ENERGINET FINGRID Statnett SVENSKA KRAFTNÄT

Batteries in the Nordic reserve markets

April 2025

Photo: Fingrid Oyj

Content

Introduction

Flexibility from batteries is valuable to the power system

Technology which can provide flexibility will play a central part in the current transition of the electrical power system. Batteries have the technical ability to provide multiple services to the system, both as grid support and market participants.

The production/import and consumption/export must always be balanced in the power system. Thus, the electricity market is designed so that electricity producers and consumers have an incentive to plan and balance their production, consumption, sales, and procurement as well as possible. However, some imbalances will always occur, and ultimately, the Nordic transmission system operators (TSOs), i.e. Energinet, Fingrid, Statnett, and Svenska kraftnät, are responsible for balancing the Nordic power system. The imbalances are corrected in real-time with the reserves that are procured from the reserve markets, and which are the focus of this report.

The ongoing clean energy transition, with growth of weather-dependent production, increase in electricity consumption, and reduced share of traditional regulated electricity production complicates forecasting and makes balancing more challenging. Accordingly, the need for last-minute adjustments in the power system balancing is increasing. Therefore, there is an increasing need for flexibility and regulating capacity in the power system.

In general, as battery energy storage systems (hereinafter batteries) have the technical capability to provide short-term flexibility, they also have good potential to provide reserves and operate in all reserve markets. Therefore, the purpose of this report is to increase the knowledge of the possibilities and challenges for participation of batteries in the Nordic reserve markets.

There is an increasing need for flexibility in the energy and reserve markets

Batteries have the capability to participate in all energy and reserve markets

Assessing the opportunities for reserve market participation with your battery

Battery size (MW)
Will your battery comply with minimum bid sizes in the markets? If not, aggregation is possible if in compliance with the rules that apply for aggregation in the respective markets. It is also an option for an asset owner to have a cooperation with an existing reserve/ balancing service provider (BSP) bidding in the market.

Activation time
How fast can your battery react and provide the reserve regulation?

Endurance (MWh)
How long can you maintain your response?

Ability to regulate
What are the possibilities for regulation in your energy management system for your battery?

Grid connection
Does your grid connection have specific requirements, such as a flexible connection agreement?

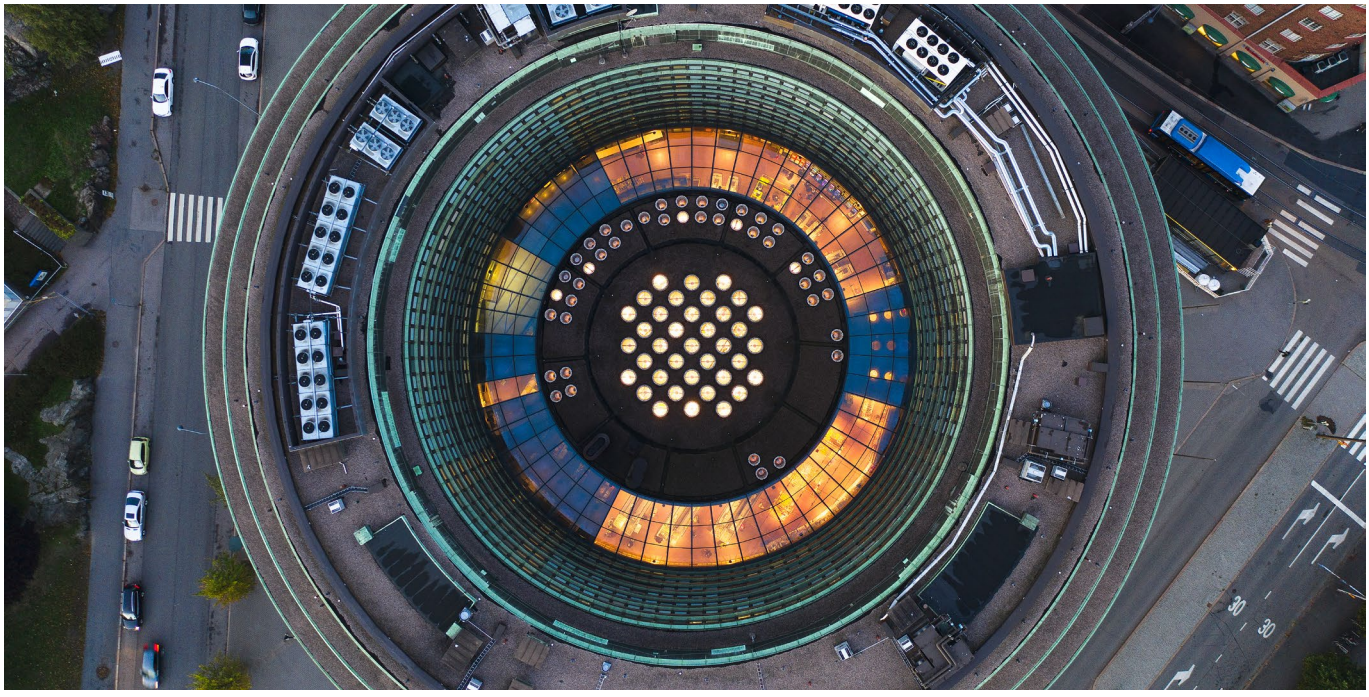
Use of your battery
What is your use of your battery – and the pattern of use, when do you have available capacity?

