MARI

Manually Activated Reserves Initiative

MARI Stakeholder Workshop

4 September 2017
ENTSO-E Brussels premises

Content

TOP 1 and 2: WELCOME and MARI INTRODUCTION

Project Background

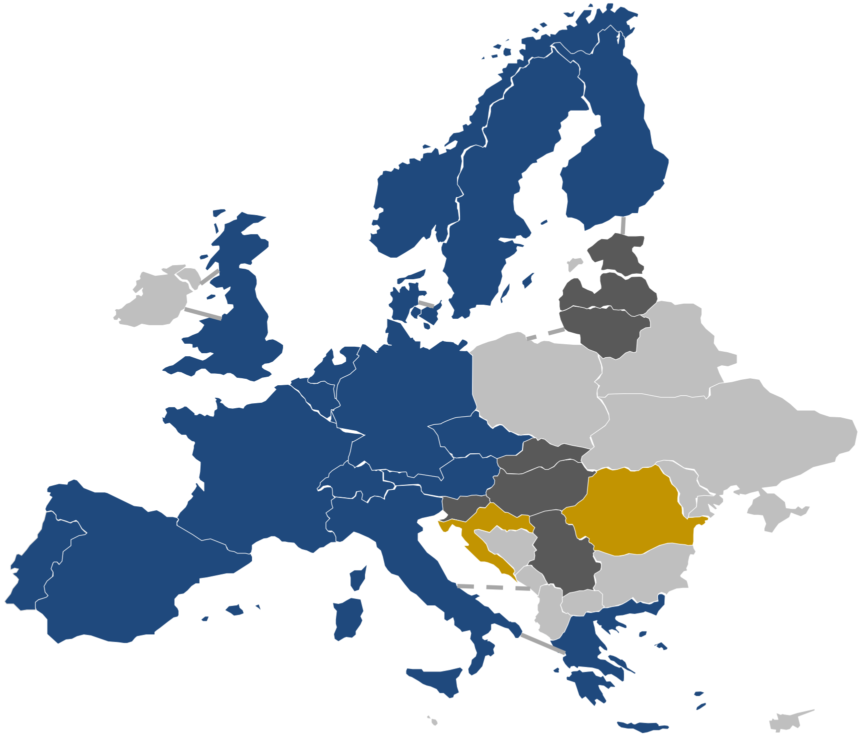
MARI project	Other/Previous Initiatives of the involved TSOs	Legal Background
❍ The goal is to create a European platform for mFRR ❍ New project independent from the existing initiatives ❍ TSOs of the cooperation started working on the principles of an mFRR platform already in 2016 ❍ 5 April 2017 TSOs signed Memorandum of Understanding, which outlines the main design features of the project as well as the governance principles	❍ Common Nordic mFRR market in operation ❍ Amprion/RTE – proposal for the design of an mFRR market DE/FR ❍ Explore – proposal for the design of an mFRR market ❍ AT/DE project for the implementation of an mFRR market ❍ mFRR discussions in the TERRE framework	❍ Guideline on electricity balancing (“GLEB”) ❍ Guideline on transmission system operation (”GLSO”) ❍ Regulation 1222/2015, (“CACM”) ❍ Regulation 1227/2011(“REMIT”) ❍ Regulation (EC) 714/2009

Involved Parties – TSOs only

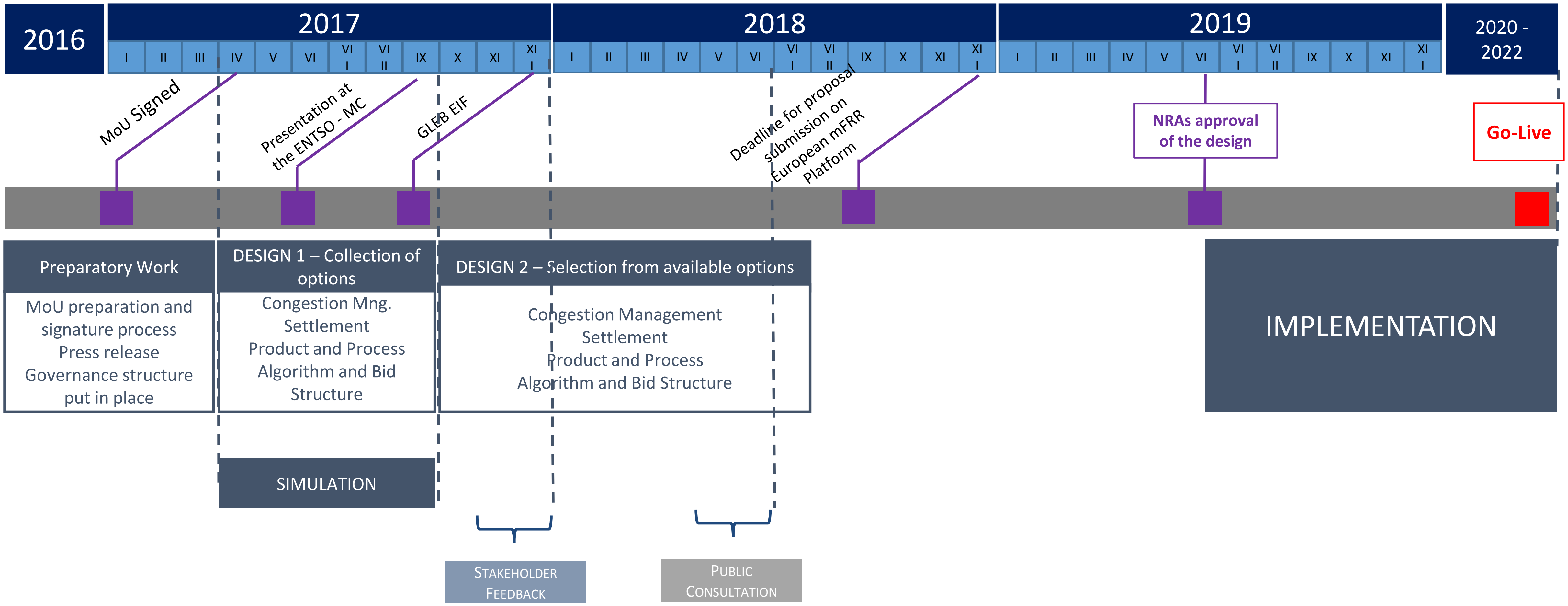
MEMBERS	
Austria	APG
Belgium	elia
Czech Republic	čeps
Denmark	ENERGINET
Finland	FINGRID
France	Rte
Germany	50hertz, amprion, TenneT, TRANSNET BW
Greece	ΑΔΜΗΕ
United Kingdom	nationalgrid
Italy	Terna Rete Italia
Netherland	TenneT
Norway	Statnett
Portugal	REN
Spain	RED ELÉCTRICA DE ESPAÑA
Sweden	SVENSKA KRAFTNÄT
Switzerland	swissgrid

OBSERVERS	
Estonia	elering
Hungary	MAVIR
Latvia	AST
Lithuania	Litgrid
Serbia	EMC
Slovakia	SEPS
Slovenia	ELES

Countries in Process of Becoming Observers	
Croatia	HOPS
Romania	Transelectrica



Project Timeline according to the GLEB



Design Roadmap Milestones

MILESTONE		DATE
1	MC Decision on the Implementation Project	7 September 2017
2	Design 1 - Identification of options finalized	30 September 2017
3	Design 2 - Selection from options and proposal finalized	30 April 2018
4	Public Consultation Conducted	30 June2018
5	Submission of the design to NRAs	1 December 2018
6	NRAs Approval	1 June 2019
7	Implementation	2019-2022

Approach to External Stakeholders

- The involvement and feedback from the stakeholders is of utmost importance
- We plan a 3-step approach in communication with the stakeholders

Stakeholder workshop	MARI Stakeholders Feedback Collection	Public Consultation according to GLEB
Date: 4 September 2017	Date: November, December 2017	Date: May, June 2018
Purpose: Introduce the project and provide information in a concise manner	Purpose: Provision of a design report for external purposes and collection of feedback through an associated questionnaire	Purpose: Standard public consultation of the finalized design proposal

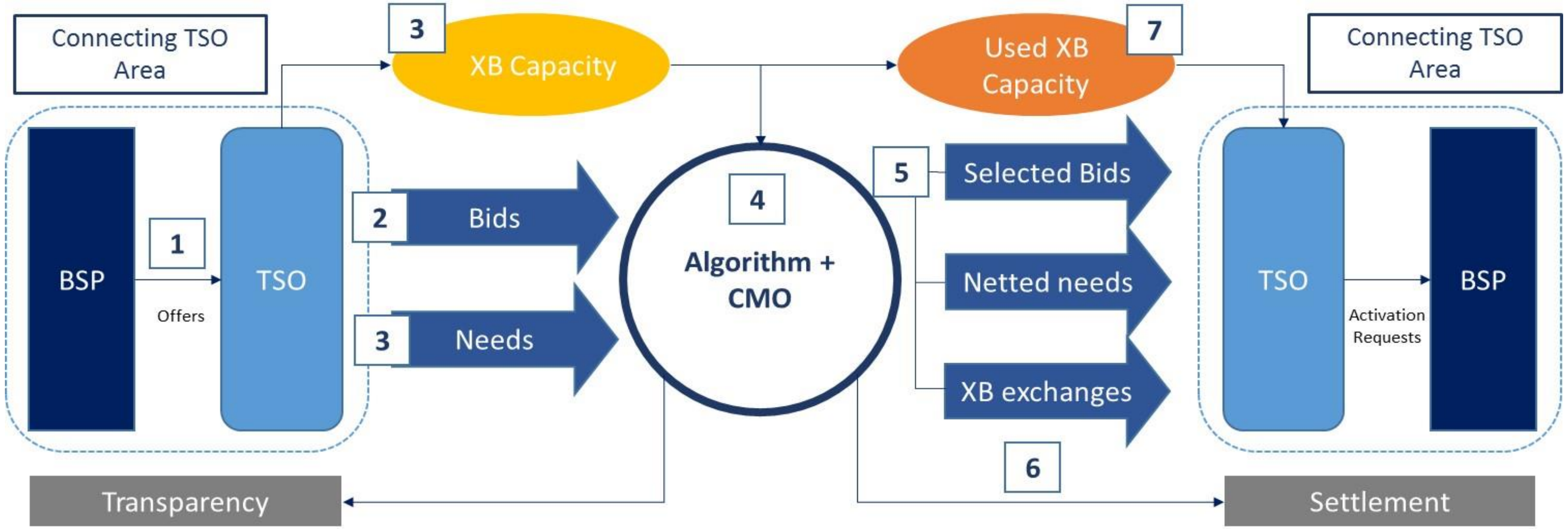
No delays in the project due to the stakeholders' feedback

Creation of a liquid platform

TOP 3: PRODUCT and PROCESS

Content

General Process



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

Product – 1/3

Main Questions

- What should the full activation time of the mFRR product be?
- What should the key characteristics of the mFRR product be?

Product – 2/3

Full Activation Time (FAT) definition

- **<u>Context:</u> GLSO (System Operation Guideline) requirements**
  - To manage the system while respecting frequency quality targets, TTRF (Time To Restore Frequency) should be harmonized at 15 minutes throughout Europe.
- **<u>Implications:</u> for mFRR, at least 2 possible interpretations:**
  - FATmFRR ≤ 15’
  - FATmFRR < 15’
- **<u>Consequences for MARI:</u> at least two options in consideration**
  - FATmFRR = 15’
  - FATmFRR = 12.5’
- **<u>Conclusion:</u> MARI will follow the recommendation from ENTSO-E and put forward the possible options as soon as possible to obtain the view of the stakeholders.**

NOTE: The illustrations in the rest of the documents consider FAT of 12.5 minutes in order not to over complexify the presentation

Product – 3/3

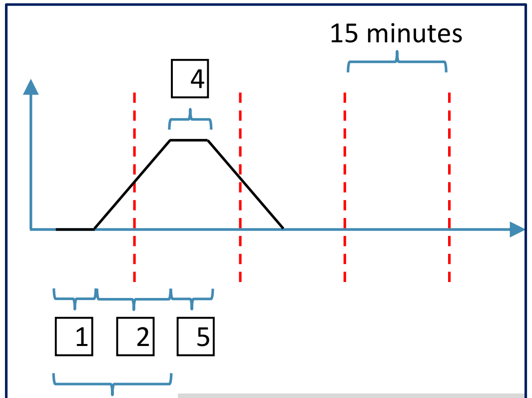
Product Properties

mFRR Product Properties are based on:

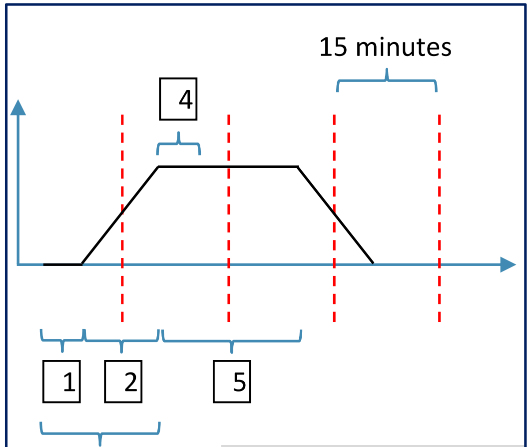
- Key characteristics of standard products from GLEB (Art. 25)
- Further properties

