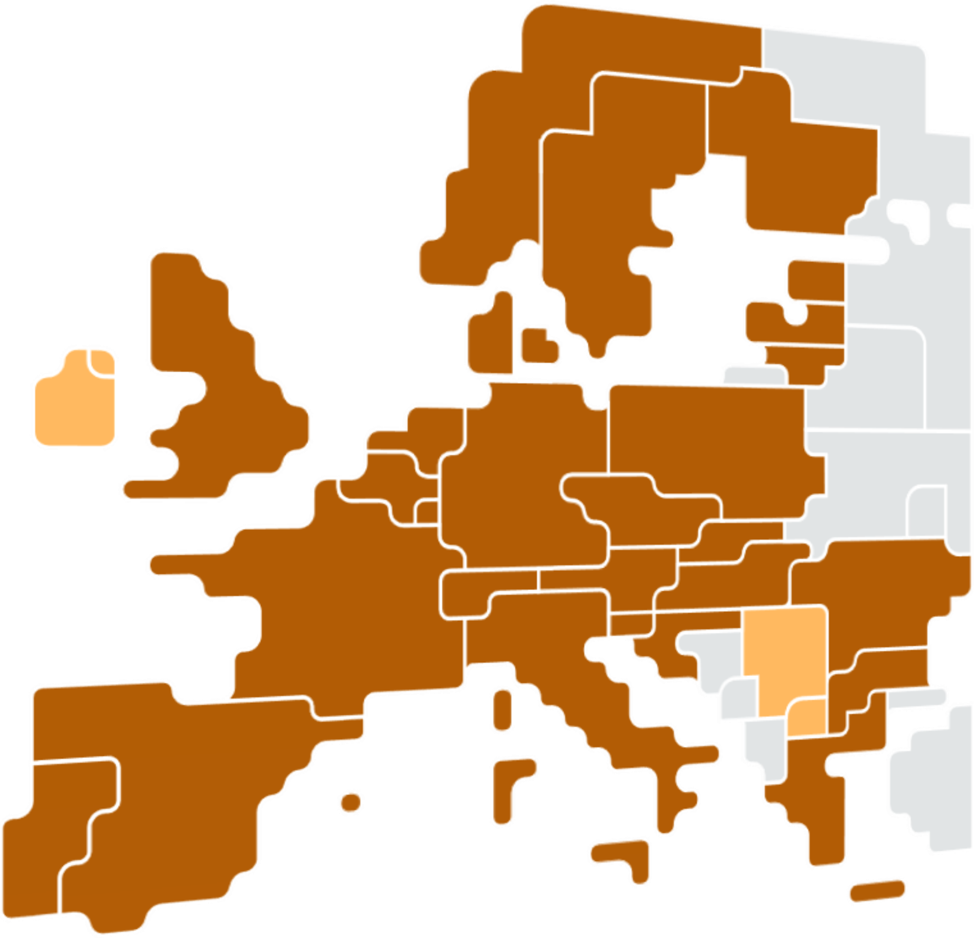
MARI

MARI Activation Optimization Function Public Description



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Content

1. INTRODUCTION

Manually Activated Reserves Initiative (MARI) is the European project for the creation of the European Manual Frequency Restoration Reserve (mFRR) platform. The platform is implemented according to the Electricity Balancing Guideline (EBGL) approved by the Electricity Cross-Border Committee on March 16th, 2017.

The Manual Frequency Restoration Reserve is a balancing reserve, activated by TSOs in order to restore the electricity system's frequency to its nominal value. mFRR services are provided by Balancing Service Providers (BSPs). mFRR is traded as a standard product which must be capable of being fully activated within 12.5 minutes, with a minimum duration of 5 minutes at full activation capacity. The MARI platform enables TSOs to activate the most cost-efficient set of mFRR bids to meet their needs, while considering constraints linked with the availability of networks to exchange these reserve products.

This document presents the Activation Optimization Function (AOF) of the MARI platform. The AOF processes the bids submitted by BSPs and optimizes the mFRR bids activation while abiding by all market rules of the balancing market.

The MARI platform is an ambitious project involving more than **30 European TSOs** that will be connected to the platform in order to purchase their mFRR activations.

Additional information can be found on the webpage for Members of the MARI project: https://www.entsoe.eu/network_codes/eb/mari/

The MARI platform is based on the LIBRA platform that has been implemented for Replacement Reserves (RR) in the TERRE project. The MARI platform consists in (i) a data management platform (Libra Data Management), handling communications and data exchanges with TSOs and ENTSO-E, pre-processing, postprocessing and archiving, and (ii) an optimization module (AOF) optimizing the activations and computing Cross Border Marginal Prices (CBMP).

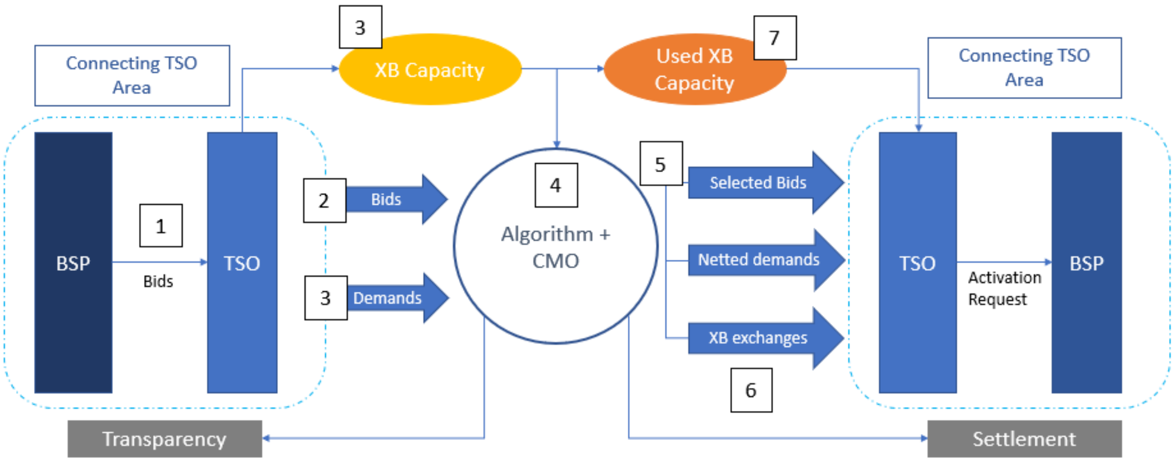


Figure 1: LIBRA platform processes

1. TSO receive bids from BSPs in local market balance area
2. Forward of coherent mFRR balancing products to mFRR platform
3. TSOs communicate their balancing demands and the available XB transmission capacities (ATC)
4. Optimization of the clearing of balancing demands against BSPs bids
5. Communication of the accepted bids, satisfied demands, and prices

6. Calculation of the commercial flow between market balancing areas and settlement of the expenditure and revenues between TSOs
7. The resulting XB schedules and remaining ATC are sent to the TSOs

This document is organized as follows:

- Section 3 presents a high-level description of the market and its particular organization,
- Section 4 describes the market rules over the power system network,
- Section 5 introduces the mFRR market bids and demands,
- Section 6 presents the CBMPs, and
- Section 7 provides a description of the MARI AOF implementation, and of the optimization models and workflows.

2. MFRR MARKET: HIGH-LEVEL DESCRIPTION

Manually Activated Reserves Initiative (MARI) is common European platform for the exchange of mFRR products between TSOs. The main purpose of the platform's Activation Optimization Function (AOF) is to select the best set of activations (bids submitted by BSPs and netting of simultaneous activation demands in opposite directions) in order to cover TSOs' mFRR demands and optimize the economic surplus.
In this section, main characteristics of the mFRR market will be described with the description of the different activation types and the physical characteristics of mFRR products. Details on the market model will be provided in the next sections.

2.1. mFRR market

The main purpose of the mFRR market is to organize and optimize the exchange of balancing activations between TSOs. Thanks to market coupling mechanisms, simultaneous TSOs demands in opposite directions can be netted, and balancing energy bids can be exchanged between scheduling areas provided there is enough Cross Zonal Capacity (CZC) to allow for such exchanges to materialize. BSPs, on their side, benefit from market coupling as they gain access to a larger market and therefore have a higher chance to be activated for competitive bids.
The Market Time Unit (MTU) period, which is the period for which bids submitted by participating TSOs and market prices are established, is 15 minutes. For each MTU period, there is a single gate closure after which no more bids are accepted. Subsequently, several types of activation can be run:

- One Scheduled Activation (SA) as first clearing at T-10 min
- Several Direct Activation (DA) launched successively between T-10 min and T+5 min

The properties of these two types of activations are described in the next section. During each process, the market is cleared considering the available bids and the TSOs demands.
As the allocated time between the data collection and the activation time is short (less than 2 minutes for the SA processes and less than 1 minute for DA processes), the MARI platform is required to perform the different processes extremely efficiently:

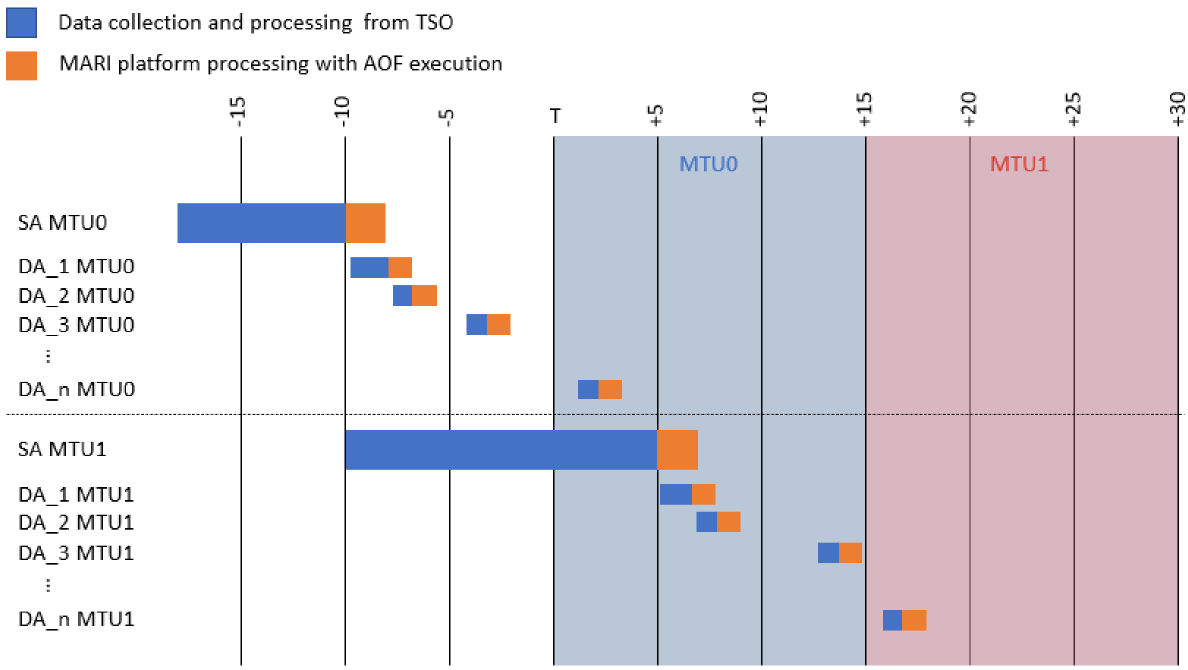


Figure 2: Example of MARI execution

In order to perform the activations optimization and compute CBMPs, the time devoted to the optimization to provide the set of selected bids and demands is 60 seconds for scheduled activations and 15 seconds for direct activations.

2.2. Activation types

MARI AOF can handle two different activation type. These correspond to different processes that uses the same MARI AOF algorithm with slightly different input. These two types are described in more detailed in the following sections.

2.2.1 Scheduled activations

Scheduled activations (SA) are typically used to de-saturate activated aFRR bids or alternatively to handle forecasted imbalances proactively depending on the TSO's balancing strategy. Upward and downward bids and positive and negative demands are included in scheduled activations clearing. The netting of simultaneous demands in opposite directions can therefore be executed in SA if there is enough cross-border capacity available. In contrast to direct activations, the timing of SA clearings and activations is known in advance so that a full MTU period will be always covered by the activations.
The Scheduled Activation is the first process that is run for each MTU period. All available bids that have been received by the MARI platform are taken into account during the clearing as well as TSO demands, in both directions. This process is the one where the activation volume is expected to be the highest, meaning that it is the most time-consuming computation for the MARI platform to perform.