Location
Bidding zone and distribution system operator (DSO).

Electricity supplier and BRP
Who is the electricity supplier and balance responsible party (BRP) for your battery? Rules for market participation and aggregation are considering these roles, and will affect which of the Nordic reserve markets you are able to participate in.

Hybrid solutions
Batteries have the ability to support other technologies in delivery in hybrid systems, e.g. in combination with hydro power, solar and wind.

Photo: Fingrid Oyj



Batteries can participate in all reserve markets

Batteries can participate with all five reserve products in the Nordic reserve markets:

1. **FFR** – Fast Frequency Reserve
2. **FCR-D** – Frequency Containment Reserve for Disturbances
3. **FCR-N** – Frequency Containment Reserve for Normal operation
4. **aFRR** – Automatic Frequency Restoration Reserve
5. **mFRR** – Manual Frequency Restoration Reserve

These reserves can be procured either on (or both):

Capacity markets (CM)
- Ensures sufficient volumes of reserves before the delivery period.
- Capacity payment is paid for available capacity based on accepted bids in the CM, independently of reserve activation.

Energy Activation Markets (EAM)
- Activation of energy bids during the delivery period.
- Energy payment is paid for activated energy bids only based on the accepted bids in the EAM.

If a BSP have submitted a capacity bid already in the CM and the bid was accepted, and in the EAM the BSP's corresponding energy bid is activated, the BSP will earn both the capacity and energy payment.

Prequalification of assets is the process of technical testing and verification that a potential reserve resource/ entity must comply with the technical requirements for reserve market participation. The prequalification tests are specific to the reserve product and must be passed to participate in the corresponding reserve market.

The BSP executes the prequalification tests, and the TSO serves the right to monitor the tests and verifies the test results.

Please note: A new installation must perform the compliance tests against the national/local grid connection code specifications which are separate from the reserve prequalification tests.

The technical requirements for prequalification for FFR, FCR-D and FCR-N are harmonized in the Nordics. As for aFRR and mFRR, the technical requirements have not been harmonized.

Specifications for data transfer requirements can be found in the respective prequalification documents. More information about prequalification can be found on each TSO's website:

Energinet: Prækvalifikation og test
Fingrid: Reservitoimittajalle
Statnett: Hvordan bli med i reservemarkedene?
Svenska kraftnät: Förkvalificering

The following pages offer a brief description of each reserve along with quick market facts, highlighting the opportunities and challenges for batteries.

FFR

Fast Frequency Reserve, FFR, is the fastest of the reserves. The purpose of FFR is to handle the initially rapid and deep frequency deviations that can occur in case of low levels of inertia in the Nordic power system. The inertia in the system varies for example with time of the day and season. Because the procurement of FFR depends on inertia, the volumes and hours to be procured may vary. The procurement is typically highest in summer when the inertia is at its lowest. FFR is an asymmetric product, only providing upwards regulation.

	Market	Sweden	Denmark	Norway	Finland
Minimum Bid size (MW)	CM	0,5	0,3	1	
Activation time		0,7 seconds, 1,0 seconds or 1,3 seconds			
Endurance		5 or 30 seconds			
Prequalified volumes of batteries (MW) on January 1, 2025					
	CM	297,2	10	8,1	102

Opportunities
- FFR requires a very fast response of ~1 second.
- The energy required for the maximum activation time in FFR is very low.
- Responds independently based on frequency measurement.

