NBM
Nordic Balancing Model

SVENSKA KRAFTNÄT ENERGINET FINGRID Statnett

Memo Algorithm description

Nordic mFRR EAM bid selection

NBM
Nordic Balancing Model

Content

1 Introduction

The purpose of this document is to describe the bid selection algorithm for the Nordic mFRR Energy Activation Market (EAM). The document provides information particularly to market participants, so they can develop new bidding strategies and join the go-live of mFRR EAM automated operation.

The Nordic mFRR EAM is developed and will be implemented as a part of the Nordic Balancing Model (NBM) programme. Automated operation is the first step for the Nordic markets to prepare for joining the common European market for the exchange of mFRR on the MARI platform. The Nordic mFRR EAM platform is built respecting the same key principles as MARI, though differences exist. The principles are described in the mFRR Implementation Framework and the Explanatory document, an implementation of the Electricity Balancing Guideline (EBGL). An algorithm description is made public by the MARI project. The MARI algorithm document describes in further detail, e.g., the mathematical model: "MARI Activation Optimization Function - Public Description" is located: Manually Activated Reserves Initiative (entsoe.eu)

It is assumed that the reader has understanding of the activation types and the mFRR EAM product (bid) (including differences between standard and non-standard products), as described in the previously published document "Memo - process for activating products in mFRR Energy Activation Market". For detailed information on the bid attributes, see Annex A - Bids.

This document covers activation processes for normal and for fallback situations. It describes the mFRR activation process and the bid selection algorithms along with their inputs and outputs, objectives, constraints, and their priorities.

In addition, national differences to the processes, bid attributes or bid selection algorithms will be noted in this document. As this document is a common Nordic document, it does not go into detail on local TSO matters and may not contain all local TSO differences.

Main changes from bid selection in the existing regulating power market

There are several changes from the existing bid selection done by the TSOs prior to the go-live automated operation. To summarize, the main changes are:

- Automatic bid selection instead of manual bid selection.
- Support for new bid attributes (to make the automatic bid selection possible).
- Bid selection each 15 minutes.
- Available transmission capacities (ATCs) based on market capacities. Today manually assessed physical capacities are used in the balancing time frame.
- Counter activations (matching of a bid with other bids) will happen when it increases the social welfare:

- This can result in opposite activation even when there is available transmission capacity for netting.
- Activation in both directions in the same bidding zone is also allowed by the bid selection algorithm. The use of day-ahead price as a floor and cap for the mFRR bid price, will limit this.

2 mFRR activation process

There will be three mFRR activation processes in the Nordic synchronous area and bidding zone DK1. Two processes occur every 15 minutes and one is incident triggered. The regular processes are the scheduled activation process and the period shift process. The period shift process will only be used in Norway. The incident-triggered process is direct activation.

Scheduled activation is the main process to handle imbalances. This is illustrated in Figure 1. TSOs receive bids from balancing service providers (BSPs) in their imbalance area[1] (1) and forward the bids to the mFRR platform (2) along with the TSOs' balancing energy demands, the mFRR requests (4). TSOs also communicate the available mFRR transmission capacity (cross border capacity limits - CBCL) and other network constraints (3) to the common platform.

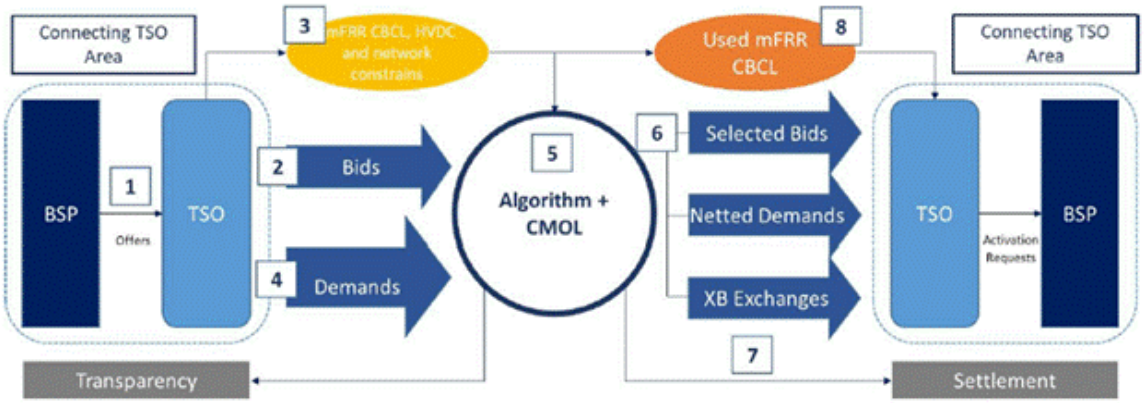


Figure 1 - Scheduled activation process

For scheduled activation, the bid selection method on the common platform is the Nordic Activation Optimization Function (AOF) (5). In general, an optimization problem aims to maximize (or minimize) an objective function, such as the maximization of social welfare, while typically being constrained by a set of limits. The AOF aims to cover the mFRR request by taking multiple objectives into account, while being constrained by the bid attributes, network constraints and other algorithm-related constraints. Bids that maximize (or minimize) the objective(s) and satisfy the constraints ought to be selected

[1] In the Nordic schyncronous area an Imbalance area equals biding zone.

by the solving algorithm. For more details on the optimization method, please refer to chapter 3.2.

Finally, the accepted bids, satisfied mFRR request, clearing prices, and cross border schedules are communicated to the TSOs, and the TSO then sends activation requests to the BSPs (6). Settlement is done (7) and the remaining CBCL is sent to the TSOs (8).

The direct activation process utilizes a stepwise rule-based method for the bid-selection. It differs from use of AOF in how the selection is done and how close the selection will be to an optimal result. For more details on the rule-based method, please refer to chapter 3.3.

2.1 General info on mFRR activation processes

2.1.1 Scheduled activation process

The scheduled activation (SA) process runs every 15 minutes and uses the Nordic Activation Optimization Function (AOF) to select bids for an upcoming 15-minute period. When the Nordic TSOs connect to MARI, the Nordic AOF will be replaced with MARI. Scheduled activation can be described as a proactive process since the mFRR request, determining the activated volumes in the AOF, is based on an imbalance forecast made by each TSO.

2.1.2 Direct activation process

The direct activation is a local process and will not be part of the Nordic Activation Optimization function. The direct activation (DA) process will mainly handle incidents in the power system, but it can also be used if scheduled activation is not sufficient to handle the imbalance. Scheduled activation and direct activation are different when it comes to initiation and duration. Because direct activation is incident triggered, it can be described as reactive. In addition, full activation (delivery at full capacity) of direct activation will always start in one quarter hour and continue into the next quarter hour.

Bid selection for direct activation will be a rule-based bid selection. It will use the remaining bids after scheduled activation that BSP has made available for direct activation.

When the Nordic TSOs connect to MARI, MARI will be the primary solution for bid selection also for direct activation process.

2.1.3 Period shift activation process

The period shift activation process is used in Norway to handle structural imbalances around quarter shifts. The process will run every 15 minutes after the scheduled

activation bid selection. The bid selection method used, is rule-based selection in the local TSO solution. It takes into account the remaining bids after scheduled activation that are available for period shift, which is indicated in the bid attributes. The period shift volume is calculated for each bidding zone based on the rest imbalance after the mFRR request, and bids are selected from the relevant control area.