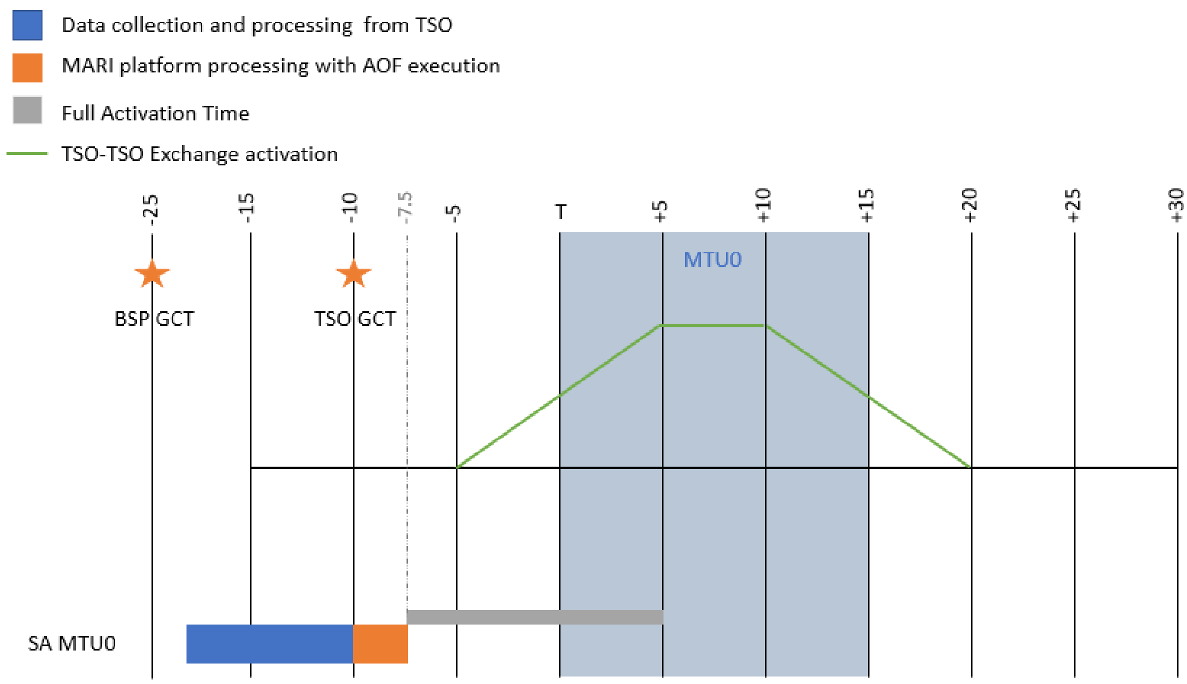


Figure 3: Scheduled Activations

The *Figure 3: Scheduled Activations* illustrates the timing and the activation of a specific bid that has been accepted during a Scheduled Activation process for a particular MTU period. First, BSP bids are received up until the BSP gate closure time at T-25 min, and processed by TSOs. Then, each TSO computes their own demands including elastic and inelastic demand. At T-10, all bids and demands have been submitted to MARI platform, this is the TSO gate closure time and the clearing of the associated activation run can be triggered. The market clearing is performed within 60 seconds and activations and CBMPs are returned. The market clearing information is then transferred to BSPs at T-7.5 which will ramp up or down according to the activation direction within 12.5 minutes. The TSOs exchange the trapezoidal shape, with full delivery / power exchange between T+5 and T+10.

2.2.2 Direct activations

In addition to Scheduled Activations, Direct Activations (DA) are required to perform further activations when imbalances occur between two scheduled activations. DA allows to activate mFRR bids at any point in time when an unexpected imbalance occurs.

Direct Activations are run after the Scheduled Activation for the same MTU period. Only TSO demand from one direction is considered per direct activation, and only the remaining bids, available for DA and in the same direction as the demands are considered.

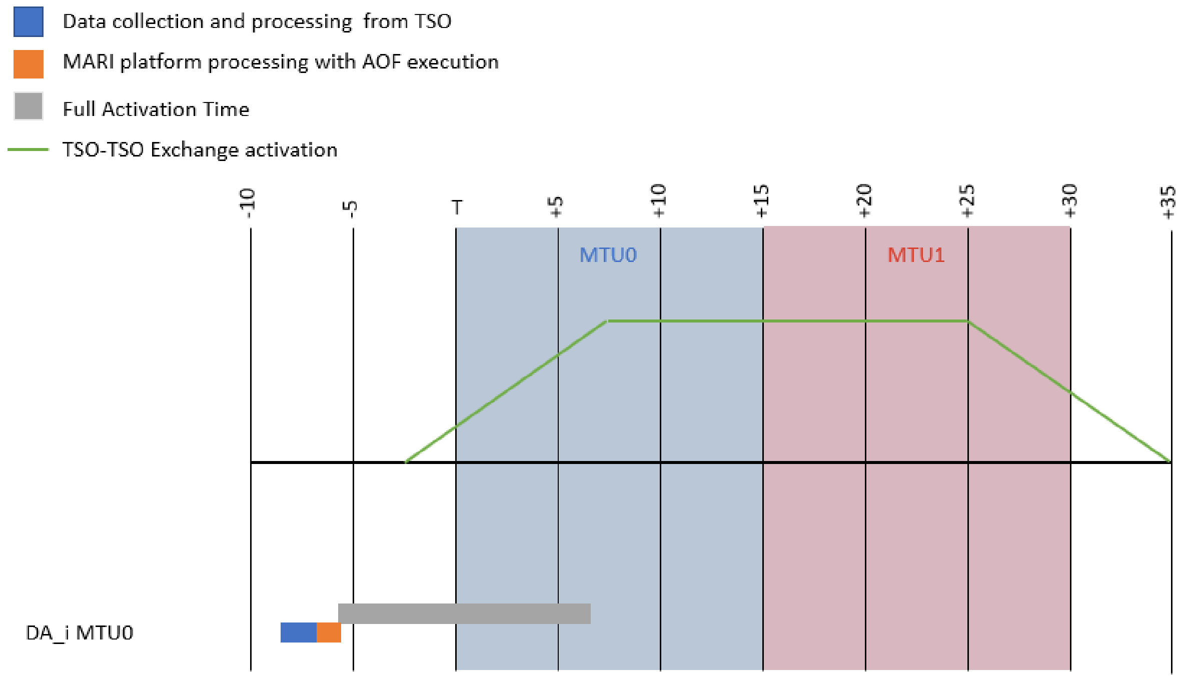


Figure 4: Direct Activation

The *Figure 4: Direct Activation* illustrates the timing and the activation of a specific bid for a direct activation. After T-10 min, TSO may submit a demand to trigger one Direct Activation where all bids eligible for DA and not activated in the previous activation run of the same MTU period can be used. The clearing is performed within 15 seconds. Depending on the timing of the DA process, information is transferred to BSPs between T-7.5 min and T+7.5 min, and the bid duration last with the end of the SA run of the next MTU period (MTU 1).

2.3. mFRR Products

2.3.1 mFRR balancing energy bids

The balancing energy bids are submitted by BSPs to with the following features:

- **Minimum and maximum quantity [MW]**: it refers to the change of power output (in MW) which is offered by the BSP and which is reached by the end of the full activation time;
- **Direction**: upward bid for power injection to the system, downward bid for power withdrawal from the system;
- **Price of bid [€/MWh]**: minimum (resp. maximum) activation price for the submitted upward (resp. downward) bid
- **Location of bid:** Scheduling area
- **Validity period**: MTU period for which the balancing energy bid offered by the BSP can be requested for activation

Additionally, the BSPs have to make sure when submitting a bid that they will be able to respect specific delivery conditions regarding the following delivery characteristics:

- **Preparation period**: the period between the activation request by the TSO and the start of the ramping period;
- **Ramping period**: the period of time after the preparation period during which the input and/or output of active power is being increased or decreased;

- **Full activation time (FAT)**: period between the activation request by the TSO and the corresponding full delivery of requestion MW power of the balancing energy product. The FAT is equal to the sum of the preparation period and the ramping period;
- **Minimum and maximum duration of delivery period**: period of time during which the BSP delivers the full requested change of power level
- **Deactivation period**: period for the ramping from full delivery to zero

The table below summarizes the expected duration of all the characteristics:

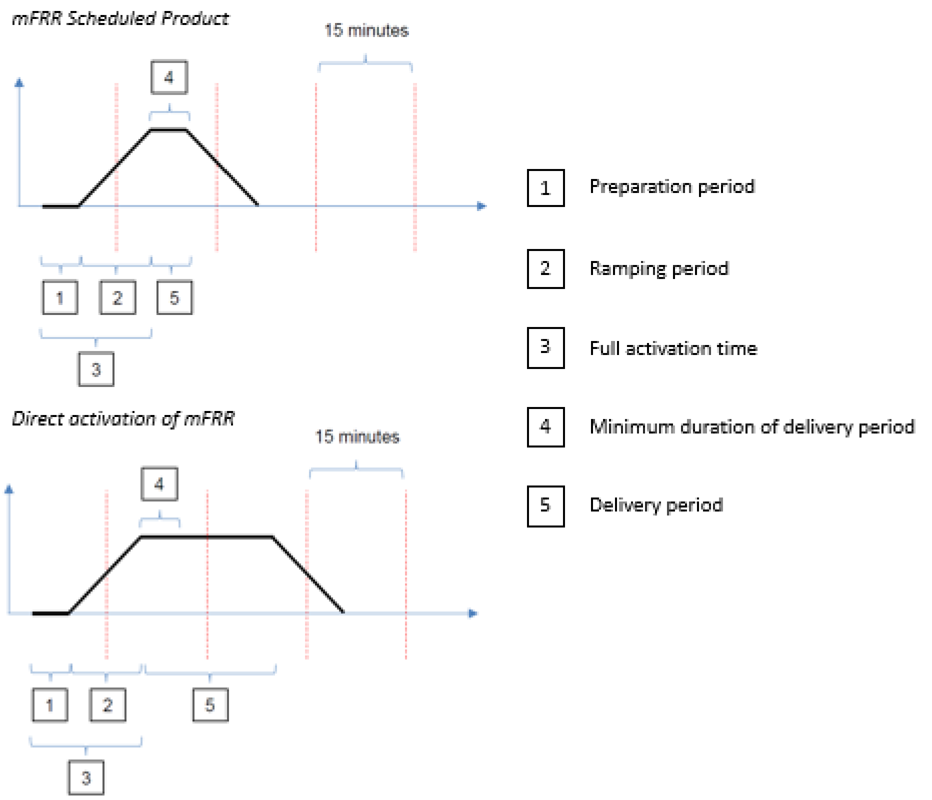


Figure 5: Summary of bids properties

Bids can have additional features, which are described in section 4.2.

2.3.2 Balancing energy demands

The balancing energy demands are submitted by TSOs to the MARI platform, and have the following features:

- Quantity [MW]
- Direction: positive demand (when the system is short) or negative demand (when the system is long)
- TSO demand price [€/MWh]: used for elastic demand, when TSOs have alternative measures to solve imbalances

- Location of demand: Scheduling area or Aggregated Area[1]
- Purpose: balancing purposes or system constraints purposes as defined in the Article 29(3) of the EBGL

Demands can have additional characteristics, which are described in section 4.1.

3. POWER SYSTEM NETWORK

The MARI Activation Optimization Function (AOF) optimizes the mFRR activation at European level, and therefore allows for mFRR energy bids to be exchanged between scheduling areas. This requires to consider constraints on the available cross-zonal capacity European network, via a set of dedicated network constraints. The topology of the European system and the associated market rules are described in the following sections.

3.1. Market areas

The different types of areas that are considered in the MARI AOF are represented in the following topology example:

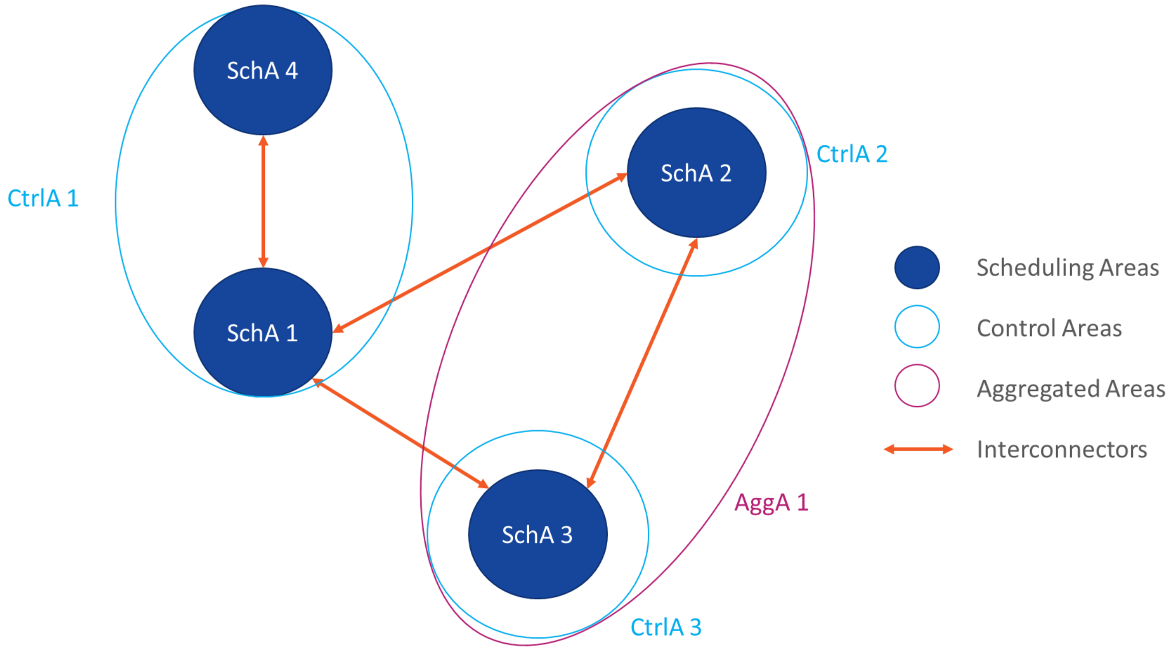


Figure 6: Topology example

A detailed description of each type of areas used in the MARI AOF is provided in the following sections. All market areas currently used in MARI can be in annex 7.2

3.1.1 Scheduling Areas

A scheduling area is the area level where the different bids and most of the demands are submitted (see aggregated areas for other ways of specifying demands). Scheduling areas cannot include any other areas, whatever their types, they are the most elementary zones modelled in MARI.

[1] set of scheduling areas that can have specific mFRR demand requirements. Full definition in 3.1.3

The interconnectors allowing exchange of mFRR energy coupling the different scheduling areas of the network.
A CBMP will be defined at the end of the activation optimization process for each of the scheduling areas.
Each scheduling area is included in at most one control area.

3.1.2 Control Areas

A control area is defined as a set of scheduling areas operated by a single system operator (TSO). It therefore can include one or several scheduling areas as shown in *Figure 6: Topology example*.
In MARI's AOF, the control areas are not directly interconnected with one another, as the interconnections are defined at the level of scheduling areas.

3.1.3 Aggregated Areas

An aggregated area is a set of scheduling areas that can have specific mFRR demand requirements. They include at least 2 scheduling areas as shown in *Figure 6: Topology example*.
Aggregated areas differ from control areas in the sense that they do not necessarily represent an area controlled by a single transmission system operator (one aggregated area can include several scheduling areas from different control areas).
Demands can be submitted at the aggregated area level and are called aggregated demands.

