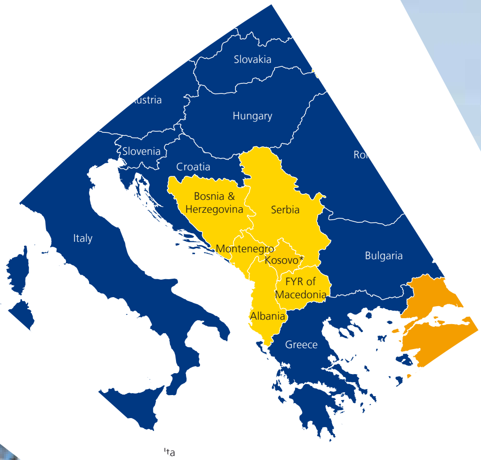

Final Report: Models of regional cooperation for balancing energy – Exchange of balancing energy (Task 4)

EKC and IMP

March 2019

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Technical Assistance to the Implementation of Cross-border Electricity Balancing

Task 4: Models of regional cooperation for balancing energy – Exchange of balancing energy

Final Report

March 2019

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1. WB6 mFRR & RR COOPERATION IN SCOPE OF EUROPEAN PROCESS

The Guideline on Electricity Balancing (EB GL) defines framework for common European technical, operational and market rules for a cross border balancing market. This market serves the purpose to secure economically efficient purchase and in time activation of control energy by simultaneously ensuring the financial neutrality of the TSOs. Important means to achieve these goals are the harmonization of the balancing energy products and a close cooperation of the TSOs on regional and European level.

Cooperation of national balancing markets in the WB6 region, according to the ongoing developments in the region and the propositions by the EB GL and SOGL, can provide significant improvements in technical performance, competition and costs savings.

The goal of this task is to provide suitable models for the processes of exchange of balancing energy from frequency restoration reserves with manual activation (mFRR) and exchange of balancing energy from replacement reserve (RR).

Balancing service	Previous name in ENTSO-E CE (UCTE OH)	Activation method	Time domain of response
Frequency Containment Reserve **(FCR)**	**Primary** control reserve	Automatic	Up to 30 seconds
Automatic Frequency Restoration Reserve **(aFRR)**	**Secondary** control reserve	Automatic	Up to 5/7.5 minutes
Manual Frequency Restoration Reserve **(mFRR)**	Fast **tertiary** control reserve (DA - Directly activated) (SA - Schedule-activated)	Manual	Up to 12.5 minutes
Replacement Reserves **(RR)**	Slow **tertiary** control reserve	Manual	30 minutes

WB6 COOPERATION

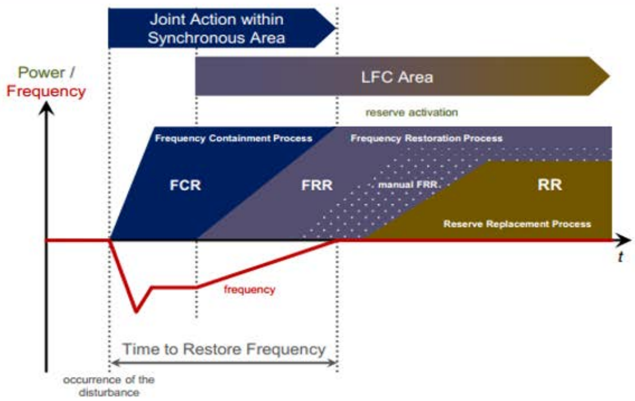


Figure 1: Balancing integration models analysed within the Study

Currently, there are two pan-European implementation projects for the creation of:

- European platform for mFRR energy exchange – MARI project
    - *Manually Activated Reserves Initiative (MARI) is the European implementation project for the creation of the European mFRR platform. MARI shall implement and make operational the European platform, where all standard mFRR balancing energy product bids shall be submitted and the exchange of balancing energy from mFRR shall be performed.*
    - The TSOs proposal on Implementation Framework for a European platform for the exchange of balancing energy from frequency restoration reserves with manual activation (MFRRIF) is submitted in May 2018. After the adoption of Implementation Framework, all TSOs shall implement and make operational the European platform in 30 months period according to EB GL Art.20. With possible 2 years derogation, full implementation of pan-European mFRR process should be completed not later than 2023.