2.1.4 Fallback processes

In addition to the normal processes, the mFRR activation processes for scheduled activation have fallback solutions. The fallback solution for scheduled activation is bid selection in local TSO systems. There are two levels of fallback. In 1st level fallback energy exchange between control areas will automatically be continued. In 2nd level fallback there will not be any energy exchange between control areas unless it is bilateral (manually) agreed.

2.2 Input

2.2.1 Bids

Bids are sent from the BSPs to their relevant TSO. The bids have attributes to ensure that physical limitations on BSP assets are not violated and that BSPs can set bid prices according to their bidding strategy.

The bid attributes are necessary since the automated bid selection process occurs every 15 minutes and there is little or no time for BSPs to continuously update their bids due to previous activations. As there is no manual assessment on the bids before sending them to the AOF, all the limitations of the BSPs assets must be described by using the bid attributes, which the algorithm can interpret. Detailed description of bids attributes can be found in Annex A - Bids.

2.2.2 mFRR request

The mFRR request is calculated by each TSO for each bidding zone based on the local TSO's imbalance forecast. The imbalance forecast aims to forecast the difference between consumption and export, and production and import for each bidding zone. The mFRR request is inelastic meaning that the entire volume shall be covered as long as there are available bids and available transmission capacity. The exception is Tolerance band, see chapter 3.2.1.

2.2.3 Available Transmission Capacity (ATC)

The ATC is the transmission capacity that will be available for the bid selection algorithms. The term CBCL (cross border capacity limits) is used in MARI documentation instead of ATC.

Each TSO calculates the ATC for all its interconnectors. For each interconnector between TSOs there will be two values for each direction, of which the lowest will be the limiting ATC. The calculations are based on the trade capacity (remaining capacity after day-ahead and intraday) as well as possible technical/system constraints. The operators can manually adjust the ATC if it is needed for system security reasons.

The ATC is sent as input to the bid selection algorithms ahead of every scheduled run each 15 min.

2.2.4 Master data

There is some master data used by the bid selection solutions. The main data is:

- Bidding zones and bidding zone connections.
- Technical profiles – used for sum restriction of total flow or ramping. E.g., sum of flow from NO2 and NO5 to NO1 is restricted by setting a capacity on NO1A to NO1 that is less than the sum of capacity for NO2-NO1/NO1A and NO5-NO1/NO1A.

2.3 Pre-processing input to the AOF

Each TSO will pre-process the bids from their BSPs. Pre-processing consists of changing the availability of certain bids for the bid selection processes. This is done based on the information from the BSPs (through the attributes set by the BSPs) (chapter 2.3.1) or based on assessments from the TSO (chapter 2.3.2). Some TSOs perform also further pre-processing based on national bid attributes (chapter 2.3.3).

The purpose of the pre-process is to make sure that bids sent to the AOF, if selected, can be activated by the BSP and that activation of the bid will not cause incidents in the grid.

2.3.1 Determining bid availability based on the BSP attributes

The bid attributes listed below, set by the BSPs, are processed by all TSOs in the following ways:

Attribute	Pre-processing outcome
Activation type (SA only or SA + DA)	If a bid is marked as 'SA only' (scheduled activation only), the TSO will change its availability to unavailable for DA (direct activation).
Conditionally linked bid	If a bid is conditionally linked, its availability depends on the activation or non-activation of specific bids in the two previous quarter hours (QHs). The TSO will change its availability if the condition is fulfilled.

Attribute	Pre-processing outcome
Technically linked bid	If a bid is technically linked to another bid in the previous QH, and this bid was used for direct activation, the TSO will change the bid availability to unavailable.

2.3.2 Marking bids unavailable for AOF due to TSO needs

Bids can be marked as unavailable for bid selection by each TSO due to different causes. These can include, for example:

- Internal congestions for operational security:
  - Bids that cannot be activated due to internal congestions.
  - Bids that are activated to solve internal congestions.
- National non-standard products:
  - If a bid does not fulfil the requirements for standard products (non-standard products).
- BSP unavailability:
  - BSP electronic availability (based on response to heart-beat signal). The use of this feature will differ between TSOs.
  - On request from BSPs after BSP gate closure time (GCT) – due to technical reasons.

Bids received from a BSP that do not follow the implementation guide will be rejected by the TSO. The BSP will be informed about the rejection and the reason for rejection. Rejected bids will not be further processed be the TSO. The BSP needs to correct and resend them.

2.3.3 TSO-specific pre-process

The national bid attributes are attributes that each TSO has individually decided whether they will apply or not.

Attribute	Pre-processing outcome	Supported by
Maximum duration	If a resource/bid has been activated for the maximum duration, the next bid for that resource (same technical link and maximum duration) will be marked as unavailable on the upcoming QH for the bid selection algorithm.	Statnett, Svenska kraftnät, Energinet
Resting time	If a bid has been deactivated, the next bids with the same technical link and resting time will be unavailable to the bid selection algorithm until the given resting time has passed.	Statnett, Svenska kraftnät, Energinet
Inclusive bid	Bids in an inclusive bid group are merged to one bid before sent to the AOF.	Statnett, Fingrid[2]

[2] Fingrid allows usage of ”Inclusive bids” attribute in some occasions only.

Attribute	Pre-processing outcome	Supported by
Slower activation time	Reserves with an activation time longer than the FAT[3] must fill out the 'activation time' attribute. It will then be made unavailable to the AOF. Activation of slower reserves will be done outside the AOF in case of, e.g: • A lack of standard mFRR bids (Energinet).	Energinet
Locational information	A bid with specified detailed locational information can be: • Activated outside the bid selection algorithm to solve an internal congestion if it is placed in a relevant location. • Marked as unavailable for the bid selection algorithm if an activation of that bid could cause a grid congestion.	Statnett, Svenska kraftnät, Energinet, Fingrid
Faster activation	Bids with this attribute will be used as ordinary bids in the scheduled activation process. The attribute for faster activation is used in pre-processing for direct activations in situations where fast system regulation is needed.	Statnett
Period shift	The attribute is used in pre-processing for period shift bid selection. Bids with this attribute can be selected for normal scheduled or direct activation.	Statnett

Based on the national bid attributes, further pre-processing is done by the TSOs applying them. See sub-chapters below for other TSO-specific pre-processes.

The other bid attributes (Minimum offered volume, Indivisible Bids, Exclusive Group and Multipart) are handled by the bid selection algorithm.

2.3.3.1 Energinet

Covered in the table above.

2.3.3.2 Fingrid

The disturbance reserve power plants are not available for the AOF. Activation is done locally for system reasons after all market-based mFRR reserves have been activated.

[3] For Automated Operation full activation time (FAT) = 12,5 min.

2.3.3.3 Statnett

Operational disturbance reserves

Statnett will allow flexible reserves that do not fulfil the requirements for the mFRR standard product to still be available for activation outside of the AOF. These reserves will submit bids marked with mFRR-D or "non-standard, other" mFRR bids and give information on how they do not fulfil the standard product. The bids will be activated manually and only in situations with operational disturbances or when the reserves for normal imbalances have been exhausted.

Guaranteed volumes

Guaranteed volume (GV) allows a TSO to guarantee a volume of bids to be available for direct activation. TSOs can specify a volume for each of its LFC areas. The most expensive direct activatable bids corresponding to this volume will be kept unavailable for scheduled auction. After scheduled auction the bid volume is released and made available for direct activation. This attribute will not be used by any TSO at go live mFRR EAM.

