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METHODOLOGY FOR TECHNICAL REQUIREMENTS FOR AND NEW PROCUREMENT METHOD OF FAST FREQUENCY RESERVE (FFR) IN DK2

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Content

Abbreviations

EMS	Energy Management System
f	Frequency
FFR	Fast Frequency Reserve
NAG	Nordic Analysis Group
N-1	Single worst possible disturbance / Reference incident
RoCoF	Rate of Change of Frequency
RGN	Regional Group Nordic
SCADA	Supervisory Control And Data Acquisition
SOGL	System Operation Guideline
SA	Synchronous Area
STD	Standard deviation

Figures

Tables

Reading instructions

Section 1 of this submission to the Danish National Regulatory Authority (NRA) states the background and justification for the need and choice of the new fast reserve, respectively.

This is followed by section 2 that describes the technical requirements necessary for FFR to maintain dynamic frequency stability in an outage situation of an extent matching the reference incident in the Nordic synchronous area.

The estimated need for FFR based on the above technical requirements is afterwards deducted in the following section 3. The need is proportional to system inertia and the regulating strength of the system.

Section 4 explains the expected number of yearly activations of FFR based on the chosen frequency threshold activation level which can be found in the Nordic frequency quality analysis performed each year by Fingrid.

The procurement model is described in section 5, where both the initial temporary solution on a monthly basis and the subsequent solution on an hourly basis are included.

Sections 6 and 7 describes the submission of bids and economic issues.

1. Background

The Nordic synchronous area (SA) is experiencing challenges with transient frequency stability. The System Operation Guideline (Commission Regulation (EU) 2017/1485 – henceforth SOGL) in article 39.3a (Dynamic stability management), states the need for an analysis every 2 years to assess the need for a minimum inertia level or other alternatives.

SOGL art. 39.3 reads as follows: "*In relation to the requirements on minimum inertia which are relevant for frequency stability at the synchronous area level:*

a) all TSOs of that synchronous area shall conduct, not later than 2 years after entry into force of this Regulation, a common study per synchronous area to identify whether the minimum required inertia needs to be established, taking into account the costs and benefits as well as potential alternatives. All TSOs shall notify their studies to their regulatory authorities. All TSOs shall conduct a periodic review and shall update those studies every 2 years;"

It is found that a new Nordic reserve, Fast Frequency Reserve (FFR), is the better alternative to securing frequency stability because of decreasing system inertia than a minimum requirement for system inertia, and this solution will thus be implemented [1]. The "*Requirement for minimum inertia in the Nordic power system*" report [1] was sent to the Nordic NRAs, and therefore also from Energinet to the Danish Utility Regulator on 14 September 2019. The report also evaluates and compares FFR in contrast to a reduction of the reference incident as an alternative to securing frequency stability, where FFR is still deemed the better alternative.

The Danish market participants have been informed about the progress of the project through different publications (04.04.2019: publications from the Nordic FCR-Design project, and 05.07.2019: publication of the technical requirements for FFR) on a Nordic level and the recent open provider meetings on ancillary services at Energinet (Minutes of meetings and presentations).

The proposed methodology

The methodology describes the need for the new Nordic Fast Frequency Reserve, FFR, and the technical requirements designed to secure transient frequency stability in both the short and long term. Furthermore, the procurement of the reserve in a national market for DK2 is described. An hourly capacity market is most suitable since the need is dynamic and changes hour by hour. Hence, a dynamic procurement method with hourly contracts can reduce the level of excess procured FFR capacity to a minimum. Hourly procurement requires IT development in Energinet which will not be ready until Q3/Q4 2020 because of a lack of resources.

Therefore, a temporary procurement method is required until hourly procurement is possible. A temporary method that does not require IT development. The best solution which is administratively realistic is monthly capacity contracts which will only be approved for the period from April 2020 to the end of 2020 when hourly procurement will be possible.

1.1 Introduction

Various options to address the challenges with the transient frequency stability have been considered and assessed. Increasing the inertia level is not the only measure to secure frequency stability. In the Nordic synchronous area, securing frequency stability in the future will be ensured by introducing a new fast reserve, Fast Frequency Reserve (FFR), complimenting the primary reserve for disturbances (FCR-D). FFR takes over as the first mitigation measure in situations of low inertia and large reference incidents [2].

It is necessary to know the amount of system kinetic energy in order to operate the system securely and as efficiently as possible since frequency behaviour in the Nordic power system is highly dependent on the amount of kinetic energy in the system. Previous projects have investigated and explored the relation between power system behaviour and system inertia, Future System Inertia phase 1 [3], and how to anticipate and avoid the effects of low inertia situations, by means of proper forecasting tools in both the short and long term and mitigating measures, Future System Inertia 2 [4]. Various mitigation measures for low inertia situations are proposed in the latter report and tested on their efficiency.

The reduction of the dimensioning incident, an existing measure, scores low in terms of cost and can be seen as a “plan B”. “Plan A” mitigation measures – being most promising in terms of potential, effectiveness, sufficiency, and cost that can be available in 2020 – consist of active power injections.

