Nordic Balancing Philosophy

Updated 2024-05-30

Nordic Operations Development Group 2024-05-30

Table of content:

1 Abbreviations and definitions

Please refer to SOGL[1] for abbreviations and definitions and to EBGL[2] for definitions, not found in below list.

'aFRR' or 'automatic FRR' means FRR activated by aFRR controllers to restore system frequency automatically after the occurrence of a frequency deviation.

'Balance Operators' mean the operators at Svk and SN responsible for balancing the Nordic synchronous area.

'Electrical time deviation' means the time discrepancy between synchronous time and coordinated universal time ('UTC').

'Fast Frequency Reserves' or 'FFR' mean a faster product than FCR to contain frequency, introduced to help stabilizing the system during times of low system inertia.

'High-voltage direct current' or 'HVDC' means an electric power transmission system that uses direct current (DC) for transmission of electrical energy.
'Imbalance Settlement Period' or 'ISP' means the period over which the imbalances of a BRP will be settled.

'Low frequency demand disconnection' or 'LFDD' means a backup measure to limit the fall in grid frequency in extreme events

'mFRR' or manual FRR' means Frequency Restoration Reserves with manual activation.
'Nordic Operational Information System or 'NOIS' is the common Nordic operational IT system processing real-time supervision and validation of planning data and is common platform for balancing energy, mFRR bids.

'Nordic synchronous area' includes the subsystems of Norway, Sweden (including the subsystem of Kraftnät Åland), Finland and Eastern Denmark which are synchronously interconnected, forming the Nordic synchronous area. The subsystem of Western Denmark is interconnected to the Nordic synchronous system using DC interconnectors. The Nordic synchronous area and the subsystem of Western Denmark jointly constitute the interconnected Nordic power system.

'Net transmission capacity' or 'NTC' is the maximum grid capacity available for exchange in markets. NTC equals TTC subtracted by TRM; (see also 'TTC' and 'TRM').
'Operational security' means the transmission system's capability to retain a normal state or to return to a normal state as soon as possible, and which is characterized by operational security limits.

'Operators' means the operators from any Nordic TSO; (see also Balance Operators).

[1] COMMISSION REGULATION (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation
[2] COMMISSION REGULATION (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing

‘RGN’ is the ‘Regional Group Nordic’. RGN conduct and promote the cooperation between the Nordic TSOs with the aim of ensuring a reliable operation, optimal management, and technical development of the Nordic synchronous area.

‘Supervisory control and data acquisition’ or ‘SCADA’ is a control system applied by the TSO.

‘SOA’ is the System Operation Agreement between the Nordic Transmission System Operators.

‘SOGL’ is the guideline on electricity transmission system operation.

‘Synchronous area framework agreement policies’ or ‘SAFA policies. Agreement to provide the legal framework for the operation of the interconnected grids by the TSOs of the Synchronous Area of Continental Europe.

‘Transmission reliability margin’ or ‘TRM’. TRM is a security margin that copes with uncertainties on the computed TTC values arising from unintended deviations of physical flows emergency exchanges between TSOs in real time and inaccuracies, e.g., in data collection and measurements.

‘Total transmission capacity’ or ‘TTC’ means the total transmission capacity on an interconnector. TTC is the maximum transmission of active power in accordance with the system security criteria which is permitted in transmission cross-sections between the Nordic subsystems.

2 Purpose

The purpose of this document is to describe the current Nordic balancing principles and procedures as information for external and internal stakeholders to promote a common understanding of the strategy behind the current Nordic rules and procedures for balancing. The report focuses on describing the current rules and procedures but will also indicate planned changes or adjustments, e.g., related to the implementation of a new ACE based model in the Nordics. This document may be a basis for related development work in Nordic or national groups.

The Nordic balancing is undergoing substantial development as current frequency-based balancing will change to ACE based balancing, see Nordicbalancingmodel.net. The ambition is to update this document regularly or in case of significant changes in the balancing principles and procedures. A new update will be made in relation with Nordic mFRR EAM go-live.

3 Framework for balancing

The Nordic TSOs have agreed on principles and procedures for balancing in the Nordic System Operation Agreement (SOA). In addition, the TSOs have made an agreement for balancing based on ACE per LFC area, The Cooperation Agreement.

3.1 Quality standards

3.1.1 Frequency quality

TSOs aim for keeping the frequency within the standard frequency range, which means a defined symmetrical interval of 100 mHz around the nominal frequency of 50.00 Hz.

The maximum value of minutes outside the standard frequency range is regulated in SOGL (article 127) to be no more than 15 000 min/year. The Nordic TSOs have agreed upon a goal for frequency deviations outside standard frequency range to be no more than 10 000 min/year. (ref. to Regional Group Nordic (RGN) decision 9 May 2014).

Frequency lower than the standard frequency range, means an increased risk for insufficient available FCR to hinder activation of low frequency demand disconnection (LFDD). The operational range of generators is limited to a certain system frequency range on both sides of 50 Hz for the various units. Frequency deviations outside of this range may trigger the automatic protection mechanisms leading to a disconnection of the generators. In worst case, these events may lead to blackouts in parts of the synchronous area.

Elaboration of understanding:
The Nordic TSOs have automatic frequency restoration reserves (aFRR) available in more than 50% of the hours. The aFRR controller will in those hours strive to maintain 50.00 Hz. The Balance Operators will however not necessarily strive to always maintain exactly 50.00 Hz, when activating manual frequency restoration reserves (mFRR). They rather try to optimize operation within the standard frequency range within and between market time units (MTUs). At certain conditions e.g. morning hours where the consumption ramp is foreseen but not known exactly with a minute resolution, the Balance Operators often choose to keep the frequency higher than 50.00 Hz before hour shift. This is done to have a better margin towards expected low frequencies shortly before and after hour shift due to ramp up of HVDC interconnectors and increase in consumption. Planned increased production will contribute to raising the frequency but is not completely correlated in time. This strategy sometimes leads to saturation of the aFRR controller, and that the system is more vulnerable to high frequency deviations. The TSOs aim for coordinating activation of aFRR and mFRR together to avoid too long lasting aFRR saturation.

The frequency deviations are followed up weekly and a frequency statistics report is created and forwarded to Nordic TSOs. The frequency statistics is reported to RGN on a regular basis by Nordic Operations Group (NOG). The development over the years is shown in Figure 1.