2.3.3.4 Svenska kraftnät

The disturbance reserve (Störningsreserven) is not available for the AOF. Activation is done locally in case of disturbance after all market-based mFRR bids have been activated.

2.4 Output

The following is output from the AOF bid selection:

- Selected bids:
  - The selected bids, given by their activation volumes.
- Covered mFRR request:
  - Satisfied and unsatisfied mFRR request for each bidding zone that has participated in the bid selection.
- Cross border flow:
  - Cross border flow for each bidding zone connection where there will be exchange of energy due to the bid selection result.
- Prices:
  - Cross border marginal prices for each bidding zone that has participated in the bid selection.

3 mFRR EAM Bid Selection Algorithms

3.1 Introduction

Bid selection can be done by the Nordic Activation Optimization Function (AOF) or by using a rule-based bid selection. The method depends on the activation process, as previously described. A cross border marginal price will be calculated for each bid selection run. If there have been several bid selection runs during an MTU, the activation and imbalance prices for the MTU will be calculated based on all bid selection runs done for that MTU. Direct activation will only impact the marginal price in the control area for which the activation was made, reason for that is direct activation being a local process.

3.2 Algorithm in the Nordic AOF

The algorithm in the Nordic AOF performs the optimization with given objectives subject to given constraints. The objectives and constraints are described in detail further below. On a high level, the algorithm seeks to satisfy the inelastic mFRR request and maximize social welfare. The top priority of the AOF is to satisfy the inelastic mFRR request. The AOF performs optimization for a given 15-minute period only.

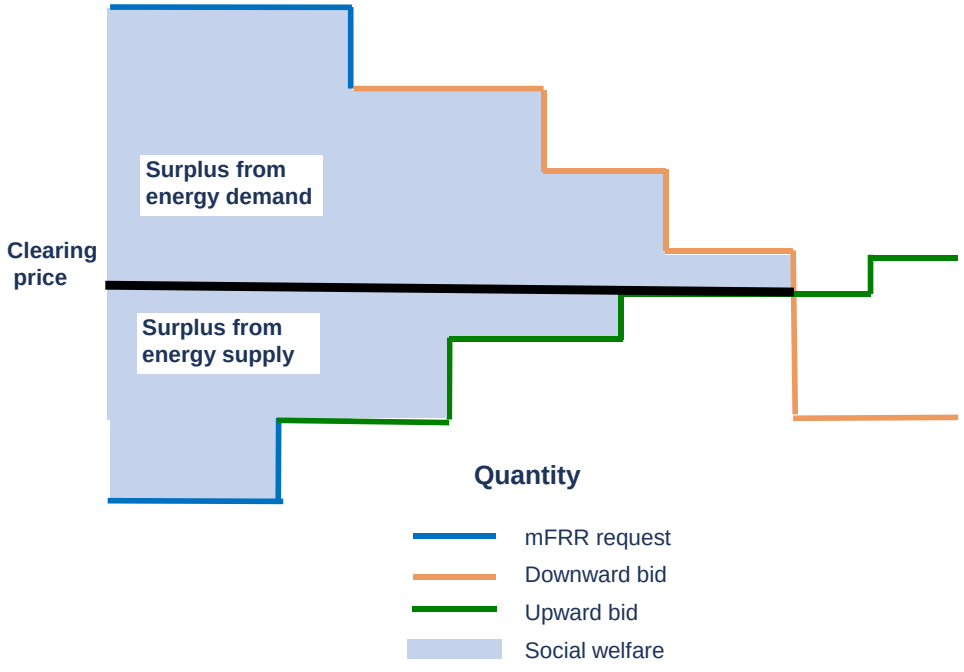
The optimization algorithm searches the solution space for the best feasible solution until some stopping criterion is met. The algorithm will first find a solution that satisfies mandatory conditions. Then it searches for other solutions that better satisfy the objective function. The stopping criteria can be that the optimal solution is found or that the available time is used.

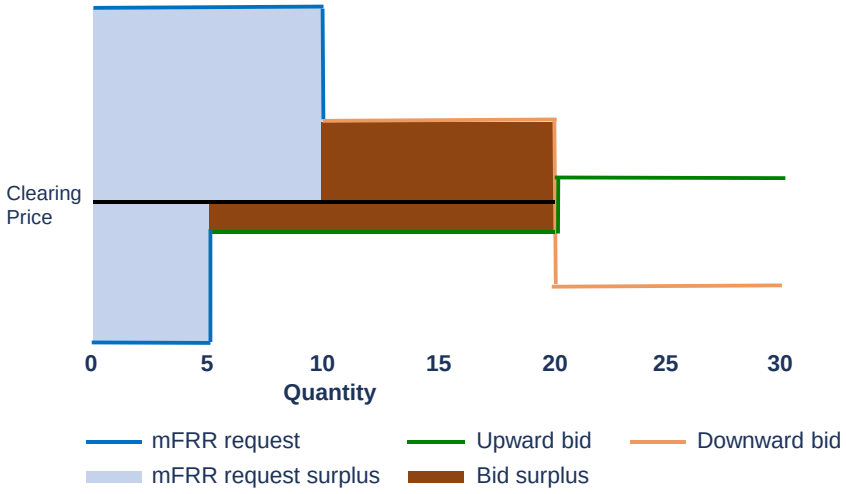
The algorithm in AOF is formulated as a Mixed Integer Linear Programming (MILP) problem.

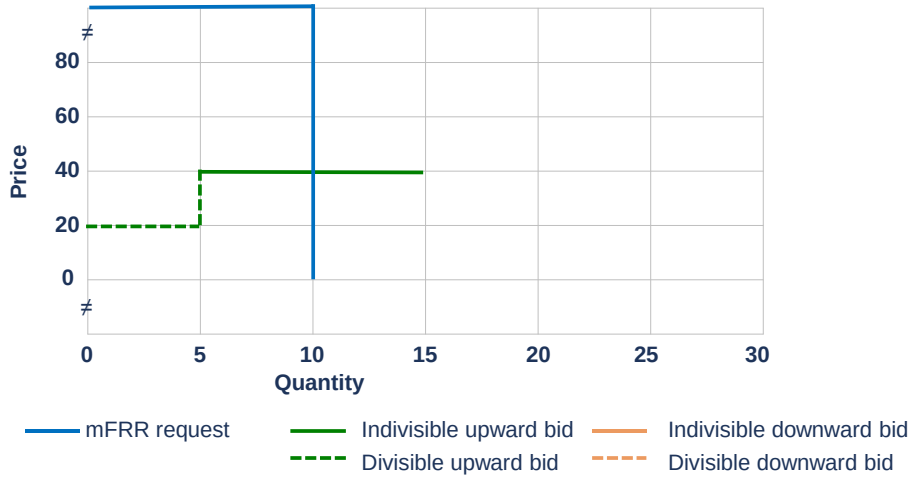
The objectives and constraints are described in detail in the following subchapters.

3.2.1 Objectives (soft constraints)

Rule	Comment
Maximize satisfied mFRR request	*Purpose*: If there are available bids (and available transmission capacity) the mFRR request will always be covered. To ensure this, if all optimization objectives cannot be fulfilled, there is an extra penalty if the mFRR request is not covered. *Enforcement*: Optimization objective to maximize the satisfied mFRR request.