The Regional Group Nordic has initiated the implementation of the Fast Frequency Reserve (FFR) based on the results from previous analyses from the Nordic Analysis Group (NAG), where both RGN and NAG represent Energinet, Fingrid, Svenska kraftnät, and Statnett, i.e. the Nordic TSOs who are responsible for the Nordic synchronous system. FFR is to be implemented on a Nordic level by summer 2020.

1.2 Justification

In this context, frequency stability mainly refers to the ability to secure the frequency above a threshold, in the Nordic synchronous area 49.0 Hz as stated in SOGL art. 127, 1 [5], in order not to activate involuntary load shedding, starting at 48.8 Hz, given the reference incident. For the time being, RoCoF is not a mentionable concern in the Nordic synchronous area; however, the concern is a maximum instantaneous frequency deviation. The current response from the primary frequency reserves in the Nordic synchronous area does not ensure frequency stability in low inertia situations given the reference incident [2].

In SOGL art. 39.3a [5], minimum inertia in the system may have to be specified, taking into account the costs and benefits as well as potential alternatives. There are more efficient mitigation measures available in the Nordic synchronous area among the alternative measures than increasing or maintaining inertia; in conclusion, there is no need to specify a value for minimum inertia [1], [6] & [7].

In situations with low inertia, most likely during periods with low demand in the summer, there will be a need for additional action. The preferred solution to handling both present and future low inertia situations in the Nordics, based on costs and benefits of the range of suggested solutions, is FFR.

The possible methods for affecting the initial rate of change of frequency are: 1) system inertia, and 2) power imbalance. For the instantaneous frequency minimum, also 3) the speed of the primary reserves comes into play.

Increasing system inertia, i.e. increasing the kinetic energy in the rotating masses of synchronous generators, is a possible solution to maintaining frequency stability. The volume needed to affect the minimum frequency by 0.1 Hz in an 80 GWs system is 20 GWs [4], p. 101. The availability of different possible techniques varies but costs will be high.

One option that transmission system operators have is to limit the power of the largest generators, loads or HVDC links connected to the system. This option does not require investments but involves costs and may be a suitable method during exceptional situations, for example, during short periods when sufficient reserve volumes are not available or when system inertia is exceptionally low. However, reducing the power of a nuclear generator may increase the risk of tripping that generator [1].

FFR is deemed the most promising mitigation measure for low inertia situations since several technologies can provide fast active power response estimated at low socio-economic costs, either as a disconnection of load or fast increase from inverter-based generation and storage. According to an internal feasibility study, FFR is a more cost-efficient and safer measure for handling low inertia challenges compared with reducing the size of the reference incident. Reducing the active power output of large nuclear units increases the risks of outages for these units.

2. Technical Requirements for FFR

The objective of FFR is to maintain frequency stability. It acts as a complement to FCR-D. FFR does not reduce the need for FCR-D and, thus, does not replace FCR-D [8]. Given the design framework, there are four main aspects to be considered in the design.

- Full activation time – Faster activation improves system frequency response
- Activation frequency – Activation in case of small frequency deviations improves system frequency response but increases the number of activation occurrences
- Duration – A long duration extracts more energy from the FFR source
- Deactivation – The combination of abrupt deactivation and short duration may cause the frequency to drop a second time. The risk of a second drop in frequency can be avoided by either extending the duration or requiring smooth deactivation

For all these four aspects, there is a need to consider the balance between system needs and the delivery capabilities of different technologies. There are basic needs that the system cannot compromise on: The frequency response must meet the system performance requirement (f > 49.0 Hz) and a short full activation time improves the response. The response is also improved by increasing the FFR volume, if it is sufficiently fast. However, an increased FCR-D volume does not result in a sufficiently fast response to satisfy the system performance requirement. In order not to have FFR activated for small frequency events and to keep the activation occurrence level low, the frequency threshold must be set sufficiently low. At the same time, in order not to require full FFR activation within a very short timeframe, the threshold should not be too low. The design needs to function for the actual frequency response in the current system as well as for the future system with both slightly decreased inertia levels and the new requirements of FCR-D implemented [2].

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.

FFR response requirements

FFR is used to stabilise the frequency, if 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 in case of 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 monitor 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. It is important to stress that the three combinations of activation level and full activation time have the same effect on securing frequency stability. Therefore, when considering the procurement of FFR, there will be no differentiation between the combinations.

Table 1 presents the three options.

Furthermore, a sequential diagram for the activation, support duration, deactivation, buffer time and recovery period are shown in Figure 1.

Alternative	Activation level [Hz]	Maximum full activation time [s]
A	49.7	1.30
B	49.6	1.00
C	49.5	0.70

Table 1 *- Three alternatives for the combination of frequency activation level and full activation time for FFR [8].*

Underfrequency situations have proven very critical compared with overfrequency situations. Therefore, FFR is only purchased for underfrequency 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 of choosing 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%.

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 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.