Challenges
- FFR is procured only for certain hours and the procured volume varies limiting the possible income from this individual market.
- FFR is asymmetrical and only provides upregulation; the technical capability of batteries to offer both up- and downregulation is not fully realized.

FCR-D

Frequency Containment Reserve for Disturbances, FCR-D, stabilizes the frequency during disturbances by activating automatically for deviations outside the normal range (49.9–50.1 Hz). It consists of two products: Upward regulation (activated below 49.9 Hz, with full activation at 49.5 Hz) and Downward regulation (activated above 50.1 Hz, with full activation at 50.5 Hz). FCR-D has the second fastest response time after FFR, with activations based on measured frequency.

	Market	Sweden	Denmark	Norway	Finland
Minimum Bid size (MW)	CM	0,1			1
Activation time		At least 86% of the activated power within 7.5 seconds			
Endurance		At least 20 minutes at 100% activation			
Prequalified volumes of batteries (MW) on January 1, 2025					
Up-regulation	CM	608,3	18,1	1	119
Down-regulation		568	18,1	0	116

Opportunities
- FCR-D requires a fast response, within a couple seconds, which is easy to fulfill with batteries.
- The FCR-D product has an endurance requirement of 20 minutes.
- Possible to participate in both upwards and downwards FCR-D simultaneously, capturing multiple revenue streams.
- Large flexibility in bidding in DK2 and SE due to two auctions.
- Responds independently based on a frequency measurement.

Challenges
- Tuning of the control of the reserve resource/ entity might be complicated and requires expertise.
- Requirements for limited energy reservoir (LER).
- FCR-D requires an additional power reservation of 20% in the other direction.
  i.e when you bid 1 MW of FCR-D upwards (discharge), you must reserve 20% of the 1 MW in the charging direction.

FCR-N

Frequency Containment Reserve for Normal operation, FCR-N, is a symmetrical product that provides both upward and downward regulation, automatically activating when the frequency deviates from 50.0 Hz. It aims to stabilize the frequency within the normal frequency band (49.9–50.1 Hz), with full activation upwards at 49.9 Hz or below and full activation downwards at 50.1 Hz or above.

	Market	Sweden	Denmark	Norway	Finland
Minimum Bid size (MW)	CM	0,1			
Activation time		Approx. 63% activated within 60 seconds and 95% within 3 minutes			
Endurance		1 hour at 100% activation in each direction			
Prequalified volumes of batteries (MW) on January 1, 2025					
	CM	297,2	8	0,4	106

Opportunities

- FCR-N is slower than FCR-D but faster than aFRR.
- The minimum bid size is very low (0,1 MW).
- Responds independently based on a frequency measurement.
- Potential revenue first from capacity market, secondly as remuneration for the reserve activation.
- As a symmetric product, the upwards and downwards activations could theoretically compensate each other. Consequently, FCR-N activations could theoretically support the state of charge management of the battery.

Challenges

- Tuning of the control of the reserve resource/ entity might be complicated and requires expertise.
- Requirements for limited energy reservoir (LER).
- FCR-N requires a power reservation of 34%.
- FCR-N requires much energy to be delivered. The minimum requirement is 1 hour in each direction.
- Potential battery wear from charging and discharging needed due to frequent activations.
- Endurance is a challenge, as batteries are usually designed for 1-hour storage. This means that at 50% SOC, they can only regulate for 30 minutes in each direction. In comparison, FCR-D requires 20 minutes, making it more feasible.

aFRR

Automatic Frequency Restoration Reserve, aFRR, is automatically activated by a control signal from the TSO when the frequency deviates from 50.0 Hz, in order to restore it back to 50 Hz. aFRR is an asymmetrical product, consisting of both upward and downward regulation, procured separately. In Sweden and Norway, the total activated volume is distributed proportionally among the capacity market participants on a pro-rata basis to satisfy the real-time demand for aFRR energy. Energinet in Denmark and Fingrid in Finland have accessed the Picasso platform meaning there are established energy activation markets for aFRR in which activated volumes are allocated based on energy bids, starting from the cheapest energy bid. In Norway and Sweden aFRR energy markets will be implemented latest when Statnett and Svenska kraftnät access the Picasso.