Rule	Comment
	Consequence: As much as possible of the mFRR request is covered, even if other objectives are not met.
Maximize social welfare	*Purpose*: One of the main objectives of the optimization. The maximization of satisfied mFRR request has the highest priority followed by the maximization of social welfare. *Enforcement*: Optimization objective to maximize the social welfare. Economic surplus (social welfare) is the total benefit available to society from an economic transaction. It is made up of the light blue area in Figure 2, which is the sum of surplus from energy demand and energy supply. Surplus from energy demand is the difference between what TSOs and BSPs are willing to pay and the market clearing price (positive TSO mFRR request and downward BSP mFRR bids). Surplus from energy supply is the difference between the price TSOs and BSPs require to "produce" and the market clearing price (negative TSO mFRR request and upward BSP mFRR bids). For an inelastic mFRR request, the mFRR economic surplus cannot be determined (in theory infinite value), as the mFRR request must be satisfied at any cost. For implementation purposes, a price will always be assigned, but for an inelastic mFRR request, this price will be higher than any mFRR bid.  Figure 2 - Social welfare

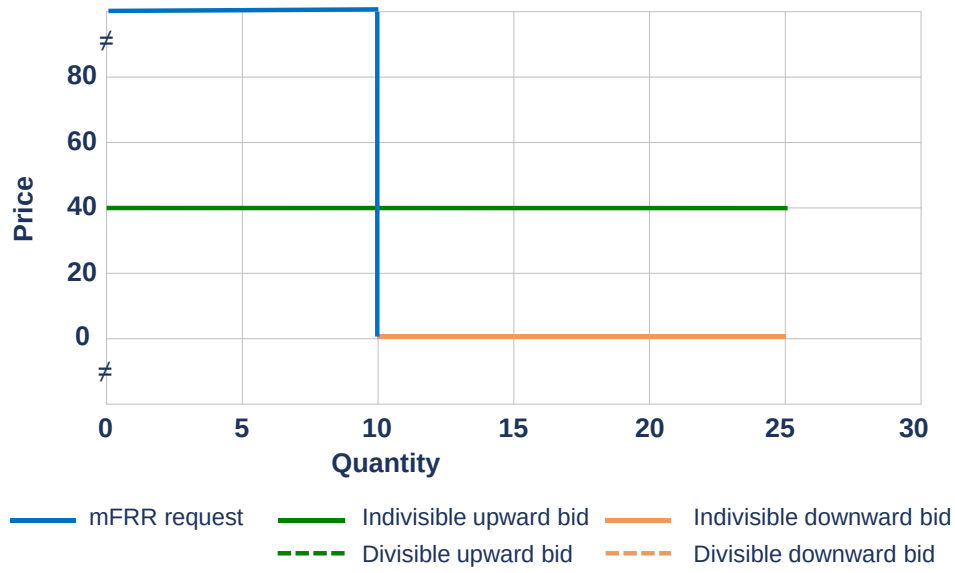
Rule	Comment
	In energy markets social welfare can also be calculated as the sum of bids and mFRR request surplus. mFRR request surplus is the product of the covered quantity with the difference between the "mFRR request price" and the market clearing price. Bid surplus is the product of the accepted quantity with the difference between the bid price and the clearing price. This is illustrated in Figure 3.  Figure 3 – mFRR request and bid surplus
Minimize unforeseeable rejected bids (URBs)	*Purpose*: Minimize the rejection of bids that are in-the-money, i.e., unforeseeable rejected bids (URB). URBs are bids that are not selected even though the clearing price is higher than the URB bid price (for upward bid). *Enforcement*: Optimization objective to minimize URBs without reducing satisfied mFRR request. *Consequence*: There can be URBs. *Illustrative example:* If avoiding URBs had been a hard constraint, then the mFRR request in Figure 4 would not have been satisfied. Since the rule is to minimize URBs, the solution in the example will be that the indivisible upward bid of 10 MW and price 40, will be selected to satisfy mFRR request of 10 MW. The divisible bid of 5 MW and price 20 will be unforeseeably rejected.

Rule	Comment
	 Figure 4 - Minimize URBs
Minimize cross border flows	*Purpose*: The bid selection will prioritize mFRR request satisfaction by bids in the same area as the mFRR request. *Enforcement*: Optimization objective to minimize cross border flows without changing the fulfilment of other optimization objectives. *Consequence*: If two potential solutions to the optimization give the same result for the optimization objective, the result with least cross border flows will be used.
Maximize traded volumes	*Purpose*: If different volumes can be accepted, the selection will prioritize highest traded volume. Traded volume is the sum of accepted quantities of bids and mFRR request. *Enforcement*: Optimization objective to maximize accepted quantities of bids and mFRR request without changing the fulfilment of other optimization objectives. *Consequence*: There can be two potential solutions with the same social welfare. This can happen if there is an upward bid and a downward bid with bid prices equal to the clearing price, and these bids can't be used to cover mFRR request or bids that are in-the-money. Given this rule, upward and downward bids with bid prices equal to clearing price will be selected as long as no other rule is violated.
Minimize tolerance matching	*Purpose*: The tolerance band is a parameter of the mFRR request submitted by a TSO that reflects the willingness of the TSO to satisfy a higher\lower volume of mFRR demand than requested with the submitted upward\downward demand, if this would increase the

Rule	Comment
	mFRR social welfare. Use of tolerance band increases the mFRR social welfare and leads to more intuitive prices. *Enforcement*: Tolerance matching is defined as matching of quantities from a bid with a need for tolerance band of opposite direction. Tolerance matching is minimized during the first step of the clearing algorithm. This is done by applying a penalty to tolerance matching quantities. *Consequence*: Increase social economic welfare by avoiding unforeseeable rejected bids due to remaining demand being just below minimum activation volume of one or several bids which is next to be selected from the CMOL. Avoid "outliers" in market result.

3.2.2 Hard constraints

Rule	Comment
Prevent unforeseeable accepted bids (UABs)	*Purpose*: The optimization algorithm shall not select unforeseeable accepted bids (UAB). UABs are bids that are accepted even though the clearing price is less than the bid price (for upward bid). *Enforcement*: Hard constraint, must be fulfilled. *Consequence*: If all objectives can't be met unless there are UABs, this rule has the priority. Therefore, it is better to not fulfil all objectives (e.g., mFRR request satisfaction or social welfare maximization) than to have a UAB. *Illustrative example:* There is an upward mFRR request of 10 MW, an indivisible downward bid of 15 MW and price 0, and an upward indivisible bid of 25 MW and price 40. The solution will be that no bid is activated, and the mFRR request is not satisfied. The reason is that if the indivisible upward bid had been accepted, the indivisible downward bid would also need to be activated to have energy balance. Then one of the activated bids would be out-of-the-money. The upward bid is out-of-money if the price is less than 40 and the downward bid is out-of-money if the price is higher than 0. Since the price can't satisfy both constraints and the prevention of UABs is a hard constraint, no bid is activated, and the mFRR request is not satisfied. This is illustrated in Figure 5.

Rule	Comment
	 Figure 5 - Prevent UABs
Prevent adverse flows	*Purpose*: Avoid activating bids in a bidding zone where the marginal price is higher than the marginal price in the bidding zone with the mFRR request. *Enforcement*: Hard constraint, must be fulfilled. *Consequence*: If all objectives can't be met unless there are adverse flows, this rule has priority. Therefore, it is better to not fulfil all objectives (e.g., mFRR request satisfaction or social welfare maximization) than to have adverse flows.
Enforce price convergence	*Purpose*: The market clearing price of the two connected bidding zones shall be equal when there is no congestion. *Enforcement*: Hard constraint, must be fulfilled. *Consequence*: If all objectives cannot be met unless there are different prices for two bidding zones without congestion, this rule has priority.