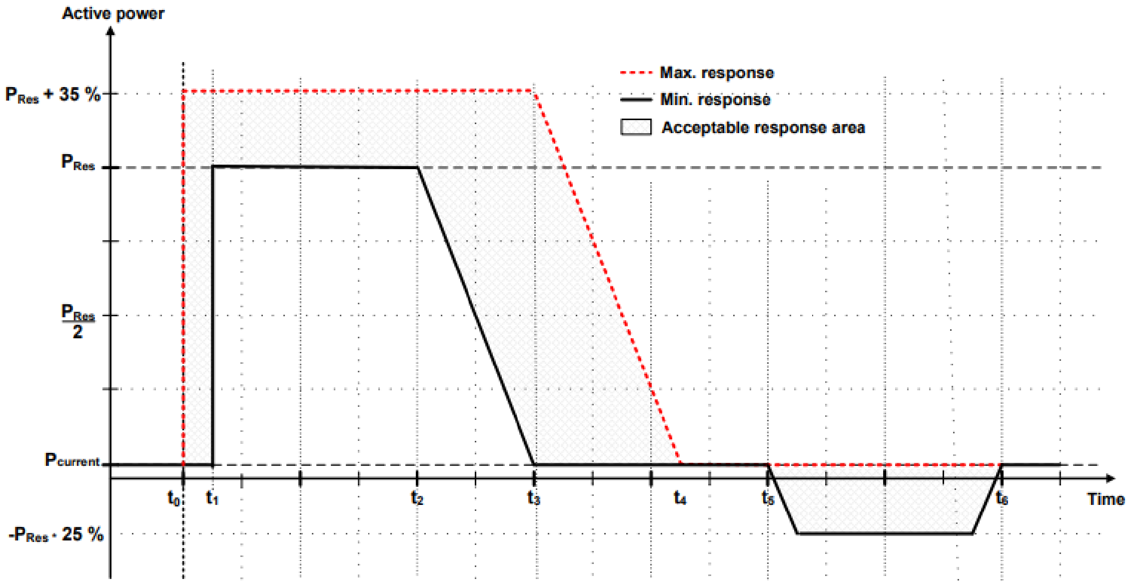


Figure 1 - FFR activation and recovery requirements; activation time at t=0 [8].

With respect to Figure 1, the following is valid:

1) Timewise, the activation instant equals zero (0).

2) The maximum time for full activation is 0.70 s (for the activation level 49.5 Hz), 1.00 s (for the activation level 49.6 Hz), and 1.30 s (for the activation level 49.7 Hz).

3) The minimum support duration is 5.0 s (for short support duration) and 30 s (for long support duration).

The prequalified FFR capacity is the minimum support power in MW from the providing entity, within the time slot of the support duration. The maximum acceptable overshoot is 35% of the prequalified FFR capacity.

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 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.

The technical requirements and prequalification test for FFR are specified in more detail in [8], as are the requirements for data exchange and data logging.

The Danish implementation of the Nordic technical requirements for FFR in the national prequalification process is stated in the English document "*Prequalification of units and aggregated portfolios*", and the Danish "*Prækvalifikation af anlæg og aggregerede porteføljer*" under the section on FFR.

3. FFR capacity estimation

Based on historical weather data from 1982 to 2012 and historical inertia data from June 2017 to November 2019, the impact of the variance of weather data (i.e. hydrological situation, wind speeds, solar irradiation and temperature) on the inertia level in the Nordic SA is analysed. Market model simulations are used to analyse the impact on inertia based on the different weather years in a Nordic 2020 electricity system. Inertia levels are then converted to a Nordic FFR need in an hourly resolution as explained above.

The Nordic FFR need is heavily impacted by the hydrological situation. One year of the simulated weather data shows a need for FFR for more than 1000 hours, while another year only shows a very limited need for FFR for approximately 100 hours. Again, the only difference in the simulation is the weather data.

The FFR need over the course of a year is concentrated around the summer. For years with a high need, FFR is needed from spring to fall as well. FFR needs are highest at night when consumption, and therefore production, is low.

By utilizing the simulation of the 34 years of weather data as a statistical foundation, the probability for the needed FFR volume can be found as shown for the mean, the mean plus standard deviation, and the maximum need on an hourly basis for the Nordics in Figure 2 and the same for the monthly values in Figure 3.

Figure 4 shows further analysis of the quantiles of the FFR need for different hours of a day, and for the different days of a week. The figure shows the relative number of hours with a non-zero FFR need. For data with a FFR need, quantiles (0, 25, 50, 75 & 100 %) are shown for each hour of each day in the week. It also reveals a need for FFR during nights and weekends.