3.2. Interconnectors

3.2.1 Available Transfer Capacities (ATC)

MARI AOF is using an ATC-based model to describe the limitations on balancing energy flows between scheduling areas that arise due to available cross-zonal capacity. The scheduling areas connected through interconnectors can exchange mFRR balancing energy with respect to the ATC limits of the interconnector.
Interconnectors are bi-directional and have one ATC limit per direction. No losses are considered on interconnectors in MARI AOF at the Go-Live of the MARI platform.
The following graph represents a feasible flow solution with respect to ATC limits:

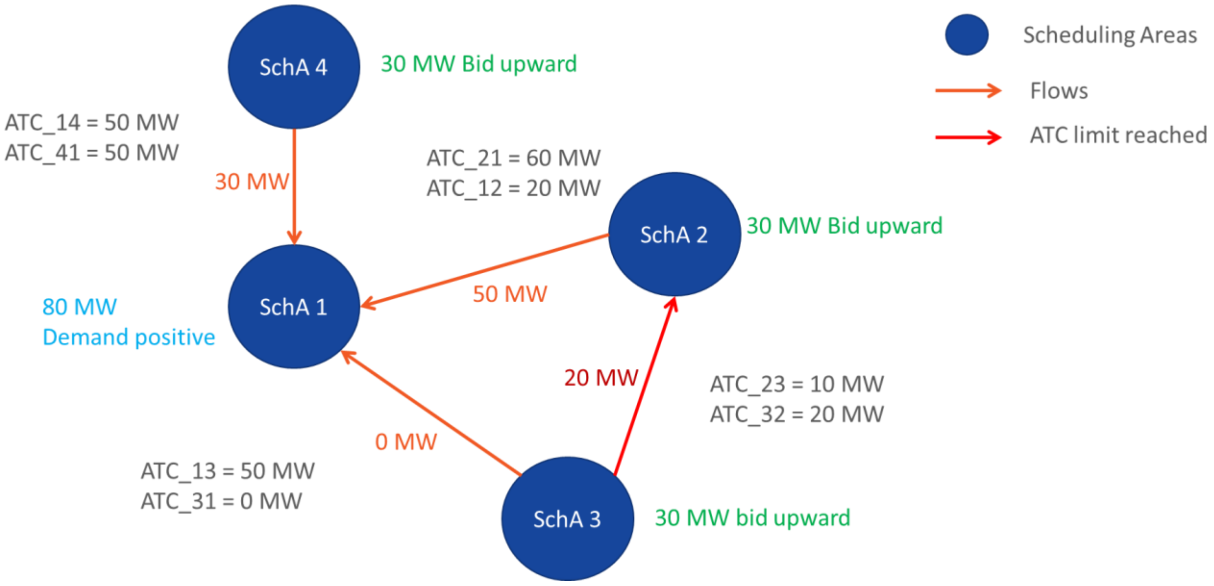


Figure 7: Example of a feasible flow solution

In this example, an 80 MW positive demand is located in SchA1. The following set of upward bids have been submitted by BSPs in the different scheduling areas:

- 30 MW upward bid in SchA2
- 30 MW upward bid in SchA3
- 30 MW upward bid in SchA4

To match the positive demand in SchA1, the upward bids in SchA2 and in SchA4 are activated, with 30 MW from SchA2 and 30 MW from SchA4 being directly sent to SchA1.

To match the rest of the positive demand in SchA1, only 20 MW of the upward bid in SchA3 can be activated as there is an ATC limit of 0 MW in the direction from SchA3 to SchA1, an ATC limit of 20 MW in the direction from SchA3 to SchA2 which is therefore congested once 20 MW of the upward bid in SchA3 are activated. This flow of 20 MW is then continuing via the interconnector SchA2-SchA1, resulting in an overall flow of 50 MW on this interconnector.

In addition to ATC limits, interconnectors can be parametrized by a weight to prioritize the scheduling of "commercial" power flow on some interconnectors rather than others. The higher the weight is on a given interconnector, the more important it becomes for MARI's AOF to minimize the cross-border flow through this interconnector. The default value of the weight is 1 between scheduling areas belonging to different control areas, and 0.01 between scheduling areas belonging to the same control area:

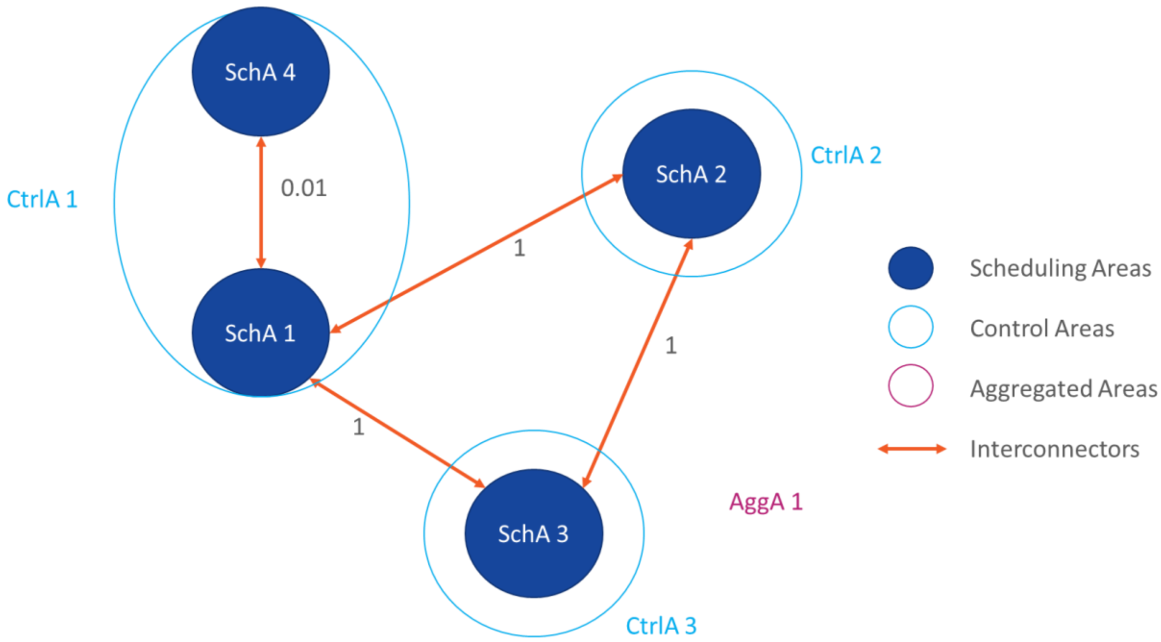


Figure 8: Default Weight values for interconnectors

Interconnectors weights are used by MARI's AOF when the cross-border flows are minimized, as described in Section 6.1.3.

3.2.2 Allocation Constraints

Technical Profiles

ATC limits on interconnectors do not take into account all the impacts of physical flows on the system, and additional constraints may be required in specific areas to better represent some of the physical constraints.

Technical profiles (TPs) are introduced to that effect, as additional constraints that can limit the flow of balancing energy between sets of scheduling areas. There are two types of technical profiles:

- Gross Technical Profiles
- Net Technical Profiles

A Technical Profile is characterized by the following elements:

- A set of interconnectors that are included in the technical profile
- A TP flow limit per direction that applies to the technical profile
- A type: Net or Gross

For instance, in our previous example, a technical profile can be defined that includes two interconnectors: the one between SchA2 and SchA1 and the one between SchA3 and SchA1.

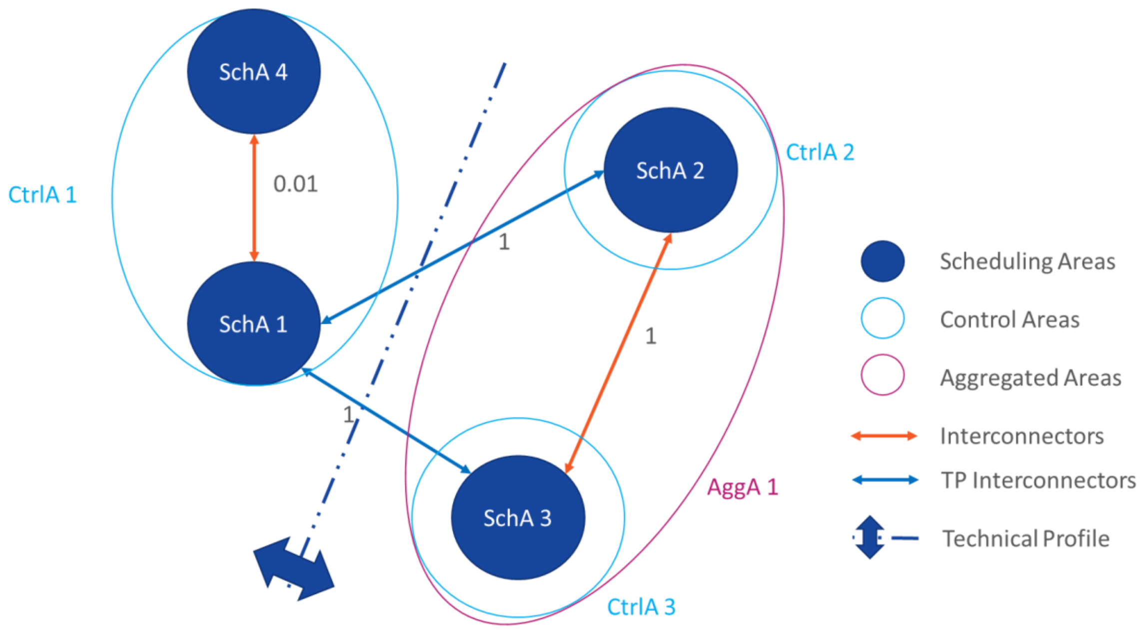


Figure 9: Technical profile interconnectors

The technical profile (TP) defines limits on the overall flow over the interconnectors included in the TP on one particular direction. For example:

- Flow going from SchA1 to {SchA2, SchA3}: TP limit of 50 MW
- Flow going from {SchA2, SchA3} to SchA1: TP limit of 25 MW

This example will be used in the next two sections to explain the difference between net and gross technical profiles.

Gross Technical Profiles

For gross technical profiles, only the sum of the interconnectors flows in the direction of the technical profile shall be less or equal to the technical profile limit, like in the following example:

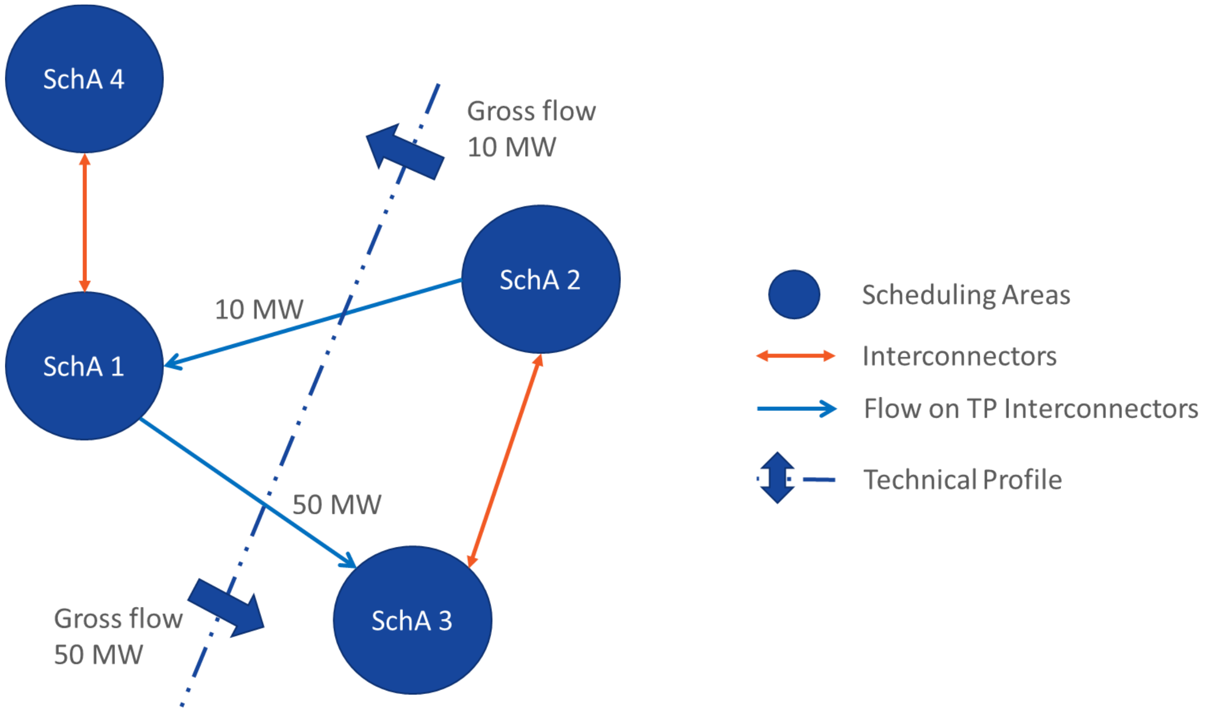


Figure 10: Gross technical profile example

The sum of the flow from SchA1 to SchA2 (0 MW) and from SchA1 to SchA3 (50 MW) is then limited by the TP limit of the gross technical profile (50 MW) in this direction.

In the opposite direction, the sum of the flow from SchA2 to SchA1 (10 MW) and from SchA3 to SchA1 (0 MW) is then limited by the TP limit of the gross technical profile (10 MW).

Net Technical profiles

For net technical profiles, the net sum of all interconnector flows under the technical profile are taken into account. This means that if a particular flow goes in a direction opposite to that of the technical profile, its value is subtracted (and not ignored as in gross technical profiles).