3.2.3 Other rules

Rule	Comment
Minimize distance to price target	*Purpose*: In case of price indeterminacy (there are multiple price solutions) the clearing engine needs rules to determine prices. *Enforcement*: The clearing engine defines price targets and minimizes the sum of squared distance between the clearing price and the associated price target over all bidding zones. *Consequence*: The method of computing the price targets is aimed towards achieving equal and fair treatment of the market participants. *Illustrative example:* The bid selection has satisfied mFRR request of 5 MW and matched downward bid of 5 MW with price 60, with an upward bid of 10 MW and price 30. To determine the price in this case the following limits to the price are determined: • The price must be less than 60, or else the selected downward bid would be out-of-the-money. • The price should be less than 50, or else the rejected upward bid would be in-the-money and we try to minimize URBs. • The price must be higher than 30, or else the selected upward bid would be out-of-the-money. • The price should be higher than 0, or else the rejected downward bid would be in-the-money and we try to minimize URBs. This give us a potential price range between 30 and 50. The price target is set to the middle point and the clearing price will be 40. This is illustrated in Figure 6.

<table>
<tr><th>Rule</th><th>Comment</th></tr>
<tr><td></td><td> 

Figure 6 - Minimize distance to price target</td></tr>
<tr><td>Prioritize fully divisible bids</td><td>Purpose: If multiple equivalent solutions exist in terms of volumes the clearing engine needs rules to select a solution.

Consequence: Following priority rules are used:
1. Fully divisible bids have priority over other bids.
2. Among fully divisible bids, the acceptance ratio should be the same for all such bids.

Illustrative examples:
For all cases:
• There is a positive mFRR request of 100 MW to be satisfied
• All bids have the same bid price

<table>
<tr><th></th><th colspan="2">Case 1</th><th colspan="2">Case 2</th></tr>
<tr><th></th><th>Offered MW</th><th>Selected MW</th><th>Offered MW</th><th>Selected MW</th></tr>
<tr><td>Divisible bid 1</td><td>100</td><td>50</td><td>0</td><td></td></tr>
<tr><td>Divisible bid 2</td><td>80</td><td>40</td><td>40</td><td>24</td></tr>
<tr><td>Divisible bid 3</td><td>20</td><td>10</td><td>10</td><td>6</td></tr>
<tr><td>Indivisible bid 1</td><td>70</td><td>0</td><td>70</td><td>70</td></tr>
<tr><td>Indivisible bid 1</td><td>30</td><td>0</td><td>30</td><td>0</td></tr>
</table>

These priority rules are only used when equivalent solutions exist in terms of volumes. In case 2 there is no solution where only divisible bids can be used, so to satisfy all mFRR request, indivisible bid 1 must be selected. For the remaining 30 MW, the prioritize bid rules are used.

Priority rule for indivisible bids:</td></tr>
</table>

Rule	Comment
	Given mFRR request of 100 MW in bidding zone 1, and the following indivisible bids (all in bidding zone 1): • Bid 1 price: 120, volume: 90 MW • Bid 2 price: 120, volume: 90 MW • Bid 3 price: 120, volume: 90 MW 90 MW of the mFRR request will be covered. AOF will select a bid randomly when there are multiple available indivisible bids with same price and volume.

3.3 Rule-based bid selection

The rule-based bid selection method is somewhat simpler than the bid selection supported in Nordic AOF, but the goal is that the bid selection result to a large extent should be the same. The rule-based selection is used for direct activation and as a fallback for scheduled activation.

3.3.1 Direct activation

When selecting bids for direct activation, the mFRR request for one bidding zone is covered at a time. So even if there is mFRR requests for direct activation for more than one bidding zone, the mFRR request is covered for one bidding zone at a time. Since direct activation is a local solution within each TSO (prior to joining MARI), mFRR request for direct activation will be satisfied by direct activation bids within the same control area.

The rule-based solution will in price order (from the least expensive to the most expensive) evaluate if a bid can be used to cover direct activation mFRR request, given ATC between bidding zones with the mFRR request and connecting bidding zones for the bid. Bids with the same price will be evaluated in random sequence.

3.3.2 Fallback solution for scheduled activation bid selection

When selecting bids for scheduled activation there are mFRR requests for several bidding zones that shall be covered in the bid selection process.

Before bids are used to cover the mFRR request, it will be evaluated whether mFRR requests from different bidding zones with opposite direction can be netted, respecting ATC between bidding zones.

The rule-based bid selection solution will in price order (from the least expensive to the most expensive) evaluate if a bid can be used to cover mFRR requests, given ATC between bidding zone with mFRR requests, and connecting bidding zone for the bid.

The method will evaluate one bid at a time whether the bid can cover the mFRR request for one and one bidding zone in sequence, until the bid volume is fully used to cover mFRR request, or until all bidding zones are evaluated.

The rule-based bid selection will not support counter activations.

To reduce the complexity of rule-based bid selection for scheduled activation (that covers the mFRR requests from several bidding zones), only one bid from each exclusive bid group will be taken into the bid selection process. The bid with the largest volume will be included in the bid selection process.

The steps in the fallback bid selection for scheduled activation for TSOs with several bidding areas.

- Netting of mFRR request
    - Netting of mFRR requests, respecting ATC.
- Cover mFRR requests with bids within the same bidding zone
    - The rule-based bid selection might have a separate step where the mFRR request is covered for a given bidding zone with bids from the same bidding zone. The selection of bids will be restricted to bids that would have covered the total mFRR request if there were no capacity limitations on balancing energy exchange.
- Cover the remaining mFRR request with bids from all participating bidding zones.

3.3.3 Price determination

In the rule-based bid selection there will not be price indeterminacy. Price indeterminacy can only happen if the bid selection solution supports elastic mFRR requests and/or counter activation. Therefore, the price determination is not similarly complex in the rule-based bid selection solution.

Cross border marginal prices are calculated for each bid selection run. Bidding zones that are part of the same uncongested area will receive the same cross border marginal price with the exception that direct activation only impacts the control area for which the activation was made.

3.4 Period shift

The period shift activation process will only be used by Statnett

Period shift activation needs are aggregated per control area and covered by bids from all bidding zones in the control area. Bids are selected in price order until sum of selected bids is equal to the sum of period shift activation needs. There were in the beginning of the mFRR EAM project a potential plan for Svenska kraftnät to use period shift but Svenska kraftnät has decided to keep the process and requirement for BRPs to limit production changes to less than 200 MW between MTUs (details can be found in the national BRP agreement).

4 Annex A - Bids

4.1 Common Nordic bid attributes

	Bid attribute	Description
Simple bids One bid, one price	Minimum offered volume	Can be applied to set a minimum volume to be activated even though the bid is divisible.
	Indivisible Bids	Bid which cannot be activated partially.
Complex bids Combination of simple bids	Exclusive Group Order	Group of bids where solely one of the bids can be activated.
	Multipart (Parent/child)	Group of bids that must be activated in strict price order, from less expensive to more expensive.
Bids linked in time Between consecutive quarter hours	Technical linking	Linking of bids in subsequent quarter hours to indicate that two bids belong to the same underlying asset. This link can ensure that a bid in QH0 is not available for clearing if the bid in the previous quarter hour was activated in direct activation
	Conditional linking	Linking of bids in two or three subsequent quarter hours to consider the activation outcome in preceding quarter hours QH-1 and/or QH-2.
Activation type	SA only or SA + DA	If a bid is marked as 'SA only' (scheduled activation only), the TSO will change its availability to unavailable for DA (direct activation).