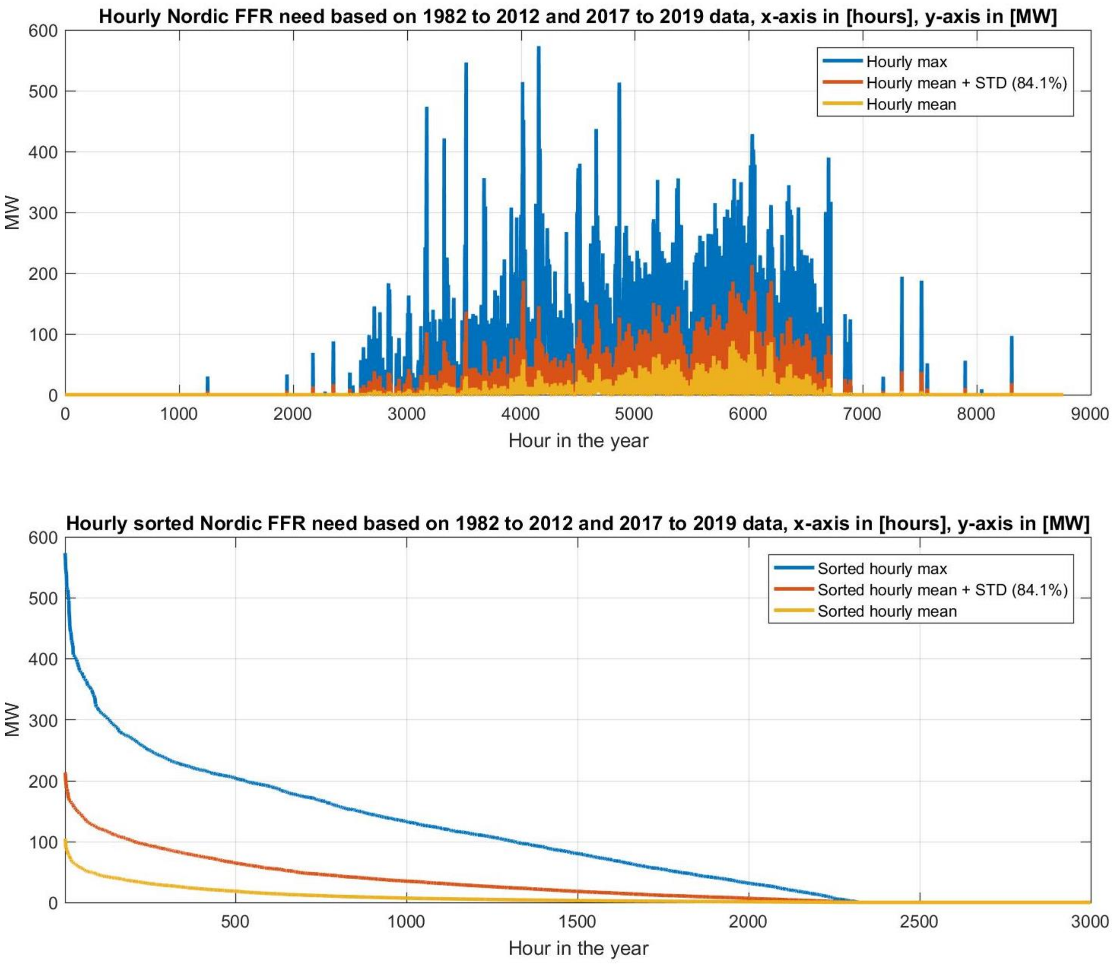


Figure 2 - Estimated need for FFR in the Nordic SA based on simulated inertia levels for the present system based on 34 different hydrological years. The top graph shows the FFR

during hours over a year and the bottom graph shows the duration curves for the FFR need. Note that the x-axis changes. Both show average need, average need plus the standard deviation and maximum need for every hour in a year (based on the same hour for the 34 simulated years).

