Nordic Balancing Markets: Overview of Market Rules

Abolfazl Khodadadi, Lars Herre, Priyanka Shinde, Robert Eriksson, Lennart Söder, Mikael Amelin
Division of Electric Power & Energy Systems
KTH Royal Institute of Technology, Stockholm, Sweden
E-mail: {abokho, lherre, pvshinde, robbaner, lsod, amelin}@kth.se

***Abstract*—System operators have the option to trade balancing reserves among countries and operators. In order to trade balancing reserves with other system operators the markets should be harmonized. While the spot and intraday markets are already harmonized within the Nordics, the balancing markets still display differences. The differences can be subtle, yet they may play a significant role for the planning, operation, modelling and control of the power system. In this paper, we conduct a thorough literature review on Nordic balancing markets and summarize the market rules and requirements. This review can help operators and modellers to better represent the Nordic power system.**

***Index Terms*—electricity markets, balancing markets, frequency reserves, power system operation.**

I. Introduction

A. Motivation

While wholesale power markets ascertain the planned balance of supply and demand, they do not ensure operational security of the power system in real-time. This task falls on the transmission system operator (TSO), who is responsible for balancing consumption and generation at every instant. In a secure state, the power system can handle any single fault without resulting in a blackout or involuntary disconnection of demand. The current balancing model in the Nordic countries builds on controlling the frequency in real-time. Recently, the frequency increasingly falls outside the limits [1]. The current Nordic balancing model also lacks the prerequisites for taking advantage of the ongoing European harmonization in the balancing area. This could bring versatile balancing markets to the Nordic region, enabling a cost-efficient use of resources within the region by increasing the trade of flexible resources with Continental Europe.

The *Guideline on Electricity Balancing* [2] includes a harmonization package of standard products and introduces common platforms for exchange of balancing products. This will affect the balancing process and the products in the Nordic region [1]. Therefore, there is a need to get everyone on a common ground and provide information with proper resources for researchers to have more access to reliable data.

Building onto [3], this paper intends to summarize the recent developments and discussions on balancing market design in the Nordic region. The contributions of this paper are twofold:

- We summarize the rules of balancing markets in the Nordics to date (June 2020).
- We gather references with the detailed market rules and requirements in order to organize a structure and ease the access to this type of information.

The aim of this paper is to facilitate information access for energy system models such as, e.g., reference [4].

B. Definitions

For further use, we first define the roles and acronyms of players in the balancing market:

- **BSPs (Balance Service Providers):** such as generators, demand response facilities and storage operators can offer balancing services (capacity and/or energy) to the TSOs, who in turn use these services to balance the system
- **BRPs (Balance Responsible Parties):** such as electricity producers, consumers and suppliers shall keep their individual position (sum of the energy volume physically injected or withdrawn from the system and their trades) in balance or help the system to be balanced, as they are financially responsible for the imbalances of their portfolios
- **TSO (Transmission System Operator):** A system operator is responsible for an area to be electrically stable, and for the security of supply in his area. The TSO is responsible for both security of supply and operating the high-voltage (transmission) grid.
- **NEMO (Nominated Electricity Market Operator)**: is the designated market operator.
- **NRA (National Regulatory Authority)** ensures that products released for public distribution are evaluated properly and meet international standards of quality and safety [5].
- **RE (Retailer)** sells electricity to the end-user. It sells and buys electricity directly from a producer, another retailer or on the wholesale market. A retailer has an agreement with a BRP.

II. Market Structure

Nord Pool is the NEMO in Norway, Sweden, Finland, Denmark, Estonia, Latvia, Lithuania, Germany, the Netherlands, Belgium, Austria, Luxembourg, France, and the United Kingdom with 15 price areas. It merges bids on the day-ahead spot market (*Elspot*) and intraday market (*Elbas*) and publishes the result on their website [6]. Other types of electricity trading are long-term contracts (future and forward contracts)