Figures legend	Properties	Expected Shape	Accepted Shape
1	Preparation Period	2.5‘	**0-12.5‘** *(Exact accepted shape set by the local TSOs)*
2	Ramping Period	10‘	**0-12.5‘** *(Exact accepted shape set by the local TSOs)*
3	Full Activation Time	12.5‘	
4	Minimum duration of delivery period	**5‘** *(scheduled and direct activation)*	*(Exact accepted shape set by the local TSOs)*
5	Maximum duration of delivery period	**20’** *(longest direct activation)* **5‘** *(longest scheduled activation)*	*(Exact accepted shape set by the local TSOs)*
-	Minimum quantity	1 MW	
-	Maximum quantity	9999 MW	
-	Deactivation period	10‘	
-	Validity period	To be analyzed in the next phase of the project	
-	Mode of activation	Manual	

NOTE: Table given with the assumption of a FAT equal to 12.5min



mFRR Product Physical Shape Scheduled Activated



mFRR Product Physical Shape Direct Activated

Timing of the Process – 1/7

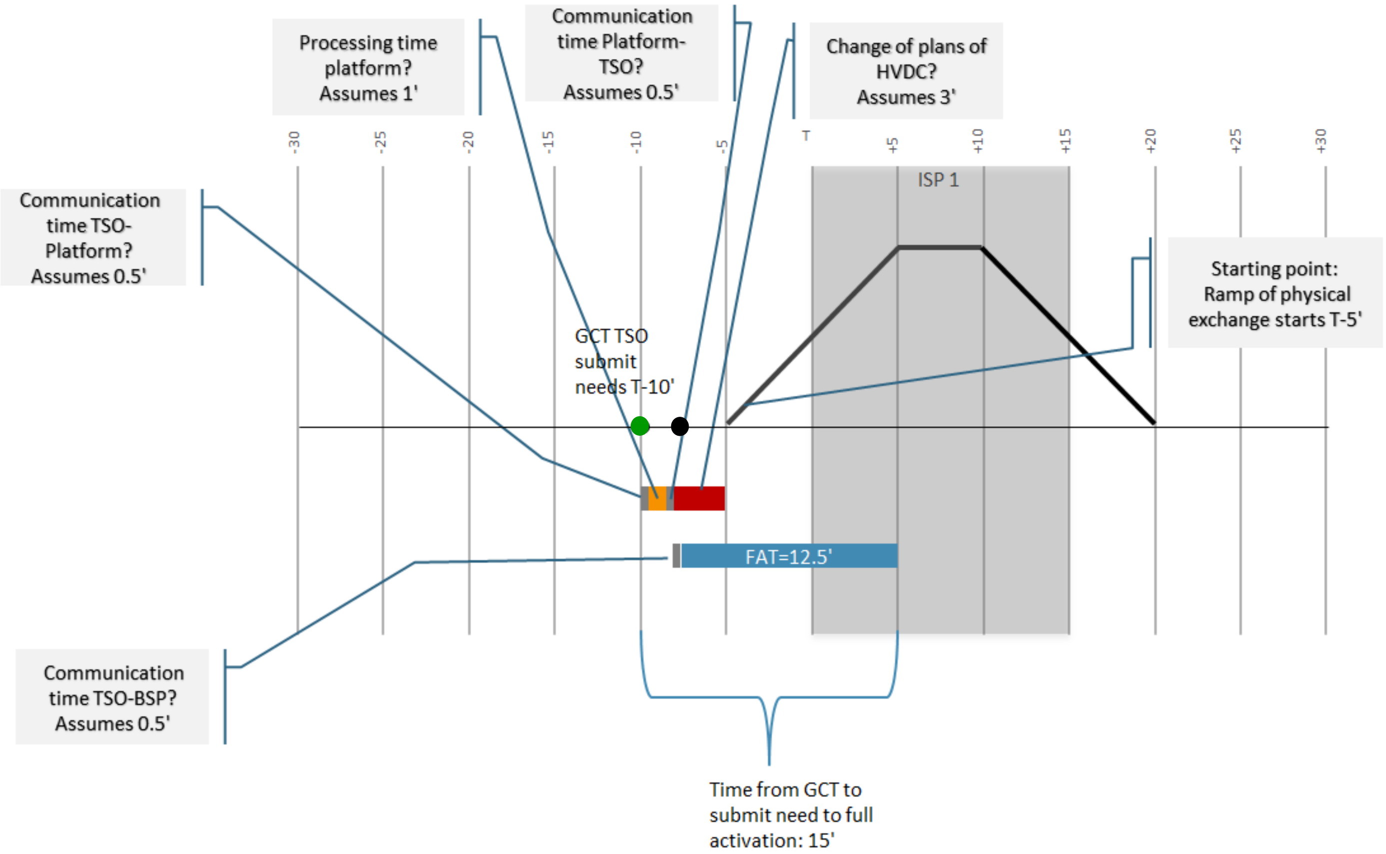
Main Questions

- How long will it take from the need of a TSO being submitted to the platform until bids are fully activated?
- When should GCT for the BSPs be?
- When should direct activations be possible in relation to the scheduled activation for the same CMOL?

Timing of the Process – 2/7

Timing of the Scheduled Process

Starting point: Activation of scheduled bids starts 7.5min before the start of the ISP



Action	Assumed duration
Communication TSO-Platform	0.5’
Processing time platform (algorithm)	1’
Communication Platform-TSO	0.5’
Communication TSO-BSP	0.5’
Change of HVDC Plans	3’

NOTE: the depicted delivery profile corresponds to the profile of the TSO-TSO cross-border exchange and expected sthape of the standard mFRR-product.

Timing of the Process – 3/7

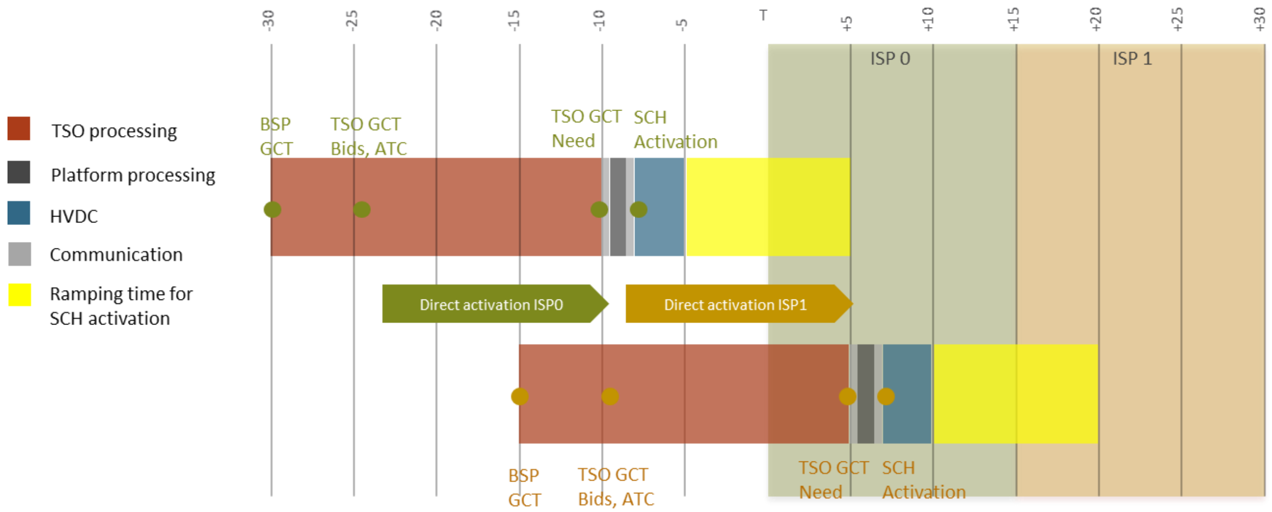
Timing of the Direct Activated Process

- **Base case: direct activation in a continuous manner**
  - However, technical limitations exist to allow a ‘continuous’ process
    - Processing and communications time
    - Change of HVDC plans
  - Note: the base case of a continuous direct activation process is used in the remainder of this presentation to illustrate the different concepts

- **Alternative option: direct activation in cycles**
  - An alternative is to perform the process of direct activation in cycles
    - Allows netting
    - Leaves time for processing
  - Example: 5min cycles
    - Per 15min period: 2 DA and 1 SA
  - Minimal cycle assuming a processing time of 1 minute (cf. SA process) = 1 min
    - Per 15min period: 14 DA and 1 SA (see illustration next slide)

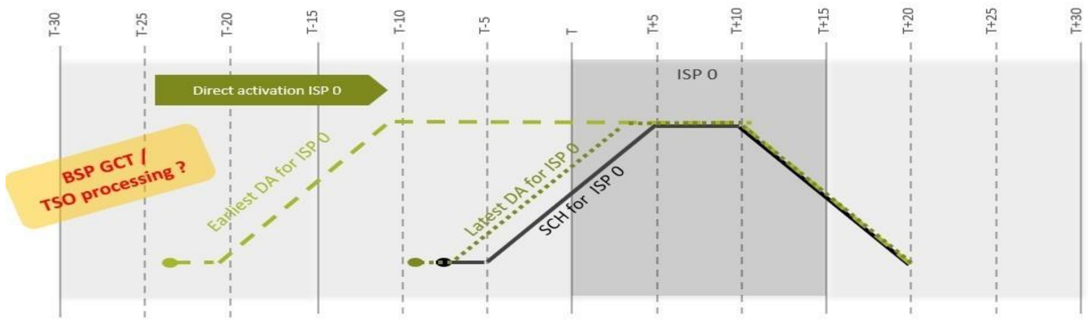
Timing of the Process – 4/7

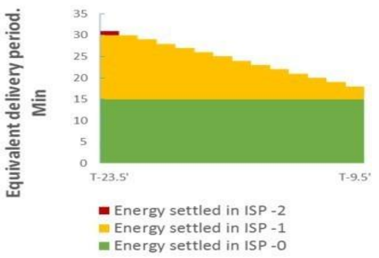
Interaction between the scheduled and direct activation process – base case scenario (1/3)



The direct activation process (DA) is assumed to be continuous and can interact in different ways with the scheduled process (SA):

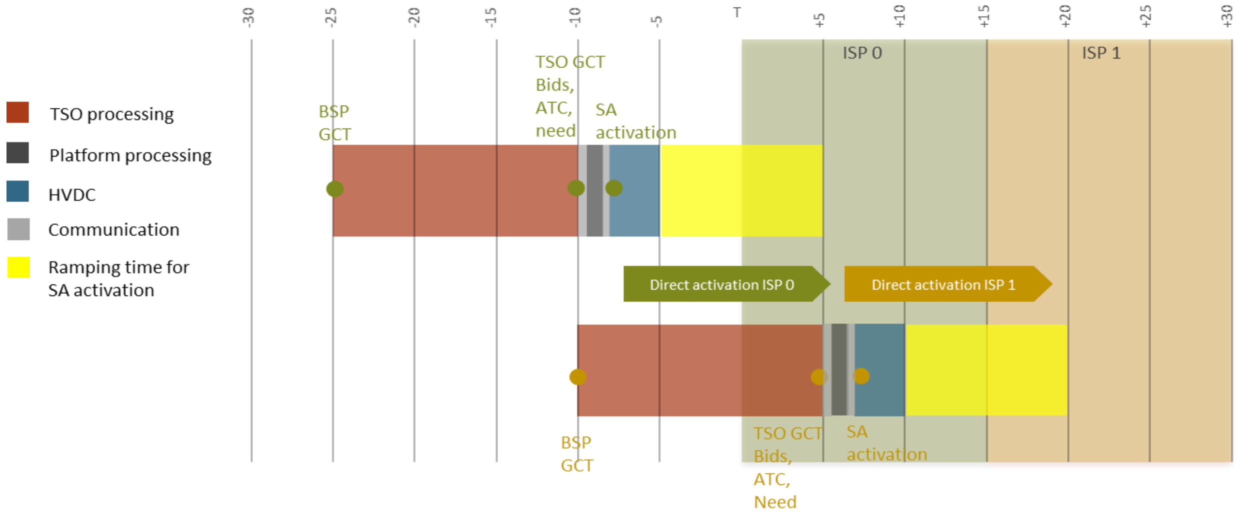
- DA before SA (both for ISP 0)
- DA after SA (both for ISP 0)
- DA before and after SA (both for ISP 0)