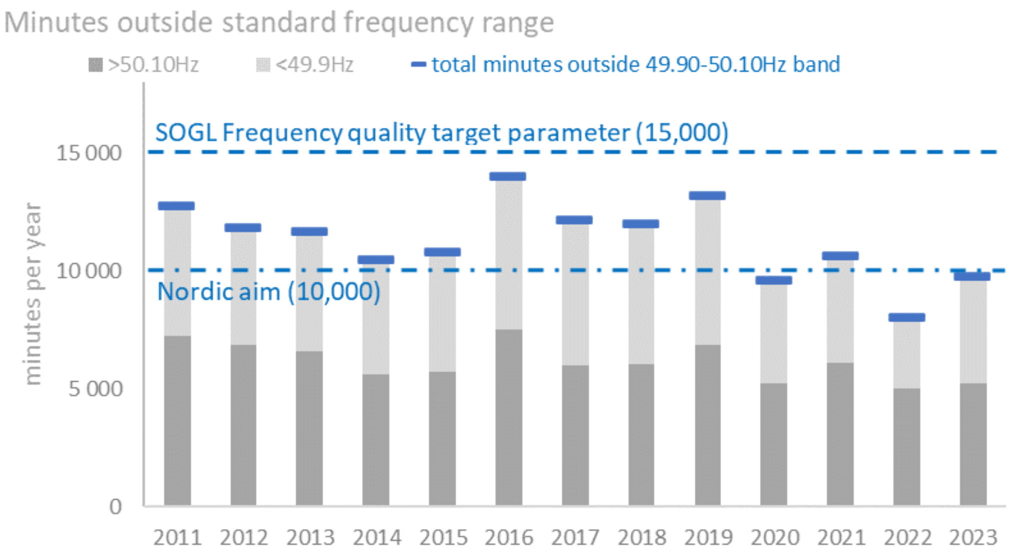

Figure 1: The minutes outside the standard frequency range for each year in the period 2011-2023 compared with the maximum value of 15 000 min/year in SOGL and the target of not more than 10 000 min/year.

3.1.2 Time control process

The objective of the time control process is to maintain the design criteria of 50,00 Hz as the mean frequency and to keep activation of normal Frequency Containment Reserve energy delivery close to zero over time.

The Synchronous area monitor (Svk) has the responsibility to maintain the electrical time deviation within a time range of ± 30 seconds. If the time deviation has reached ± 15 seconds, the Balance Operators of the Synchronous area shall make a plan to reduce the time deviation. In hours with aFRR available, the aFRR controller automatically and continuously adjusts the frequency target slightly to keep time deviation low.

3.2 Responsibilities for balancing

Balancing energy activation is activation to maintain the Nordic frequency in accordance with the set quality standards.

3.2.1 TSO responsibility for balancing

Within each country the respective TSO is responsible for operational security which includes having sufficient resources available for maintaining the operational security within the operational limits. This may include agreements/arrangements with other TSOs within available grid capacity.

Article 152 in SOGL dictates that: "Each TSO shall operate its control area with sufficient upward and downward active power reserve, which may include shared or exchanged reserves, to face imbalances between demand and supply within its control area. Each TSO shall control the FRCE as defined in the Article 143 in order to reach the required frequency quality within the synchronous area in cooperation with all TSOs in the same synchronous area."

Elaboration of understanding:

The TSOs have agreed that Nordic balancing process shall be conducted in such a way that activation of balancing resources take place at the lowest cost considering congestions in the grid, current legislation and secure operations.

The balancing process is divided into two balancing areas. Svenska kraftnät and Statnett operate the balancing for the synchronous area by activating mFRR and aFRR from their control areas and initiating FRR activation for other control areas while Energinet balances DK1.

Each TSO is responsible for, that sufficient balancing measures are available for the TSO to handle imbalances that may occur within its control area as well as potential fault situations. The TSOs shall see to that the flow on the interconnectors to other control areas can be adjusted if needed to correspond to the resulting schedule from the energy markets.

The TSOs shall also have measures to handle reduced transmission capacity in case of tripping of lines or for other reasons after confirmation of the schedule from the energy markets.

Imbalances in each control area shall not lead to violation of the operational security limits in other control areas or burden other control areas (subsystems).

In case of an operational N-1 disturbance, the frequency must have been restored within 15 minutes. The system is restored when it once again complies with the operational security limits. The system is not dimensioned to handle multiple operational disturbances within the same 15-minute period or a new large operational disturbance shortly after the first 15-minute period. In these situations, each TSO is responsible for having the necessary mitigating measures within their control area to handle the situation including automatic and manual emergency measures.

As the Nordic TSOs cooperate in using reserves in a region in common balancing arrangements, a prerequisite for the arrangements is that the TSOs are collectively responsible for making sufficient reserves available for regional balancing with minimum volumes agreed between the TSOs in the region. Location of the reserves may be considered from a regional perspective taking congestions in the grid into account. This does not reduce the national TSO responsibility but contributes to a more efficient use of the regional resources.

The TSOs are responsible for the ability to balance their own control area. For regional balancing, the TSOs are responsible for making reserves available with minimum volumes agreed between the TSOs in the region.

3.2.2 Distinction of TSO and BRP responsibility of balancing

BRPs are in general expected to balance their portfolio per hour before operational hour. This is done by trade in day-ahead, in the intraday market and bilateral trade between BRPs within bidding zones. Gate closure for intraday trading is 1 hour before operational hour except for Finland which has later internal gate closures. Gate closure for bilateral trade is not harmonised.

After day-ahead trade, the BRPs will provide the TSOs with information needed for balancing such as preliminary production plans for the next day. Possible updates to the production plans can be sent until 45 minutes before operational hour. As gate closure for intraday trade in Finland is different, Finnish BRPs can update their production plans until 25 min before the start of the MTU.

The BRPs shall follow the production plans delivered to their respective TSO for their portfolio. The TSOs will monitor if there will be large and/or systematic deviations in realised production compared with the plans. If needed, the TSOs will ask for clarification and corrective actions from BRPs.

After final updates of the production plans, the responsibility for balancing is taken over by the TSOs.

System imbalances may occur right up until and during the actual operational hour. Some imbalances are unforeseeable while the TSOs can prepare themselves for others. The imbalances are due to:

- Current market setup where the trade is performed on hourly basis whilst the consumption changes continuously. This means that there may be imbalances within the hour even if the BRP plans are correctly balanced for the hour.
- Differences between forecasted and actual consumption and production.
- Events causing loss of production or consumption.
- Differences between hourly energy plans and actual flow on HVDC (ramping)
- mFRR activated for system constraints by the TSOs.
- Self-balancing by BRPs.