With a net technical profile, the example given in 0 is feasible with a net technical profile limit of 50 MW in direction from SchA1 to {SchA2, SchA3}, and would even allow an additional 10 MW from SchA1 to SchA3 as displayed in the following graph:

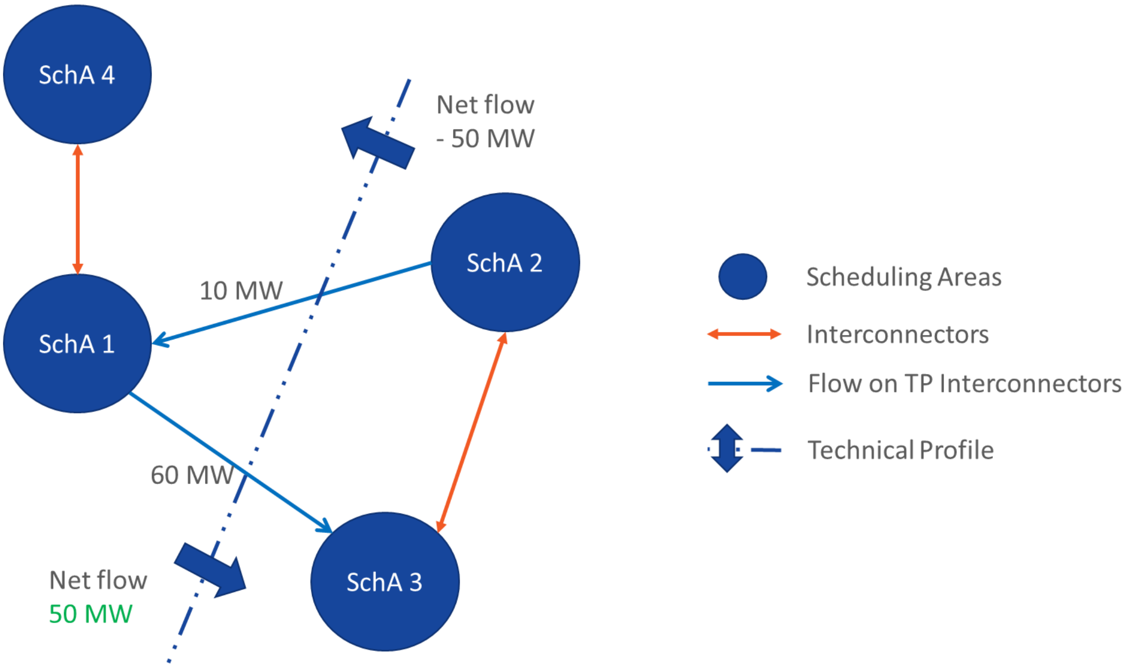


Figure 11: Net technical profile example

Net Position Limits

Net position limits are another set of constraints that are implemented in MARI's AOF to represent limits of the import and/or export of energy in a given scheduling area or aggregated area.
There are two types of net position limits considered in MARI's AOF:

- Net position limit import
- Net position limit export

As these limits are applied on the net position of a scheduling or aggregated area, transit flows are not impacted by the constraints. For instance, net position limits could be defined as follow on the same example:

- In SchA4, an export net position limit of 20 MW limits the flow that goes to SchA1 to a maximum of 20 MW
- In AggA1, an export net position limit of 25 MW limits the flow on interconnectors SchA1-SchA2 and SchA1-SchA3, in this case limiting the flow on the interconnector from SchA2 to SchA1 to 25 MW.

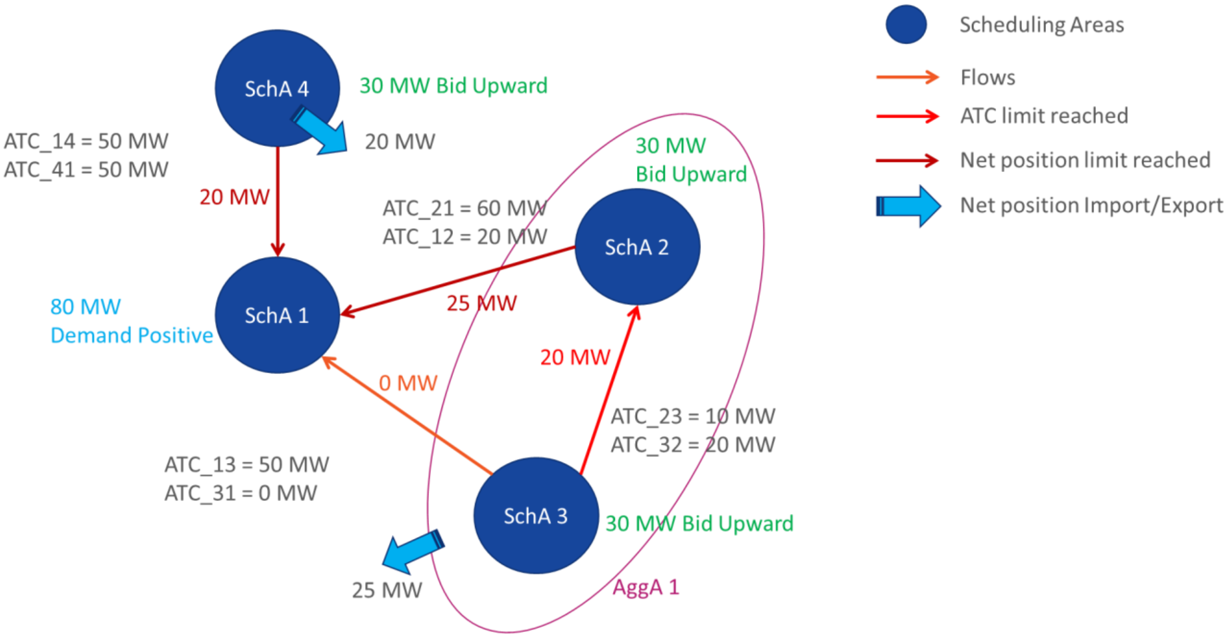


Figure 12: Feasible flow solution with net position limit

4. MFRR BIDS AND DEMANDS

MARI's AOF is designed to optimize the activation of mFRR bids to balance the system at the European level, allowing for exchanges of energy between scheduling areas. The following paragraphs describe the representation of market products in MARI's AOF.
Two main types of orders can be submitted for activation by MARI AOF:

- Balancing Bids
  Bids are defined as market orders originally submitted to TSOs by BSPs.
- Balancing Demands
  Demands are defined as market orders submitted by a TSO.

MARI AOF performs the optimization on a single MTU. Intertemporal constraints, especially for Direct Activations are not taken into account in AOF. However, these constraints resulting from activations are taken into account by the platform and accounted for in the AOF input data for next direct and scheduled activations.
Bids and demands are submitted to MARI AOF with the following common characteristics:

- **<u>Direction</u>**
  The direction of a bid can be either Upward or Downward and the direction of a demand can be either Positive of Negative.
  For bids, Upward direction means an increase of energy production or a decrease of energy consumption, while Downward direction means a decrease of energy production or an increase of energy consumption.
  For Demands, Positive direction means a request for an increase of energy production or a decrease of energy consumption, while Negative direction means a request for a decrease of energy production or an increase of energy consumption.
- **<u>Price [€/MWh]</u>**

Bids and demands shall have an activation price in €/MWh. In the case of inelastic demands, no price will be considered since this type of demands must be activated at any cost.

- **Localization**
  A bid or demand is always submitted on a scheduling area, except for specific demands that can be submitted at the aggregated area level.
- **Maximum Quantity [MW]**
  Indicates the amount of energy that can be selected from a bid or demand. A maximum quantity always has to be defined.
- **Minimum Quantity [MW]**
  Indicates the minimum amount of energy that can be activated by AOF if the bidis activated. All demands have a minimum quantity of 0 MW.

The characteristics on quantity are used to define different types of bids to be considered by MARI AOF:

- ***fully divisible***: any quantity of the bids can be selected.
- ***divisible***: the activated quantity of the bids must be within the minimum – maximum quantity range
- ***Indivisible***: the bids can only be activated at its full quantity, or completely rejected.

4.1. Balancing Demands

Balancing demands represent TSOs' needs for mFRR balancing energy to be activated in a given direction in a given location (scheduling area or aggregated area).
Balancing demands are fully divisible and therefore have a minimum quantity of 0 MW.
Two types of balancing demands can be submitted by TSOs depending on the nature of their needs:

- Inelastic demand
- Elastic demand

4.1.1 Inelastic Demands

Inelastic demand represents a specific demand that shall be satisfied whatever the price. As a consequence, inelastic demands do not have any price characteristic, and the non-satisfaction is strongly penalized in the objective function of MARI AOF.
Inelastic demands can be submitted at scheduling area level or aggregated area level.
In addition to the characteristics listed in Section 4, balancing demands must also have the following additional characteristic:

- **Purpose**
  The purpose is a characteristic that is introduced for demands only. It indicates the reasons a given demand has been submitted. It can be either be "System constraints purpose" or "Balancing purpose".

The demands for "Balancing purpose" have a higher priority for MARI AOF than the demands for "system constraints purpose".

4.1.2 Elastic Demand

Elastic demand represents a specific balancing demand with a given maximum price in €/MWh.
Unlike inelastic demand, elastic demands will be satisfied at its limit price or better. Usually, it means that the TSOs submitting such demands can fulfil them via other means that are out of the market.

4.2. Balancing Bids

Balancing bids are initially submitted by Balancing Service Providers to its connecting TSO if they are willing to provide balancing energy in one particular direction in a given scheduling area. Unlike demands, bids cannot be submitted at the aggregated area level.

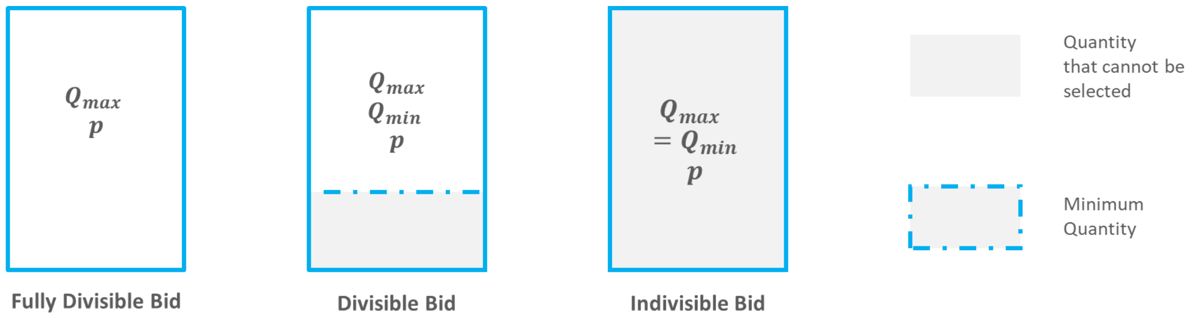
In addition, to the characteristics listed in Section 4, balancing bids may be grouped and have specific clearing constraints linked to the other bids of the same group.

The different bid group types that are handled by MARI AOF are described in Section 4.2.2

Bids can be activated to match with demand with same direction, or with a bid of opposite direction.

4.2.1 Bid Types

Depending on their divisibility and their linking structure, several types of bids can be submitted to MARI's AOF. Bids can be of the following types as described above: fully divisible, divisible or indivisible.



It should be noted that indivisible and divisible bids modify the merit order and makes it more complex. In a simple case where all bids and demands are fully divisible, activation of bids would follow a merit order curve as represented below:

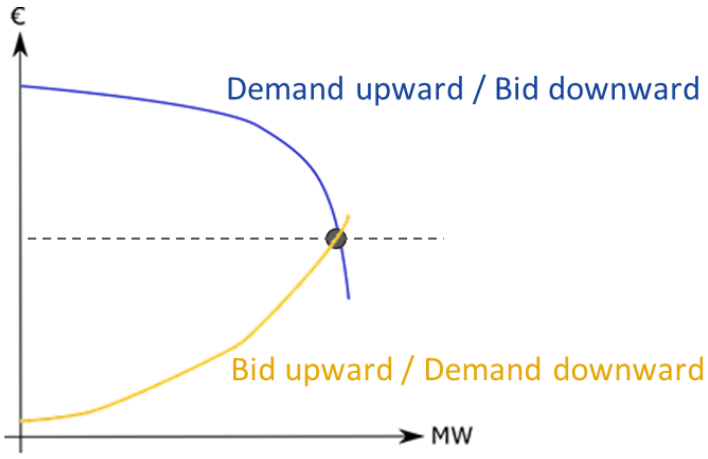


Figure 13: Basic supply and demand curve

In the presence of complex bids, it is not sufficient to activate bids and demand by increasing (resp. decreasing) order of prices.

4.2.2 Complex Bids

MARI AOF can handle several types of bids linking:

- **Exclusive groups:**

  Exclusive groups are sets of bids submitted in a given scheduling area where at most one bid can be accepted (even partially). No other restriction is made on the bids within the group:

  - Some bids can be upward while others are downward
  - Bids can be either fully divisible, divisible or indivisible:

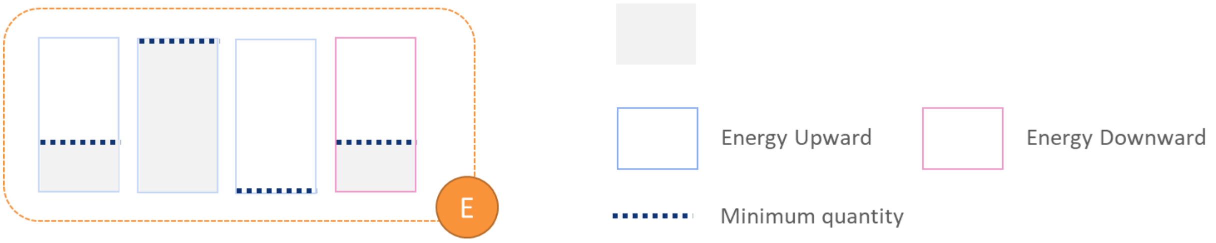


Figure 14: Exclusive bid group

- **Multipart groups:**

- Multipart groups are sets of bids submitted in a given scheduling area. All bids in the same multipart group should either be upward or downward. MARI's AOF shall strictly respect the following merit order rules:
  - For upward multipart bids, whenever a bid of a multipart group is activated, all associated bids with lower prices must be fully activated.
  - For downward multipart bids, whenever a bid of a multipart group is activated, all associated bids with higher prices must be fully activated.