Timing of the Process – 5/7

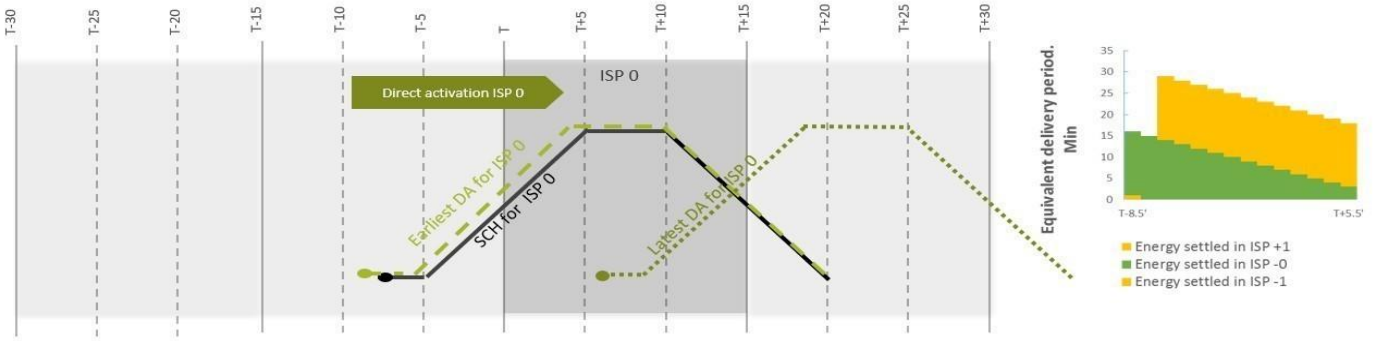
Interaction between the scheduled and direct activation process – base case scenario (2/3)



The direct activation process (DA) is assumed to be continuous and can interact in different ways with the scheduled process (SA):

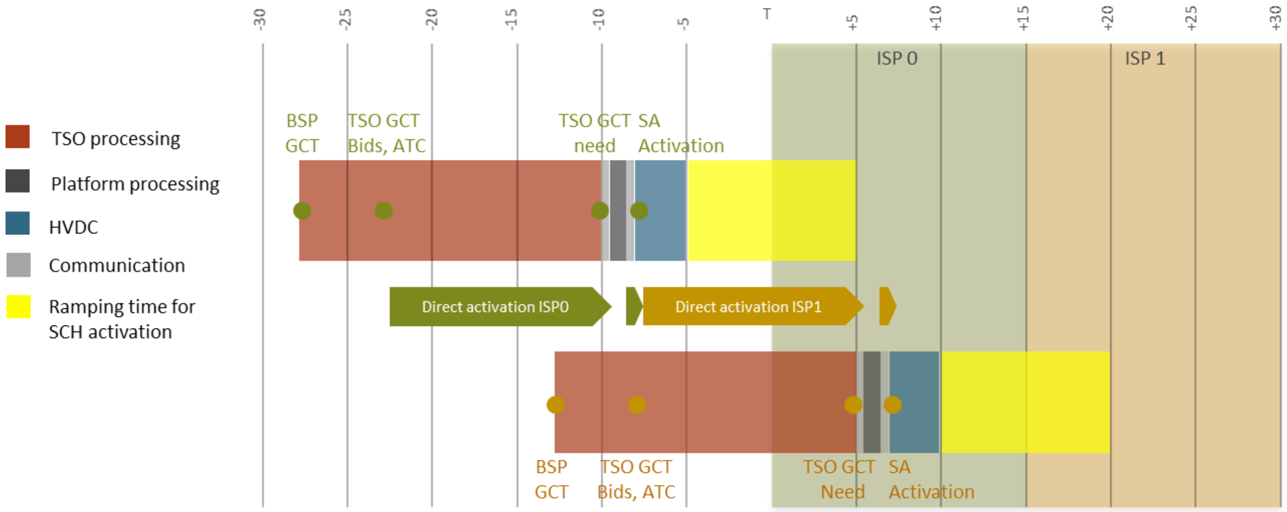
- DA before SA (both for ISP 0)
- DA after SA (both for ISP 0)
- DA before and after SA (both for ISP 0)

- DA before T-7.5’ will end in ISP 0
- DA after T-7.5’ will end in ISP 1



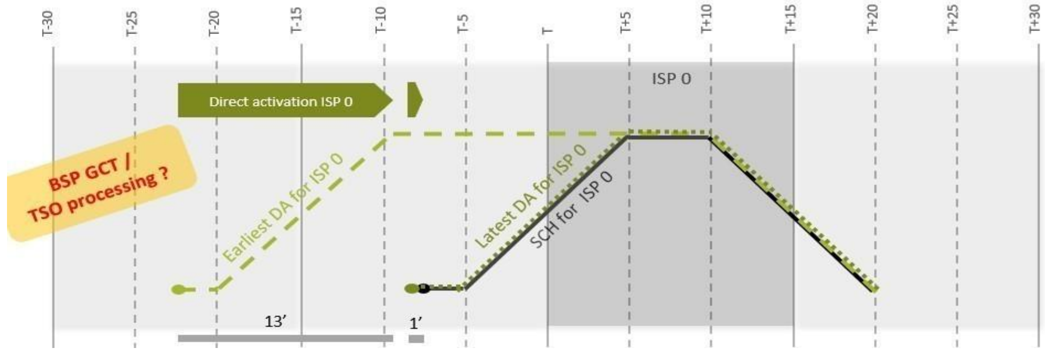
Timing of the Process – 6/7

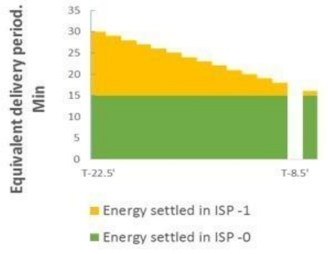
Interaction between the scheduled and direct activation process – base case scenario (3/3)



The direct activation process (DA) is assumed to be continuous and can interact in different ways with the scheduled process (SA):

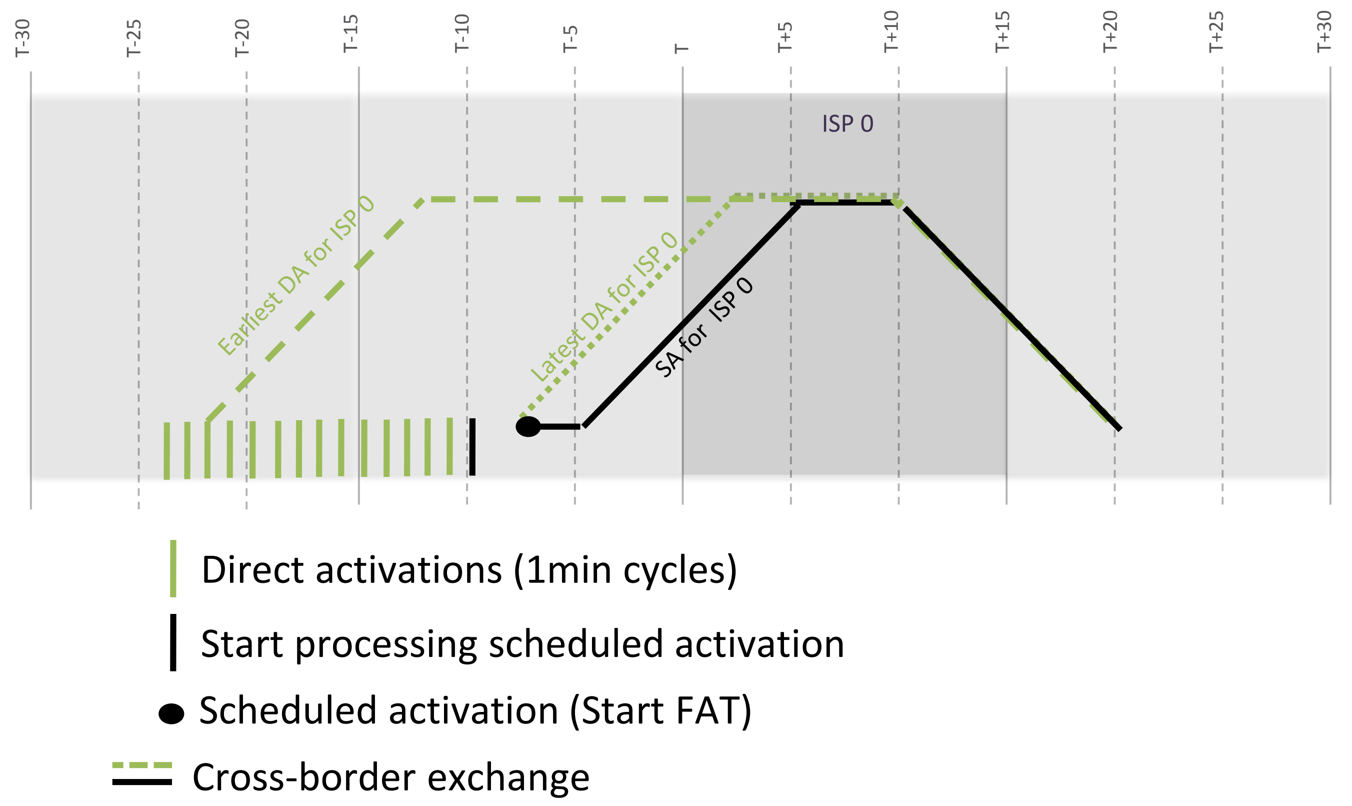
- DA before SA (both for ISP 0)
- DA after SA (both for ISP 0)
- DA before and after SA (both for ISP 0)





Timing of the Process – 7/7

Illustration of a DA process with 1min cycles



Bid Structure – 1/4

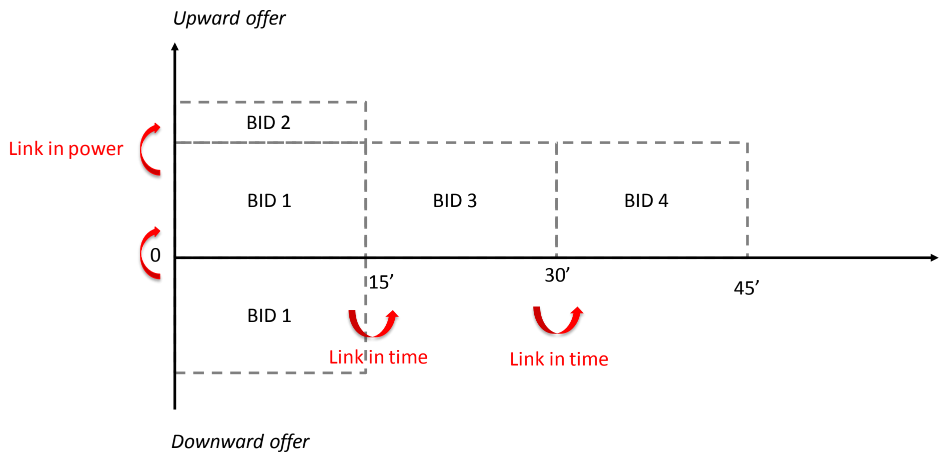
Main Questions

- Should there be the possibility to link bids and if yes, which kind of linked bids?
- What should the maximum bid size for indivisible bids be?
- What are the requirements concerning reliability?

Bid Structure – 2/4

Linking Bids

- In general, bids can be linked in power and in time for economical reasons.
  - Linking of bids in time by BSPs is not feasible because optimization is done per 15’ period and not over several periods.
  - Linking in power is feasible and economically advantageous for both BSPs and TSOs. However, not all possible links will be allowed and there will be limits to the possibilities (e.g. max number of linked bids).
  - Different options will be investigated:
    - Linked bid orders
    - Exclusive group orders
    - …



Note:

There exists a need to link bids in time, i.e. over different periods, for technical reasons.
A methodology for this will be developed

E.g.: a scheduled activated bid in ISP0 that is also offered for ISP1 cannot be direct activated at the start of ISP1. Since GCT for BSPs for ISP1 will fall after the clearing of scheduled bids for ISP0, this information must be known to the platform.

Bid Structure – 3/4

Indivisible Bids - Maximum Bid Size

- **Current Situation:** Most of the TSOs in the cooperation allow indivisible bids. Nevertheless, the maximum bid size varies from a minimum of 25 MW (Germany) to a maximum of approximately 300 MW (Portugal).
- **Allow indivisible bids**: Since most TSOs allow indivisible bids, this should be allowed in the MARI cooperation as well.
- **Maximum bid size:** Different criteria have to be considered in order to determine the maximum bid size

Advantages of small maximum bid size	Disadvantages of both options	Advantages of big maximum bid size
Avoid market abuse	Implementation effort	Liquidity
Smaller deviations from need	Changes to current market design	
Incentives for BSPs to be flexible		

Bid Structure – 4/4

Reliability of Bids

Two possibilities to understand the reliability of bids are considered

- Reliability of the cross-border exchange
  - This describes the reliability of the cross-border exchange if a bid in LFC block A has been activated for LFC block B.
  - Reliability should be 100%, meaning that non-compliancy will lead to aFRR-demand or even ACE in the non-compliant LFC block.

- Reliability of bids
  - This describes the reliability of a bid which can vary from BSP to BSP and from country to country depending on multiple factors (e.g. back-up requirements).
  - This type of reliability shall be elaborated within the MARI project when harmonization of TSO-BSP rules is treated.

Rules for Balancing Need – 1/3

Main Questions

- Should price dependent needs be allowed?
- Should a TSO be allowed to activate a larger volume of bids than the TSO has made available for the platform?

Rules for Balancing Needs – 2/3

Price Dependent Needs

- For a TSO, price dependent needs may be required:
  - There are several balancing products available
  - Optimized use of these products can reduce balancing cost

- Three options for price dependency are investigated:
  - Inelastic: not priced (the volume is absolutely required by the TSO)
  - Inelastic with a limit price: i.e. TSO sets a max/min price that they are willing to pay/receive
  - Elastic: several request levels with volume and price, demand curve.