The Nordic TSOs are the ones who before and during operational hours have the best overall information regarding the balance situation and potential grid congestions. The Nordic TSOs balance the system by using the cheapest available mFRR bids in the Nordic area considering the congestions.

It is the responsibility of the TSO to balance the system by using available means after final updates of the production plans and during the operational hour to maintain the frequency and to secure a stable operation.

3.3 Operational planning data

3.3.1 Productions plans – basic definitions

Production plan is a schedule with hourly or quarterly resolution that BRPs send to the TSOs to notify the TSO about expected production.

- *Hourly production plan* (market notification in Denmark) is the hourly production schedule the BRPs send to the TSO with hourly resolution.
- *Quarterly production plan* is a production schedule with quarterly resolution. Requirements for quarterly production plan are rules describing that quarterly production plans must be made in a specified way (applied in Norway and Sweden).
- *Operational schedules for DK1 and DK2* are power schedules with 5 minutes resolution; the schedules shall be updated at any time by the BRP if changes occur in planned production.

3.3.1.1 Tools for the TSO to adjust production plans

Quarterly adjustments of hourly production plans
This is a requirement applied by the TSOs in Finland, Sweden, and Norway on the BRP when the hourly production plan changes more than 200 MW at hour shift to reschedule their plan with quarterly steps 15 minutes before hour shift, at hour shift and 15 minutes after hour shift. This is to adjust the plans to better correspond to the consumption and HVDC ramping pattern.

Smoothing of hourly production plans
In Norway a voluntary alternative to the requirement above, "Smoothing", is implemented. The system service allows the TSO to reschedule hourly production plans D-1 into production plans with quarterly steps. In the smoothing process, Statnett levels out hourly plans in quarterly steps based on known information at the time to reduce deterministic imbalances per quarter.

Production shift schedules is a system service used after intraday gate closure that allows the TSO to reschedule the changes in the production plans to better correspond to the consumption and HVDC ramping pattern.

3.3.2 Production forecast

In addition to the production plans sent by the BRPs, the TSOs make own production forecasts for intermittent production like wind and solar power, which are used in the planning of balancing.

3.3.3 Consumption forecast

Each TSO has its own tools for a consumption forecast which are used in the planning of balancing. The tools are based on historical data and are calendar- and temperature dependent.

BRPs do not send their forecast of consumption as separate information to the Nordic TSOs, except for large consumption units such as electric boilers.

3.3.4 HVDC scheduling

The HVDC schedules are based on the hourly results for exchange between bidding zones in the day-ahead and intraday energy markets. These exchange plans are converted to power plans according to specific rules.

The HVDC scheduling process is operated bilaterally between the connected TSOs.

3.4 Products for balancing

To balance a system, different types of reserves must be available.

Since the grid is not a copperplate and congestions occur in the grid, there is a need for a distribution of the reserves through specific agreements (SOA) or market arrangements.

The reserve products used in the Nordic power system are shown in Figure 2.

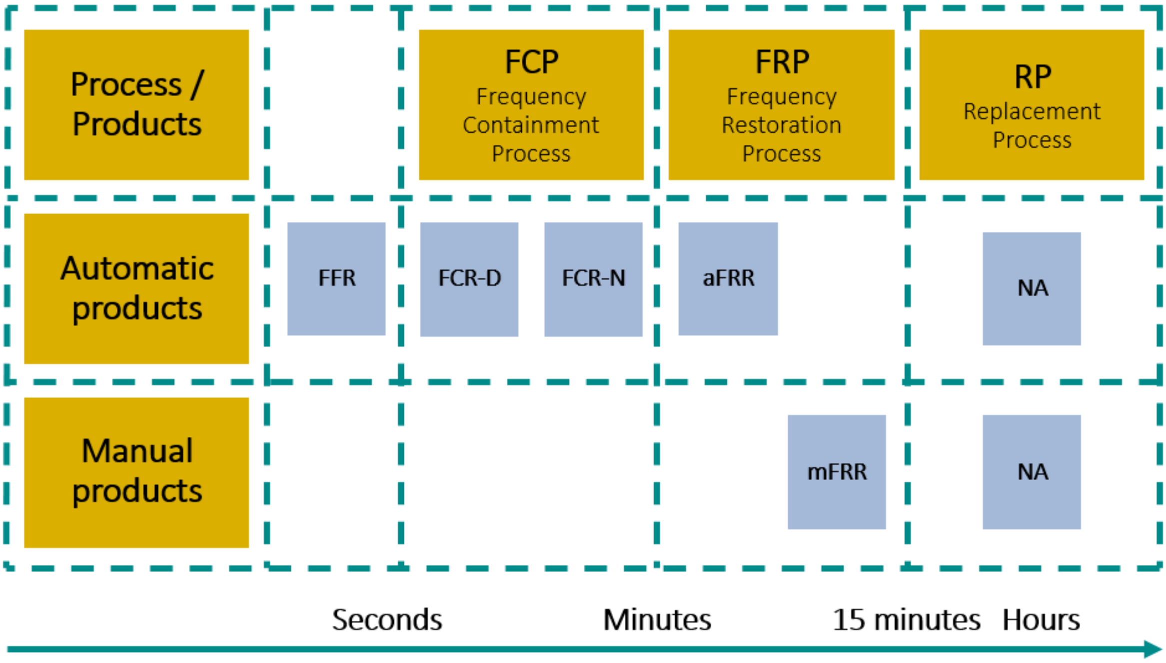

Figure 2: Reserve products in the Nordic Power system

3.4.1 Fast Frequency Reserves (FFR)

The objective of the Fast Frequency Reserve (FFR) is to assist the Frequency Containment Process (FCP) during times of low system inertia to such an extent that after a sudden imbalance the frequency change can be successfully stopped before the instantaneous frequency deviation would have reached the maximum instantaneous frequency deviation. The ultimate objective of FFR is to prevent for Low Frequency Demand Disconnection (LFDD).

FFR is procured only as upward balancing energy when the system inertia is so low and the size of the reference incident is so high that the Frequency Containment Reserve for Disturbances (FCR-D) alone is not able to contain the frequency before reaching the maximum instantaneous frequency deviation in case the reference incident were to occur.

3.4.2 Frequency Containment Reserves (FCR-N and FCR–D)

Frequency containment reserves have the purpose of balancing the system within the standard frequency range and in case of disturbances.

3.4.2.1 Frequency Containment Reserve - Normal (FCR-N)

FCR-N is a specific Nordic product with the purpose of balancing the system within the standard frequency range (49.90<f<50.10 Hz). FCR-N is not used in Western Denmark (DK1).