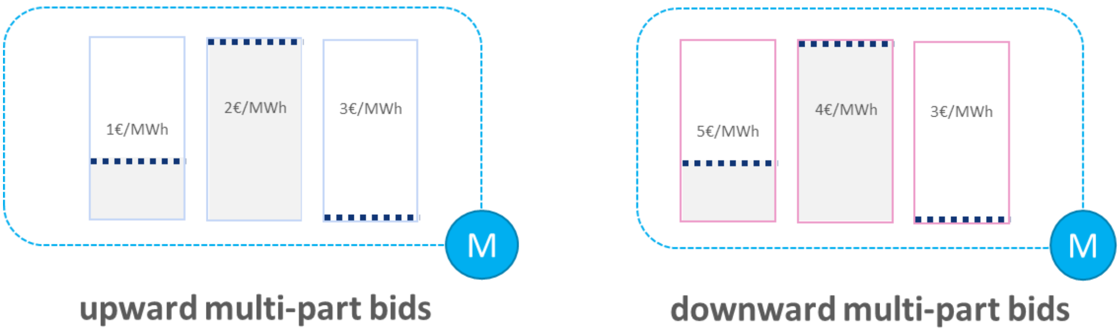


Figure 15: Multipart bid group

4.3. Priority Rules

Several types of bids and demands have been described in the previous sections. Although several criteria are optimized by MARI's AOF, cases with equivalent solutions may materialize. In such cases, specific priority rules are applied by MARI AOF:

- **Strong priorities independent from prices**

  The minimization of the non-satisfaction of inelastic demand is one of the main objectives of MARI AOF. This confers to all inelastic demands the highest priority over all types of bids and demands, whatever the price. Additionally, within the two types of inelastic demand, balancing purpose demands have higher priority than system constraint purpose demands. The way these priorities are implemented is described in Section 6

- **Weak priorities among bids and demands with equivalent price**

Among elastic demands and all other types of bids, different levels of priority are implemented in MARI AOF. In MARI AOF, elastic demands are prioritized over all bids, and fully divisible bids are prioritized over all other types of bids. These priorities are implemented as a dedicated post-process of MARI AOF.

5. PRICE RULES

The overall objective of MARI AOF is to optimize the activation of bids and demands to maximize the economic surplus while following a set of market rules and constraints. When the solution is found (selected demands and bids), MARI AOF needs to define the Cross Border Marginal Price (CBMP) for each scheduling area. The CBMP of mFRR activation in MARI AOF should satisfy a set of market rules described in the following sections. These rules can be related to:

- Price bounds due to bids and demand acceptance / rejection rules
- Market coupling rules due to interconnectors between scheduling areas
- Price indeterminacy

5.1. Price Bounds

These rules are applied similarly in Scheduled and Direct Activations.

The first set of market rules related to the CBMP in MARI AOF are the upper and lower bounds defined by the accepted or rejected bids and demands of the relevant scheduling area. Once the market clearing solution is defined, the following characteristics can be defined on bids and elastic demands:

- Out of the money:
  - A bid upward or elastic demand downward is out of the money if its price is above the CBMP
  - A bid downward or elastic demand upward is out of the money if its price is below the CBMP
- At the money:
  - A bid upward or elastic demand downward is at the money if its price is equal to the CBMP
  - A bid downward or elastic demand upward is at the money if its price is equal to the CBMP
- In the money:
  - A bid upward or elastic demand downward is in the money if its price is below the CBMP
  - A bid downward or elastic demand upward is in the money if its price is above the CBMP

The price bounds may not be strictly enforced as explained in the next two sections.

5.1.1 Unforeseeable Accepted Bids

Unforeseeable accepted bids (UABs) are bids or elastic demands that have been accepted while being out of the money. In MARI AOF all accepted bids or elastic demands shall be in or at the money, meaning that there are no accepted bids or elastic demands that are out of the money (no UABs).

This rule provides a first set of upper and lower bound constraints on the CBMP by examining the prices of all accepted bids and elastic demands.
In the following graph, unforeseeable accepted bids or demands are all accepted bids or demands that are in the two quadrants on the right part of the graph.

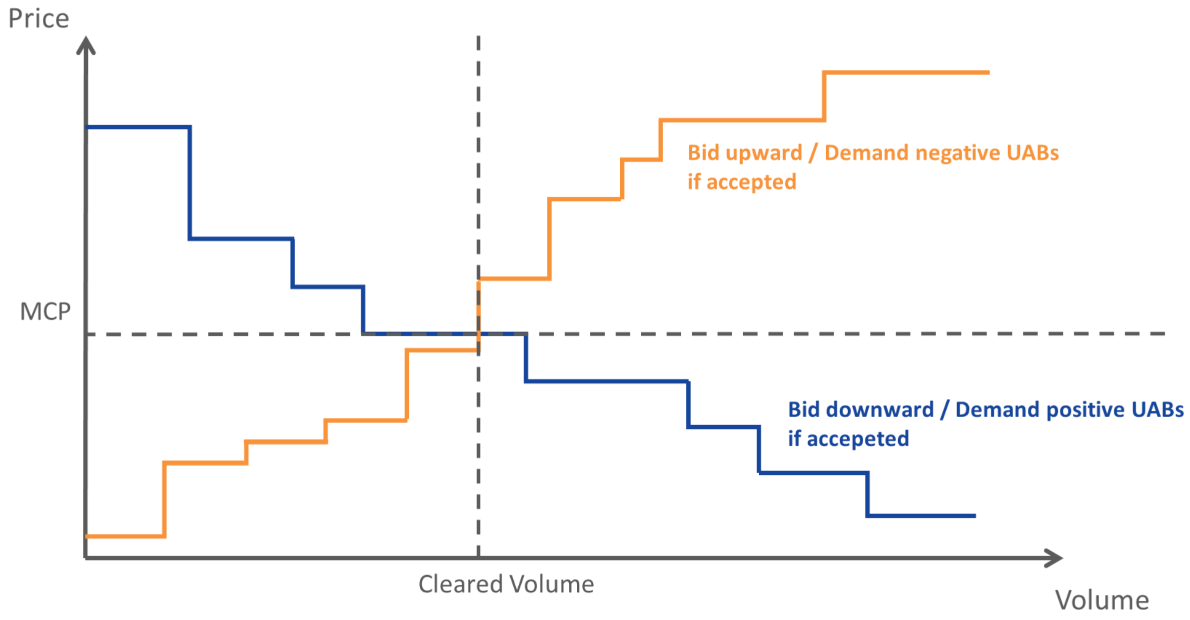


Figure 16: Unforeseeable accepted bids and demands

5.1.2 Unforeseeable Rejected Bids

Unforeseeable rejected bids (URBs) are bids or elastic demands that have been rejected while being in (or at) the money. In MARI AOF, worst URBs (rejected bids that are the deepest in the money) on each scheduling area are minimized. Only the following bids and demands are considered while minimizing URBs:

- Partially accepted elastic demands
- Partially accepted fully divisible bids
- Partially accepted bids with a non-zero minimum quantity
- Partially accepted bids that belong to an exclusive family
- Partially accepted bids that belong to a multi-part family
- Rejected elastic demands
- Rejected fully divisible bids
- Rejected bids with zero minimum quantity that belong to an exclusive family and such that the whole family is rejected
- Rejected upward bids with zero minimum quantity that belong to a multi-part family, and such that all associated bids with lower prices are fully accepted
- Rejected downward bids with zero minimum quantity that belong to a multi-part family, and such that all associated bids with higher prices are fully accepted

The URB rule is not strictly enforced so that URBs can appear in the MARI AOF solution. However, this rule provides a set of additional upper and lower bounds on the CBMP that MARI AOF will seek to satisfy. For instance, a rejected upward bid of 10€/MWh would introduce an upper bound on the CBMP of its scheduling area because otherwise it would become URB. This bound might not however be strictly respected to avoid infeasibility with respect to other constraints on CBMP.
In the following graph, unforeseeable rejected bids or demands are all rejected bids or elastic demands that are in the two quadrants on the left part of the graph.

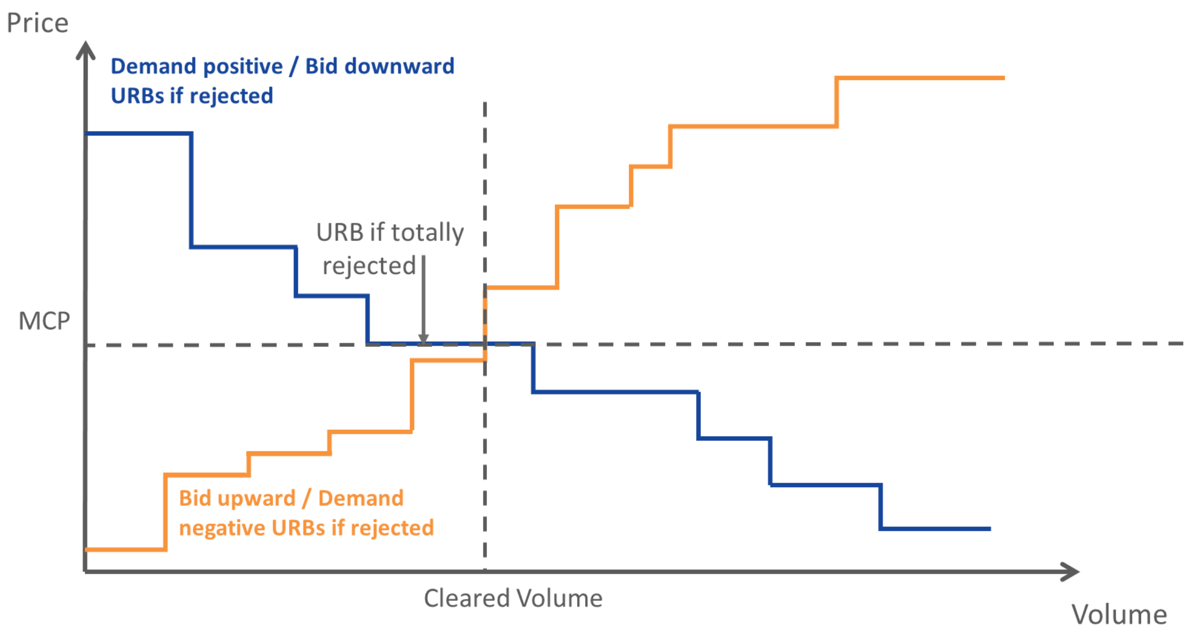


Figure 17: Unforeseeable rejected bids and demands

5.2. Market Coupling Rules

These rules are applied similarly in Scheduled and Direct Activations.
The determination of the CBMP in MARI AOF has to satisfy a set of rules related to interconnector flows between scheduling areas. Indeed, the CBMP of a given scheduling area is coupled (meaning that the CBMP of one given scheduling area cannot be determined independently without the other CBMPs of the connecting areas) with the CBMP of other scheduling areas, and in particular the ones of its neighbouring scheduling areas. The rules described in this section are implemented in MARI AOF to take congestions, price convergence and adverse flows into account when setting the CBMPs.

5.2.1 Interconnector Congestion

The presence of a congestion on a given interconnector has direct impacts on the CBMP of the two interconnected areas. Indeed, if two adjacent interconnected areas are linked by a congested interconnector, a price differential can appear between the two zones.
Interconnectors are considered as being congested in a particular direction in the following situations:

- **ATC interconnector congested**: mFRR flow on the interconnector reaches the ATC limit in the corresponding direction

- **Technical profile congested**: The interconnector is part of a congested technical profile and the interconnector flow is in the same direction as the congested technical profile
- **Net position limit congested**: The interconnector is connected to a scheduling area with a net position limit saturated and the interconnector flow is the direction limited by the net position limit.

Let us consider an example with the following net position limits and technical profiles:

- Net position limit:
  - Export from SchA4 limited to 30 MW
- Technical profile:
  - Gross technical profile of 60 MW that includes
    - Interconnector SchA1 -> SchA2
    - Interconnector SchA1 -> SchA3

  The 60 MW technical profile is acting as a limit in the direction from SchA1 to {SchA2, SchA3}.

In the following solution, the congested interconnectors, technical profiles and net position limits are coloured in red:

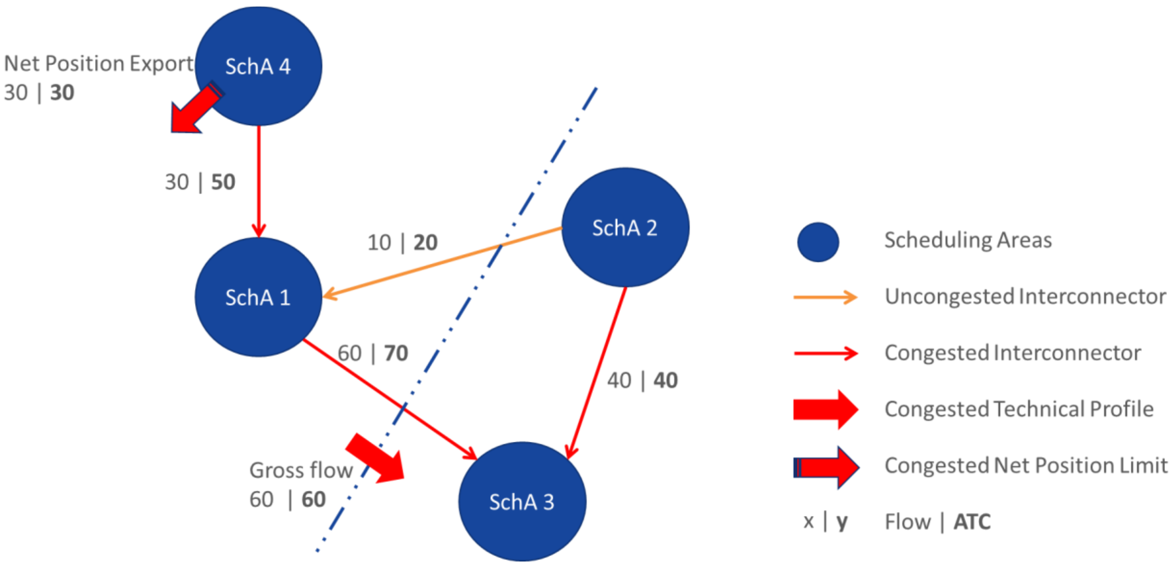


Figure 18: Flow feasible solution with congestions

Interconnector SchA4 – SchA1 is **net position limit congested**, because the net position limit export in SchA4 of 30 MW is saturated.