- Proposal
  - Design phase will consider price dependent needs
  - Subsequent impact on Timing and Settlement to be assessed

Rules for Balancing Need – 3/3

TSO activation volume

- In normal conditions there could be two restrictions:
  - A TSO or LFC block cannot activate more bid volume than it has made available to the platform
  - A TSO or LFC block cannot activate more DA bid volume than it has made available to the platform

- Example
  - TSO1 makes available the following bid volumes to the MARI platform:
    - Direct 50 MW
    - Schedule 100 MW
  - With the above conditions, TSO1 could submit the following needs:
    - A maximum of 150MW in total
    - A maximum of 50MW in direct needs
    - A maximum of 150MW in schedule needs

Cross-Border Exchange – 1/2

Main Questions

- How should the physical properties of HVDC interconnectors and TSO imposed restrictions be considered in project MARI with respect to GLSO?

Cross Border Exchange – 2/2

Physical Feasibility

- In some situations, TSOs need the facility to manage the operational flow range of HVDC links.
- The concept of ‘physical feasibility’ on HVDC interconnectors is introduced in order to manage:
  - Min/max acceptable ramp rates
  - Unsecure flow intervals
  - Imbalances created by a difference between commercial and physical flow set points
- This ‘physical feasibility’ may be an input to the MARI platform. The algorithm would have to compute a solution that will respect the physical properties of the interconnector and limitations imposed by the TSO.
- For settlement and apportionment of costs, two optimizations will run:
  - Constrained – as above with HVDC limitations included
  - Unconstrained – only considering mFRR needs for calculation of marginal price

TOP 4: SPECIFICATION of ACTIVATION OPTIMIZATION FUNCTION

Content

Algorithm Components – 1/4

Main Questions

- What should the objective of the activation optimization function be?

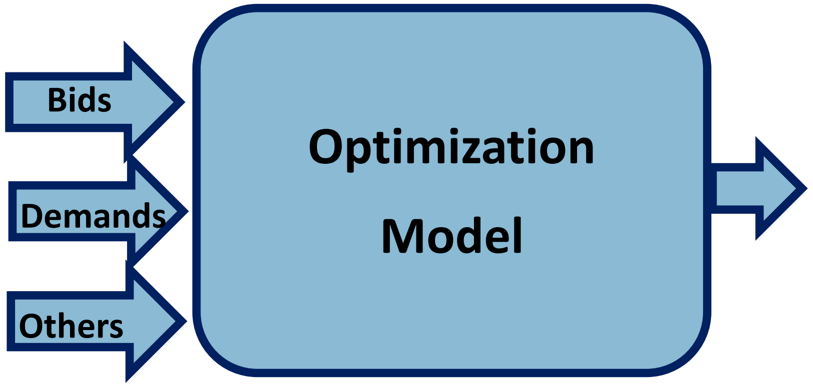
Algorithm Components – 2/4

Inputs	Optimization Model	Output
❍ Bids • Divisible • Indivisible ❍ Demands • Elastic • Inelastic ❍ Power Flow Limits • Available transmission capacity • Other congestion constraints	❍ **Objective function** • Maximizing social welfare (i.e., minimizing balancing cost) ❍ **Constraints** • Power balance equation (netting) • Power flow constraints • HVDC constraints	❍ Accepted bids ❍ Satisfied demands ❍ XB marginal prices ❍ Social welfare/Balancing cost

Computation Time

Multiple Optimal Solution

Feasibility Checks



Accepted bids

Satisfied demands

XB marginal prices

Optimal social welfare (Balancing cost)

Algorithm Components – 3/4

Core Optimization Model

Objective:
Maximize social welfare (minimize balancing cost)

Subject to:

1. Power Balance Constraints	→	Accepted bids/offers are equal to TSO demands
2. Power Flow Constraints	→	Power flow due to accepted bids/offers is within required limits (ATC & other congestion constrains)
3. Divisibility of Bids/Offers	→	Bids can be divisible or indivisible, linked bids, mutually exclusive bids etc.
4. Elasticity of TSO Demands	→	TSO demands can be either elastic or inelastic

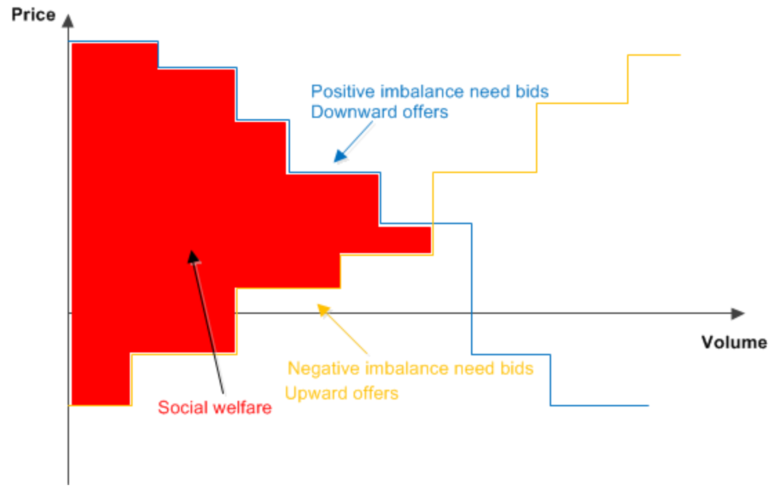
Algorithm Components – 4/4

Main Constraints

- **Maximizing social welfare (i.e., Minimizing balancing cost)**

- Power balance constraint: **Netting of the TSO demands inherently occurs**. The netting of the TSO demands occurs as long as it results in higher social welfare and it does respect other technical constraints, e.g. power flow constraints.

- Power flow constraint: ATC and other congestion constraints→ **TSOs with other congestion constraints might also need to specify the location of their bids & offers accordingly**



Unforeseen Rejected Bids– 1/5

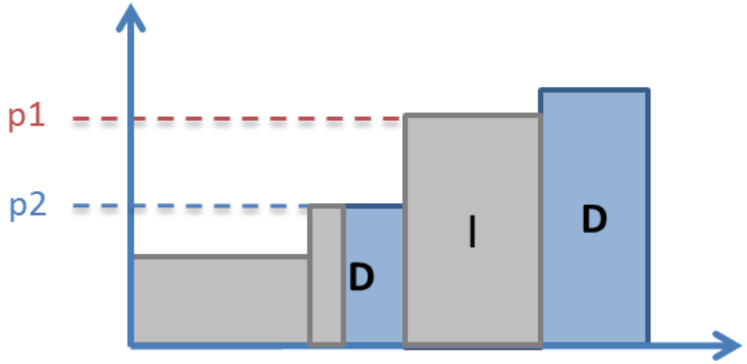
Main Questions

- How unforeseen accepted divisible bids shall be treated?

Unforeseen Rejected Bids – 2/5

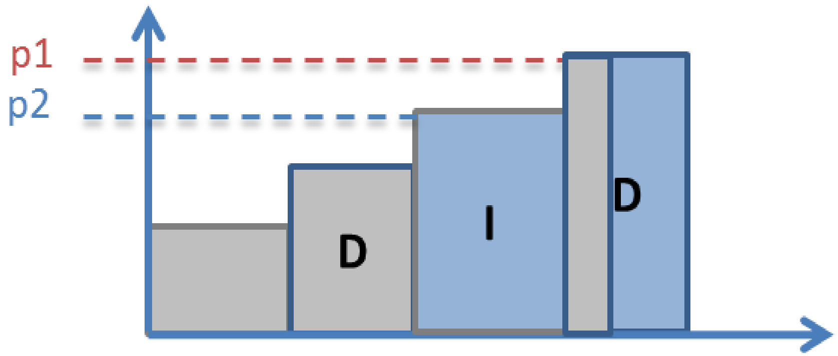
- The algorithm handles **complex** bid formats → unforeseen rejected bids

Unforeseen rejected divisible bid



D: divisible bid
I: indivisible bid
accepted part
not accepted part

Unforeseen rejected indivisible bid



p1 – Clearing price
p2 – Price of the unforeseen rejected bid

Unforeseen Rejected Bids– 3/5

Unforeseen Rejected Divisible Bids - 1/2

INPUT:

TYPE	Quantity (MW)	TSO Demand Price/Offer Price (€/MWh)	Elasticity of Demand	Divisibility of Offers
Demand (TSO 1)	+100	--	Inelastic	--
Demand (TSO 2)	+100	--	Inelastic	--
Upward Offer (UO BSP1)	190	10	--	Indivisible
Upward Offer (UO BSP2)	8	20	--	divisible
Upward Offer (UO BSP3)	10	21	--	Indivisible
Upward Offer (UO BSP4)	2	30	--	Indivisible

OUTPUT:

Type	Output of Balancing Cost minimization (allowing unforeseen rejected divisible bids) Activated Quantity/Satisfied Demand (MW)	Output of Market-Coupling model (avoiding unforeseen rejected divisible bids) Activated Quantity/Satisfied Demand (MW)
Demand (TSO 1)	+100	+100
Demand (TSO 2)	+100	+100
Upward Offer (UO BSP1)	190	190
Upward Offer (UO BSP2)	0	8
Upward Offer (UO BSP3)	10	0
Upward Offer (UO BSP4)	0	2
Marginal Price (€/MWh)	€21/MWh	€30/MWh
Balancing cost (€)	2110	2120

Unforeseen Rejected Divisible Bids – 2/2

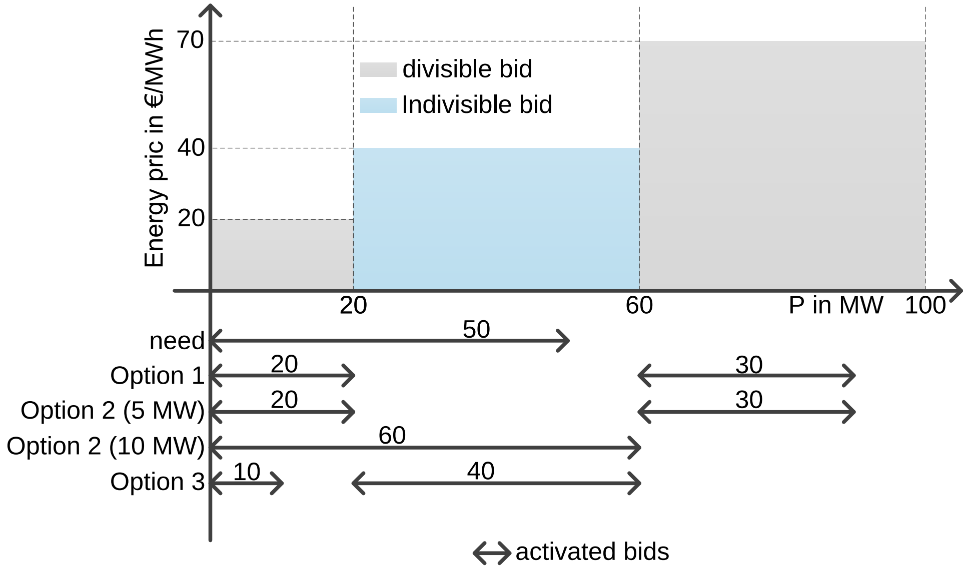
QUALITATIVE ANALYSIS:

Criteria	Allowing Unforeseen Rejected Divisible Bids (Social-Welfare Maximization)	Avoiding Unforeseen Rejected Divisible Bids (Market-Coupling Algorithm)
Optimal Social Welfare (Minimum Balancing Cost)	Smaller Balancing Cost	Higher Balancing Cost
Complexity Level of Algorithm	Low (Simple) (solving a primal clearing model)	High (Complex) (including a non-linear constraint and solving a primal-dual problem)
Computation Time	Lower computation time	Higher computation time
Bid structure	No particular incentive	Incentivize (a) divisible bids and (b) indivisible bids of lower volume

Unforeseen Rejected Bids– 5/5

Indivisible Bids – Algorithm

- There are different options to consider indivisible bids in the algorithm. The activation of indivisible bids is more likely if a tolerance band is applied to the need of a TSO.
- The following table shows a first comparison of the options.



	Tolerance band	No tolerance band	No tolerance band – all bids can be rejected
Complexity algorithm	-1	0	0
Incentives to offer divisible bids	0	1	-1
Transparency for TSOs	-1	0	-1
Acceptance BSPs	1	1	-1
Social welfare	0	0	1
Consistency with other markets	-1	1	-1

Computation Time – 1/2

Qualitative Statement

- **Impact of linking bids/offers:**

  → *Linear constraint should be tractable in a reasonable time.*

- **Impact of zones with different resolution (size) in the power flow constraints:**

  → *Linear constraint should be tractable in a reasonable time.*

- **Impact of avoiding unforeseen rejected divisible bids:**

  → Non-*linear constraint may influence computation time.*

Computation Time – 2/2

Quantitative Statement

Need of Simulations:

- **Actual Market Size**
  - Actual number of divisible and indivisble bids
  - Available transmission capacity & Internal Zones

- **Strong Computation Engine**
  - RAM > 512 GB
  - Processor Clock > 2.9 GHz

- ***Know-how of techniques reducing the computation time***
  - Decomposition & Parallel Computing

Multiple Optimal Solutions– 1/3

Main Questions

- How should multiple optimal solutions be treated?