	Market	Sweden	Denmark	Norway	Finland
Minimum Bid size (MW)	CM	1			
	EAM	N/A	1	N/A	1
Activation time		Within 5 minutes			
Endurance		1 hour	4 hours	1 hour	Max. 1 hour
Prequalified volumes of batteries (MW) on January 1, 2025					
Up-regulation	CM	0	5,3	0	40
Down-regulation		0	5,3	0	40

Opportunities

- In Norway and Sweden, potential revenue first from capacity market as capacity payment, additionally as remuneration for the delivered energy over the imbalance settlement.
- In Denmark and Finland, a BSP can potentially earn both the capacity payment through CM and energy payment through EAM.

Challenges

- aFRR has a large energy requirement which can make it difficult for batteries to act on their own.
- Need for a signal/two-way real-time communication, compared to frequency measurement in FCR which is easier to implement.
- High endurance required (1–4 hours).

mFRR

Manual Frequency Restoration Reserve, mFRR, is designed to restore the frequency to 50 Hz during normal imbalances and in the event of disturbances in the Nordic system. mFRR is an asymmetric product consisting of up-regulation and down-regulation, procured as separate products and activated separately via electronic signals to market participants.

	Market	Sweden	Denmark	Finland	Norway
Minimum Bid size (MW)	CM	1			
	EAM	1			5/10*
Activation time		Full activation time of 12.5 minutes, with a preparation time of 2,5 min and a 10 minutes ramping period			
Endurance		CM: Requirements varies in the Nordics. EAM: One quarter for scheduled activations and two quarters for direct activations			
Prequalified volumes of batteries (MW) on January 1, 2025					
Up-regulation	CM	3	0	N/A**	0
	EAM	117,5	0	N/A**	0
Down-regulation	CM	4	0	N/A**	0
	EAM	118,5	0	N/A**	0

* Statnett will lower the bid size to 1 MW latest with the implementation of MARI (Manually Activated Reserves Initiative).
** In Finland, prequalification tests are not required for mFRR.

Opportunities
- Activation according to the mFRR standard product is recommended, meaning that automated control systems are needed to manage the ramping process effectively.
- Potential revenue to be earned first from the CM, secondly as remuneration for the delivered energy in the EAM through the imbalance settlement.

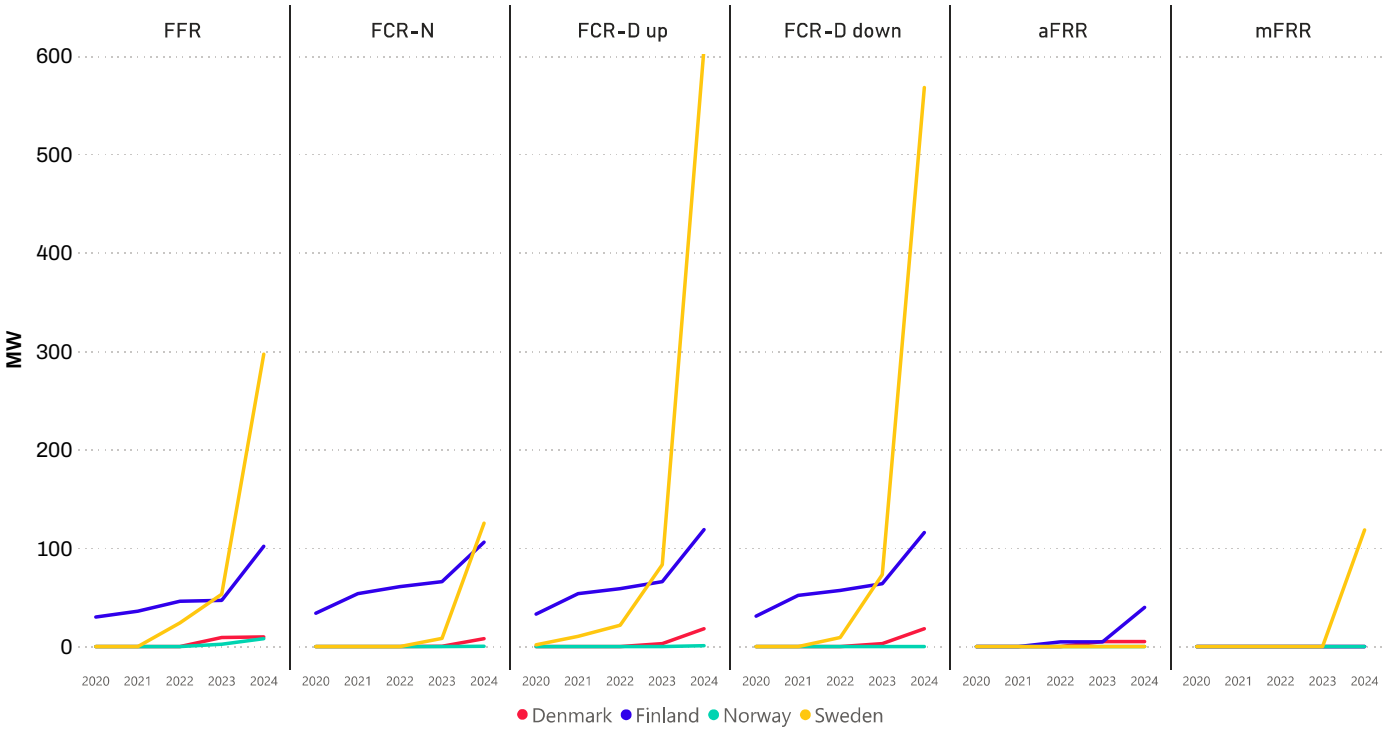
Challenges
- Batteries' quick ramping ability (a few seconds) is not fully utilized with the 10-minute ramping period of the standard product.
- Participating in the CM requires submitting at least 1 MW bid for each quarter in one hour in the EAM.
- Units must be able to deliver all the capacity and energy sold. Participants must note national requirements to limited energy resources (LER).
- Limited energy requires bidding to manage the state of charge, ensuring that if bid availability depends on the previous quarter, bid attributes such as technical linking and resting times are applied to meet the commitment.