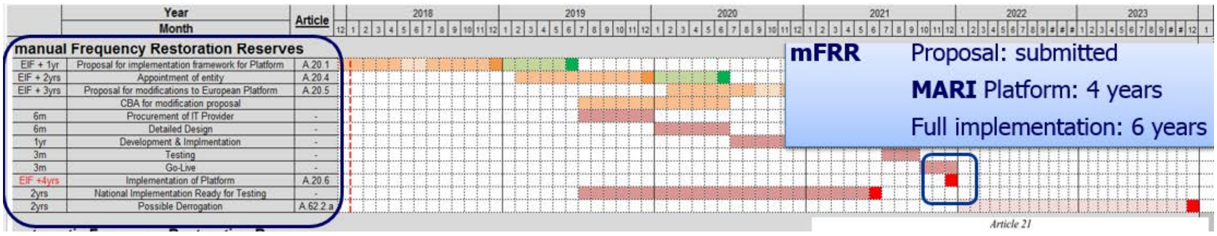


Figure 2: Envisaged mFRR process in Europe

- European platform for RR energy exchange – TERRE project
    - *Trans European Replacement Reserves Exchange (TERRE) is the European implementation project for exchanging replacement reserves in line with the Guideline on Electricity Balancing. The aim of TERRE is to build the RR Platform and set up the European RR balancing energy market in order to create harmonized playing fields for the Market Participants.*
    - The TSOs proposal on Implementation Framework for a European platform for the exchange of balancing energy from restoration reserves (RRIF) is submitted in June 2018. Full implementation of pan-European RR process should be completed in 2021.

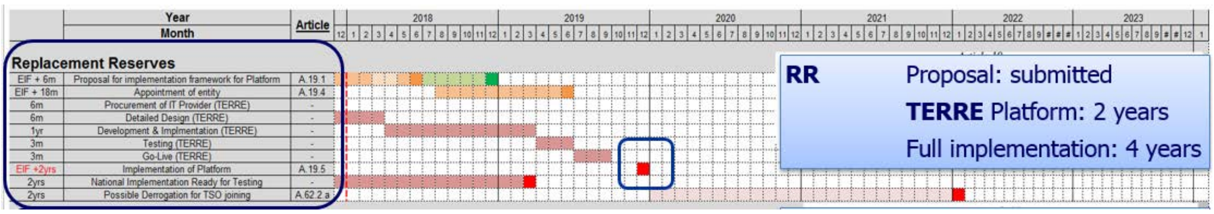


Figure 3: Envisaged RR process in Europe

This Study proposes the following approach[1] for WB6 members in the process of balancing energy exchange cooperation:

- Each WB6 member, when market ready and compliant with the European process, should apply to join the relevant European platform for the balancing energy exchange (aFRR – Picasso, mFRR – MARI, RR – TERRE (optional[2]))
- In a meantime, as intermediate step, implementation of regional cooperation could be beneficial for both technical and economic reasons compared to national balancing market operation only. This would accommodate transformation of current practice with bilateral agreements for “tertiary energy” exchange into multilateral regional balancing cooperation, which would boost the efficiency of balancing energy deployment, as well as overall balancing market welfare. In addition, this interim solution would provide smother transition and harmonization with EB GL.
- **Therefore, the design of regional mFRR & RR balancing cooperation described in Chapter 2 is tailored to address key requirements defined by EB GL and relevant draft Implementation Frameworks (MFRRIF, RRIF), as well as to take into account the specific characteristics of WB6 region.**

[1] **The detail elaboration of the proposed roadmap is provided within the Task 5 of the Study.**

[2] TERRE platform is relevant for the TSOs which use replacement reserve. For the TSOs that only use Frequency Restoration Reserve (both automatic and manual), only PICASSO and MARI should be regarded as mandatory target platforms. In the WB6 region, most of the members deploy balancing energy activation still recognized as “secondary” and “tertiary” control, which correspond to the aFRR and directly activated mFRR.