Multiple Optimal Solutions - 2/3

Case 1: a set of optimal solutions with different marginal prices:

TYPE	Quantity (MW)	TSO Demand Price/Offer Price (€/MWh)	Elasticity of Demand	Divisibility of Offers
Demand (TSO 1)	+100	--	Inelastic	--
Demand (TSO 2)	+100	--	Inelastic	--
Upward Offer (UO BSP1)	190	10	--	Divisible
Upward Offer (UO BSP2)	8	20	--	Indivisible
Upward Offer (UO BSP3)	10	21	--	Indivisible
Upward Offer (UO BSP4)	2	25	--	Indivisible

Type	Solution A Activated Quantity/Satisfied Demand (MW)	Solution B Activated Quantity/Satisfied Demand (MW)
Demand (TSO 1)	+100	+100
Demand (TSO 2)	+100	+100
Upward Offer (UO BSP1)	190	190
Upward Offer (UO BSP2)	0	8
Upward Offer (UO BSP3)	10	0
Upward Offer (UO BSP4)	0	2
Marginal Price (€/MWh)	€21/MWh	€25/MWh
Social welfare (€)	-2110	-2110

SUGGESTION:

Solution A → Optimal Solution with Smaller Marginal Price

MARI

Multiple Optimal Solutions – 3/3

Case 2: a set of optimal solutions with same marginal prices

TYPE	Quantity (MW)	TSO Demand Price/Offer Price (€/MWh)	Elasticity of Demand	Divisibility of Offers	Area
Demand (TSO 1)	+100	--	Inelastic	--	Area 1
Demand (TSO 2)	+100	--	Inelastic	--	Area 2
Upward Offer (UO BSP1)	190	10	--	Divisible	Area 1
Upward Offer (UO BSP2)	8	20	--	Indivisible	Area 2
Upward Offer (UO BSP3)	10	20	--	Indivisible	Area 3
Upward Offer (UO BSP4)	2	20	--	Indivisible	Area 4

Type	Solution A Activated Quantity/Satisfied Demand (MW)	Solution B Activated Quantity/Satisfied Demand (MW)
Demand (TSO 1)	+100	+100
Demand (TSO 2)	+100	+100
Upward Offer (UO BSP1)	190	190
Upward Offer (UO BSP2)	0	8
Upward Offer (UO BSP3)	10	0
Upward Offer (UO BSP4)	0	2
Marginal Price (€/MWh)	€20/MWh	€20/MWh
Social welfare (€)	-2110	-2110

SUGGESTION:

Solution B → Optimal Solution with Smaller Energy Exchange between TSOs connections (power flow)

Feasibility Checks – 1/2

- The main source of an infeasible solution is to have a total demand quantity higher than the total quantity of offers/bids.
- **Solution A**: Each TSO is allowed to submit a demand which is not larger than the total bids/offers from the BSPs associated with this TSO. That is, if there are TSOs whose demand is more than their total amount of its associated offers, these TSO are excluded from the algorithm in that interval (both their demands and associated bids).
- **Solution B**: Another alternative solution is that only a part of the demand of this TSO will be satisfied (up to the amount which does not lead to infeasibility).

Feasibility Checks – 2/2

TYPE	Quantity (MW)	TSO Demand Price/Offer Price (€/MWh)	Elasticity of Demand	Divisibility of Offers	Area
Demand (TSO 1)	+10	--	Inelastic	--	Area 1
Demand (TSO 2)	+10	--	Inelastic	--	Area 2
Demand (TSO 3)	+10	--	Inelastic	--	Area 3
Upward Offer (UO BSP1)	10	40	--	Divisible	Area 1
Upward Offer (UO BSP2)	10	50	--	Indivisible	Area 2
Upward Offer (UO BSP3)	7	60	--	Indivisible	Area 2
Upward Offer (UO BSP4)	2	70	--	Indivisible	Area 2

Type	Solution A Activated Quantity/Satisfied Demand (MW)	Solution B Activated Quantity/Satisfied Demand (MW)
Demand (TSO 1)	+10	+10
Demand (TSO 2)	+10	+10
Demand (TSO 3)	0	+9
Upward Offer (UO BSP1)	10	10
Upward Offer (UO BSP2)	10	10
Upward Offer (UO BSP3)	0	7
Upward Offer (UO BSP4)	0	2
Marginal Price (€/MWh)	€50/MWh	€70/MWh
Social welfare (€)	-900	-1460

SUGGESTION:

Solution B → Higher social welfare (due to satisfying a higher demand)

Summary - To be Decided

- The objective function is to maximize social welfare (i.e. minimizing balancing costs)
- Elasticity of TSO demand will be allowed
- Several constraints are to be satisfied: Balance constraints, power flow constraints and HVDC constraints
- Computation time may become a relevant issue when increasing algorithm complexity
- Proposals for dealing with multiple optimal solutions were presented
- Feasibility checks to be implemented as well

TOP 5: SETTLEMENT

Content

Introduction

Main Settlement Principles:

- Settlement process shall be based on marginal pricing (pay-as-cleared)
- In case of congestion, there will be different marginal prices for the same imbalance settlement period (ISP) on both sides of the congested border.
- Direct and scheduled activation of bids will be allowed.

Working Assumptions (for the given examples):

- Trapezoid cross-border exchange profile with 10 min. ramps
- Direct activation takes place ahead of scheduled activation (see figure 2).
- The delivery period (TSO-TSO) is 5 minutes for scheduled activation (SA) and a maximum of 20 minutes for direct activation (DA).

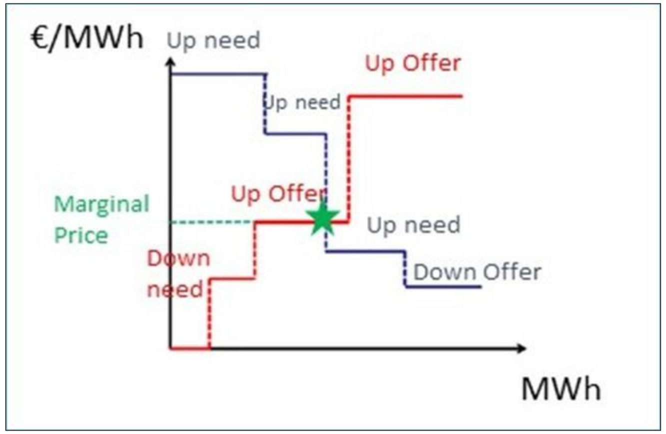


Figure 1: Cost Curve Formed by Bids and Elastic Demands

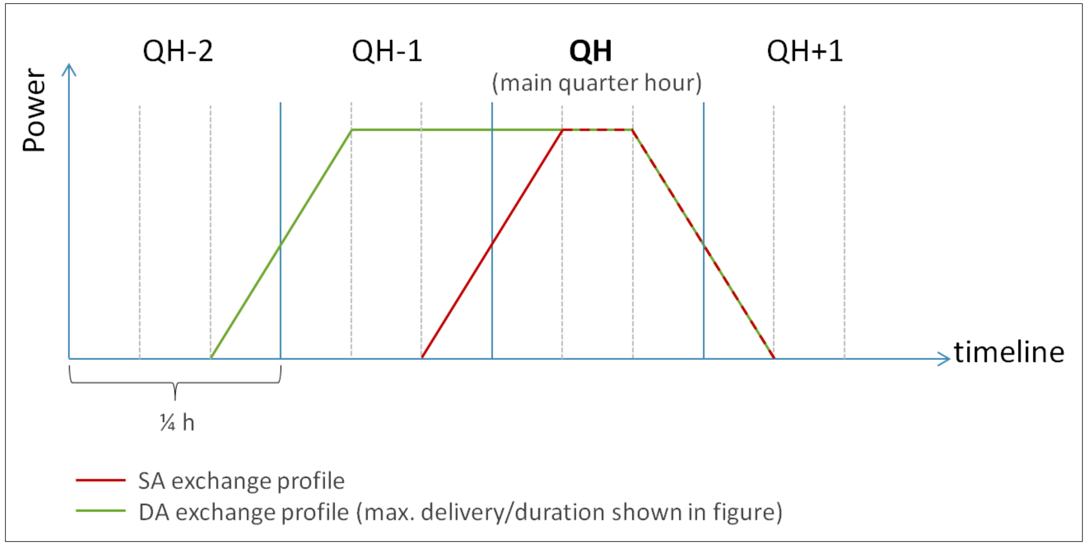


Figure 2: Exchange of direct and scheduled activated energy between TSOs

TSO-TSO Settlement – 1/6

Main Questions

- Which energy volumes and which prices should be applied for settlement?

TSO-TSO Settlement – 2/6

Determination of the Settlement Energy Volume – **Option 1**

- For scheduled activation, the exchanged energy is settled within the main quarter hour (QH), as represented by the red shaded area Vi in figure 3 .
- For direct activation, the same principle applies, i.e. area Vi is independent from the point in time of the direct activation, but all the additional volume exceeding area Vi is settled in QH-1 and is represented by the dark or light green shaded area in figure 4.
- The evaluation of option 1 for both SA and DA will be based on the following criteria:

	Criterion
a.	**Consistency with algorithm:** Volumes considered in the algorithm should be consistent with the volumes for TSO-TSO settlement
b.	**Simplicity & transparency:** The number of quarter hours affected by an activation should be limited
c.	**Settlement energy volume = exchanged energy volume:** The settlement volume should be equal to the total energy volume exchanged between the TSOs according to the cross-zonal schedule.

Figure 5: Assessment of Option 1 for SA and DA

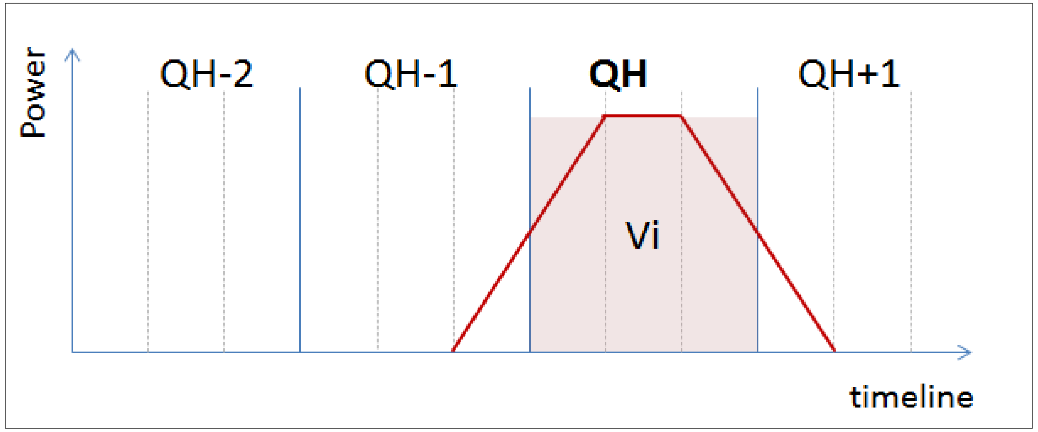


Figure 3: Settlement Energy Volume - Option 1 for SA

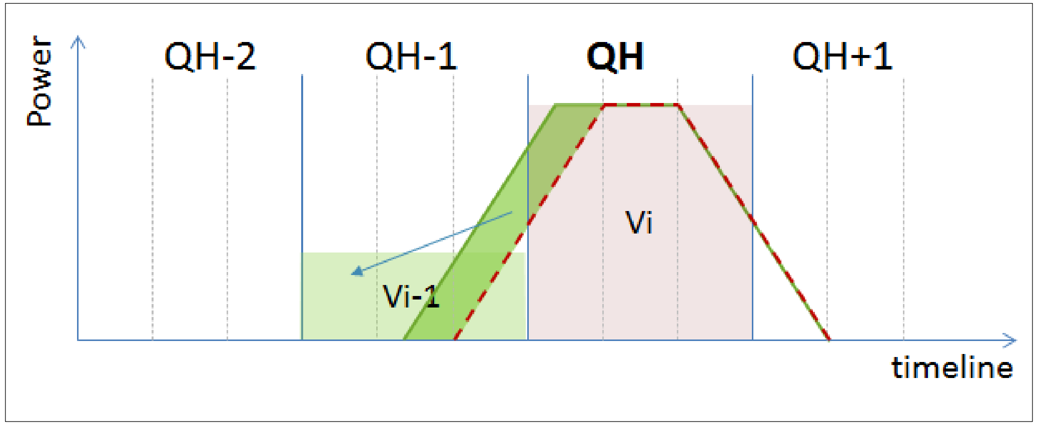


Figure 4: Settlement Energy Volume - Option 1 for DA

TSO-TSO Settlement – 3/6

Determination of the Settlement Energy Volume – **Option 2**

- For scheduled activation, the exchanged energy is settled in each quarter hour affected.
- Not be consistent with the algorithm. Moreover, the number of quarter hours affected is at maximum.

	Criterion
a.	**Consistency with algorithm:** Volumes considered in the algorithm should be consistent with the volumes for TSO-TSO settlement
b.	**Simplicity & transparency:** The number of quarter hours affected by an activation should be limited
c.	**Settlement energy volume = exchanged energy volume:** The settlement volume should be equal to the total energy volume exchanged between the TSOs according to the cross-zonal schedule.