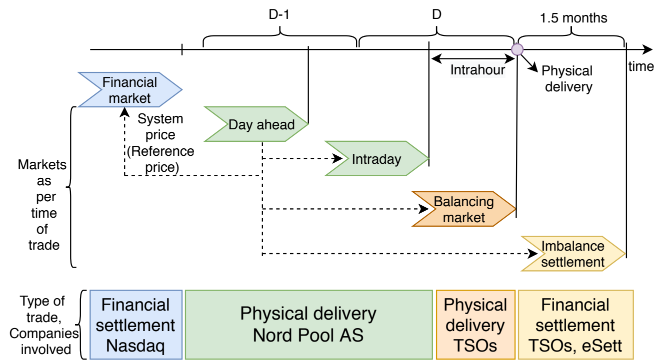

Fig. 1. Electricity market timeline

operated by Nasdaq and short-term markets (balancing markets) operated by the respective TSO. Market participants who are responsible for imbalances are invoiced after the delivery day through the Imbalance Settlement which is executed by eSett Oy [7]. In Fig. 1, the aforementioned markets and their timeline are illustrated. The imbalance settlement is outside the scope of this paper and a detailed description of the dominant systems in the Nordics can be found in [8].

A. Financial market

The financial market is a commercial market, where contracts for securing future prices are traded. These markets are settled against the fluctuations in the spot prices through futures and other derivatives. These contracts hedge against the risks in the markets and are crucial for market participants in the absence of long-term physical contractual markets [9].

B. Day-ahead spot market

The day-ahead (DA) spot market is a marketplace in which the price for each hour of the next day is established through a competitive auction. Participants submit their production or consumption in the respective price area before gate closure time at 12:00 CET D-1, i.e., the day before operation. Then, the system price is calculated and released at 12:42 CET. In the case of transmission congestion between price areas, the bids on each side of the congestion are aggregated into supply and demand curves in the same way that the system price is calculated. Also, the maximum import and export over the congested line is calculated [9].

C. Intraday market

The intraday (ID) market is a continuous market that opens at 14:00 CET D-1 and closes 1 h before the respective delivery hour. There are many subtle Gate Opening Times (GOTs) and Gate Closure Times (GCTs) specific to each Nordic country that can be found in [10]. In the Nordic countries, energy can be traded in volumes of hourly or block bids. According to the Single Intraday Coupling (SIDC) project it is possible to perform cross-border trade between 22 European countries (including the Nordic countries) on the intraday continuous trading platform [11]. The prices for this market are set on a *pay-as-bid* basis [6].

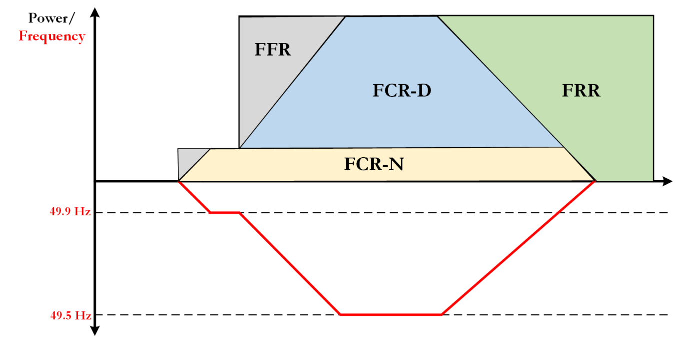

Fig. 2. Frequency restoration process, adapted from [17]

D. Capacity Markets

Capacity adequacy expresses the ability to provide sufficient energy and power capacity in all situations. The accelerating growth of intermittent energy sources to cut down greenhouse gas emissions has left the energy sector exposed to capacity adequacy issues. The replacement of conventional power generation with renewable generation has raised concerns regarding the loss of load probability (LOLP) [12]. Hence, the capacity market has been formed to ensure sufficient generation capacity through competitive prices for reliable system operation [13].

In Finland and Sweden, the *strategic reserves*, or peak load reserve (PLR), are the main backup mechanism to handle capacity shortage. The PLR in Sweden and Finland currently consist of 750 MW [14] and 611 MW [15], respectively, consistent of both generation and demand. While generators that offer capacity in the PLR cannot bid the same capacity in the DA, the demand in the PLR may bid in the DA market. If the DA market fails to establish an equilibrium, generation reserves are freed into the DA and tertiary reserve markets. The bidding rules for PLR are harmonised, and the TSOs aim to minimise the market impact from the reserves. Therefore, the price of the PLR bid must exceed the highest bid in the DA market. The Danish TSO is evaluating the option of a time-limited strategic reserve in order to maintain generation adequacy in Eastern Denmark [16]. Norway does not have a similar reserve. However, the Norwegian TSO Statnett has had two mobile gas turbines (300 MW) in a region (within, but not including an entire bidding zone) in Norway where there is a risk of energy shortage [13].