According to SOA, the FCR-N shall be at least 600 MW in the synchronous area. This volume is divided between the control areas within the synchronous area as national requirements on basis of annual consumption and production in Eastern Denmark (DK2), Finland, Norway, and Sweden. The consumption and production for the previous calendar year are used for calculating the required control area volumes for the coming year.

3.4.2.2 Frequency Containment Reserve – Disturbance (FCR-D)

FCR-D has the purpose of balancing the system in case of disturbances where frequency drops below 49,90 Hz or above 50,10 Hz and to stabilize the frequency after the disturbance. After a large disturbance in production, consumption or HVDC, inertia prevents the frequency from dropping below or above an acceptable level before FCR-D stabilizes the frequency at a steady state level.

According to SOA there shall be FCR-D of such a volume and composition that a Reference Incident (RI) (largest fault of production or HVDC interconnectors) does not cause a steady state frequency below 49.5 Hz or above 50.5 Hz in the synchronous area.

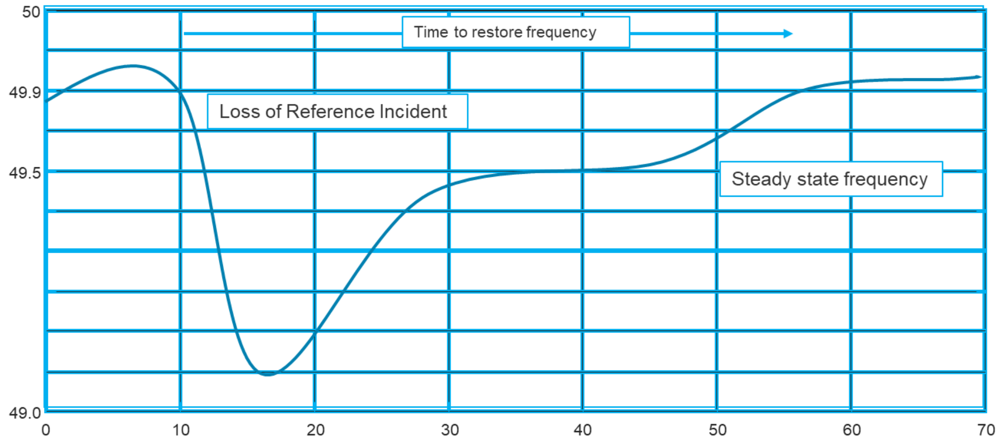

Figure 3: Simplified you may say that the inertia defines the lowest frequency point after the Nordic RI, the FCR-D defines the steady state frequency and the FRR defines the time to restore frequency (TRF). The minimum acceptable steady state frequency is 49.5 Hz

The activation of the FCR-D shall not result in other problems in the power system. When the transmission capacity is being determined, the location of the FCR-D shall be considered in the TTC calculation.

Distribution of the requirement for the FCR-D between the TSOs shall be according to the same distribution key as for FCR-N. The requirements are updated each day.

<u>The 2/3 rule:</u>
According to the SOA, each TSO shall have at least 2/3 of their initial FCR obligation in its own control area. The 2/3 obligation can be partly fulfilled by guaranteed FCR provision from another synchronous area.

RGN has decided exceptions from this rule for Energinet and Fingrid within certain limits. This is conditioned on that grid capacity is available to transfer the extra volume of FCR cross national interconnections. Countertrade is made when needed.

Statnett also practices a limitation on sale of FCR of max 1/3 of Norway's FCR requirement. This means e.g., that Norway cannot deliver 1/3 of the requirement of both Sweden and Finland in the same hour.

3.4.3 Frequency Restoration Reserves (automatic and manual)

Frequency restoration reserves are necessary to bring the frequency back to 50 Hz after a frequency deviation has occurred and by that restore the activated FCR. FRR can also be activated proactively when future imbalances are known with a high probability. FRR can be both automatic and manually activated. Manual FRR is also used to mitigate congestions.

3.4.3.1 Automatic Frequency Restoration Reserve (aFRR)

The product aFRR was introduced in the Nordics in January 2013. The background for implementing and developing aFRR in the Nordics was the deteriorating frequency quality and aFRR was identified and agreed upon as one of the main measures to stop the weakening trend of the frequency quality. aFRR has a faster response than mFRR and will due to that restore the frequency faster than mFRR.

The aFRR product shall be seen as an automatic “complement” to mFRR in the FRR process. aFRR activations shall handle short term variations in imbalance which are not appropriate to be handled by mFRR activations.

The aFRR reserve differs from FCR in the way that the reserve is remotely controlled by a centralised controller while FCR is locally controlled. There is also a difference in activation time. In hours where aFRR is active, there is an interaction between FCR and aFRR where FCR stabilizes the frequency while aFRR brings frequency back to 50.00 Hz given sufficient available volumes. aFRR activation replaces the activation of fast-responding frequency containment reserves (FCR).

aFRR can be exchanged between synchronous systems. To secure this, a reservation of grid capacity is necessary.

aFRR volumes and procurement hours for the Nordic Synchronous Area are decided on a Nordic level and distributed between TSOs by an agreed distribution factor described in SOA.

The dimensioned amount of aFRR capacity shall be based on the targeted frequency quality and shall include the hours where the frequency variations are most challenging. When applied, the dimensioned aFRR capacity will be at least 300 MW.

3.4.3.2 Manual Frequency Restoration Reserve (mFRR)

The manual part of FRR, mFRR, is used for balancing and to handle congestions in normal and disturbance situations. mFRR is the main balancing resource which when activated replaces both remaining FCR and aFRR activations and brings frequency back to the frequency target. In case of proactive activations, the mFRR may be activated in the opposite direction of FCR and aFRR. Due to limited volume of aFRR and many congestions in the grid, the Nordic system is dependent on mFRR activations. It is expected that mFRR will continue to be the main balancing resource in the system but that aFRR volumes will increase and be used continuously.

The mFRR capacity dimensioned for the control area shall at least cover the reference incident of the control area. The ‘reference incident’ is defined as the maximum positive or negative power deviation occurring instantaneously between generation and demand. This means ‘the largest imbalance that may result from an instantaneous change of active power of a single power generating module, single demand facility, or single HVDC interconnector or from a tripping of an AC line within the control area. Both upward and downward mFRR shall be dimensioned.

The BSP can submit bids to the Nordic mFRR market. The mFRR market is a tool for the TSOs to perform the balancing and is set up in a market-based way meaning that the mFRR bids are activated in price order when needed considering congestions in the grid. This is considered as an efficient (and a socio-economic) way of using the Nordic resources.