Figure 5: Assessment of Option 2 for SA and DA

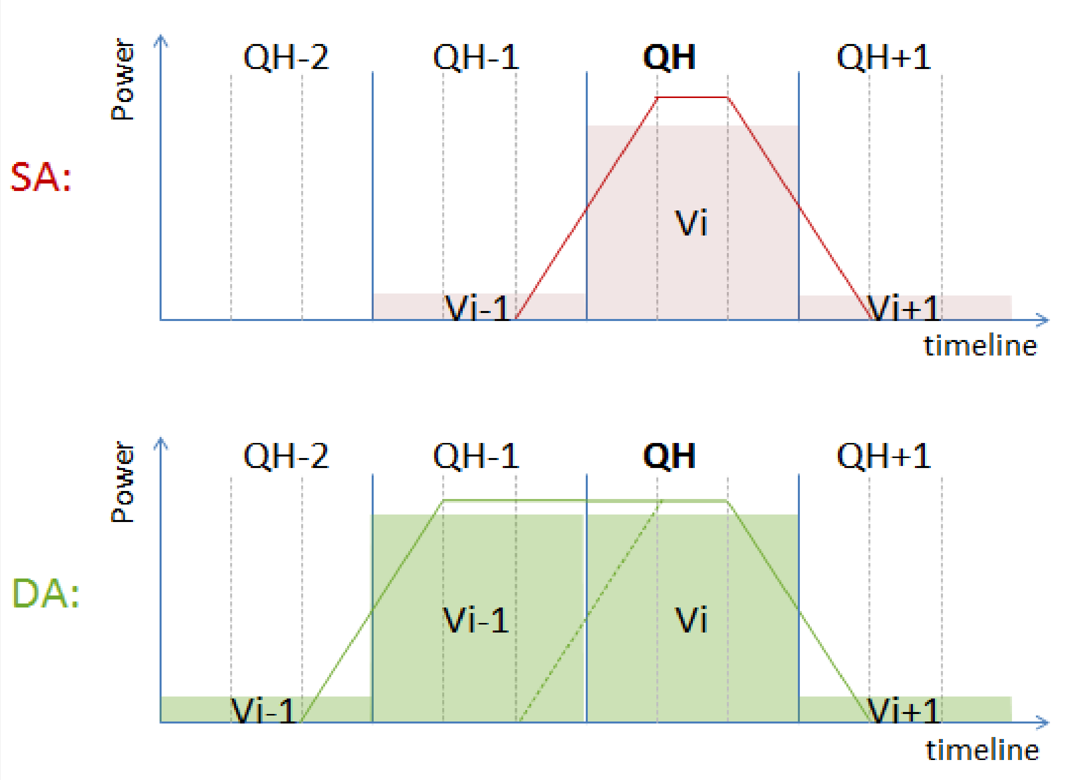


Figure 4: Settlement Energy Volume - Option 2 for SA and DA

TSO-TSO Settlement – 4/6

Determination of the Settlement Price - Criteria

Criterion	
a.	Pay at least a bid price for all energies
b.	Price formulas for DA should not include prices (bid prices or clearing prices) of quarter hours which are not affected by the DA.
c.	No financial incentive for TSO to activate sooner (DA before SA). DA bids should at least get what they would have gotten if they were schedule activated.
d.	No financial incentive for TSO to activate sooner (DA before DA)
e.	No incentive for TSO to use DA for the next QH instead of SA (DA after SA)
f.	Incentives for BSP to submit direct activatable bids = no incentive to submit only SA bids
g.	Pay all mFRR energy volumes exchanged within the same QH at the same MP (transparency & simplicity reasons)
h.	Incentives for BSPs to bid at their marginal cost
i.	Limited number of settlement prices for a single bid (simplicity) = 1 price (the same price for volumes in QHi-1 and QHi)
j.	Do not create a « Paradoxically Rejected Bids case » (i.e. SA bids with a price under the most expensive DA bid but over the price of SA need); transparency issue

TSO-TSO Settlement – 5/6

Determination of the Settlement Price – A-Options

- **A-Options**: The clearing price **includes** DA bids for the respective main quarter hour QH_i.

Pclearing,A (QHi) **= Max (**activated **SA and DA bids** from CMOL QHi**)**

	A-Options:	QH-2	QH-1	QH_i	QH+1
Clearing price		$P_{clearing,A}(QH_{i-2})$	$P_{clearing,A}(QH_{i-1})$	$P_{clearing,A}(QH_i)$	$P_{clearing,A}(QH_{i+1})$
SA Settlement Price	A	$P_{clearing,A}(QH_{i-2})$	$P_{clearing,A}(QH_{i-1})$	$P_{clearing,A}(QH_i)$	$P_{clearing,A}(QH_{i+1})$
DA Settlement Price (for bids from CMOL QH_i)	A1	-	$P_{clearing,A}(QH_{i-1})$	$P_{clearing,A}(QH_i)$	-
	A2	-	Max ($P_{clearing,A}(QH_{i-1})$; prices of DA bids activated for the main QH_i)	$P_{clearing,A}(QH_i)$	-
	A3	-	$P_{clearing,A}(QH_i)$	$P_{clearing,A}(QH_i)$	**-**
	A4	-	Max(prices of DA bids activated for the main QH_i)	$P_{clearing,A}(QH_i)$	-
	A5	-	Max($P_{clearing,A}(QH_i)$, $P_{clearing,A}(QH_{i-1})$)	Max($P_{clearing,A}(QH_i)$, $P_{clearing,A}(QH_{i-1})$)	**-**
	A6	-	Max($P_{clearing,A}(QH_i)$, $P_{clearing,A}(Qh_{i-1})$)	$P_{clearing,A}(QH_i)$	-

TSO-TSO Settlement – 6/6

Determination of the Settlement Price – B-Options

- **B-Options**: The clearing price **excludes** DA bids for the respective main quarter hour QH_i, i.e. the clearing price can be higher or lower than the highest direct activated bid price.

$P_{clearing,B}$ (QHi) = Max (prices of **SA bids** activated for the main QHi**)**

B-Options:		QH-2	QH-1	QH_i	QH+1
Clearing price		$P_{clearing,B}(QH_{i-2})$	$P_{clearing,B}(QH_{i-1})$	$P_{clearing,B}(QH_i)$	$P_{clearing,B}(QH_{i+1})$
SA Settlement Price	B	$P_{clearing,B}(QH_{i-2})$	$P_{clearing,B}(QH_{i-1})$	$P_{clearing,B}(QH_i)$	$P_{clearing,B}(QH_{i+1})$
DA Settlement Price (for bids from CMOL QH_i)	B1	-	Max($P_{clearing,B}(QH_i)$; prices of DA bids activated for the main QH_i)	Max($P_{clearing,B}(QH_i)$; prices of DA bids activated for the main QH_i)	-
	B2	-	Max($P_{clearing,B}(QH_i)$; $P_{clearing,B}(QH_{i-1})$; prices of DA bids activated for the main QH_i)	Max($P_{clearing,B}(QH_i)$; $P_{clearing,B}(QH_{i-1})$; prices of DA bids activated for the main QH_i)	-

Congestion Rent – 1/3

Main Questions

- How to share the surplus which results in the case of congestions?

Congestion Rent – 2/3

Concept and Formula

❍ Concept:

- **Congestion** is the situation where transmission capacity available between areas is not sufficient to accommodate all transactions
- **“Congestion rent” =** In case of congestion, there is a price difference between the price that an area is “willing to pay” and the price that the other area is “willing to receive” at either side of the interconnector.
- **→ Thus, a surplus from the congested interconnection will occur.**

❍ Definition/Formula:

Congestion rent [€] **= Imported volume** [MWh] **x (MP of the exporting TSO** [€/MWh] **– MP of the importing** TSO [€/MWh]**)**

❍ Sharing:

- Congestion rent resulting from mFRR activations = “congestion income” (Regulation 714/2009 article 16-6)?

Working assumption: Yes → implicit allocation of available capacity in the context of balancing services.

Congestion Rent – 3/3

Possible Sharing Options

OPTION A: Importing TSO

- Distribution of the global congestion rents between importing countries, proportional to their imports.

OPTION B: Exporting TSO

- Distribution of the global congestion rents between exporting countries, proportional to their exports.

OPTION C: All countries

- Sharing of the global congestion rents, proportional to the absolute value of their net position.

OPTION D: Sharing based on existent methodologies currently applied for long-term/day ahead/intraday market

- First, distribution by interconnector: **proportional to installed cross-border capacity** (or allocated capacity for HVDC) of interconnectors in relevant borders.
- Second, distribution between TSOs/interconnector owners by applying different possible keys: 50/50, 100% to one entity, or other agreements.

OPTION E: Distribution based on congestion income distribution methodology for DA/ID market ("All TSO proposal")

- First, distribution by interconector: depending on the capacity calculation approach (either NTC or FB)- **Based on a parameter** (agreed between TSOs and approved by relevant **NRA**s) which takes into account the interconnector´s contribution to the allocated capacity
- Second, distribution between TSOs/interconnector owners by applying different possible keys: 50/50, 100% to one entity, or other agreements.

[Net Position (NP) = allocated volumes – TSO needs]

TSO-BSP/BRP Settlement 1/3

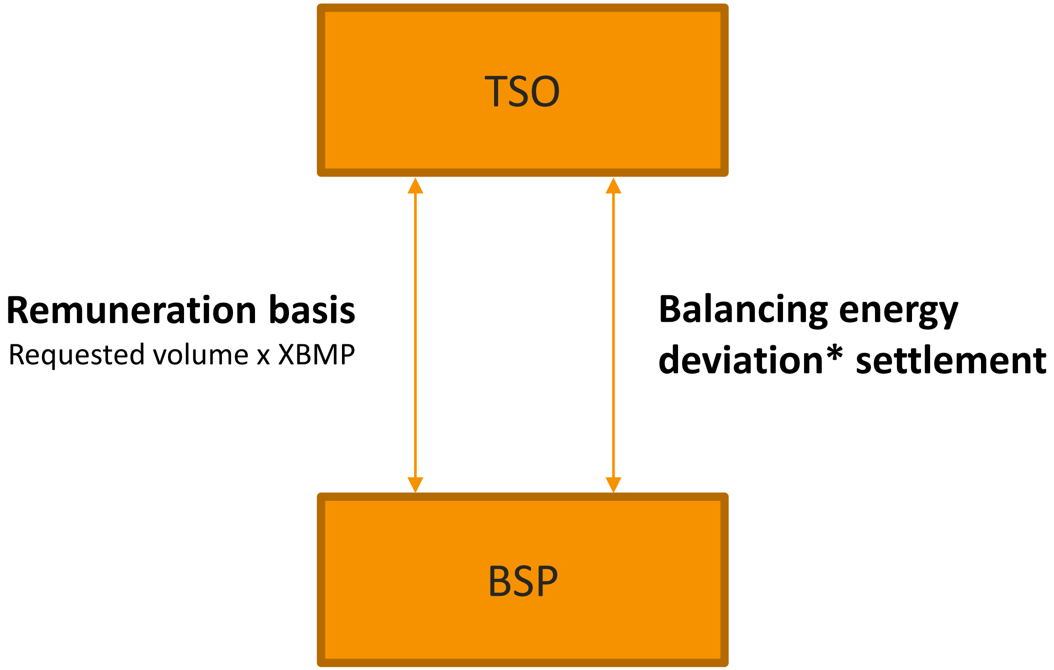
Main Questions

- Necessity for harmonization?
- Which incentives should be given to the market participants?

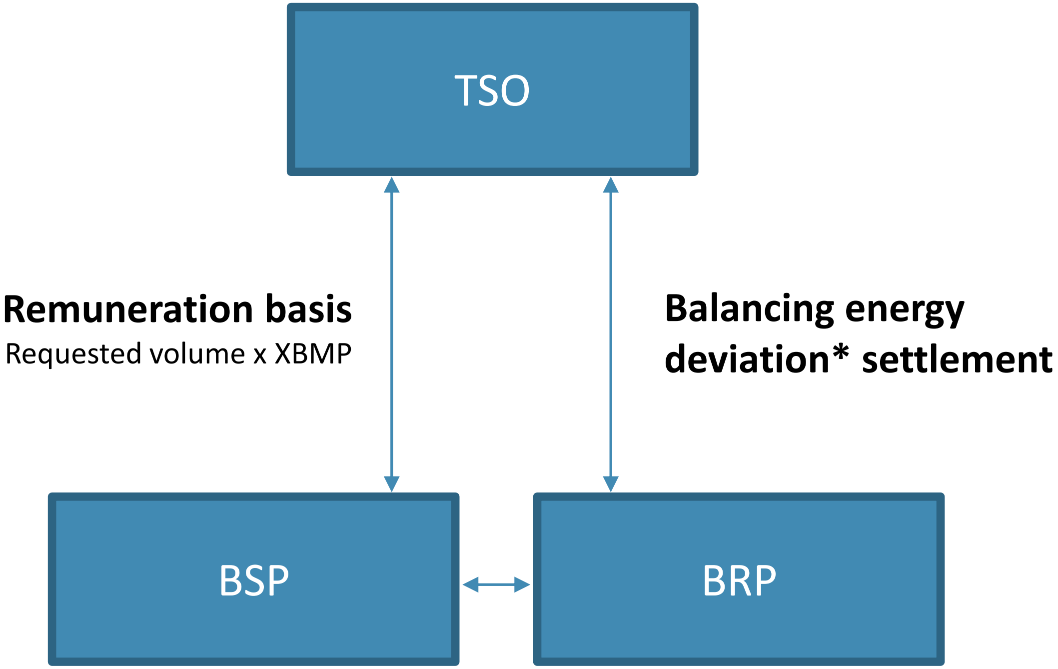
TSO-BSP/BRP Settlement 2/3

Imbalance Adjustment options

Option 1 : Imbalance Adjustment based on **metered** volume



Option 2 : Imbalance Adjustment based on **requested** volume



Options 1 and 2 can be chosen based on the national regulation regarding the roles of BSPs and BRPs.