III. Balancing Markets

One of the main responsibilities of the TSO is to keep the balance between production and consumption at all times which is executed by running balancing markets. The volume of the procured reserve in each market follows the N-1 criterion with the capability to handle the Dimensioning Incident (DI). The DI as well as other faults are reflected in a change of system frequency. To reduce the impact on the system frequency, the TSO manages a portfolio of frequency reserves. Fig. 2 illustrates the stages of activation in case of an under-frequency, i.e., when up-regulation is required.

TSOs can trade and share reserves with other Nordic TSOs. The rules governing the Nordic balancing market are detailed in the Nordic Balancing Philosophy [18]. According to the System Operator Agreement [19], each TSO is required to procure an individually determined minimum amount of balancing capacity. Since the rules and quantities differ among TSOs, we will use the example of Sweden in this section. The respective information on other Nordic countries is given in Table I.

A. Frequency Containment Reserve (FCR)

FCR products are automatically activated by local frequency measurement in the time frame of seconds to minutes. FCR-N and FCR-D are operating reserves which contain the deviation of the frequency from the nominal value.

FCR-N bids are symmetrical ($\frac{\mathrm{MW}}{\Delta f[\mathrm{Hz}]}$), which means that the same volume for up- and down-regulation is offered. In order to fulfill the requirements of Svk, at least 63 % of the capacity must be be activated within 60 s and 100 % within 3 min [20].

FCR-D is automatically activated when the frequency drops below 49.9 Hz (i.e. disturbed operation is detected). Bids are not symmetrical and at the moment only up-regulation is required. The requirement is more strict; 50 % needs to be activated within in 5 s and 100 % within 30 s [21].

The single-buyer reserve market is organized at a national level by the TSO. The rules of the market have been largely harmonized within Nordic TSOs [18] and are equal for both production and consumption. The relevant rules are summarized below and detailed in [20], [31]. Bids for the following 24 hours must be submitted before the first gate closure at 15:00 CET D-2 or the second gate closure at 18:00 CET D-1. It is allowed to bid in only one of the two FCR markets.

The procurement is finalized by Svk at 21:00 CET D-1 and 16:00 CET D-2 respectively, and average prices are published on Mimer [32] in the early morning of the day of delivery. The participants are compensated *pay-as-bid* for the procured capacity, while the remuneration for the balancing energy (only FCR-N) is calculated hourly based on the frequency measurements and the price of the activated tertiary reserves, in its dominant direction of activation. Note that the activated energy is relatively small. Therefore, the major turnover lies in capacity provision rather than the remuneration of activated energy.

In the mandatory procurement scheme the generators connected to the grid are obligated to reserve a certain amount of capacity in order to meet TSO requirements, for a fixed price set by TSO or NRA, or for free. However, in the market based scheme, there is no contract or obligation to offer reserves. The grid user can voluntary participate in the market (e.g. tender, auction, market platform) and bid a price or customize his offer (e.g. the volume, timeframe). The market result may lead to a bilateral contract.

B. Frequency Restoration Reserve (FRR)

There are two types of frequency restoration reserves; automatic (aFRR) and manual (mFRR). The product aFRR was introduced in the Nordics in 2013. The background for developing and implementing aFRR was the deteriorating frequency quality and aFRR was identified as one of the main counter measures. A benefit is that aFRR can be based on merit order and take into account grid congestions. Additionally, aFRR has a faster response than mFRR.The aFRR product shall be seen as an automatic *complement* to mFRR in the FRR process. The aFRR reserve differs from FCR in the way that the reserve is remotely controlled by a centralized controller while FCR is locally controlled. There is also a difference in activation time. During the time when aFRR is active, there is an interaction between FCR and aFRR, where FCR stabilizes the frequency while aFRR brings the frequency back to its nominal value. aFRR can be exchanged between synchronous systems. To achieve this, it is necessary to have a grid capacity reservation. Till December 2015, the procured volume of aFRR in the synchronous area for each specific hour was similar to the distribution pattern of FCR. As of January 2016, the aFRR procurement was stoped because SVK decided to wait for a permanent agreement among Nordic TSOs. [33].