The required activation time in the mFRR market is 15 min. Different delivered response times of different production units, e.g., hydro and slower thermal plants have to be taken into account in the balancing process in stressed situations. In addition to 15 min mFRR, automatic reserves and mFRR with faster response time than 15 min secure that the system, after an operational disturbance, can be restored within the standard frequency range within Time to Restore Frequency (TRF) which is 15 min.

There are different capacity arrangements for mFRR in the Nordic countries. Both voluntary mFRR bids and resources that TSOs pay capacity payment for are submitted to the mFRR market for activation. The reserves with capacity payment are for securing capacity for disturbances, congestions, or imbalances. Peak load reserves may also be available for the mFRR market. The different resources are gathered in a Nordic merit of order list for activation (Nordic mFRR list).

FCR stabilizes the frequency while FRR brings frequency back to the frequency target. All categories of reserves need to be distributed in the system due to potential congestions in the grid.

Use of mFRR for system constraints

mFRR for system constraints means activation of mFRR bids ordered by a TSO in the mFRR market for a reason other than the needs of balance management. For this purpose, TSO uses mFRR bids which are suitable in terms of congestion management or other specific reasons, and the mFRR bids are not necessarily used in the price order.

mFRR activated for system constraints is priced in accordance with the bid activated; however, in case of upwards balancing energy activation, the mFRR price for system constraints must be higher than or equal to the balancing energy price for the hour in question. Correspondingly, in case of downwards balancing energy activation, the mFRR price for system constraints is lower than or equal to the balancing energy price for the hour in question. mFRR activated for system constraints is not considered in the determination of the price of imbalance power.

Interaction between Nordic and other synchronous areas

mFRR can be traded from a power system outside the common Nordic mFRR market to support or balance any Nordic bidding zone. There are currently different rules whether mFRR activated from an adjacent power system outside the Nordic mFRR market shall influence the pricing in the mFRR market in the same way as bids ordered from the Nordic mFRR list (NOIS).

The Nordic mFRR market can also support surrounding systems with mFRR for balancing of those systems. Currently this is not influencing the marginal pricing in the Nordic mFRR market. Only actions taken to balance the Nordic system shall influence the mFRR price in the Nordic mFRR market.

There is also the possibility to use imbalance surplus or deficit without activating mFRR for exchange with other systems.

The TSOs are currently applying different rules for bid activations due to disturbances and reduced capacity on interconnectors from the Nordic countries.

3.5 Pricing methods

3.5.1 Capacity prices

aFRR and mFRR capacity bids are procured in the respective common aFRR capacity market and national mFRR capacity markets. The most socio-economic efficient bids are selected to fulfil the reserve requirements in each bidding zone. The reserve requirements in one bidding zone can be fulfilled by selecting bids in another, if it is deemed more efficient. This results in a cross zonal capacity (CZC) reservation. Currently, mFRR capacity is procured nationally.

The aFRR and mFRR capacity prices for each bidding zone is determined by the marginal price (EUR/MW) for procured aFRR and mFRR CM bids.

3.5.2 Balancing energy prices

The objective is the optimal use of the mFRR bids in the merit order and the balancing energy price is determined by the marginal price for activated mFRR bids up and/or down respectively for each market time unit (MTU). When congestion occurs between two bidding zones in the operational phase, the TSOs jointly determine when the zones no longer can be mutually regulated. If it is not possible to use the mFRR bids in price order, a splitting of the balancing energy prices occurs.

Mutually balanced areas consist of several bidding zones which obtain the same balancing energy prices. The reasons for different balancing energy prices of different bidding zones can be excess transmission on corridors between bidding zones, or if trading or operational rules restrict activation of bids from the Nordic mFRR list (NOIS) in the price order. The TSOs determine jointly when and between which zones the separation of balancing energy prices occurs.

3.5.3 Price for BRP imbalances

In case there is an activation of mFRR in the uncongested area, a dominating direction for activation for each market time unit (MTU) will be established to determine the imbalance price for BRPs. The dominating direction which will be either "Up" or "Down", corresponds to the net positive (upward) activation of mFRR or net negative (downward) activation of mFRR respectively for balancing purposes.

In case there is no activation of mFRR in the uncongested area in a market time unit (MTU), the day-ahead price will be used as the imbalance price.

3.5.4 Publishing of prices

The mFRR energy activation prices are not determined until the hour has passed. This is because there is a need for assessing which mFRR bids that have been used for normal balancing and which for congestions to determine the correct prices for the market.

During normal operation, prices and volumes are to be published no later than 60 minutes after the hour of operation.

It is important that the market receives a correct price signal on an accurate base. To avoid self-balancing from BRPs that could disturb the balancing process performed by the TSOs, preliminary prices are currently not published during operational hour. However, a TSO can also publish preliminary prices in real-time when a TSO is operating as its own balancing area and using only locally balancing resources.

3.6 Ramping of exchange on HVDC connections

The trading plans on the HVDC interconnectors from the Nordic synchronous area change so much from one hour to the next that the changes in power flows at the change of hours must be restricted to be able to manage the balancing process. Restrictions are placed on speed of change of the flows.

As a basic rule, the change may be a maximum of 600 MW from one hour to the next on each of the interconnectors.

3.7 Tools for the operators

The TSOs balance the system based on the information that is available for the operators. Each TSO has their own real time monitoring and control system (SCADA) and a planning system.

The TSOs also have their own systems for forecasting consumption and wind and even if the bases for them are similar there are some differences as well.

As one tool to collect the planning data on a Nordic level, the Nordic TSOs use a common platform called NOIS (Nordic Operational Information System). The NOIS system was introduced in 2002 and has since then been developed to match upcoming needs and new operational functions used for Nordic coordination have been implemented.

The information compiled in NOIS is meant to give the operators a basis on which they can plan and estimate the need of balancing in the upcoming hours. As the information in NOIS is provided by each TSO it is of great importance that the submitted data is comparable when it comes to resolution and quality to be able to perform proactive balancing.

An important part in the balancing process is the ability to compare the planning data with real time measurements. This gives valuable and immediate information on trends that can be used when deciding balancing actions. There are currently different levels of detailed real time information among the TSO’s, and this is therefore an area where development is needed.

4 Balancing process

Balance energy activation within the synchronous system shall be conducted in such a way that specified quality standards regarding frequency and time deviation are met. Requirements regarding frequency response and automatic reserves shall also be maintained. Furthermore, activation of mFRR bids shall be conducted in such a way that the transmission capacity is not exceeded.