4.2 Simple bids

Simple bids are valid for one quarter hour and have one quantity and one price.

A simple bid can be fully divisible, divisible, or indivisible. The differences are illustrated in Figure 7.

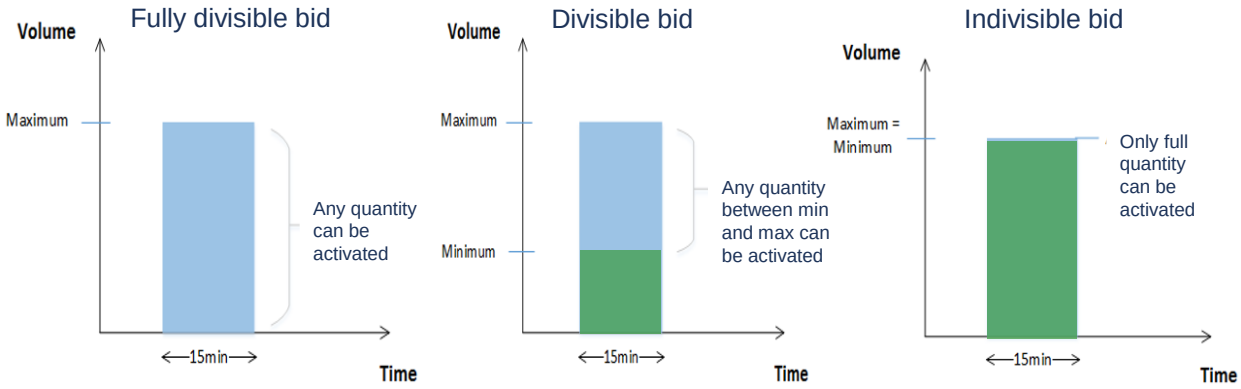


Figure 7 - Simple bids

4.3 Complex bids

Complex bids are combined simple bids either as multipart bid or as exclusive group order bid.

4.3.1 Multipart bid

As illustrated in Figure 8 a multipart bid is activated in strict price order, activating the cheapest bid first. All bid components must:

- Have same direction and activation type.
- Have different prices.
- Belong to the same quarter hour.

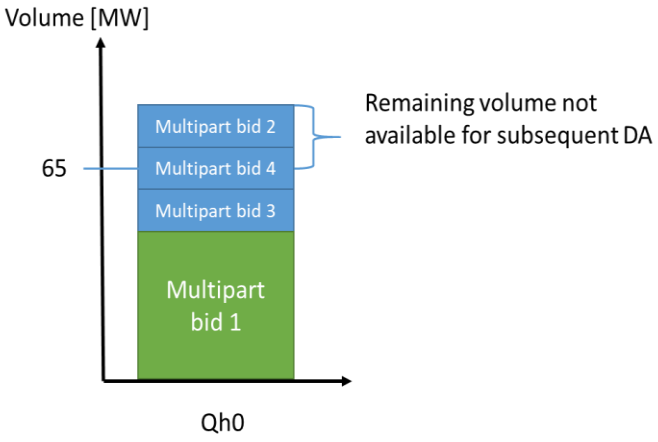


Figure 8 - Multipart bid

4.3.2 Exclusive group of bids

Only one bid in an exclusive bid group can be activated. All bid components must:

- Have same activation type.
- Belong to the same quarter hour.

Example:
If there is a start-up cost of 200 EUR and a marginal cost of 10 EUR/MW, an exclusive bid group with indivisible bids could be:

QH	Bid	Price (EUR/MW)	Volume (MW)
QH1	bid a	30	10
QH1	bid b	20	20
QH1	bid c	17	30
QH1	bid d	15	40

4.4 Bids linked in time

Bids can be linked in time, but only back in time. This is because the AOF does not look ahead, but only solves the coming 15-minute period. If bid is linked in time, linking must be attached to the bid by the BSP using the relevant bid attributes.

4.4.1 Technical linking

Technical linking indicates that bids in two consecutive quarter hours belong to the same underlying asset. A bid selection solution will not activate a bid if it has a technical link with a direct activated bid in the preceding quarter hour. Technical linking is allowed for both simple and complex bids.

Direct activations last until the end of the next quarter hour. To avoid double activation, it is necessary that the BSP links bids for which the underlying asset is the same.

Example:
If bid A is direct activated in QH0 it will also be activated in QH1. Consequently, bid B will not be available for scheduled activation in QH1, see Figure 9.

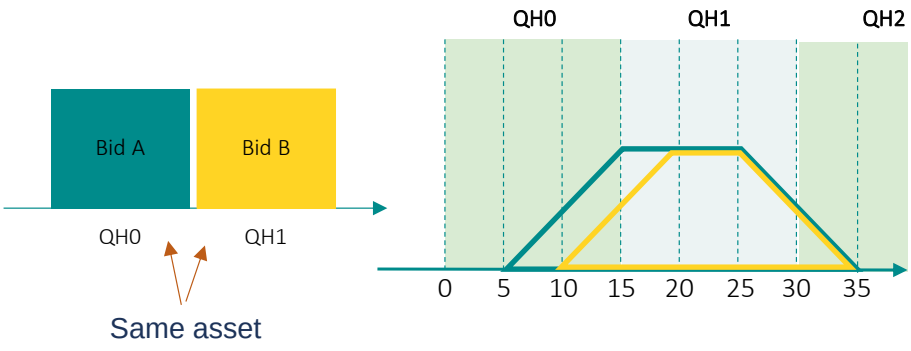


Figure 9 - Technical linking

4.4.2 Conditional linking

Conditional linking can be used in several cases, e.g.:

- To avoid activation that due to ramping is not possible.
- To model start-up cost across quarter hours.

Avoid activation that due to ramping is not possible

Direct activation in next quarter hour may conflict with ramping constraints. BSP must use conditional linking to avoid "impossible" ramping. In Figure 10 bid A is scheduled activated in QH0. The ramp down extends into QH1. Direct activation of Bid B requires the underlying asset to ramp up while ramping down.

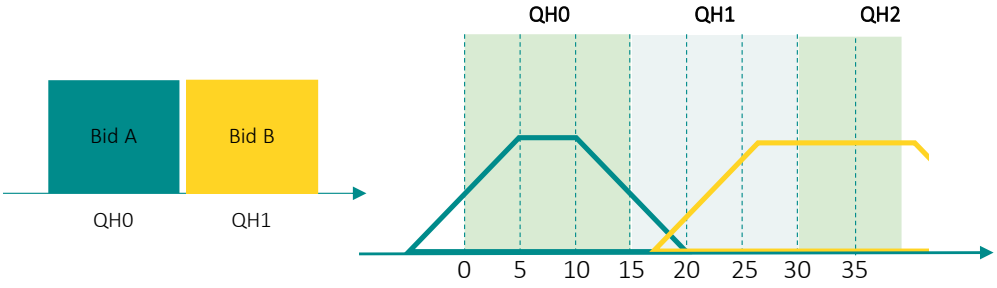


Figure 10 - Conditional linking

In Figure 11 bid A is direct activated in QH0. The ramp down extends into QH2. Direct activation of Bid B requires the underlying asset to ramp up while ramping down.