Both options can result in the exact same incentives to market parties and can then coexist within MARI.

NOTE: Penalties can be also applied

*Balancing energy deviation = metered volume - requested volume

TSO-BSP/BRP Settlement 3/3

Proposed scope for TSO-BSP/BRP Settlement harmonization

Harmonized settlement rules for the BSPs' remuneration basis

Harmonized incentives for BSPs that can be given by different settlement rules

- **Consistency with TSO-TSO settlement**
  Volume = requested
  Price = cross-border marginal price

- **Incentive to deliver the standard power profile** (if needed) (consistency with the XB- exchange profile)
- **Incentive to deliver the requested volume**
  (no incentive to under or over deliver)
- **Incentive to participate in the market**
  (maximization of liquidity; ensure a level playing field)
- **Incentive to report any defect as soon as it is known**

All these incentives should apply for all types of assets/market parties (level playing field)

Consequences of XBMP on Imbalance Pricing and Local Imbalance - 1/2

Main Questions

- What are the consequences of cross-border marginal pricing in regard to TSO operation and incentives for market participants to support the system to be balanced?

Consequences of XBMP on imbalance pricing and local imbalance - 2/2

one price for mFRR balancing energy for all BSPs

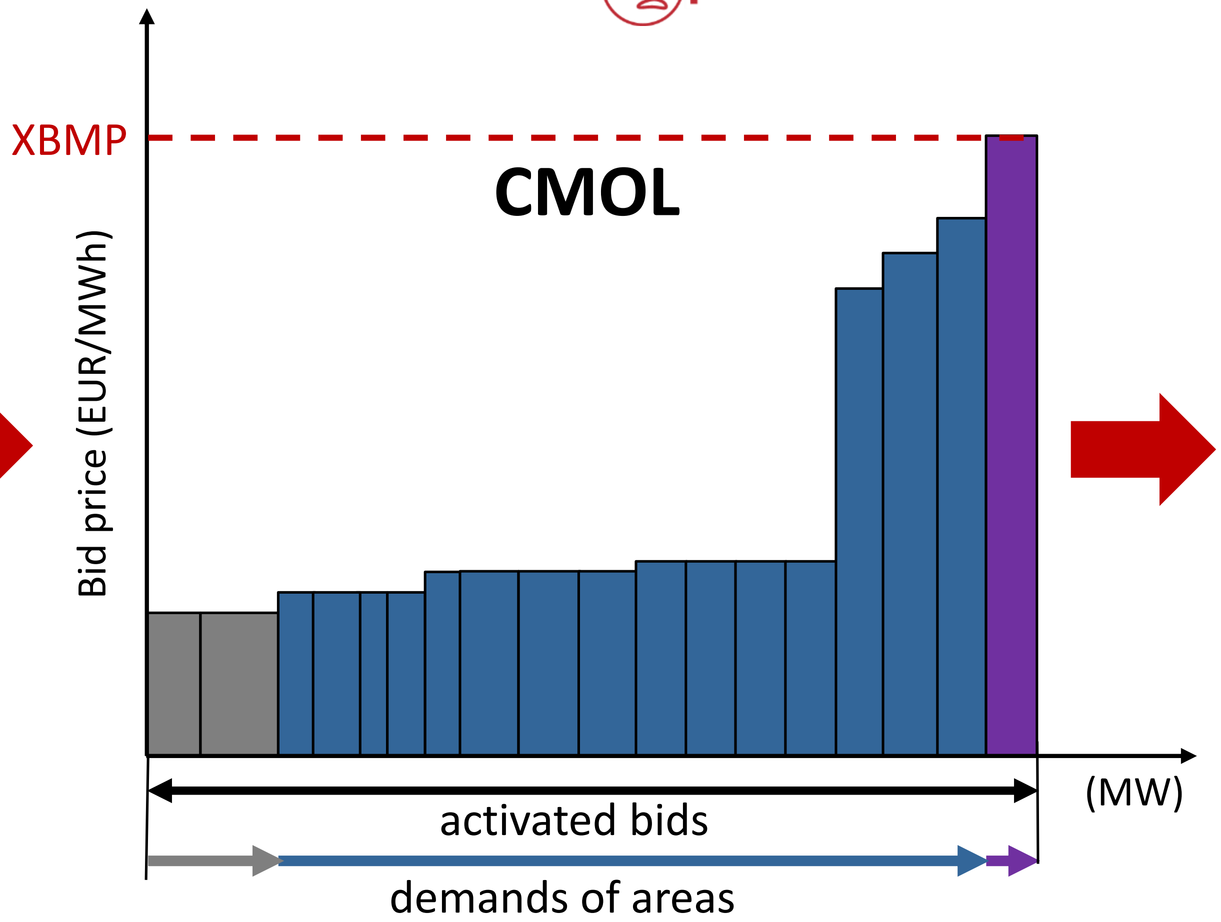
influence on imbalance price for all BRPs

motivation for BRP to keep imbalance low in its area

Area A has a small imbalance

Area B has a small imbalance

Area C has a high imbalance



Imbalance of area C affects imbalance prices in areas A and B

Next steps

TSO-TSO Settlement

- Selection of settlement option after having decided upon the explicit process and product.

Congestion rent

- Comparison and evaluation of defined sharing options and selection of a solution.

TSO-BSP/BRP settlement

- Different imbalance adjustment options can coexist.
- Consideration of defined settlement rules by each TSO.

Consequences on Imbalance Pricing and Local Imbalance

- Consequences of XBMP on Imbalance Pricing and Local Imbalance have to be further investigated.
- Cooperation with ENTSO-E Project Team Imbalance Settlement to investigate possible mitigation measures.

TOP 6: CONGESTION MANAGEMENT

Content

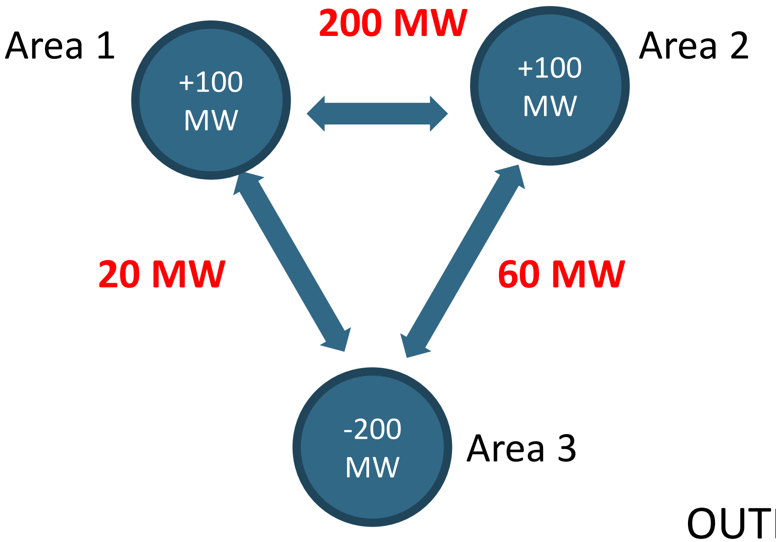
Main Question

- What are the measures available to the TSOs to handle congestions?

Options Overview

1. Limiting ATC
2. Filtering Bids and Re-dispatch
3. Critical Network Element
4. Smaller internal mFRR Zones
5. Several TSOs Build a Cluster

Option 1 – Limiting ATC



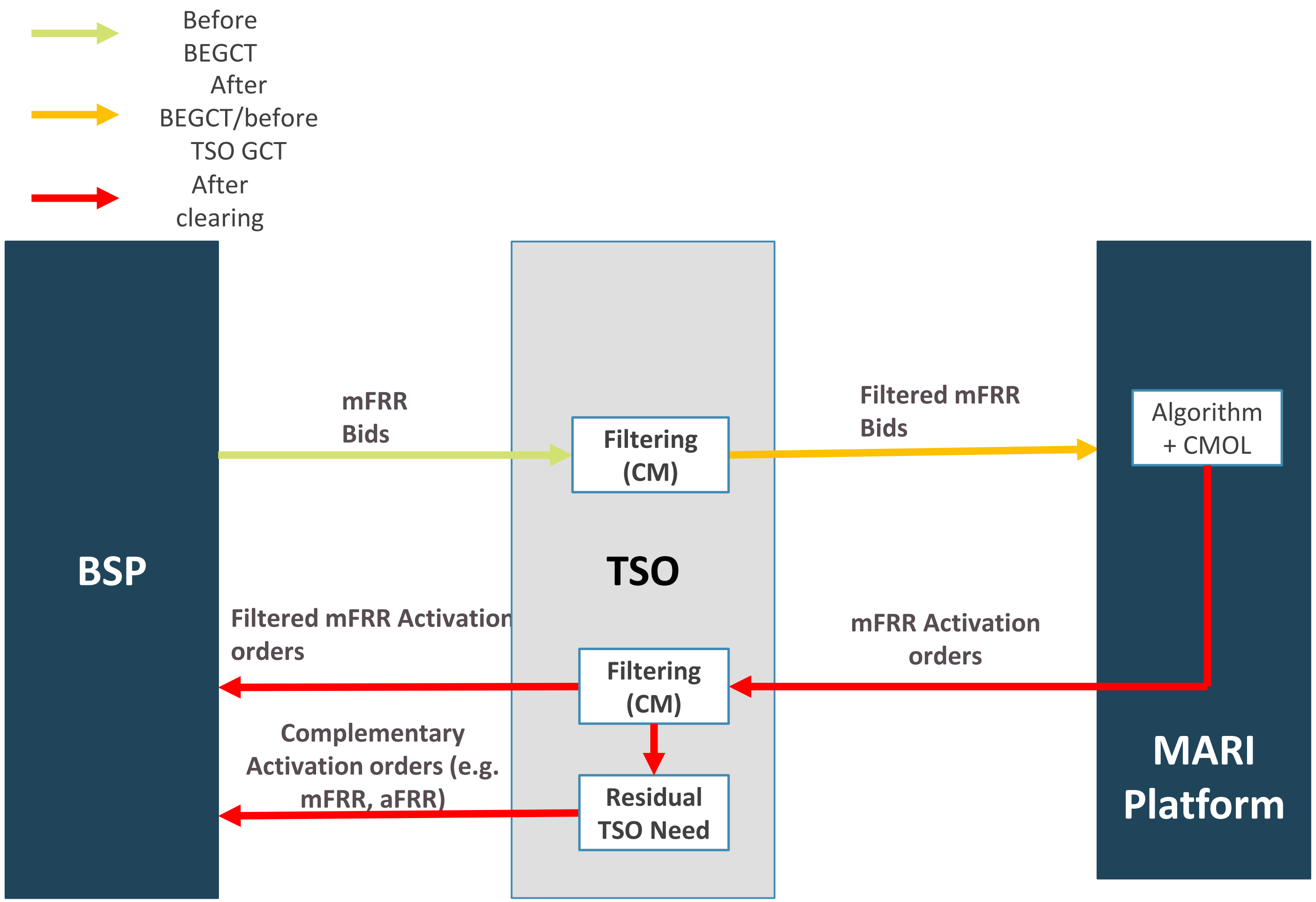
ATC limits are set to the remaining capacity after preceding usage for each border

TYPE	Quantity (MW)	TSO Demand Price/Offer Price (€/MWh)	Elasticity of Demand	Divisibility of Offers	Area
Demand (TSO 1)	+100	--	Inelastic	--	Area 1
Demand (TSO 2)	+100	--	Inelastic	--	Area 2
Demand (TSO 3)	-200	--	Inelastic	--	Area 3
Upward Offer (UO BSP1)	100	10	--	Divisible	Area 1
Upward Offer (UO BSP2)	30	20	--	Divisible	Area 2
Downward Offer(DO BSP2)	-50	-20	--	Divisible	Area 2
Downward Offer (DO BSP3)	-200	-50	--	Divisible	Area 3

OUTPUT

Type	Activated Quantity/Satisfied Demand (MW)	
Demand (TSO 1)	+100	
Demand (TSO 2)	+100	
Demand (TSO 3)	-200	
Upward Offer (UO BSP1)	100	
Upward Offer (UO BSP2)	20	
Downward Offer (UO BSP2)	0	
Downward Offer (DO BSP3)	-120	
Social Welfare (€)	XB Marginal Price (€/MWh)	
-(10*100+20*20+120*50) =-7400	Area 1 & 2: 20 €/MWh	Area 3: 50 €/MWh

Option 2 – Filtering bids and re-dispatch – 1/2



Option 2 - Filtering bids and re-dispatch – 2/2

- **Before the algorithm (filtering)**
  - BSP will send the mFRR bids to the TSO.
  - Each TSO will have the possibility to filter the bids which contain a unit which may endanger network security if activated.
  - The TSO will then send the corresponding bid with status unavailable to the MARI platform.
- **Within the algorithm**
  - The algorithm shall only clear with the bids with a status available.
- **After the algorithm (re-dispatch)**
  - If a congestion appears after the bids were already sent to the MARI platform, then if the bids were selected by the clearing for activation, the TSO has the possibility to block the activation and do re-dispatch if the TSO has the time to do so. Otherwise aFRR (or other complementary activation orders) will have to compensate the non-activation.