The replacement of the remaining FCR and aFRR is handled through the manual part of FRR, mFRR. It is the main balancing resource and in the long run, keeps the frequency at the nominal value. The Nordic system is highly dependent on mFRR activations because of the limited volume of aFRR and the possibility of congestions in the grid; therefore, it is expected to act as the main balancing resource in the system. [18]. For comparison, Table II shows the size of the different reserves in Sweden [34], [35].

C. Time-Shift Regulation

On March 1$^{\text{st}}$, 2013, new requirements were introduced for BRPs to re-plan their production if the change of production plan in Sweden between two hours exceeds 200 MW. The requirement was a Nordic decision and harmonization and a step towards improved frequency quality. The re-planning applies to the entire production change and happens per price area. The start and stop of the units are distributed evenly on the basis of the unit's physical conditions between 15 min before the hour shift to 15 min after the time shift [36]. Fig. 3 graphically depicts the operation of this regulation. However, this regulation will be terminated by the time the 15-minutes market time unit is launched.

D. Fast Frequency Reserve (FFR)

With the accelerating application of renewable energy resources, the low-inertia incidents in the power systems have been increased. Also, the current reserve products are not fast enough to respond to fast enough to low-inertia situations. To address this problem, Nordics TSOs have launched FFR from June 1, 2020 [37].

IV. Future of the Nordic Balancing Market

In 2019, the Nordic TSOs have released a draft roadmap for the future of the Nordic Balancing Model (NBM), containing several market reforms [38] which are summarized in Table III and briefly introduced in the following subsections.

TABLE I
BALANCING MARKET SPECIFICATIONS FOR FREQUENCY RESERVE PROCUREMENT IN NORDIC COUNTRIES[22]

	Variable	Sweden [23]–[25]	Norway [26]	Denmark [27]	Finland [28]–[30]
FCR-N, FCR-D	Procurement Scheme	Market	Hybrid	Market	Market
	Minimum Bid	0.1 MW	0.1 MW	0.1 MW	0.1 MW
	Capacity Provider	Generators	Generators	Generators+Battery+Loads	Generators
	Symmetrical Product	Symmetrical (FCR-N)	Unsymmetrical	Unsymmetrical	Symmetrical (FCR-N)
	Pricing	Pay as bid	Regulated pricing	Marginal pricing	Regulated pricing
	Cost recovery agent	Grid user and BRPs	BRPs	Grid user	grid user and BRPs
	Gate Closure Time(GCT)	16:00 D-2 18:00 D-1	Weekly 18:30 D-1	15:00 D-2 18:00 D-1	Yearly 18:30 D-1
aFRR	Procurement Scheme	Market	Market	Hybrid	Market
	Minimum Bid	5 MW	5 MW x 10 MW	1 MW	5 MW
	Capacity Provider	Generators	Generators	Generators+Battery+Loads	Generators
	Symmetrical Product	Unsymmetrical	Unsymmetrical	Symmetrical	Unsymmetrical
	Pricing	Pay as bid	Marginal pricing	Pay as bid	Pay as bid
	Cost recovery agent	Grid user and BRPs	Grid user	Grid user	Grid user
	Gate Closure Time(GCT)	Weekly auction	Weekly auction	9:30 D-1	17:00 D-1
mFRR	Procurement Scheme	Market	Market	Market	Market
	Minimum Bid	10 MW (5 MW in SE4)	1 MW	5 MW	10 MW
	Capacity Provider	Generators+Loads	Generators+Loads	Generators+Loads	Generators+Loads
	Symmetrical Product	Unsymmetrical	Unsymmetrical	Unsymmetrical	Unsymmetrical
	Pricing	Marginal pricing	Marginal pricing	Marginal pricing	Pay as bid
	Cost recovery agent	Grid user and BRPs	Grid user and BRPs	Grid user	Grid user and BRPs
	Gate Closure Time(GCT)	One hour ahead	45min before delivery	9:30 D-1	13:00 D-1

Market: market-based procurement, Hybrid: partially mandatory and partially market based procurement.
Grid user: The natural or legal person supplying to, or being supplied with active and/or reactive power by a TSO or DSO.
Regulated pricing: Price for this service is based on a price that is set by the relevant regulatory authority.