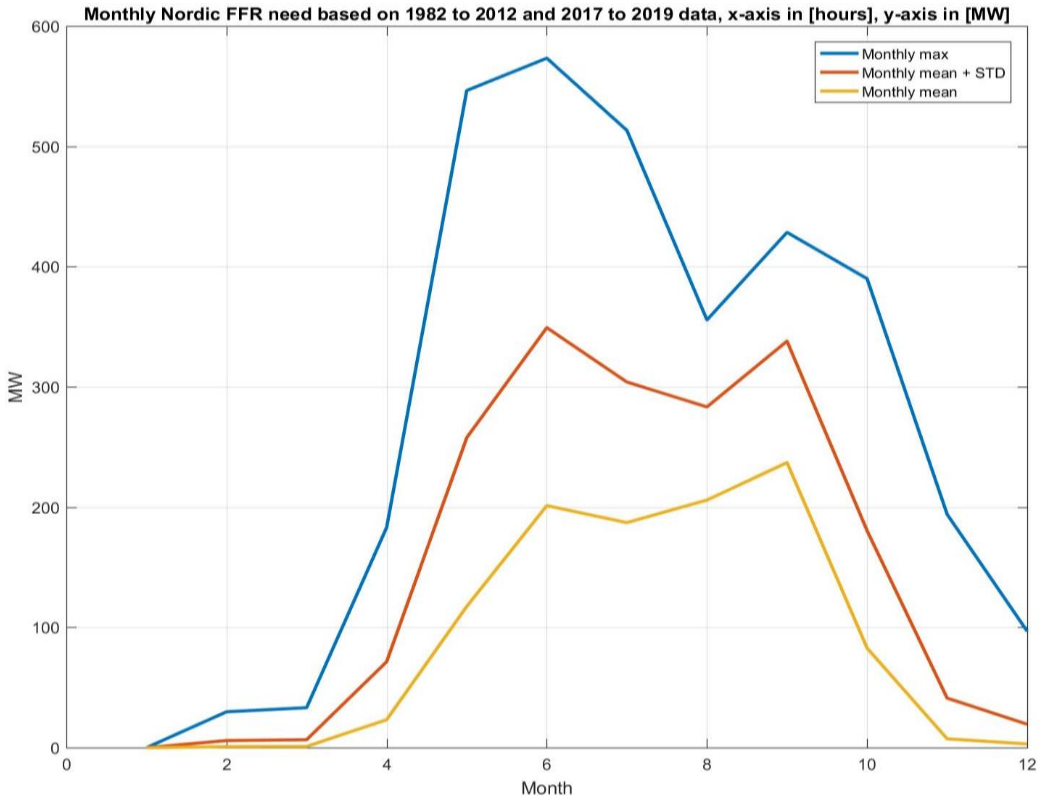
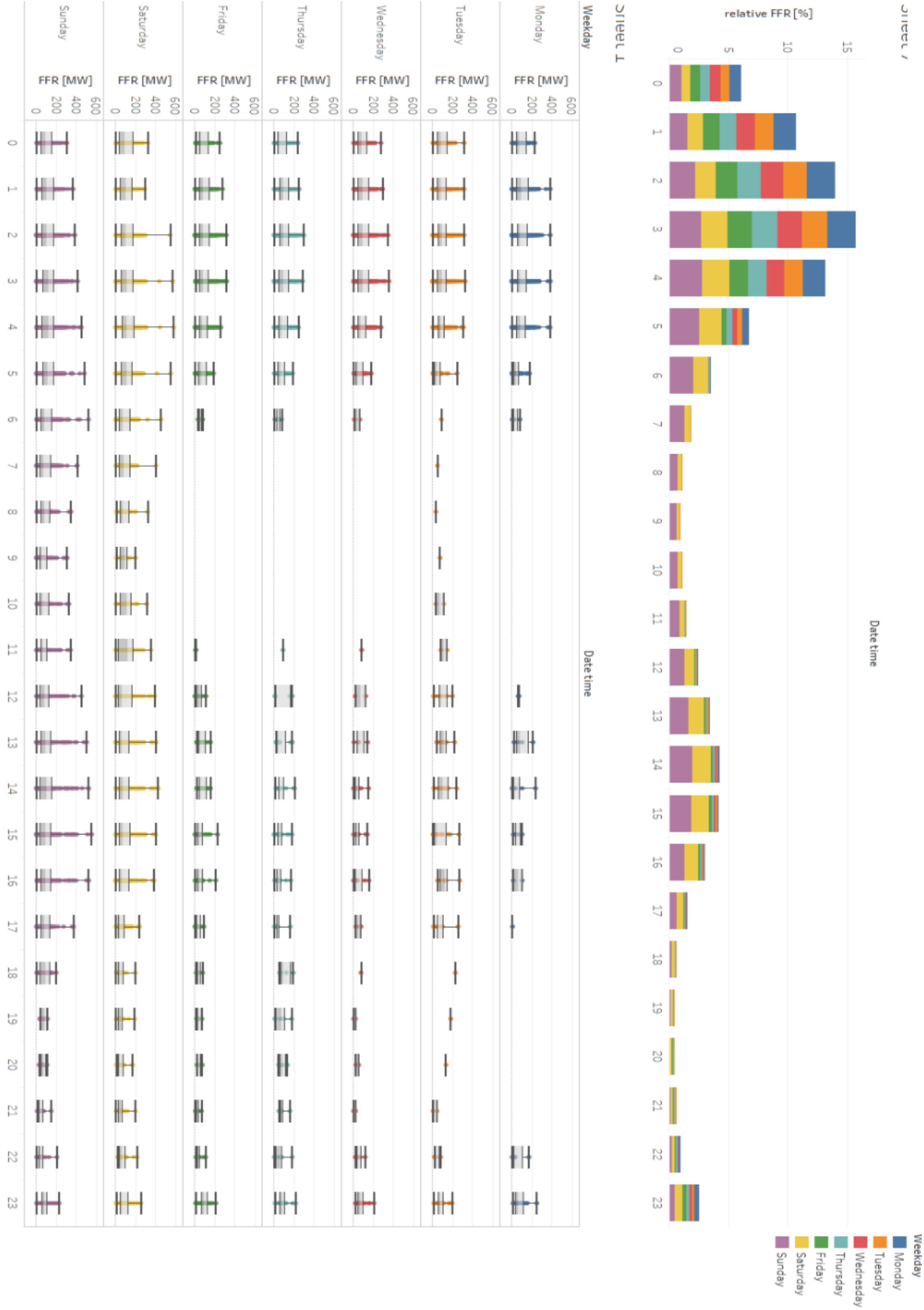