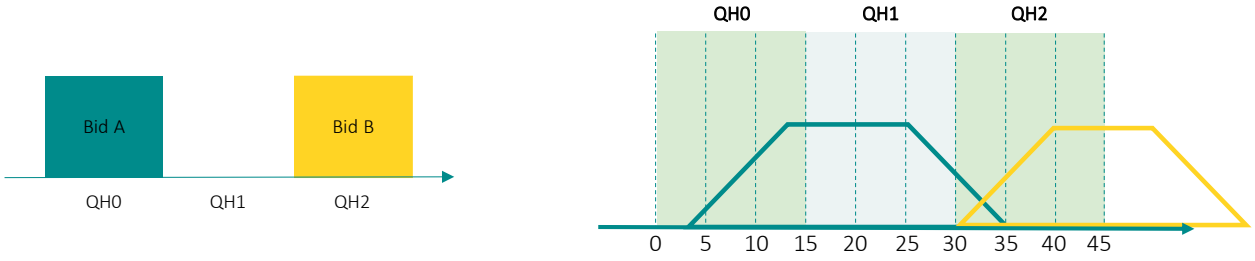


Figure 11 - Conditional linking

In Figure 12 the ramp from upward x MW to downward –x MW requires twice the ramping speed as required for Bid A and Bid B. If the underlying asset is not able to fulfil the faster ramping curve, conditional linking should be used.

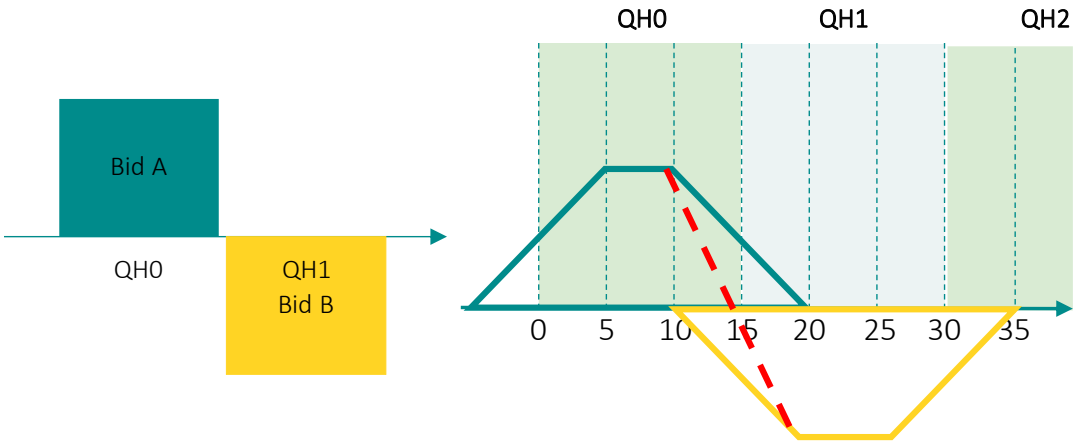


Figure 12 - Conditional linking

Model start-up cost across quarter hours

If the activation of a resource in one quarter hour impacts the price in the next quarter hour, conditional linking can be used.

QH	Bid	price	Bid available if and only if
QH1	bid a	50	
QH2	bid b	50	Bid a not activated
QH2	bid c	40	Bid a activated
QH3	bid d	50	Bid b and c not activated
QH3	bid e	40	Bid b or c activated

4.5 National bid attributes

Bid attribute	Description	Supported by
Resting time	The BSP can add information on the required minimum duration between the end of deactivation and the following activation.	Statnett, Svenska kraftnät, Energinet
Maximum duration	BSPs include information on the technical limitations regarding how long a resource/bid can be activated. This attribute is necessary to allow BSP to send in bids in advance so that they do not need to update bid if they are activated.	Statnett, Svenska kraftnät, Energinet

Bid attribute	Description	Supported by
Inclusive bids	If one bid is activated, another bid (e.g., a resource downstream) must also be activated.	Statnett, Fingrid[4]
Locational information	More detailed location on where the resources in the bid are situated, than bidding zone (e.g., on station level).	Statnett, Svenska kraftnät, Energinet, Fingrid
Slower activation time	Indicate activation time that is longer than standard FAT[5]. The attribute indicates that the product is non-standard and cannot be activated through Nordic AOF. **Bids with this attribute will only be activated locally.**	Energinet
Faster activation	Indicate a possible activation time that is shorter than 12,5 min. Faster activation will only be used for direct activation and only to handle grid problems. Bids with this attribute can also be selected for normal scheduled or direct activation. **Faster activation will only be asked for when activating manually.**	Statnett
Period shift attribute	Indicate that the bid can be used for Period Shift. The bid can be selected for activation for only the start of or the end of the quarter hour. Bid selection for period shift will be done after the AOF and will therefore not affect the bid selection in the AOF. Bids with this attribute can also be selected for normal scheduled or direct activation. Use of period shift will replace the use of the existing products "kvartersflytting".	Statnett

4.5.1 Resting time

The BSP can add information on the required minimum duration between the end of quarter hour where deactivation start, and the following activation. Technical linking of the bids must be in combination with this bid attribute. All the linked bids must have the same resting time.

[4] Fingrid allows usage of ”Inclusive bids” attribute in some occasions only.

[5] For Automated Operation full activation time (FAT) = 12,5 min

In Figure 13 bids A, C and D are in the money in the particular QH. Bid B is not in the money and is not selected for activation. Bids are ”technically linked”. Resting time is set to 30 min for all four bids. The right part of the illustration shows the resulting activation.

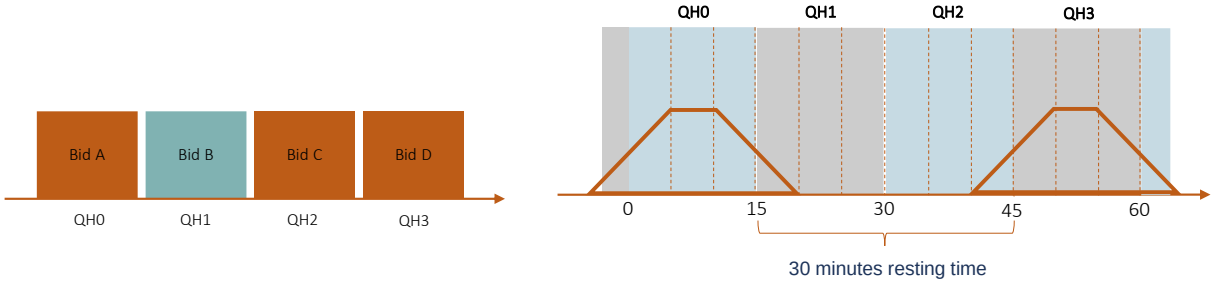


Figure 13 - Resting time

4.5.2 Maximum duration

BSPs can include information on the technical limitations regarding how long a resource/bid can be activated. If a BSP would like to send in bids in advance, this attribute is necessary so that they do not need to update their bid if they are activated. Technical linking of the bids must be used in combination with this bid attribute. All the linked bids must have the same maximum duration.

In Figure 14 all four bids are in the money in the particular QHs. Bids are ”technically linked” and Maximum duration is set to 30 min for all four bids. Resting time is set to 15 min for all four bids. The right part of the illustration shows the resulting activation.