2. WB6 mFRR & RR BALANCING ENERGY EXCHANGE MODEL

2.1 Cornerstones of regional cooperation

The EB GL defines European platforms for the exchange of FRR and RR based on a TSO-TSO model in line with the following articles:

EB GL Article 19 paragraph 2 (related to exchange of Replacement Reserve)

> *The European platform for the exchange of balancing energy from replacement reserves, operated by TSOs or by means of an entity the TSOs would create themselves, shall be based on common governance principles and business processes and shall consist of at least the activation optimisation function and the TSO-TSO settlement function. That European platform shall apply a multilateral TSO-TSO model with common merit order lists to exchange all balancing energy bids from all standard products for replacement reserves, except for unavailable bids pursuant to Article 29(14).*

EB GL Article 19 paragraph 2 (related to exchange of Frequency Restoration Reserve)

> *The European platform for the exchange of balancing energy from frequency restoration reserves with manual activation, operated by TSOs or by means of an entity the TSOs would create themselves, shall be based on common governance principles and business processes and shall consist of at least the activation optimisation function and the TSO-TSO settlement function. This European platform shall apply a multilateral TSO-TSO model with common merit order lists to exchange all balancing energy bids from all standard products for frequency restoration reserves with manual activation, except for unavailable bids pursuant to Article 29(14).*

Consequently, the proposal for the exchange of mFRR and RR in the Western Balkans is also based on the TSO-TSO model. The TSO-TSO model means that the exchange of any kind of balancing services is possible exclusively by involved Transmission System Operators (requesting TSO and connecting TSO). It means that all activations of Balancing Service Providers (BSPs) of both mFRR and RR energy in another area of responsibility are realized through the Connecting TSO.

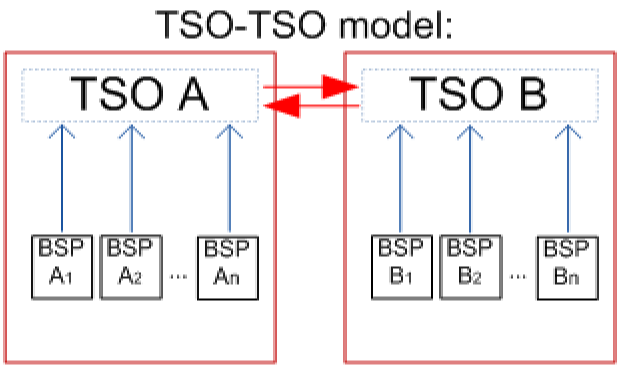


Figure 4: TSO-TSO model

The process of exchange of balancing energy (both mFRR and RR), from the balancing cooperation point of view, can be summarized in the following high-level activities:

- **Definition of standard product** – Activity is performed before close to real-time operation, in which TSOs set the technical requirements for mFRR and RR products and perform prequalification testing of the BSP's technical capabilities to provide required products (in accordance with harmonized national Balancing rules or Grid codes); BSP are obliged to fulfil these requirements if they want to participate in the regional balancing market.
- **Bidding** – Activity is performed close to real-time operation with the goal to create Common Merit Order List (CMOL) based on individual offers for balancing energy provision from the Balancing Service Providers on the national level.
- **Activation and balancing energy exchange** –Close to real time (RR&Scheduled Activation of mFRR) and real time operation (Direct Activation of mFRR) in which each participating TSO submits its current requests for activation of balancing energy (RR, SA mFRR or DA mFRR), while Activation Optimization Function (AOF) optimizes all submitted requests and bids, and sends back the most efficient economic solution for bids activations under the given transmission constraints (limited Cross-Zonal Capacity). The cross border exchange is executed physically through existing interconnection lines and administratively through virtual tie lines.
- **Settlement** – Ex-post activity in which participating TSOs calculate and settle volumes and prices of activated balancing energy with BSPs, as well as among themselves.

The high-level description of balancing exchange process on Regional Balancing Platform is presented in the figure bellow (Figure 5).