Figure 3 *– Estimated need for FFR in the Nordic SA based upon simulated inertia levels for the present system based on 34 different hydrological years. The graph shows the FFR need during the months over a year, respectively average need, average need plus the standard deviation and maximum need for every month (based on the same hour for the 34 simulated years).*

Figure 4 – *In the top (to the right) of the figure, the relative share of hours with a Nordic FFR need above zero is shown for the different hours of the day for the different days of the week based on simulated inertia levels for the system based on 34 different hydrological years. The bottom (to the left) of the figure shows the quantiles (0, 25, 50, 75 & 100 %) only for the data-points differing from zero for the different hours of the day for the different days of the week.*



4. Frequency statistics for recent years

The frequency crossed the activation threshold values for FFR in 2017 and 2018 very rarely, as shown in Table 2. For the full frequency analysis, see the report Frequency quality analysis, p. 60 onwards for 2013 to 2018 statistics.

Alternative	Activation level [Hz]	Activation times in 2017 and 2018
A	49.7	9
B	49.6	3
C	49.5	0

Table 2 *– Number of times when frequency crossed activation thresholds for the different FFR alternatives.*

5. Procurement model in DK2 for FFR capacity

FFR will be procured on national markets, and market setup will vary between the countries. The sharing key for FFR is based on FCR-N/D with a correction factor for the contribution to inertia and the size of the reference incident of the country. The sharing key to be used during year 2020 is shown in Table 3.

FFR sharing key	Energinet	Fingrid	Statnett	Svenska kraftnät
Obligation [%]	14	20	42	24

Table 3 *– FFR sharing key for the procurement of FFR. Division of the Nordic need on the different TSO obligations.*

5.1 Market design in DK2

The national market in Energinet (for DK2 only) will be based on monthly capacity auctions until hourly procurement becomes possible. Hourly procurement demands an implementation of new IT solutions to handle auctions on a daily/hourly basis. Hourly procurement is found to be possible for Energinet with the needed IT implementation by the end of 2020 at the latest. When ready, the procurement method will change from the beginning of the following month. This will be communicated by Energinet at least two months in advance of the change to hourly procurement.

Hence, the monthly capacity auction is an initial temporary solution. The subsequent solution, when implemented by the end of 2020 at the latest, will be hourly capacity auctions.

This is as stated earlier on. It is important to stress that the three combinations of activation levels and full activation time have the same effect on securing frequency stability. Therefore, when considering the procurement of FFR, there will be no differentiation between the combinations.

Market designs in the Nordics

In Finland, Fingrid will implement hourly capacity contracts from the beginning of the procurement of FFR. In Norway and Sweden, Statnett and Svenska Kräftnet will implement seasonal contracts since they are not able to develop the required IT to handle neither hourly nor monthly contracts. Energinet will use monthly, not seasonal contracts, until hourly contracts become possible, since the FFR excess procurement is much larger for seasonal than monthly contracts.

Emergency procedure

The back-up procedure for both procurement methods, if the number of bids received is insufficient to cover Energinet's requirements, is for Energinet to send an email to all participants, asking them to submit more bids.

If the number of bids is still insufficient, the emergency procedure is to request an additional procurement of FFR in the other Nordic countries. In this situation, Energinet will cover the extra costs for the procurement placed on the other TSO procuring the additional FFR.

If this is not possible, the reference incident will be reduced (i.e. maximum production restriction for Oskarshamn 3), corresponding to the missing FFR capacity. In this situation, Energinet will cover the costs for the restriction set for the reference incident/incidents.

If this is not possible either, then the Emergency Power Control capabilities on the HVDC connections will be considered as remedial action for an N-1 contingency situation, instead of its actual purpose as emergency power control function for N-2 (or worse) contingency situations.

5.1.1 Monthly capacity auctions

Energinet will procure monthly capacity based on the statistical analysis shown in section 3 based on FFR need for the months during the year. Procurement will be based on the statistical level of the mean value plus the standard deviation in Figure 3. These values will be updated during the year based on the current hydrological situation, which may significantly narrow down the possible spread of the system inertia forecast.

Monthly procurement of FFR

Energinet procures FFR capacity at monthly auctions for one month at a time. Only upwards products are procured. The deadline for receipt of FFR capacity bids by Energinet will be announced on Energinet's website. This will take place simultaneously with the announcement of the coming month's requirement for FFR capacity. FFR capacity bids must be valid for the entire month, and the contract cannot be terminated by either party during the contract term.

Combined deliveries

A delivery may be made up of supplies from several production units with different properties which, collectively, can provide the required response within the required response time. A delivery may also be made up of supplies from several consumption units with different properties which, collectively, can provide the required response within the required response time. Any system for such combined deliveries must be verified with Energinet.