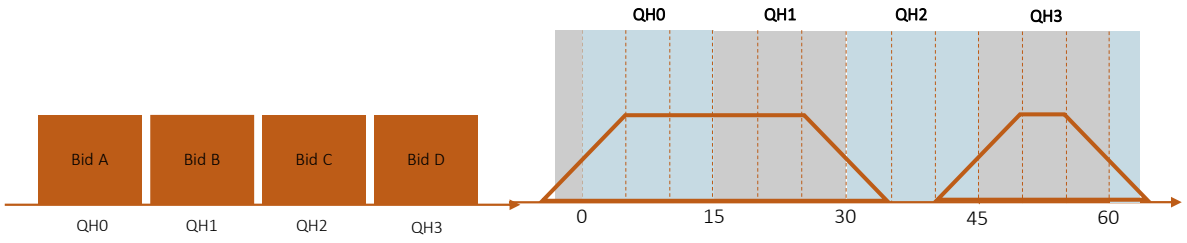


Figure 14 - Maximum duration

4.5.3 Inclusive bids

If one bid in an inclusive bid group is activated, another bid (e.g., a resource downstream) must also be activated.

In Figure 15 bids A and B are inclusive bids and bids C and D are inclusive bids. All four bids are in the money in the particular QH. Bid B is unavailable for activation due to e.g., an internal congestion.

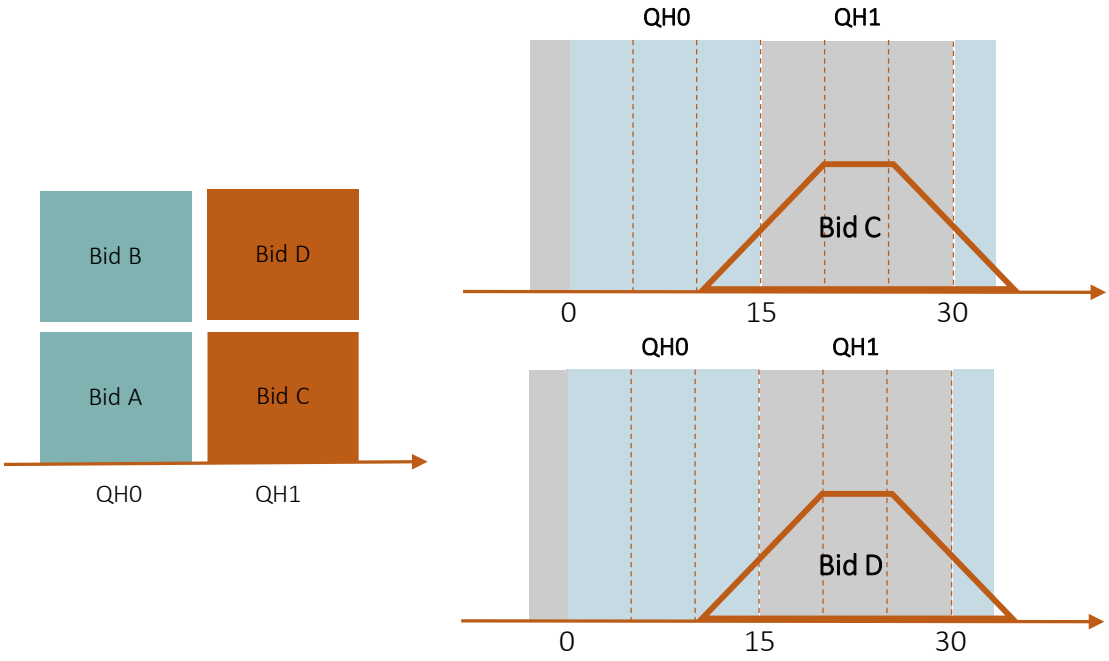


Figure 15 - Inclusive bids

5 Annex B Glossary

Terminology	Abbrev.	Description
Activation optimization function	AOF	Solution used to select bids to cover mFRR request, respecting (amongst others) available transmission capacity between bidding zones.
Adverse flow		A positive flow through an interconnector is *adverse* when the Delta-P of the interconnector in the flow direction is negative, *i.e.,* when the flow goes from an area with higher market clearing price to an area with lower market clearing price.
Available Transmission Capacity	ATC	Capacity limits on interconnectors. The term CBCL (cross border capacity limits) is used in MARI documentation instead of ATC.
Balancing bid or offer		A balancing bid (or offer) is a set of technical and financial conditions under which the BSP makes a proposal to the mFRR energy activation market to change its production or consumption. A balancing bid may either be upward or downward. Upward is increased production or decreased consumption and downward is vice versa.
Balancing Service Provider	BSP	Market actor who is able to supply or demand electricity for the purpose of balancing the power system.
Bid surplus		When a bid is accepted, the bid surplus is the product of the accepted quantity with the difference between the bid price and the clearing price. For in-the-money bids, the surplus is positive.
Common merit order list	CMOL	Bids sorted in price order.
Congestion		Interconnector congestion is identified by remaining capacity equal to zero. Together with diverging prices on each side of the interconnector, such situation leads to a positive congestion rent (import price * import flow - export price * export flow). There can also be congestion within a bidding zone, these do not impact bid selection directly, but can be the cause of a bid being marked as unavailable.
Control area		An area consisting of all bidding zones within a synchronous area where one TSO is responsible.
Counter-activations		A counter-activation corresponds to the matching of a bid with other bid(s).

Terminology	Abbrev.	Description
Cross border capacity limits	CBCL	Capacity limits on interconnectors. The term CBCL is used in MARI documentation. In this document ATC (Available Transmission Capacity) is used.
Cross-border		Indicative of a flow from a bidding zone to another.
Direct activation	DA	Direct activation
Electricity Balancing Guideline	EBGL	Electricity Balancing Guideline
Energy Activation Market	EAM	Energy Activation Market
Full activation time	FAT	Full Activation Time
Guaranteed volume	GV	Guaranteed Volume
Interconnector flow (or flow)		In the present documentation, a flow always refers to the energy flow due to mFRR activations. Interconnector flows considered in the optimization module do not take into account energy flow due to other coupling markets or exchange mechanisms.
In-the-money / Out-of-the-money / At-the money		In simplified terms, a supply (resp. demand) bid or elastic mFRR request is said to be: a) in-the-money if its price is lower (resp. higher) then the clearing price, b) Out-of-the-money if its price is higher (resp. lower) then the clearing price, c) At-the-money if its price equals the clearing price.
Market Clearing Price		Price determined by the clearing engine at which power is traded within the market.
Market Time Unit	MTU	The period for which the market price is established or the shortest possible common time period for the two bidding zones, if their market time units are different.
mFRR request		Calculated activation needed to balance the transmission system. Upward mFRR request represents a lack of energy and is satisfied by activating upward bids. Downward mFRR request represents an excess of energy and is satisfied by activating downward bids.

Terminology	Abbrev.	Description
mFRR request surplus		When an mFRR request is covered, the mFRR request surplus is the product of the covered quantity with the difference between the mFRR request price and the market clearing price. For in-the-money mFRR request, the surplus is positive.
Nordic Balancing Model	NBM	Nordic Balancing Model programme
Price convergence		Price convergence between two bidding zones is achieved when there is at least one connecting interconnector that is at-the-money.
Quarter hour	QH	Quarter hour
Scheduled activation	SA	Scheduled activation
Social welfare		The social welfare is the sum of mFRR request surplus and bids surplus.
Unforeseeable accepted bid	UAB	An unforeseeable accepted bid is an accepted bid that is out-of-the-money.
Unforeseeable rejected bid	URB	An unforeseeable rejected bid is a rejected or partially accepted bid, that is in-the-money.