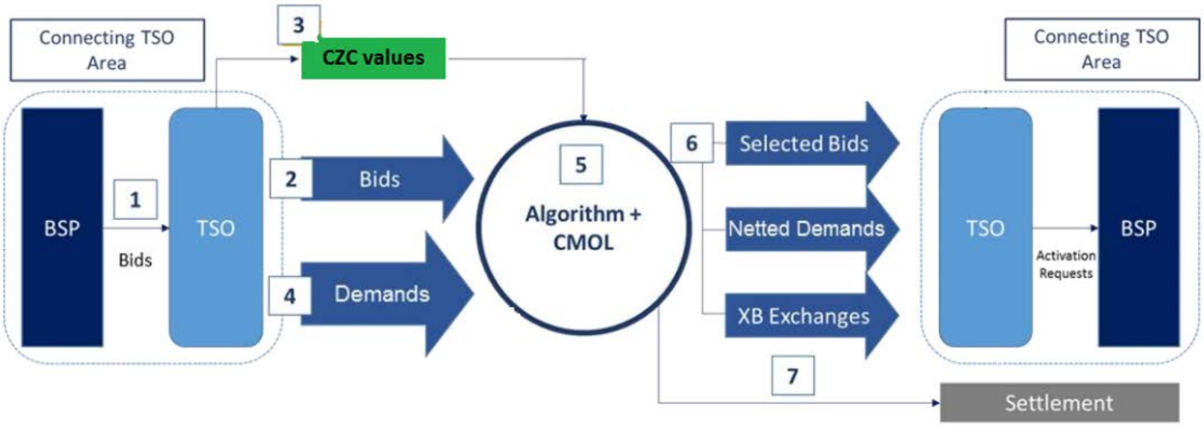


Figure 5: Overview of balancing exchange process

1. TSOs receive bids from BSPs in their control area
2. TSOs forward local merit order list to the Regional Balancing Platform
3. TSOs upload the available cross zonal capacities (CZC) to the Regional Balancing Platform
4. TSOs submit their balancing energy requests
5. Centralized optimization of clearing the TSOs energy requests against balancing energy bids is performed
6. Optimization outputs that include accepted balancing bids, satisfied TSOs requests, balancing energy prices and cross border exchanges are produced
7. Calculation of settlement of the expenditures and revenues between the TSOs and TSOs-BSPs in cooperation is performed

2.2 Definition of standard product

Standard Product stands for a harmonised balancing product, defined by TSOs, for the exchange of balancing services.

Standardization of balancing products needs to be done in order to exchange balancing energy. Regardless of the BSP bid characteristics accepted locally, the product exchanged between the TSOs through Regional Balancing Platform, needs to have the same “TSO-TSO exchange shape”. The TSO-TSO exchange shape refers to how the changes in physical flows resulting from activations of the platforms are realized. In that sense, it is necessary to set the minimum of product attributes that allow activation within the suitable algorithm for balancing capacity and balancing energy. The explanation of the standard balancing product definition is shown in the following figure.

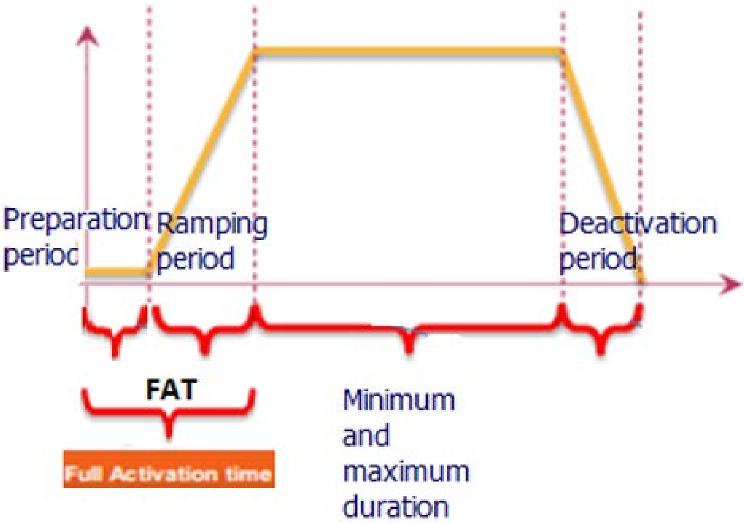


Figure 6: Standard product specification

- **Preparation period** - the period between the activation request by the connecting TSO and the start of the ramping period;
- **Ramping period** – the period of time defined by a fixed starting point and a length of time during which the input and/or output of active power will be increased or decreased;
- **Full activation time (FAT)** – the period between the activation request by the connecting TSO and the corresponding full delivery of requested MW power of the concerned balancing energy bid;
- **Minimum and maximum quantity** - refers to the change of power output (in MW) which is offered in a bid by the BSP and which will be reached by the end of the full activation time.