TABLE II
TECHNICAL REQUIREMENTS ON RESERVE PRODUCTS

	FCR-N	FCR-D	aFRR	mFRR	FFR
Activation type	Automatically at frequency deviation 49.9-50.1 Hz	Automatically at frequency < 49.9 Hz	Automatically if frequency deviate 50 Hz	Manually at SVK	Stepwise 49.7 Hz 49.6 Hz 49.5 Hz
Activation time	63 % within 60 s and 100 % within 3 min	50 % within 5 s and up to 100 % within 30 s	100% within 120 s	Within 15 min	Stepwise 1.3 s 1.0 s 0.7 s
Volume	600 MW (237 MW for Sweden)	1450 MW (573 MW for Sweden)	300 MW (150 MW for Sweden)	Upon Request	200-300 MW

A. Cross-Border aFRR Capacity Market

One of the main targets of Nordic TSOs is to establish a Nordic cross-border aFRR capacity market. They predict an accelerated need for automation of all parts of the balancing process. Achieving this goal, an increased volume of aFRR capacity plays a crucial role to have updated balancing process. Cross-border capacity reservation is a prerequisite for acquiring an effective regional aFRR capacity market, which would bring considerable socio-economic benefits to the Nordic market [1]. One of the main advantages of providing common Nordic aFRR capacity procurement with daily dynamic reservation of transmission capacity between bidding zones as well as cross-border activation, is to increase the availability of balancing resources. This will lead to more flexibility in the Nordic power system. The new Nordic balancing concept will also introduce the option for market participants to submit voluntary aFRR bids close to real-time [39].

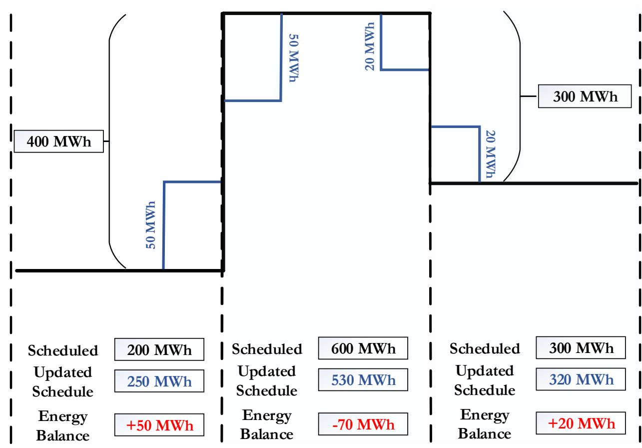

Fig. 3. Illustration of an exemplary time-shift schedule

B. Cross-Border mFRR Capacity Market

The same principle as aFRR capacity market will be applied to the Nordic mFRR capacity market. Due to the dependency on the ongoing regulatory process for aFRR capacity market, the exact timeline for a common Nordic mFRR capacity market realization is uncertain. It should be noted that the mFRR capacity market does not have a core impact on the development process of other milestones on this road map. Therefore, the TSOs will provide a preliminary timeline for the mFRR capacity market which needs to be updated further when the result of the regulatory process for the aFRR capacity market is known [40].