The planning of balancing is based on all available information from all TSOs. It is Statnett and Svenska kraftnät, the Balance Operators, who jointly decides and executes the balancing actions. Sweden and Norway represent approx. 75% of the annual consumption of the synchronous area and thus it is agreed in the SOA that Svenska kraftnät and Statnett have the task of maintaining the frequency and time deviation within the set limits.

In addition, Nordic TSOs have agreed that Svenska kraftnät has the role as Synchronous Area Monitor while Statnett has the role as LFC block Monitor.

Energinet belongs to two different synchronous areas. Although DK1 is part of the Nordic mFRR market, DK1 is balanced as its own area inside the Central European synchronous system and shall keep its balance on the Danish – German border. Activation of reserves in DK2 for optimisation of the balance in the Nordic system is done in cooperation with the Balance Operators.

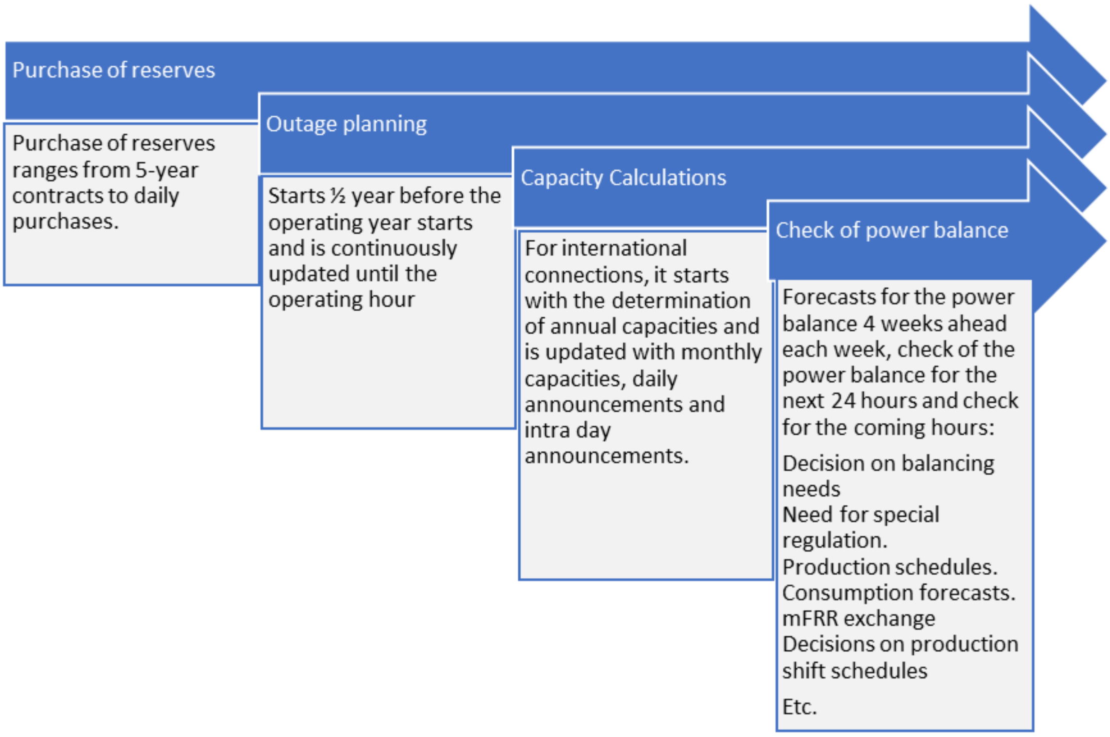

Figure 4: The balance process is a long-term process that starts years in advance with long-term capacity contracts with suppliers of reserves - followed by long to short-term planning of outage work in the electricity system - long-term short-term planning of capacity on exchange connections - concluding with forecasts for power balance and dynamic stability from weeks before, the day before up to the operational hour.

4.1 Before day-ahead market closing

The operational balancing process can be considered as a long-term process starting years ahead entering into long term capacity contracts with suppliers of reserves, followed by long to short term outage planning, long to short term grid capacity planning on interconnectors, ending up with forecasts for power balance and dynamic stability from weeks before, days ahead up to the hour of operation.

The following text focuses on the balancing process that takes place a couple of weeks ahead of real time and later.

4.1.1 Adequacy for mFRR

A common Nordic objective is to assess sufficiency in available resources in the balancing with respect to always being able to respect the N-1 criteria. If sufficiency cannot be ensured by normal procedures, specific actions need to be taken. Thus, this is especially important in situations with risk of power shortage or lack of mFRR bids in either direction. For the assessment, each TSO makes a power balance evaluation in various time frames.

Methods to ensure availability of resources for balancing

Statnett secures mFRR capacity for up- and downward balancing in a daily auction in a national capacity market. In addition, Statnett has a seasonal capacity market for upward balancing in wintertime.

Svenska kraftnät has long term contracts to handle the Swedish reference incident in upward direction. The capacity is offered in the mFRR market and submitted (by Svenska kraftnät) to the merit order list as "special mFRR bids". In situations with several simultaneous outages on contracted capacity and where the volume for reference incident cannot be secured otherwise, Svenska kraftnät will increase the procurement volumes on the mFRR capacity market to cover the reference incident need.

Fingrid has own and contracted gas turbine capacity to ensure the sufficiency of mFRR resources in upward direction. Additionally, Fingrid has a capacity market for both up and downward direction.

At Energinet, mFRR for upward balancing capacity in DK2 is procured in both monthly (~60%) and daily (~40%) capacity markets. Energinet has a common DK1-DK2 mFRR capacity market. Up to 10% of the transmission capacity on the Great Belt interconnector can be reserved for mFRR capacity if the reservation is socio-economically viable. Energinet shares reserves between DK1 and DK2 with an amount of up to 300 MW, reducing the procurement need for mFRR in DK1.

Svenska kraftnät and Energinet coordinate the mFRR in Southern Sweden and Eastern Denmark (south of cross-section 4) by summing up all available reserves in the region. If the total amount of reserves is not enough, the requirements will be distributed in accordance with the following distribution rules:

(Reference Incident) x (Own Reference Incident) / (Own Reference Incident + Counterparty Reference Incident)

Svenska kraftnät contracts a peak load reserve during winter season. The volumes are only available to the TSOs, not to the market.

All Nordic TSOs procure aFRR on the common Nordic aFRR capacity market. In the aFRR capacity market balancing service providers (BSPs) can offer bids for aFRR capacity to a common capacity platform.