- **Deactivation period** - the period for ramping from full delivery to a set point, or from full withdrawal back to a set point.
- **Minimum and maximum duration of delivery period** - 'delivery period' means the period of time during which the BSP delivers the full requested change of power in-feed to/withdrawal from the system.
- **Validity period** - period when the balancing energy bid offered by the BSP can be activated, where all the characteristics of the product are respected. The validity period is defined by a start time and an end time.
- **Mode of activation** – refers to the implementation of activation of balancing energy bids, manual or automatic, depending on whether balancing energy is triggered manually by an operator or automatically in a closed-loop manner.

2.2.1 mFRR standard product

The summary of standard product bid characteristics proposed for the WB6 regional cooperation related to exchange of mFRR energy is provided in the table below (*Table 1*). The designed standard product is fully in line with the proposed European Implementation Framework (mFRRIFF), except the deviation in delivery period due to the currently used imbalance settlement period (ISP) in WB6. Since ISP=60min is common and harmonized in all of the WB6 parties, the proposed platform is envisaged to facilitate the suitable product (50min of minimum delivery for scheduled activated bid). After the transition period and shift to ISP=15min, the WB6 parties are expected to switch to standard product with 5min of minimum delivery, and later join pan-European mFRR platform (MARI).

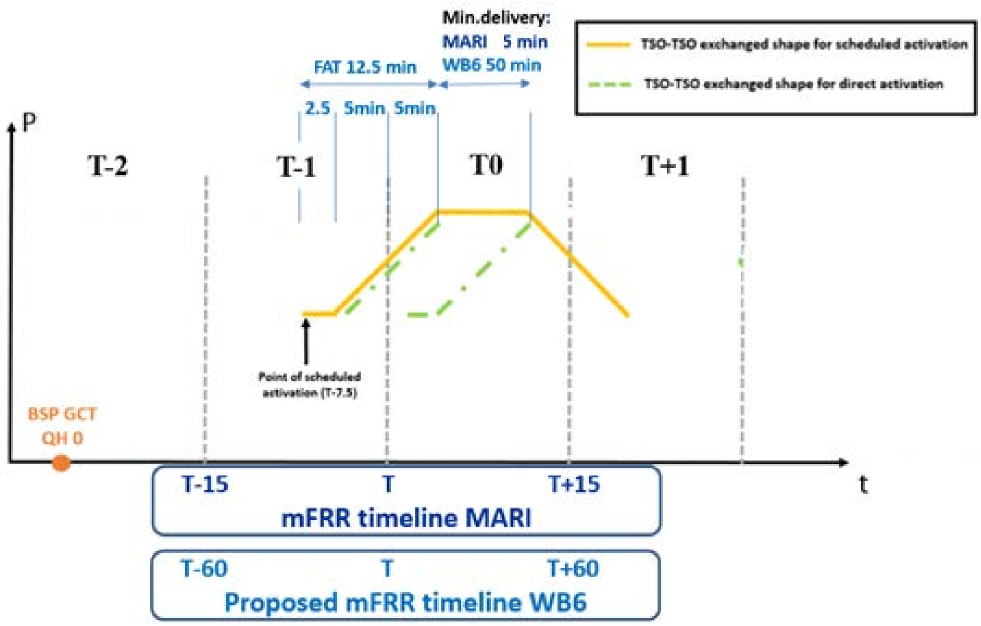


Figure 7: Proposed TSO-TSO exchange shape

Main mFRR product features	ENTSO-E MARI proposal for mFRR standard product to be exchanged on the Platform	Proposal for WB6 cooperation and mFRR standard product to be exchanged on the Platform
Mode of activation	Manual	Manual
Activation type	Direct or Scheduled	Direct or Scheduled
Full activation time ("FAT")	12.5 minutes	12.5 minutes
Minimum quantity	1 MW	1 MW
Bid granularity	1 MW	1 MW
Maximum quantity	9999 MW	9999 MW
Minimum duration of delivery period	5 minutes (SA mFRR)	50 minutes* (SA mFRR)
Validity Period	Scheduled activation can take place at the point of scheduled activation only (T-7.5minutes). Direct activation can take place in any period of time between two points of schedule activation.	Scheduled activation can take place at the point of scheduled activation only (T-7.5minutes). Direct activation can take place in any period of time between two points of schedule activation.
Price	in EUR/MWh	in EUR/MWh
Price resolution	0.01 EUR/MWh	0.01 EUR/MWh
Location	At least the smallest of LFC area or bidding zone.	At least the smallest of LFC area or bidding zone.