Interconnector SchA1 – SchA3 is **technical profile congested** (although its own ATC limit is not reached), because it is part of a congested technical profile.

Interconnector SchA1 – SchA2 is not congested because its own ATC has not been reached, and it is not part of a congested technical profile. The technical profile is only congested in the other direction (from SchA1 to {SchA2 – SchA3}). An increase of the flow from 10 to 15 MW from SchA2 to SchA1 would be feasible.

Interconnector SchA3 – SchA2 is **ATC interconnector congested** because the flow has reached its own ATC limit of 40 MW.

5.2.2 Price Convergence

In MARI AOF, a set of scheduling areas interconnected by uncongested interconnectors define a price zone (congestion on interconnector and thus price divergence, can happen due ATC constraints or allocation constraints as well). Within a price zone, all areas are coupled and shall satisfy a price convergence rule. This rule enforces that the price must be the same for all scheduling areas of a given price zone.

If there is a congestion on an interconnector connecting two scheduling areas, then the price convergence rule does not apply, and price in these two scheduling areas can diverge.

From the previous example, the following price zones will be defined by MARI AOF:

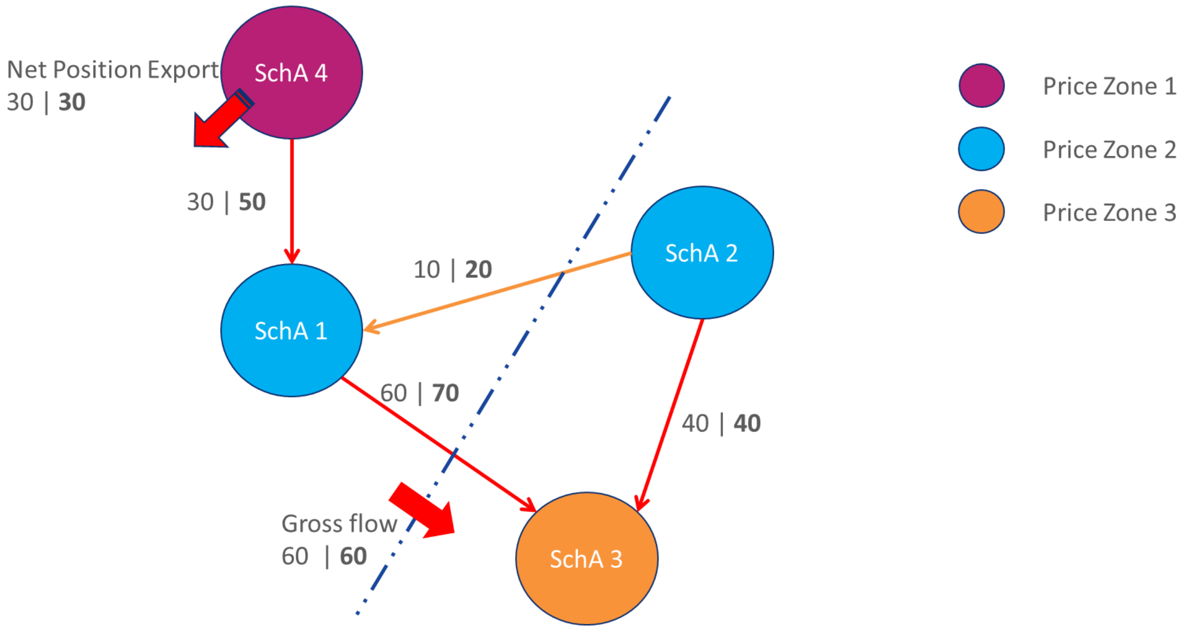


Figure 19: Price zone example

5.2.3 Adverse Flows

Adverse flow rules in MARI AOF constrains the CBMP of a given scheduling area to be higher or lower than the CBMP of an interconnected area depending on the direction of the flow.

When price convergence is not reached because of congestions, the CBMP has to respect the following rules between two congested scheduling areas:

- The exporting scheduling area must have a price lower than or equal to the price of the importing scheduling area.

If we consider the example introduced in Section 5.2.1, the following rules between the CBMP of the different price areas would be introduced:

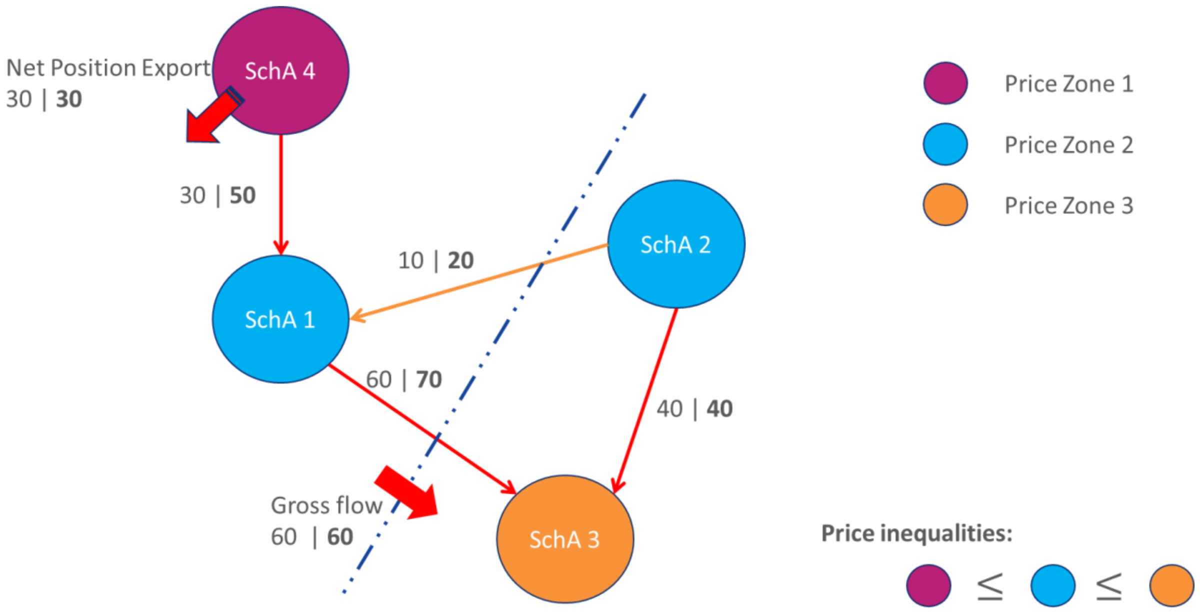


Figure 20: Adverse flow inequalities

5.3. Price Targets

Scheduled Activation

In case of price indeterminacy, the CBMP should be set at a price target which is defined by considering the characteristics of the accepted and rejected bids/demands in each price zone.
The price targets are computed per price zone, based on the bounds defined from accepted and rejected bids and elastic demands following the UAB and URB rules (see Section 5.1).
The following situations are considered when calculating price targets:

- A price upper bound and a price lower bound are defined
  - ⇨ The target is set as the middle point between the two bounds
- A price upper bound is defined, without any price lower bound
  - ⇨ The target is set at the upper bound
- A price lower bound is defined, without any price upper bound
  - ⇨ The target is set at the lower bound
- No price bounds:
  - ⇨ No price target is defined

If no price target is defined in a Decoupled Area, the price target is set to 0.

For instance, if we consider the same price zones as defined in sections 5.2.1 and 5.2.3 :

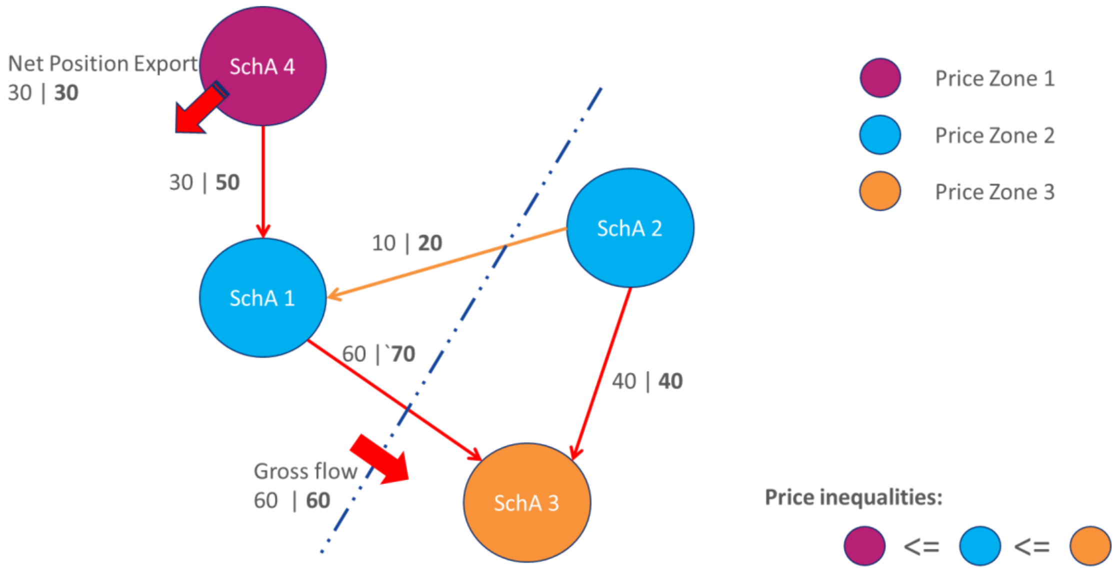


Figure 21: Price targets

If we assume the following bids have been accepted/rejected in the different price zones:

- SchA4:
  - Price of last accepted upward bid: 10€/MWh
  - Smallest price of rejected upward bids: 50€/MWh
- SchA1 and SchA2:
  - Price of last accepted upward bid: 35€/MWh
- SchA3:
  - Price of last accepted positive demand: 40 €/MWh

In such a configuration, the following bounds and price targets are defined:

- In price zone of SchA4, the following price bounds can be derived thanks to UAB and URB rules (Section 5.1.1 and Section 5.1.2: [10;50] which would lead to a price target of 30€/MWh in this price zone.
- In price zone of SchA1 and SchA2, there is no upper bound since no upward bid has been rejected or negative demand being accepted. The target is set to the lower bound which is 35 €/MWh.
- In price zone of SchA3, there is no lower bound since there is no accepted upward bid or rejected negative demand. The price target is set to the lower bound which is 40€/MWh.

MARI AOF determines the CBMPs for all price zones that minimize the squared distance to their price target. In the example presented in this section, the target prices are feasible since they do not interfere with price convergence and adverse flows constraints. However, it may not always be possible to reach the price targets when considering these constraints. In that case, MARI AOF determines the set of CBMPs that respects all the constraints and that are closest to the price targets.

Direct Activation

In case of price indeterminacy, the CBMP should be set at a price target which is defined by considering the characteristics of the accepted bids in each price zone.

The price targets are computed per price zone, based on the bounds defined from accepted bids following the UAB rules (see Section 5.1).6.1).6.1).6.1).
As there is only one direction in Direct Activation, the price target will be set to:

- the most expensive accepted bids per price zone in upward direction
- the least expensive accepted bids per price zone in downward direction

If no price target is defined in a Decoupled Area, the price target is set to 0.

6. ACTIVATION OPTIMIZATION FUNCTION

In this section, the MARI AOF algorithm process is described in more details:

- The implementation of market rules in MARI AOF is discussed in Section 6.1
- The optimization process of MARI AOF is discussed in section 6.2, by introducing the different steps of the optimization,
- Specific market situations are discussed in Section 6.3
- Finally, the MARI AOF safeguard functionalities aiming at increasing the robustness of the solution are introduced in Section 6.4

In this section, the term "constraints" refers to market rules implemented as hard constraints in the optimization model, while the term "objectives" encompass market rules implemented as soft constraints (i.e., relaxed constraints with an associated penalty in case they are violated) and criteria to optimize.
MARI AOF overall objectives have been defined in article 11 of mFRR implementation framework and are the followings:

- Economic surplus maximization
- mFRR cross border flow minimization

However, additional mathematical objectives are implemented in MARI AOF in order to consider soft constraints.

6.1. Optimization model

The AOF optimization model has been designed to respect a number of market rules. Some market rules have to be strictly satisfied and are implemented as hard constraints, while other rules are implemented as soft constraints and are therefore considered in the objective function.

6.1.1 Market constraints

Market constraints are market rules that have to be enforced strictly in MARI AOF:

- **Unforeseeable accepted bid rule**

  This UAB rule, introduced in Section 5.1.1 ensures that all accepted bids and elastic demands are in or at the money. This is a hard constraint since it ensures all market participants will have their accepted bid in or at the money. This rule applies for all types of bids and elastic demands.
  A market with fully divisible products only could be cleared by simply considering the merit order list. In such case, the UAB rule has no impact on the economic surplus. However, in a market with non-fully divisible products, preventing UABs may have an impact on the overall economic surplus.

- **Adverse flow rule**

The adverse flow rule, introduced in Section 5.2.3 is implemented as a hard constraint. It applies to all interconnectors and ensures that each flow goes from a scheduling area with a lower CBMP to a scheduling area with a higher CBMP.

- **Price convergence rule**

The price convergence rule, introduced in Section 5.2.1, enforces that scheduling areas that are interconnected without any congestion have to have the same CBMP. This rule is enforced strictly in MARI AOF algorithm via a dedicated set of constraints.

- **Area energy balance**

MARI AOF ensures that balancing energy balance is reached for each scheduling area. The difference between upward and downward energy of each scheduling area shall be balanced with its import and export flows.

- **ATC limits for interconnectors, technical profiles and net position**

ATC limits on interconnectors, technical profiles and net position limits, introduced in Section 3.2 are implemented as hard constraints. These constraints being related to network security constraints, they must be respected at any cost.

- **Bid and demand characteristics constraints**

All bid characteristics described in Section 4.2.1 are implemented as hard constraints as well as all constraints related to bids group type (see Section 4.2.2 for more details).

