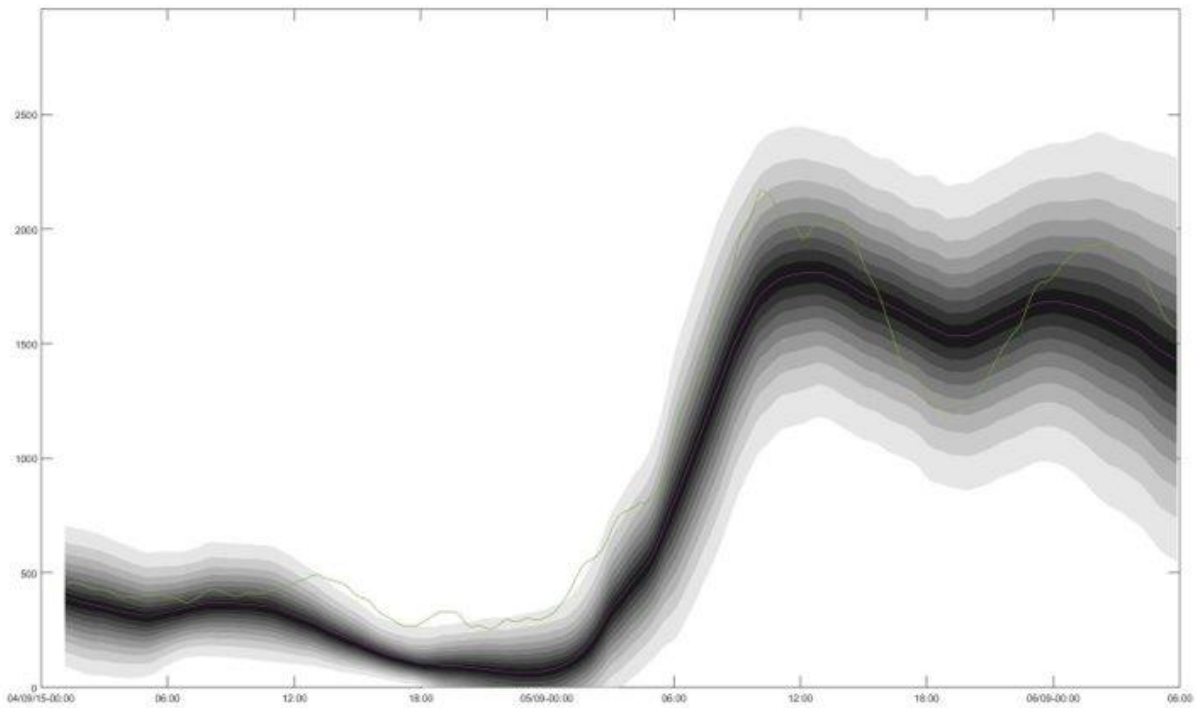
reserve activation had not happened. The calculations are allowed to be performed ex-post for the purpose to be able to validate the ancillary service response. For down regulation, it is assumed that the difference between those two, are the activated flexibility, because of a reserve activation. For upregulation, it depends on the chosen regulation method.

There are no specific requirements for the precision of a baseline compared with historical data. But it must be emphasised that the baseline from the participant will be used as a reference to calculate the actual delivered flexibility. An imprecise baseline will because of that lead to an ancillary service response looking inadequate without necessarily being it. This will potentially lead to payment being repaid, or exclusion from the market, which is why the precision of the baseline calculation is very important.

Requirements for data, type approval, and inadequate in deliveries for baselines are identical with the corresponding requirements for the prognosis (ex-ante)

Requirements for the time resolution for prognosis and baseline

The baseline calculation is, dependent on the capacity reserve, on an appropriate time resolution. For FFR, FCR, FCR-D and FCR-D the operational data must be at minimum per second, while the baseline itself must be at minimum pr minute. For aFRR the operational hour must be on a minimum 10 second resolution, while the baseline is also at minimum pr minute. For mFRR the operational data must be minimum 1 minute resolution, where the requirement for the baseline is on a minimum 15-minute resolution. The resolution for the prognosis for the available flexibility at the time of bidding, must at minimum reflect the purchased period on the market. With one purchase pr hour, the prognosis must then be minimum pr hour.



Figur 1 – Graphic illustration of application of 10% fractile in a probabilistic prognosis to estimate available capacity at the time of bidding for mFRR (9 o clock, D-1).