Bidding by participant

Bids for the monthly auction can be submitted via email to info@energinet.dk marked 'FFR capacity bid (month/year)'.

Each bid must be for at least 0.3 MW and no more than 50 MW. A bid must always be stated in MW to one decimal point, while the price must be stated in DKK/MW to two decimal points.

The technical properties of plants belonging to suppliers wishing to bid on FFR capacity must be approved in advance.

Energinet's acceptance of bids

Energinet selects bids that ensure that the total requirement is met at the lowest possible cost. Bids are accepted in their entirety or not at all.

If the number of bids received is insufficient to cover Energinet's requirements, Energinet will send an email to all participants, asking them to submit more bids.

Pricing and payment

All bids for upward regulation accepted will receive availability payment corresponding to the price of the highest bid for upward regulation accepted (marginal price).

No calculation is made of energy volumes supplied from FFR. Supplies of energy from the reserve are settled like ordinary imbalances.

Feedback to participant

Immediately after the auction is closed, Energinet will notify all participants of the result by email.

The volume and price for all accepted bids will also be announced in anonymised form on Energinet's website no later than the day after the auction.

Obligations of participants

All participants with an FFR capacity contract must be able to deliver FFR when the frequency activation threshold is crossed. The size of the activation must at least correspond to the volume stated in the participant's contract for FFR capacity. Hence, for availability payment to be effected, the capacity must in fact be available. This means that availability payment is cancelled if, subsequently, it turns out that the capacity is not available, for example due to breakdowns

In case of incidents resulting in a plant being unable to supply secondary reserve, the reserve must be re-established at one or more plants which can supply the reserve as soon as possible and within 30 minutes of the incident at the latest. If the supplier is unable to re-establish the reserve, Energinet should be contacted within 15 minutes and informed where and when the reserve can be re-established

If the supplier is unable to re-establish the reserve and hence unable to meet the obligation for the remaining duration of the contract, the contract can be transferred to another supplier also qualified to deliver the reserve. If this is not possible either, then the contract for the remaining period will be procured in an ad-hoc auction by Energinet, where the original supplier will cover the costs for the ad-hoc auction.

Checking the services

The services are checked on a sample basis and in case of significant frequency deviations. Energinet's checking takes the form of requesting documentation from the participant's SCADA system of the plant's response to naturally occurring frequency deviations.

Short-term forecast for need of FFR to “free” capacity from monthly auctions

Energinet will utilise the D-2 inertia forecast to “free” capacity procured in the monthly capacity auctions, as explained below. The “freed” capacity will be equally spread relatively between the contractors.

Using monthly procurement grants the opportunity to allow the provider to reduce the actual capacity to be delivered in a specific hour where the monthly procured volume exceeds the actual need. This will “free” capacity for every hour where the monthly forecast for FFR exceeds the actual hourly need for FFR.

For a contracted volume from the monthly capacity auction of, i.e. 10 MW, the short-term inertia forecast could reveal that the need for provision from that provider is only half, hence 5 MW, during a specific hour or day. The “freed” capacity is the difference between the monthly procured volume and the short-term forecast. The FFR need from the short-term forecast is specified in an hourly resolution two days before operation, to allow the TSO to give the provider a chance to trade in the day-ahead market accordingly and to allow the “freed” capacity to i.e. participate in other reserve markets if relevant.

Hence, the available FFR capacity that the provider must deliver will be based on the short-term inertia forecast, with a maximum of the monthly contracted volume and a minimum of zero. The short-term inertia forecast, converted to FFR need in DK2, will be published D-2 by 10.00 a.m. on the Energy Data Service webpage by Energinet.

It is important to stress the conclusion from Figure 4 that for more than 99 % of the time there will not be a need for FFR in daytime hours on weekdays, and only a small need during the daytime on weekends.

5.1.2 Hourly capacity auctions

When the required IT has been implemented in Energinet, capacity auctions will change from monthly to hourly. This will change the nature of the procurement to be very similar to the FCR procurement in DK1.

The technical properties of plants belonging to suppliers wishing to bid on FFR capacity must be approved in advance.

Daily procurement of FFR

An auction for FFR is held once a day for the coming day of operation. For the purpose of the auction, each hour of the coming day is a block. The procurement need will be calculated daily based on a short-term inertia forecast.

Combined deliveries

A delivery may be made up of supplies from several production units with different properties which collectively can provide the required response within the required response time. A delivery may also be made up of supplies from several consumption units with different properties which, collectively, can provide the required response within the required response time. Any system for such combined deliveries must be verified with Energinet.

Bidding by participant

Bids in connection with daily capacity auctions should be submitted to Energinet via ECP/MADES or via the Self-service portal.

Bids must be submitted so that they reach Energinet by 15.00 p.m. on the day before the day of operation. Registration is based on Energinet's automatic registration of time of receipt. Bids received after 15.00 p.m. are rejected unless all participating bidders are otherwise notified by email. Participants may amend bids already submitted up until 15.00 p.m. Bids received by Energinet by 15.00 p.m. are binding on the bidder.