4.1.2 Allocation of capacity for exchange of reserves in the planning phase

The fact that the grid is not a copperplate, leads to requirements for distribution of all types of reserves. For each interconnection between bidding zones, a Total Transmission Capacity (TTC) is defined. From this capacity a margin, the Transmission Reliability Margin (TRM), is subtracted to find the maximum grid capacity available for exchange in markets, the Net Transmission Capacity (NTC). A market-based allocation process determines the grid capacity to be allocated to the Nordic aFRR (and coming mFRR) capacity market. The TSOs define needed FRR volumes available for each bidding zone and an algorithm distributes the BSP contracts according to a merit order principle and available exchange capacity. The common market is cleared D-1 and grid capacity is allocated for FRR capacity exchange between bidding zones whenever socioeconomically beneficial compared to giving all the available grid capacity to the day ahead market. The FRR allocation can be up to 10% (20% if necessary) of the total cross-zonal capacity.

4.2 After day-ahead market closing

After the day-ahead clearing, the BRPs/BSPs submit preliminary plans on production and mFRR bids for the next day. Together with exchange plans between bidding zones due to trade on the day-ahead market, this gives the TSOs a first overview on how the next day is planned hour by hour. It gives e.g., indication if there will be congestions in some hours.

To ensure that sufficient resources are available an assessment is made both separately by each TSO but also by the Synchronous area/LFC block monitors. This assessment is made based on the following information:

- Preliminary forecast on consumption (hourly/quarterly resolution in TSO tools and operational experience of consumption pattern)
- Preliminary production plans (hourly and quarterly resolution)
- Day-ahead exchange plans on AC- and DC-connections (hourly resolution, 5 min linear piecewise plans and knowledge of ramping pattern)
- Potential congestions from exchange schedules in the energy market
- Preliminary mFRR bids

During wintertime the first balancing action in Sweden is to consider if peak load reserves are needed for balancing and should be put/kept on stand-by for the next day. This is decided shortly after the day-ahead result is known.

Should there be a risk for lack of mFRR, the responsible TSO asks for additional mFRR bids from the providers in the mFRR market. This is however only a request as there are no legal obligations for the BRP to participate or to submit all available capacity.

In critical operational situations with a lack of resources, BSPs can be ordered by phone to deliver up- or downward balancing energy activation from any available resource. This may be both consumption and production.

After day-ahead market closing, Energinet receives market notifications and operational schedules from the BRPs. The operational schedules (5-minutes power schedules) comprise the BRPs' operational schedules including mFRR activations, if relevant, and is used by Energinet for the continuous monitoring and handling of the balance in the power system.

4.3 After intraday gate closure

When plans and mFRR bids are known 45 minutes before operational hour, the Operators have the following updated information as basis for their planning of the balancing approximately one hour ahead:

- Updated forecast on consumption (hourly/quarterly resolution in TSO tools and operational experience of consumption pattern)
- Updated production plans (hourly and quarterly resolution)
- Updated exchange plans on AC- and DC-connections (hourly resolution, 5 min linear piecewise plans and knowledge of ramping pattern)
- Potential congestions from exchange schedules in the energy market
- Available mFRR bids
- Real time information (note that there is some lack of available real time data for e.g. wind production)

All information above with exception on real time information is compiled in a common information system (see also chapter 3.7).

Based on the planning information in the common information system and real time information, Svenska kraftnät and Statnett are evaluating an expected balancing volume in the synchronous system in the next hour and Energinet is doing the same for DK1. This is done by assessment of the present operational situation and estimate how this could remain or change depending on the plans for upcoming changes in production, consumption, and exchange.

Based on these evaluations an optimal use of mFRR bids in the two systems is agreed between relevant TSOs and new power schedules over HVDC are made. This is normally done 30-40 minutes before operational hour as ramping up or down on some of the HVDC connections currently starts 10-15 minutes before the hour shift. In normal cases, the Operators make the final decision on which mFRR bids to activate from the start of the next hour approx. 15 min before the hour shift.

The mFRR bids are used in price order. However, there are some differences in the Nordics on how the reserves with capacity payment are activated vs. the voluntary mFRR bids.

Svenska kraftnät and Fingrid activate voluntary mFRR bids and bids reserved on the capacity market first and after those long-term pre-contracted reserves. This is due to that both the peak load and disturbance reserves can be seen as subsidized in comparison to the voluntary mFRR bids sent by BRPs. Peak load reserve can only be submitted to the mFRR market during the winter period in certain circumstances. Peak load reserves have priority to disturbance reserves in order of activation when available on the mFRR market.

When activating mFRR, Energinet and Statnett do not distinguish between voluntary mFRR bids and bids with capacity payment.

When one control area only has mFRR corresponding to N-1 left in the Nordic mFRR bid list , reserve capacity can be "shared" between the control areas after an evaluation of whether the operational security allows it.

In addition to Nordic mFRR and especially in cases where there are few mFRR bids in certain Nordic areas, there can be possibilities to buy supportive energy from TSOs outside the Nordics for balancing purposes. In general, these resources (or prices for them) are not known in advance when e.g., the operator at Svenska kraftnät contacts the counterpart to ask if it is possible to activate mFRR bids for exchange.

In the same period as evaluation of expected imbalances for the next hour is made, the Balance Operators assess whether the planned production changes in the Nordic area and the HVDC exchange around hour shift are too large and hence will impact the frequency in a way that cannot be met entirely by activation of mFRR bids in the minutes before and after operational hour. If so, there is a need to advance or delay parts of planned production steps at the hour shift. The power schedules may be changed from 30 minutes before until 30 minutes after hour shift.

This is mainly important during morning and evening hours and also around day shift. If the changes are deemed to be high, the Balance Operators make a plan on how to level out these changes by an agreement with BRPs to reschedule the production. In situations with congestions, there is also a need to decide in which order the rescheduling should take place. E.g., in case of close to congestion on Hasle from Norway to Sweden it may be wise to start with increased production in Sweden/Finland 15 minutes before hour shift and decreased production in Norway in the first 15 minutes after the hour shift. In Norway and Sweden, it is sometimes possible to reschedule production steps within the hour if there are available production changes to reschedule.

In this first assessment a plan for volumes to be shifted both before and after the hour shift is made. The volumes to be shifted after the hour might be reassessed closer to the hour shift if something unplanned occurs that would interfere with the initial plan.

The production shift scheduling is made by calling the BRP and when relevant it is also made a check if the BRP has any activated mFRR bids that can affect the rescheduling.

4.4 During operational hour

During the operational hour the Balance Operators follow the trend of the operational situation and continuously estimate the upcoming need for readjusting the balancing. This is done in the same way as planning before the hour (as described above) but with a shorter time span in mind.