TABLE III
FUTURE TRENDS IN THE NORDIC BALANCING MARKET

Trend	Aim	Additional note
Nordic aFRR Capacity Market	Establishing Nordic cross-border aFRR Capacity Market	Bring socio-economic benefits for NBM
Nordic mFRR Capacity Market	Establishing Nordic cross-border mFRR Capacity Market	Not correlated to other trends
Single Price Model	Establishing one single imbalance settlement price	May cause power oscillations in system imbalance
15 minutes time resolution	Reducing market time unit to 15 minutes	Increases the maximum allowed ramping on HVDC interconnectors Decreases the total hourly imbalance
mFRR Energy Activation Market	Determining the mFRR per bidding zone (instead of total Nordic) Providing necessary automation for 15 minutes time resolution	Prerequisite before joining MARI
aFRR Energy Activation Market	Activation of aFRR based on merit order	mACE based calculation Prerequisite before joining PICASSO
Transparency	Publishing balancing and market data to the EU platform	

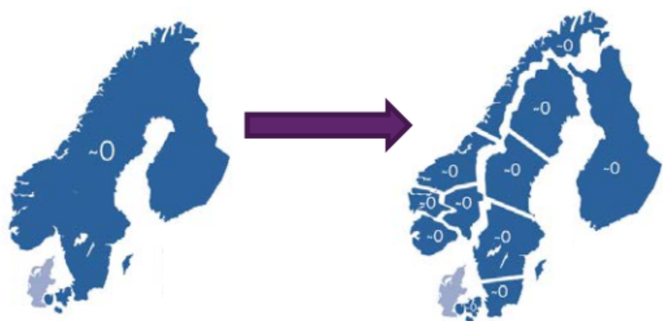

Fig. 4. Frequency regulation vs. mACE [1]

C. 15-minutes time resolution

A transition from 1 hour to 15-minutes market interval requires significant changes, from metering to processing and communication infrastructure. The reasons for a market with 15-minutes time resolution include lower demand for reserve capacity, better optimization of reserve power, reduced deterministic imbalance, wider access to balancing, day-ahead and intraday markets, and increase in the maximum allowed ramping on the HVDC interconnectors out of the synchronous area. The first decision is to implement a 15-minutes imbalance settlement period (ISP) and then extend to day-ahead, intraday, and reserve markets. The current go-live status of the 15-minutes ISP is planned for May 22$^{\text{nd}}$, 2023 [41].

D. Modernized Automatic Control Error (mACE)

Currently, the goal of TSOs is to minimze the area control error (ACE) in the entire Nordics as a whole by using aFRR and mFRR, see left side of Fig. 4. The NBM roadmap aims to minimize the imbalance on a smaller geographic area, i.e., the error in each price area individually, see right side of Fig. 4. This new method is called modernized ACE (mACE). This concept is already used in Continental Europe since it better represents network constraints and allows for cross-border activation of imbalance netting. Furthermore, better control of imbalance per price area increases accountability per price area and harmonization with the rest of Europe [1].

E. mFRR Balancing Process Automation

In the current mFRR setup, the TSO manually activates the required mFRR capacity. In the new approach, based on the forecasted imbalance, each TSO will determine the demand for mFRR in each price area on a 15-minutes market interval. These changes should be aligned with MARI, the European platform for mFRR energy activation [38].

F. aFRR Energy Activation Market

Currently, aFRR is activated pro-rata based on the joint Nordic ACE. Pro-rata means that all BRPs activate aFRR simultaneously to make sure that aFRR is activated in a distributed fashion across all price areas. In the future, aFRR will be activated based on the energy bids in merit order. The observed system imbalance in each price area (mACE) determines the volume of the activated aFRR energy. The mACE in each area is the input to the controllers of participating generators and the required aFRR is the output. The Nordic TSOs within ENTSO-e are establishing a European platform for the exchange and activation of balancing energy. The goal is to trade and activate aFRR on this pan-European aFRR energy activation market [42] called PICASSO.

G. Data and transparency

The *Guideline on Electricity Balancing* and Transparency Regulation [2] states that TSOs will publish balancing and market data to the ENTSO-e Transparency Platform to increase the transparency and incentivize competition and innovation. This is a prerequisite to facilitate the automation of aFRR and mFRR markets.

V. SUMMARY

System operators have the option to trade balancing reserves among countries and operators. In order to trade balancing reserves with other system operators the markets should be harmonized. While the spot and intraday markets are already harmonized within the Nordics, the balancing markets still display differences. We have performed a survey on the Nordic balancing market rules to provide an overview for those who want to carry out research in this context. This overview can help energy modelers to represent the market rules and framework in more detail into their tools, since many of the practical implementations are only available in the national language of the respective TSO.

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