Development of prequalified battery volumes in the Nordic reserve markets

The figure below illustrates the development of prequalified battery volumes from 2020 to 2024 across each reserve product, with each bar representing the prequalified battery volume at the end of each year.

During the last 5 years, the prequalified battery volumes have increased in Finland and especially in Sweden. In Denmark and in Norway the volumes are lower, yet with a slight increase in the last two years. All countries have prequalified batteries for FFR and FCR, whereas only Denmark and Finland have batteries prequalified for aFRR. Sweden is currently the only country with batteries prequalified for mFRR.

Note that the prequalified volumes do not reflect the total capacity of the participating batteries, as a single battery can be prequalified in multiple markets and for both up- and downregulation. Furthermore, prequalified volumes do not automatically imply that resources are actually active in the specific markets (actual supply).



Assessing the potential income from reserve market participation

Historical market data for reserve markets, such as procurement volumes and prices, are available from several different sources:

ENTSO-E Transparency Platform and Nordic Unavailability Collection System (NUCS)
Energinet: Indkøb og udbud
Fingrid: Reservimarkkinainformaatio and Fingrid Avoin Data
Statnett: Tall og data fra reservemarkeder
Svenska kraftnät: Handel och prissättning

To enable a better understanding of potential income streams from reserve markets, the Nordic TSOs have developed reserve markets income calculators and examples that can be found on each TSO's website.

Energinet: Revenue calculator
Fingrid: Reservituottolaskuri
Statnett: Reservemarkedskalkulator: Hvor mye kan du tjene på å være fleksibel?
Svenska kraftnät: Bidra med reserver

Photo: Fingrid Oyj

Multiple income opportunities for batteries

Due to their flexible nature, batteries are able to participate in all reserve markets. However, batteries also bring other functionalities, enabling multiple possible value streams. These different value streams make it possible to spread the investment risk and participate where the value is highest. Still, with the many different options, including for multi-market optimization, it is important to consider the various limitations following the reserve market participation. For instance, bidding the same capacity in multiple markets at the same time is not possible, as the respective market sequences and requirements for availability must be followed.

Batteries have the capability of delivering all reserve products.

Batteries can be suited for energy arbitrage buying power in low-price periods and selling it when high-priced.

Batteries can support flexibility needs on DSO level (dependent on national DSOs).

Batteries can contribute to reduce imbalances for wind, solar and other unregulated power generation.

Batteries can support flexible industrial production where needed.

Batteries can support renewable production in periods of low prices to avoid curtailment situations.

Photo: Statnett / Johan Wildhagen

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Photo: Energinet