Option 3 - Critical Network Element – Objective - 1/2

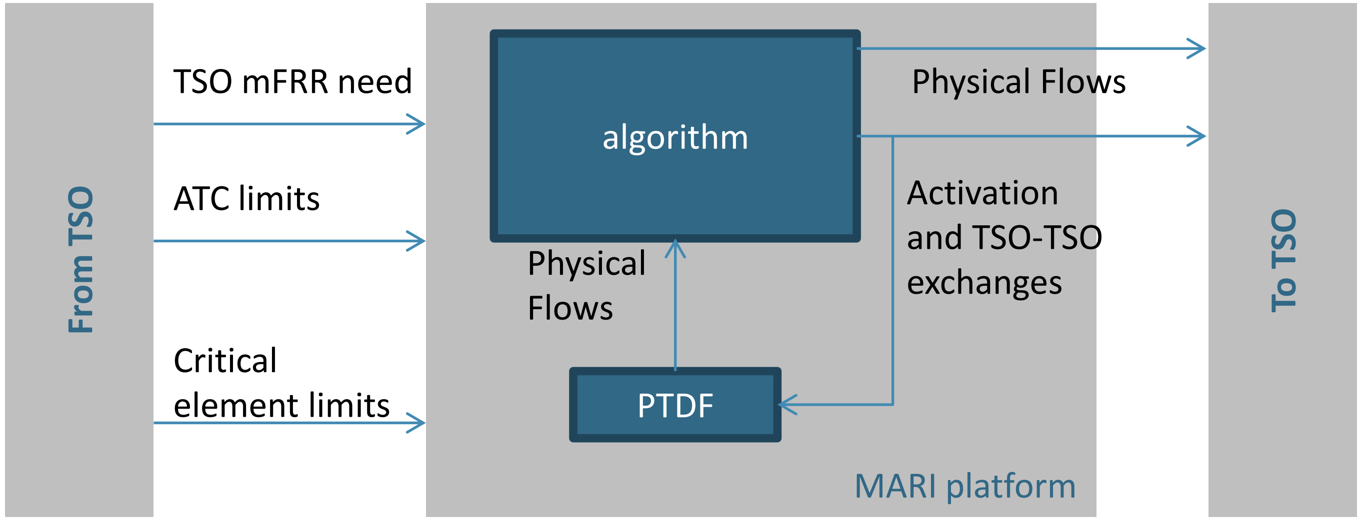
❍ **Principles:**

- The usage of ATC limits shall provide enough security to cover most of the operational cases. However, in some rare cases it may not be sufficient to guarantee enough security for some critical network element influenced by the exchanges of mFRR.
- In such a case, it would help TSOs to have a real time monitoring of the impacts in terms of physical flows of mFRR exchanges on a predefined set of critical network elements.
- And then when a situation in real time leads to a congestion on one of the critical elements, a limit of admissible physical flow shall be set on this network element and taken into account by the algorithm in order to guarantee the clearing will not induce higher physical impact on this network element.
- Once the congestion is relieved, then the limit may be released by the operator.

❍ **Notes:**

- The advantage of this approach is that it is not needed at least at the first step of defining a complete flow-based safety domain calculation (such as for flow-based Market Coupling) to be able to manage congestion on critical elements.
- This approach enables to target the element which is concerned by the congestion (explicit for the operators)

Option 3 - Critical Network Element – 2/2

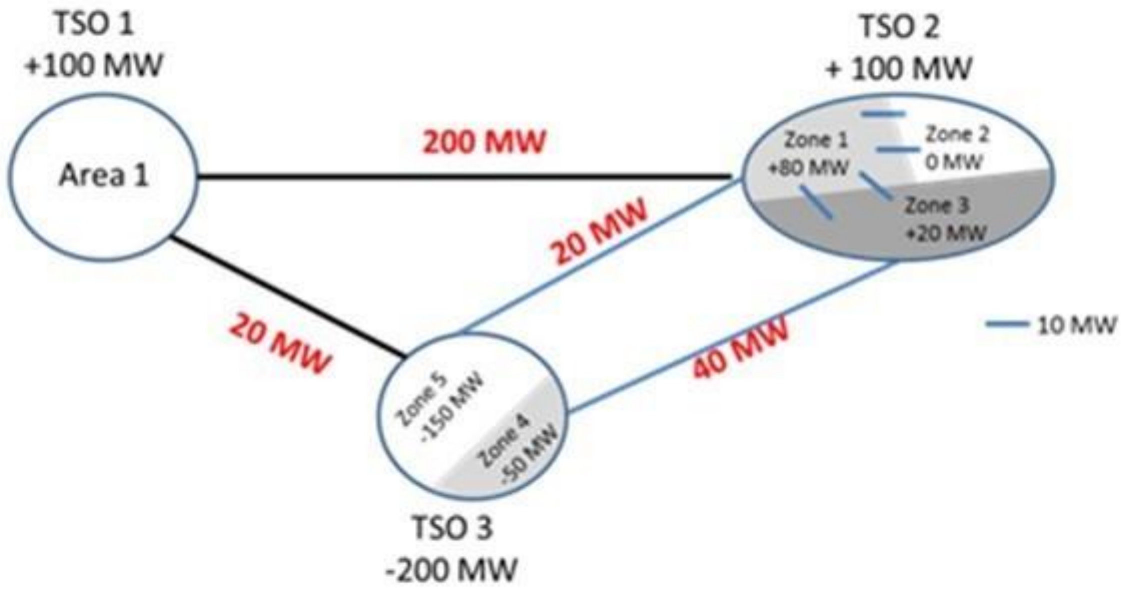


- **Notes:**
  - The critical element limits are additional to the ATC limits
  - A PTDF matrix has to be defined and used by the algorithm to:
    - Provide inn real time the physical flows induced by MARI activation
    - Integrate a limit when applied on a network element to guarantee the resulting exchanges will not induce higher physical flows than the limit provided by the TSO

Option 4 - Smaller internal mFRR zones

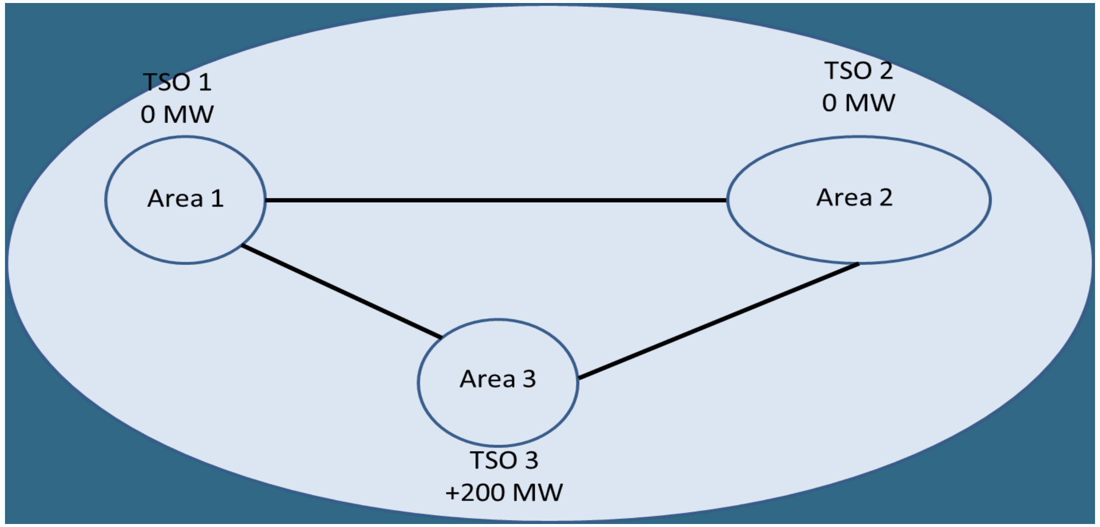
- Some TSOs may need to divide their area into several smaller internal mFRR zones to handle internal congestions within the ID bidding area.

- The algorithm contains a finer network model according to internal congestions than used by the XBID model. TSOs use this option to submit bids and request for each of these smaller internal mFRR zones.



Option 5 - Several TSOs Build a Cluster

- Some TSOs have a need for representing their network model, building a cluster together with other TSOs
- If bids were to be activated within this cluster, bids from a certain TSO would be given precedence over the other TSOs to a certain amount of MWs.
- The inputs to the algorithm include the control zones involved, the priority TSO and the amount of MW to be activated from this TSO



Conclusions and Next Steps

- There are two aspects of congestion management that the MARI has recognized.
    1. To make sure in the Platform that bids that are activated for balancing purposes are not going to downgrade or endanger the system security. This aspect shall be mandatory for MARI implementation.
    2. TSOs need to activate bids for other purposes such as counter trade/re-dispatch for already identified or occurred congested situations. This aspect is open to further investigation for MARI implementation.
- For the first aspect, it has interpreted from the GLEB that same area definition should be used for mFRR as intraday: i.e. same cross-zonal capacities as defined between Intraday Bidding zones.
    - In such a case, to handle internal and external congestion TSOs foresee a need for additional measures. The following measures have been identified so far and will be further analyzed for potential implementation in the MARI project .
        - TSO limits ATC before the mFRR algorithm
        - TSO filters bids (make them unavailable) before the mFRR algorithm
        - Smaller internal mFRR zones in the mFRR algorithm
        - Critical network elements in the mFRR algorithm
        - Several TSOs form a cluster in the mFRR algorithm
        - Re-dispatch the resulting flow after the mFRR algorithm

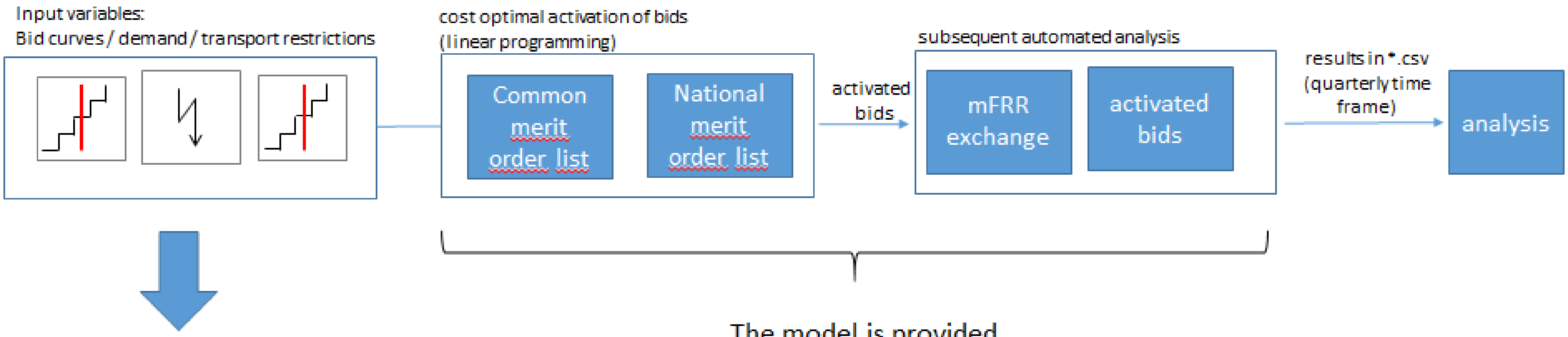
TOP 7: INFORMATION on SIMULATION

Content

Simulation Goals

- Demonstrate the benefit of the cooperation
- Demonstrate the social welfare impact of the cooperation

Simulation Model: Set-Up



Demand, bid curves and ATC values where provided by participating TSOs

The model is provided by one of the project members: 50Hertz

Objective of the model is to compare a Common Merit Order List based activation to a National Merit Order List based activation strategy

Simulation Model: Assumptions

- **Based on historical data (2016)**
  - Demand per bidding zone
  - ATC values
  - Representative bid curves
- **Simulation on a quarter-hourly timescale**
  - All demand and activations are considered scheduled, not direct
  - Netting of up- and downwards demands
- **All bids considered divisible**
  - No quantification of the effect of indivisible bids
- **ATC values only, no flow-based approach**
  - No view on actual energy flows, loop flows,…

MARI

Simulations: Status

- 22 TSOs out of 26 current members/observers were modeled
  - Remaining 4 joined the cooperation after data gathering phase or couldn‘t deliver the required data in due time
- First simulation results have been generated, while analysis and post-processing of these results is ongoing.

Thank you for your attention!

For further details please contact:

Steering Committee Chairman
Martin Høgh Møller
mhm@energinet.dk

Technical Working Group Conveners

Aurelien Peyrac
aurelien.peyrac@rte-france.com

Markus Speckmann
Markus.speckmann@amprion.net