There are always risks of unpredictable events such as trip of production etc. When this occurs, the operators must make fast decisions on how to relieve the situation. The operators make a judgement based on the available real time data and planned information in order to make a decision on appropriate action. In such cases mFRR bids with faster response time than 15 minutes can be given priority over the price order if needed. These are then handled in the same way as mFRR activations for system constraints. The mFRR bids that are skipped will thereafter be activated if needed and the activated bids with faster response time than 15 minutes will be changed to balancing energy activation when mFRR bids no longer are skipped.

When congestion occurs between two bidding zones in the operational phase, the TSOs jointly determine when the areas no longer can be mutually regulated.

There is congestion between the bidding zones when it is not “possible” to carry out activation of mFRR bids based on the joint Nordic mFRR list without deviating from the normal price order of the Nordic mFRR list. The reason for this not being “possible”, can be flows that are too high on the cross-border link itself or on other lines/transmission constraints or operational/trading rules which entail that it is not permitted to activate mFRR bids in the joint Nordic mFRR list. For activation of mFRR bids carried out for network reasons on the border between bidding zones, the cheapest mFRR bids in the subsystems which rectify the network problem are normally used.

Activation of mFRR bids for both frequency and congestions must be performed simultaneously and depending on which need that is the dominant there will be an iterative process in choosing the right actions to take.

Congestions and frequency are balanced out simultaneously at the latest within 15 minutes, but overloaded grid have priority over frequency in operations.

4.4.1 Need of activation of mFRR bids for low/high frequency-situations with no congestions

If there are no congestions to consider, the activation of mFRR bids is performed by activating mFRR bids in price order.

4.4.2 Need of activation of mFRR bids for high/low frequency-situations with exceeding NTC

In the operational phase, the operators will normally have NTC as the "target flow". When the flow exceeds the "target flow" in real time, the operators will have to consider if this is due to activations of aFRR or FCR or not. If the frequency is 50.00 Hz so there is no aFRR and FCR activations, then mFRR needs to be activated to bring the flow back to the "target flow" to prepare for potential upcoming imbalances. If the frequency is different from 50.0 Hz, then the operators will have to evaluate which share of the flow higher than the "target flow" that is due to activations of FCR and aFRR before deciding on potential activations of mFRR.

When NTC is exceeded, the following measures are relevant dependent on frequency:

- Low frequency
  Upward balancing energy must be activated in the importing area.
- High frequency
  Downward balancing energy must be activated in the exporting area.
- Frequency 50 Hz
  First activation of mFRR bids in the importing area and thereafter in the exporting area.

4.4.3 Need of activation of mFRR bids for high/low frequency-situations and with “full" grid corridors

When the need of activation of mFRR bids is primarily for frequency but the planned flow on grid corridors is “full”:

- Low frequency
  Upward balancing energy is activated in the importing area until there is a sufficient margin in the flow and thereafter activation in the exporting area can be done if needed.
- High frequency
  Downward balancing energy is activated in the exporting area until there is a margin in the flow and thereafter activation in the importing area can be done if needed.

The volume of activated mFRR bids on both sides of the congestion is dependent on the distribution of aFRR and FCR.

4.4.4 Congestion management

Congestion caused by a reduced transmission capacity to/from a bidding zone after day-ahead clearing due to disturbances or forced outages, are managed using counter trading and mFRR bids for system constraints.

There is an issue on how long a "target flow", an NTC or a TTC can be exceeded. This is first of all a question about expected development for the relevant flow, probability for severe additional incidents and how much the limits are exceeded.

The system is in general dimensioned for exceeding of the TTC in up to 15 minutes in case of a failure. In normal operation, the "target flow" should be NTC or lower, to be prepared to handle an N-1 fault. It could be relevant to introduce an indicator for system performance with minutes higher than TTC per year on some highly congested corridors in the same way as minutes outside the band for frequency. In case of congestions in the energy market, the flow should be equally distributed on each side of the "target flow" to reduce costly adverse (opposite direction to price difference) balancing power. However, a common operational view is that the TRMs on many corridors are too small in practice to fulfil this due to uneven FCR-distribution, ramping on HVDC, changing consumption and other dynamic variations through the hour.

4.4.5 Manual load/production shedding

In a power shortage/surplus situation, the TSOs might have to decide an area where load/production shedding is required. The area(s) selected for load/production shedding is the area(s) with the largest gap between its imbalances(shortage/surplus) and its available reserves.

5 Topics for/under development

This chapter lists identified projects and activities which are supposed to be implemented during 2024 – 2026 and which will have impact on the future Nordic balancing philosophy. This chapter is not necessarily complete and dealing with all topics which are under development.

5.1 Nordic mFRR EAM (Governed by Nordic Balancing Model program, NBM)

The new Nordic automated mFRR energy activation market (mFRR EAM) will replace the current manual Nordic regulating power market. The mFRR EAM introduces e.g., new bid attributes, automatic activation of mFRR bids, market clearing every 15 minutes and ACE-based balancing. The Nordic mFRR EAM prepares Nordic TSOs and BSPs for the transition to the common European mFRR energy activation market and platform, MARI.

More information on: https://nordicbalancingmodel.net/roadmap-and-projects/

5.2 Multinational mFRR CM

Currently, mFRR capacity is procured locally in each control area. An integration of these local markets will allow for a more liquid and efficient multinational capacity market. All Nordic TSOs and BSPs will then use the same market platform, Fifty Nordic MMS, to sell and procure mFRR capacity.

The current plan is to launch a multinational mFRR capacity market comprising Denmark, Sweden and Finland before go-live of mFRR EAM.

5.3 aFRR energy activation market (PICASSO)

The Nordic TSOs will onboard a common European energy activation market for aFRR (PICASSO). Fingrid and Energinet are planning to onboard in 2024.

5.4 15 min MTU in ID and DA (Governed by Nordic Balancing Model program, NBM)

The market time unit (MTU) in the intraday and balancing markets will be 15 minutes as well as in the automated mFRR energy activation market.
More information on: https://nordicbalancingmodel.net/roadmap-and-projects/
With the introduction of 15 min MTU in DA/ID an amended methodology for ramping restrictions for DA and ID will be implemented.

5.5 Dynamic dimensioning of mFRR and aFRR (Governed by Regional Group Nordic, RGN)

A new dynamic FRR dimensioning method is being developed to determine the FRR needs more precisely.

5.6 Flow-based capacity calculations (Governed by Market Steering Group, MSG)

New “Flow Based” capacity calculation method and IT-tools are being prepared as a substitute for the existing NTC calculation method.