The gate closure time is after the spot market since the energy deliveries of the reserve are close to zero. The technologies that are expected to deliver are consumption or storage, and they can therefore base their bids on the result from the spot market and the resulting plans.

The bids must state an hour-by-hour volume and a price for the following day of operation. The volume stated is the number of MWs which the bidder is offering to make available, and it must be the same within each block. The price is the price per MW asked by the bidder to make the volume stated available. The price must be stated as a price per MW per hour.

Each bid must be entered for a minimum of 0.3 MW and must always be stated in MW to one decimal point, and the price must be stated in DKK/MW/h or EUR/MW/h to two decimal points.

Energinet's acceptance of bids

Energinet sorts the bids for upward regulation capacity according to the price per MW and covers its requirements by selecting bids according to increasing price.

Bids are always accepted in their entirety or not at all. In situations where the acceptance of a bid for more than 5 MW will lead to excess fulfilment of the requirement for reserves in the block in question, Energinet may disregard such bids.

If two bids are priced the same, and Energinet only needs one, a mechanical random generator is used to select the bid to be included in the solution. The same applies if three or more bids are priced the same.

If the number of bids received is insufficient to cover Energinet's requirements, Energinet will send an email to all participants asking them to submit more bids.

Pricing and payment

All bids for upward regulation accepted will receive an availability payment corresponding to the price of the highest bid for upward regulation accepted (marginal price).

No calculation is made of energy volumes supplied from FFR. Supplies of energy from the reserve are settled like ordinary imbalances.

Feedback to participant

At 15.30 p.m., Energinet informs the participant of the bids which Energinet has accepted and of the availability payment allocated on an hour-by-hour basis.

Energinet does not send signals for the reserve to be activated during the day of operation. Activation of reserves is based on the supplier's own frequency measurements.

Obligations of participant

For the availability payment to be effected, the capacity must in fact be available. This means that the availability payment is cancelled if, subsequently, it turns out that the capacity is not available, for example due to breakdowns.

In case of incidents which mean that a plant cannot supply FFR, the reserve must be re-established at one or more plants capable of supplying the reserve as soon as possible and within 30 minutes of the incident at the latest. If the supplier is unable to re-establish the reserve, Energinet should be contacted within 15 minutes and informed where and when the reserve can be re-established

Checking the services

The services are checked on a sample basis and in case of significant frequency deviations. Energinet's checking takes the form of requesting documentation from the participant's SCADA system of the plant's response to naturally occurring frequency deviations.

5.2 Expected yearly procured FFR capacity based on procurement period

For a dynamic need changing by the hour, a monthly capacity auction will result in procurement of excess capacity. This owes to the hours with less or no need for FFR compared to the procured capacity for the given month, but also because of the increased uncertainty of the need for FFR due to procurement for an extended period that must be included as a margin and procured as extra capacity.

Hence, based on data from 34 hydrological years, the average yearly procured volume of FFR calculated from the sum of the hourly need for every hour equals 3.75 GW, equal to 0.43 MW/hr in DK2. To compare with 2018, it would have been 7.77 GW, equal to 0.89 MW/hr. As shown earlier, the need is concentrated around weekends and nights in the summer months.

For the monthly procurement, assuming that the monthly capacity is procured for every hour of the month, and inclusion of a margin to statistically cover 84,1 % of the sample space (average plus standard deviation), the yearly procured volume of FFR in DK2 equals 190.05 GW or 21.69 MW/hr.

Hence, the difference in the procured FFR capacity is very large depending on procurement method. The procured FFR volume for seasonal capacity contracts will be much larger than the monthly contracts. Hence, Energinet will utilise monthly, and not seasonal, contracts until hourly contracts become a possibility.

6. Time schedule

The plan is to initiate monthly capacity procurement in DK2 when the forecasted need for FFR occurs in 2020, which Figure 3 shows to be in April 2020. Hence, the tender for the monthly contract will start in the last week of March.

Before the tender, units must be prequalified to participate in the market by Energinet. This must be arranged bilaterally between the provider and Energinet.

The monthly capacity contracts will run every month until hourly procurement is possible in Energinet. This will by the end of 2020 at the latest.

For your information, Fingrid will implement hourly markets to be ready for April 2020. Statnett and Svenska kräftnet will procure FFR seasonally.

7. Economy

The yearly expected costs to procure FFR capacity will differ based on the procurement method. Costs per [MW/hr] for FFR capacity are estimated from the price of the slightly similar FCR-D reserve. This estimate is multiplied by the yearly procured volumes.

For monthly procurement, costs are expected to range from 20-40 million DKK / year.

For hourly procurement, costs are expected to range from 0.5-1.5million DKK / year.

Naturally, these are cost estimates, and the actual costs will be very dependent on the actual need for FFR and the price of FFR capacity, which the Danish market participants will submit.

It is proposed that Energinet's yearly costs for procurement of FFR will be financed via the system tariff. Hence, costs will be socialized and paid by the electricity consumers.

8. References

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