This set of hard constraints is implemented in MARI AOF across all steps of the optimization algorithm. The interested reader can refer to Section 6.2 for more details on the workflow of the MARI AOF algorithm.

6.1.2 Main objectives

The main objectives are a set of market rules that are implemented as soft constraint with different priorities. These market rules are defined in the objective function in order to maximize their satisfaction with an associated penalty in case of constraint violation.

The main objectives implemented in the main optimization problem in MARI AOF are presented hereunder, in order of decreasing priority:

- **Maximization of Inelastic demand satisfaction**

The first main objective of MARI AOF is to satisfy all inelastic demands. Indeed, as detailed in Section 4.1.1, inelastic demand refers to a particular mFRR need of energy that shall be covered whatever the costs, for either security or balancing reasons. The unsatisfaction of inelastic demand is strongly penalized in the objective function. However, it may not be possible to satisfy all inelastic demands because of the hard constraints defined in the previous section (e.g., not sufficient cross border capacity available, or prevention of UABs and of adverse flows). This objective has been introduced although it is not part of the defined legal objective from the implementation framework to improve robustness of the algorithm. Indeed, inelastic need un-satisfaction is supposed to be model as a strong constraint, however in order to avoid infeasibilities, it has been introduced in the objective with a very high penalties so that if inelastic need cannot be satisfied, MARI AOF still return a solution.

- **Economic surplus maximization**

The maximization of the economic surplus is the last main objective implemented in MARI AOF. It has aa lower priority compared to the inelastic need satisfaction objective. The economic surplus is usually represented graphically as the area between the supply and demand curves, as shown below.

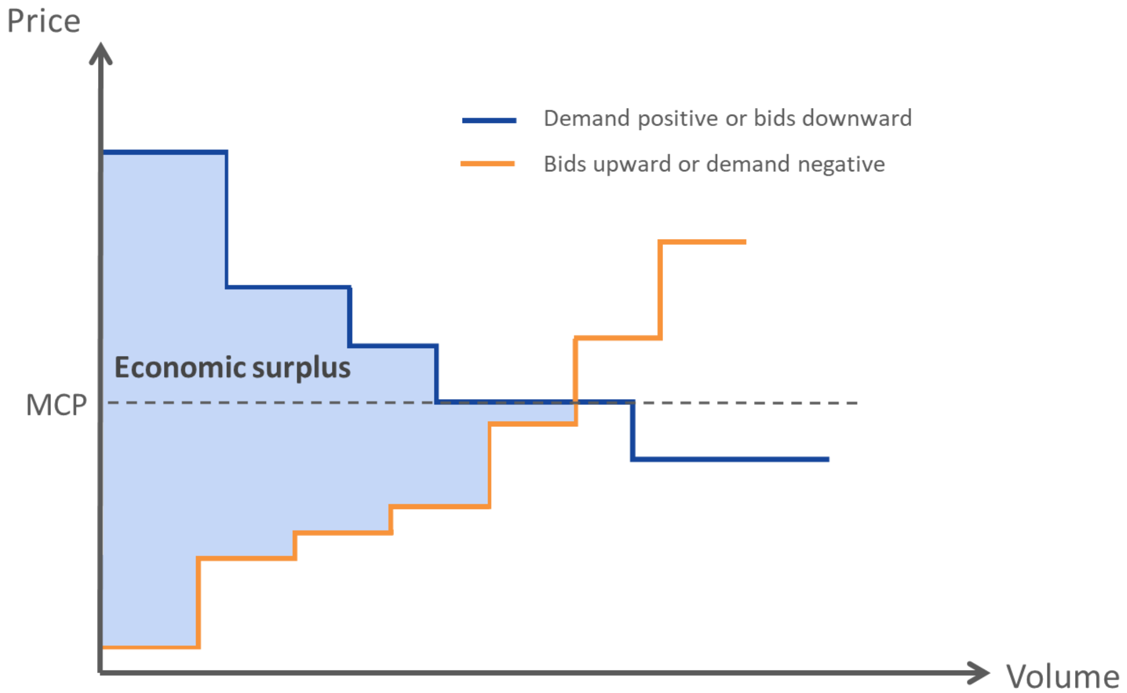


Figure 22: Economic surplus

The economic surplus (blue area) is usually maximized when following the merit order starting with the cheapest upward bids or negative demand, and with the most expensive positive demand or downward bids. However due to the introduction of specific MARI market rules (in particular the ability to use indivisible bids), the maximization of the economic surplus may not be reached by strictly following the merit order.

6.1.3 Secondary objectives

Secondary objectives are optimized successively in the finalization while ensuring that this process does not affect the main objectives that have been reached. The following market rules are implemented as secondary objectives in MARI AOF (in order of decreasing priority):

- **Cross border flow minimization**

In order to prioritize demand satisfaction by local bids (bids located in the same scheduling area as demands), the MARI AOF minimizes cross-zonal flows. This is performed by minimizing the weighted sum of squared interconnector flows. All interconnectors are not treated equally by MARI AOF. Indeed, MARI AOF will put greater focus on minimizing cross-zonal flows for interconnectors with higher weights than interconnectors with lower weights. All interconnectors are considered for minimization of the flows, including interconnectors within a control area.

- **Traded volume maximization**

This secondary objective aims at determining the final selected volume in case of volume indeterminacies. Such indeterminacies may occur when several solutions with different selected volume are equivalent solutions (with the same objective values on the previous objectives). Typically, indeterminacies appear when the buy and supply curves cross horizontally:

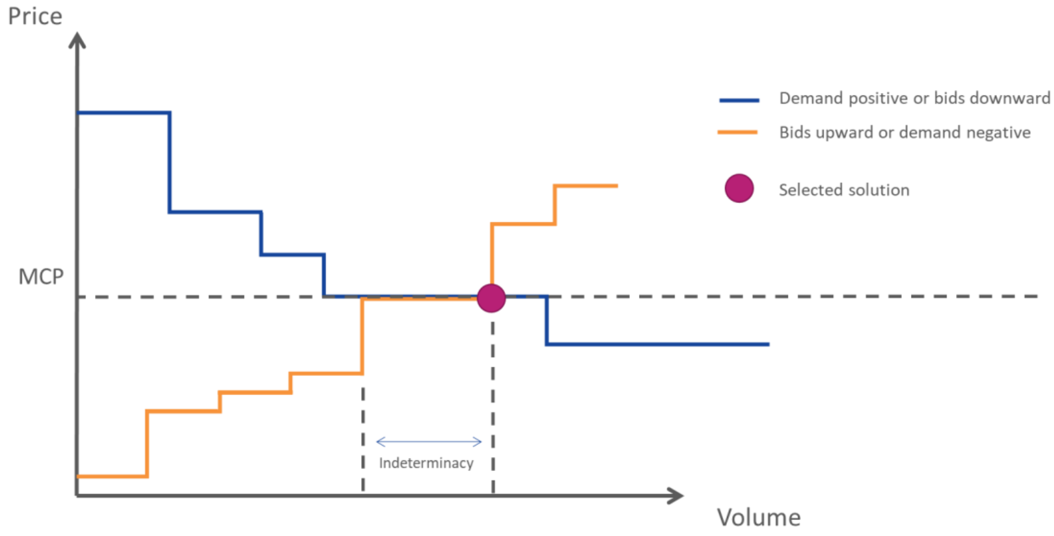


Figure 23: Volume indeterminacy

MARI AOF selects the solution that maximizes the activated volume.

- **Minimization of URBs**

This step aims at finding solutions, in particular CBMPs, that minimize URBs. MARI AOF considers for each price zone the deepest in the money rejected bids in order to define additional bounds that apply to CBMPs. The satisfaction of these new price bounds is maximized in this step. Not all bids and elastic demands are being considered in this process, more information can be found in Section 5.1.2.

- **Minimization of distance to price target**

In case of price indeterminacy, a price target is defined in order to finalize the calculation of the CBMP. The price target is defined by price zone as the middle point between the price bounds computed with the accepted and rejected bids and elastic demands. This step consists in minimization the squared distance of the CBMPs to their target (see Section 5.3 for more details on price targets).

6.2. Algorithm workflow

In order to improve robustness, the main objectives are optimized first, and intermediate solutions are finalized in parallel in order to optimize secondary objectives.
The following diagram shows all the optimization steps of the MARI AOF algorithm.

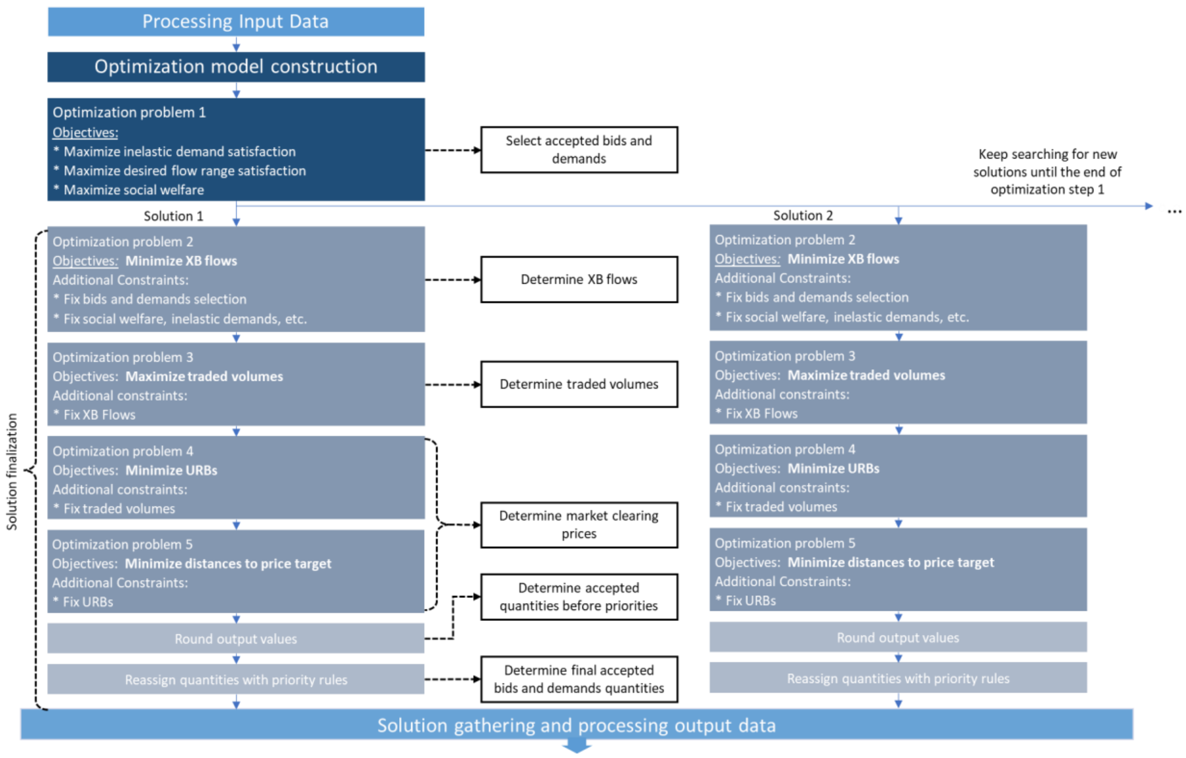


Figure 24: MARI AOF algorithm workflow

The optimization problems solved in the different steps include all the hard constraints presented in Section 6.1.1 including:

- Bids and demand models
- Price rules over interconnectors and accepted bids
- Interconnectors flow constraints

The main problem (optimization **problem 1** in *Figure 24: MARI AOF algorithm workflow*) corresponds to the optimization of the main objectives described in Section 6.1.2 and is expressed as a MILP (Mixed Integer Linear Programming) problem. Once a solution of the main problem is found, this solution is used as a starting point for the finalization process.

The finalization consists of successive optimizations in order to maximize all secondary objectives described in Section 6.1.3:

- **Optimization Problem 2**: The minimization of cross-zonal flow is expressed as a MIQP (Mixed Integer Quadratic Programming) problem
- **Optimization Problem 3**: The maximization of traded volumes is expressed as a MILP (Mixed Integer Linear Programming) problem
- **Optimization Problem 4**: The minimization of URBs is expressed as a MILP problem
- **Optimization Problem 5**: The minimization of the distance to price targets is expressed as a MIQP problem

Once the last optimization problem (Problem 5) is computed, the solution is rounded before being exported.

6.3. Additional rules

Additional market rules are included in MARI AOF. They concern particular situations in decoupled areas. A **decoupled area** is the maximum set of scheduling areas linked with interconnectors allowing balancing energy flows between the scheduling areas. Therefore, a decoupled area has zero ATC (on both direction)

on its border to other decoupled areas. Decoupled areas may appear when some ATC limits on particular interconnectors are set to 0 in both directions.
In MARI AOF market rules have been introduced to deal with special situation that may arise in decoupled areas:

- When a decoupled area has no demand, no bids will be activated within the decoupled area and the whole decoupled area will be ignored by MARI AOF.
- When no bids and demands have been activated in a decoupled area, no CBMP will be computed.

6.4. Algorithm safeguards

6.4.1 Decoupled mode

The decoupled mode is a special mode available in MARI AOF where some scheduling areas are decoupled from their neighbouring scheduling areas as some interconnectors between scheduling areas are considered to have an ATC of 0 in both directions.
For instance, let us consider the example below, where we assume that the following interconnectors are unavailable:

- Interconnector between SchA1 and SchA4
- Interconnector between SchA2 and SchA3

The decoupled mode problem will consist in the following topology:

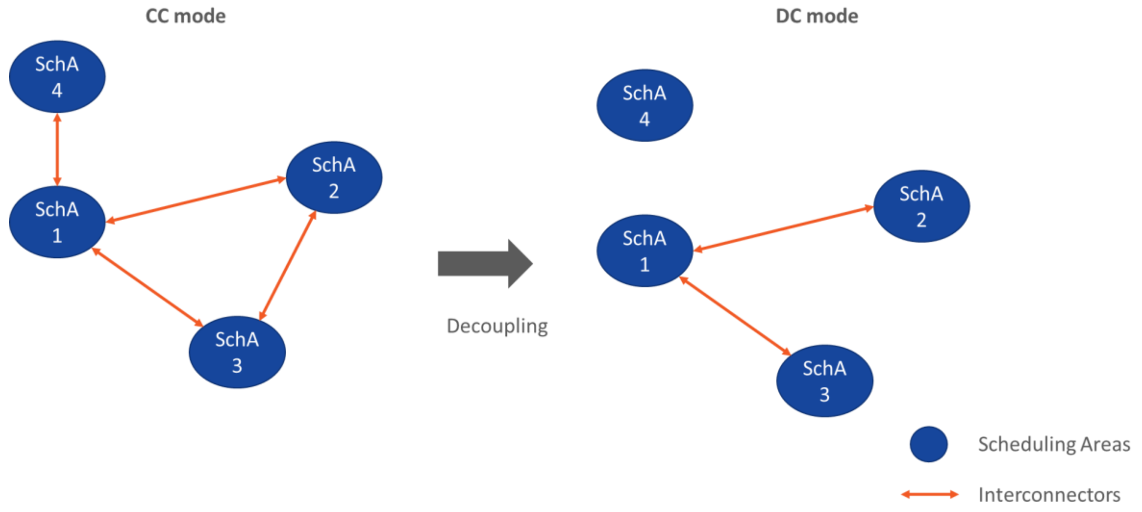


Figure 25: DC mode decoupling

Scheduling area 4 is decoupled from the rest of the network (SchA 1, SchA2 and SchA 3 in this example).

6.4.2 Heuristic

A heuristic procedure is available in MARI AOF as a back-up solution, and provides a solution to the decoupled mode only in case the other modes (coupled and decoupled) fail to provide a solution.
The heuristic solves a simplified decoupled mode problem, where only fully divisible bids are considered, and no technical profile or net position limits are taken into account.
The heuristic is an iterative algorithm aiming at accepting the bids and demands following the merit order list while it is feasible regarding all the market constraints.

7. APPENDICES

7.1. Glossary

AOF	Activation Optimization Function
LDM	Libra Data Management
MARI	Manually Activated Reserves Initiative
mFRR	Manual Frequency Restoration Reserve
TERRE	Trans European Replacement Reserves Exchange
RR	Replacement Reserve
CtrlA	Control Area
SchA	Scheduling Area
AggA	Aggregated Area
TSO	Transmission System Operator
MTU	Market Time Unit
BSP	Balancing Service Provider
CZC	Cross Zonal Capacity
TP	Technical Profile
CBMP	Cross Border Marginal Price
UAB	Unforeseeable Accepted Bid
URB	Unforeseeable Rejected Bid
MIP	Mixed Integer Program
LP	Linear Program
MIQP	Mixed Integer Quadratic Program

7.2. Market areas list

TSO	Control Area	Scheduling Area
50Hertz	50Hertz	50Hertz
Amprion	Amprion	AMP+CREOS*
APG	APG	APG
AST	AST	AST
CEPS	CEPS	CEPS
ELERING	ELERING	ELERING
ELES	ELES	ELES
Elia	Elia	Elia
Energinet	Energinet	DK 1
		DK 2
ESO	ESO	ESO
Fingrid	Fingrid	Fingrid
HOPS	HOPS	HOPS
IPTO	IPTO	IPTO

Litgrid	Litgrid	Litgrid
MAVIR ZRt.	MAVIR	MAVIR
MEPSO	MEPSO	MEPSO
REE	REE	REE
REN	REN	REN
RTE	RTE	RTE
SEPS	SEPS	SEPS
Statnett	Statnett	NO1
		NO2
		NO3
		NO4
		NO5
SVK	SVK	SE1
		SE2
		SE3
		SE4
Swissgrid	Swissgrid	Swissgrid
TenneT GER	TTG	TTG
TenneT NL	TenneT NL	TenneT NL
Terna	Terna	IT-CENTRE_NORTH
		IT-CENTRE_SOUTH
		IT-NORTH
		IT-CALABRIA
		IT-SARDINIA
		IT-SICILY
		IT-SOUTH
		IT-SACODC
Transelectrica	TEL	TEL
TransnetBW	TNG	TNG

* Scheduling Areas from Amprion and Creos constitute a single LFC area

7.3. Mathematical models

This section provides the mathematical formulation used to describe the MARI AOF objective functions. Not all MARI AOF models are described, but only the objectives as defined in sections 6.1.2 and 6.1.3, as well as the set of variables and parameters that are required in the corresponding equations.

7.3.1 Mathematical definitions

General Parameters

Parameter	Unit	Notation
Process delivery period (set of MTUs)		T, |T|=1 In MARI only one MTU per process is considered
Duration of MTU t	h	|t|

Set definition

Set	Notation
Set of scheduling areas	$SchA$
Set of control areas	$CtrlA$
Set of aggregated areas	$AggA$
Control area associated to Scheduling area b	$CtrlA_{\mathrm{b}}$
Scheduling Area included in Aggregated area d	$SchA_d$
Set of price zones	$PriceZ$

The following definitions are used in the next sections:

Set	Notation
Bids	$\mathrm{I}, I_b = \{i \in \mathrm{I} \mid \mathrm{b_i} = b\}$
Upward bids	$I^+, I_b^+ = I^+ \cap I_b$
Downward bids	$I^-, I_b^- = I^- \cap I_b$
Demands at SchA level	$N, N_b = \{\mathrm{n} \in \mathrm{N} \mid \mathrm{b}_n = b\}$
Demands at AggA level	$D, D_b = \{\mathrm{d} \in \mathrm{D} \mid \mathrm{b}_d = b\}$

Virtual demands at SchA level	$V, V_b = \{\mathrm{vn} \in \mathrm{V} \mid \mathrm{b}_{vn} = b\}$ Virtual demand at SchA level belonging to aggregated demand d: $V_d = \{\mathrm{vn} \in \mathrm{V} \mid \mathrm{b}_{vn} \in \mathrm{SchA_d}\}$
Positive demands at SchA level	$N^+, N_b^+ = N^+ \cap N_b$
Negative demands at SchA level	$N^-, N_b^- = N^- \cap N_b$
Inelastic demand at scheduling area level	$N^I, N_b^I = N^I \cap N_b$
Elastic demand at scheduling area level	$N^E, N_b^E = N^E \cap N_b$
Positive virtual demands at SchA level	$V^+, V_b^+ = V^+ \cap V_b$
Negative virtual demands at SchA level	$V^-, V_b^- = V^- \cap V_b$
Inelastic demands at SchA level for balancing purpose	$N^{BI}, N_b^{BI} = N^{BI} \cap N_b$
Inelastic demands at SchA level for system constraints purpose	$N^{SI}, N_b^{SI} = N^{SI} \cap N_b$
Inelastic demands at AggA level for balancing purpose	$D^{BI}, D_b^{BI} = D^{BI} \cap D_b$
Inelastic demands at AggA level for system constraints purpose	$D^{SI}, D_b^{SI} = D^{SI} \cap D_b$
Interconnectors	C

**A couple of 2 scheduling areas belong to the price coupling border set is they are interconnected with positive ATC defined on their interconnectors.*

Variables and parameters for bids and demand

Parameter	Notation
Price of bid i	$P_i \in [\overline{P}, \underline{P}] \; \forall \, i \in \mathrm{I}$
Price of demand n	$P_n \in [\overline{P}, \underline{P}] \; \forall \, n \in \mathrm{N}^E$
Maximum Quantity of bid i	$\overline{Q_i}, \forall \, i \in \mathrm{I}$
Maximum Quantity of demand n	$\overline{Q_n}, \forall \, n \in \mathrm{N}$

Parameter	Notation
Minimum Quantity of bid i	$\underline{Q_i}$, $\forall$ i $\in$ I\I^F
Maximum quantity of aggregated demand d	$\overline{Q_d}$, $\forall$ d $\in$ D

Variable	Notation/Range
Basic bid acceptance ratio	$r_i \in [0,1] \; \forall \; i \in \mathrm{I}$
SchA demand acceptance ratio	$r_n \in [0,1] \; \forall \; n \in \mathrm{N}$
AggA demand acceptance ratio	$r_d \in [0,1] \; \forall \; d \in \mathrm{D}$
Virtual demand acceptance ratio	$r_{vn} \in [0,1] \; \forall \; vn \in \mathrm{V}$
Basic bid accepted quantity	$Q_i = \overline{Q_i} * r_i$, $\forall \; i \in I$
Demand satisfied quantity	$Q_n = \overline{Q_n} * r_n$, $\forall \; n \in N$
Virtual demand satisfied quantity	$Q_{vn} = \overline{Q_{vn}} * r_{vn}$, $\forall \; vn \in V$

Variables and parameters for power system network

Parameter	Notation
Weigth of interconnector c	$weigth_c$, $\forall \mathrm{c} \in \mathrm{C}$

Variable	Notation/Range
Interconnector flow (in MW)	f_{12c} , f_{21c} $\in \mathrm{R} \; \forall \mathrm{c} \in \mathrm{C}$

Variables and parameters for price rules

Parameter	**Unit**	**Notation**
URB price upper bound: the lowest bid price among rejected upward bids and negative demands	€/MWh	$\overline{MCP_b}^{URB}$
URB price lower bound: the highest bid price among rejected downward bids and positive demands	€/MWh	$\underline{MCP_b}^{URB}$
Price target of price zone z	€/MWh	$MCP_z^0 \ \forall z \ \in PriceZ$

Variable	**Notation/Range**
Cross border marginal price (in €/MWh)	$MCP_b, \forall \text{ b } \in \text{SchA}$
cross border marginal price of a price zone z	$MCP_z, \forall \text{ z } \in \text{PriceZ}$

7.3.2 MARI AOF Objective functions

Main Objective

The market rules associated with the main objective are described in the section 6.1.2.
The mathematical function that implements these rules is made of the following terms with their associated weights (the sign indicates the direction of the optimization, "-" indicates minimization):

Objective	**Weight**	**Definition**
Economic surplus	K	$$\sum_{n \in N^+} P_n * Q_n * \lvert t \rvert - \sum_{n \in N^-} P_n * Q_n * \lvert t \rvert$$ $$+ \sum_{i \in I^-} P_i * Q_i * \lvert t \rvert - \sum_{i \in I^+} P_i * Q_i * \lvert t \rvert$$

Objective	Weight	Definition
Non-satisfied inelastic demands for balancing purpose	-l	$\sum_{n \in N^{BI} \cap N^+} (\overline{Q_n} - Q_n) * \lvert t \rvert + \sum_{n \in N^{BI} \cap N^-} (\overline{Q_n} - Q_n) * \lvert t \rvert$
Non-satisfied inelastic demands for system constraint purpose	-m	$\sum_{n \in N^{SI} \cap N^+} (\overline{Q_n} - Q_n) * \lvert t \rvert + \sum_{n \in N^{SI} \cap N^-} (\overline{Q_n} - Q_n) * \lvert t \rvert$
Non-satisfied inelastic aggregated demands for balancing purpose	-n	$\sum_{d \in D^{BI} \cap N^+} (\overline{Q_d} - \sum_{vn \in V_d^+} Q_{vn}) * \lvert t \rvert + \sum_{d \in D^{BI} \cap N^-} (\overline{Q_d} - \sum_{vn \in V_d^-} Q_{vn}) * \lvert t \rvert$
Non-satisfied inelastic aggregated demands for system constraint purpose	-o	$\sum_{d \in D^{SI} \cap N^+} (\overline{Q_d} - \sum_{vn \in V_d^+} Q_{vn}) * \lvert t \rvert + \sum_{d \in D^{SI} \cap N^-} (\overline{Q_d} - \sum_{vn \in V_d^+} Q_{vn}) * \lvert t \rvert$

The different weights can be parametrized; however, they shall respect the following relation:

$$\mathrm{k, l, m, n, o} \geq 0$$

$$\mathrm{l, m, n, o} \gg k$$

$$\mathrm{l = n}\ and\ m = o$$

$$\mathrm{l > m}$$

Secondary objectives

The next objectives described in this section are secondary objective optimized during the finalization as described int the section 6.1.3**Error! Reference source not found.**. Their weights are always +1 or -1 since they are optimized independently from each other. A weight of +1 indicates the objective is to be maximized, and a weight of -1 indicates the objective is to be minimized.

Objective	Weight	Definition
XB flows	-1	$\sum_{c\in C} weitgh_c * (f_{12_c})^2 + weitgh_c * (f_{21_c})^2$
Traded volumes	1	$\sum_{n\in N^+} Q_n * \lvert t\rvert + \sum_{n\in N^-} Q_n * \lvert t\rvert$ $\sum_{i\in I^+} Q_i * \lvert t\rvert + \sum_{i\in I^-} Q_i * \lvert t\rvert$
Minimize URBs	-1	$\sum_{b\in SchA} \max\left(0, MCP_b - \overline{MCP_b}^{URB}\right) + \max\left(0, \underline{MCP_b}^{URB} - MCP_b\right)$
Distance to price targets	-1	$\sum_{z\in PriceZ} (MCP_z - MCP_z^0)^2$

7.4. References

ENTSOE (2018), *All TSOs' proposal for the implementation framework for a European platform for the exchange of balancing energy from frequency restoration reserves with manual activation in accordance with Article 20 of Commission Regulation (EU) 2017/2195 establishing a guideline on electricity balancing*.

ENTSOE (2018), *Explanatory document to all TSOs' proposal for the implementation framework for a European platform for the exchange of balancing energy from frequency restoration reserves with manual activation in accordance with Article 20 of Commission Regulation (EU) 2017/2195 establishing a guideline on electricity balancing*.

ENTSOE (2018), *All TSOs' proposal for classification methodology for the activation purposes of balancing energy bids pursuant to Article 29(3) of Commission Regulation (EU) 2017/2195 establishing a guideline on electricity balancing*

Commission Regulation (2017), *Electricity Balancing Guidelines (EBGL), Article 20*, *European platform for the exchange of balancing energy from frequency restoration reserves with manual activation*.