Table 1: mFRR standard product characteristics

The proposed cooperation envisages the standard product as manually activated bids with FAT of 12.5min. The TSO-TSO exchange shape envisages 2.5min of preparation period and 10min of ramping period, and the accepted TSO-BSP shape is set by the local TSOs (with condition to fulfil the 12.5min FAT).

The cooperation shall support both direct (DA) and scheduled (SA) activations. For direct activations, the activation request from the TSO can be issued to the BSP at any point in time after the scheduled auction for each delivery period. Direct activation (DA) is needed for the TSOs using mFRR to resolve sudden non-predictable imbalances within the Time To Restore Frequency. Typically, these are outages of generation units or demand facilities.

For scheduled activations, the activation request from the TSO is issued to the BSP at a specific point in time (point of scheduled activation). The envisaged scheduled activation point is 7.5min before the delivery hour T. Scheduled activation is typically used to replace previously activated aFRR bids or alternatively to handle forecasted (predictable) imbalances proactively depending on the TSO's balancing strategy. For the TSOs, this allows the gathering of several demands and realizing benefits from the netting demands in opposite directions, if possible (e.g. if TSO A sends schedule activation request of 10MW and TSO B sends schedule activation request of -10MW, the requests will be netted without any balancing activations if sufficient CZC is present). For the BSPs, it gives certainty on the timing of any activation which is useful when the capacity is subsequently offered in different markets (for instance: used in intraday market and then offered as mFRR). The defined schedule activation point (T-7.5min), also determines the earliest point of direct activation (T-7.5min) and the latest point of direct activation (T+52.5min) for the delivery hour T.

For the standard bid, minimum quantity of 1MW is proposed in order to balance the current TSO practice that aims to avoid excessive bids fragmentation, and BSPs needs for smaller entry barriers. The maximum quantity is 9999MW, which is mainly justified by IT factors. However, the maximum bid size in the WB6 region is not expected to be larger than few hundred MWs.

The proposed price shall be defined in EUR/MWh and with 2 decimal price resolution (0.01EUR/MWh). The location of a bid should correspond to the smallest of LFC area or market bidding zone. Beside main features described above, after the implementation and first period of operation, the Regional Balancing Platform could be further enhanced to support introduction of more complex bid features, such as technical and economic links between bids, indivisible bids, etc.

2.2.2 RR standard product

The summary of standard product bid characteristics proposed for the WB6 regional cooperation related to exchange of RR energy is provided in the table below (*Table 2*). Similar to the above described mFRR process, the designed standard product is fully in line with the proposed European Implementation Framework (RRIFF), except the deviation in delivery period (due to the imbalance settlement period (ISP) in WB6). Since ISP=60min is common and harmonized in all of the WB6 parties, the proposed platform is envisaged to facilitate the suitable product (60min of minimum delivery). After the transition period and shift to ISP=15min, the WB6 parties, which utilize RR activations, are expected to switch to standard product with 15min of minimum delivery period, and later join pan-European RR platform (TERRE).

Main RR product features	ENTSO-E TERRE proposal for RR standard product to be exchanged on the Platform	Proposal for WB6 cooperation and RR standard product to be exchanged on the Platform
Mode of activation	Manual and Scheduled	Manual and Scheduled
Preparation Period	From 0 to 30min	From 0 to 30min
Ramping period	From 0 to 30min	From 0 to 30min
Full activation time (“FAT”)	30 minutes	30 minutes
Deactivation period	Under national responsibility	Under national responsibility
Minimum quantity	1 MW	1 MW
Minimum duration of delivery period	15 minutes	60 minutes*
Location	Bidding Zone	Bidding Zone
Validity Period	Defined by BSP and respecting the min and max delivery period.	Defined by BSP and respecting the min and max delivery period.
Price	in EUR/MWh	in EUR/MWh

Table 2: RR standard product characteristics

The proposed cooperation envisages the standard product as manual and scheduled activated bids with FAT of 30min. It should be noted, that current WB6 parties practice when it comes to manually activated balancing products is still based on an old categorization (“tertiary control”), but from technical and operational point, it can be characterized as mFRR (with dominant direct activations). Therefore, mFRR integration process in WB6 region should be observed with higher priority compared to RR integration process, which should be considered as optional for the TSOs that decide to apply RR activations.

2.3 Balancing energy bids & creation of common merit order list

Balancing energy bidding list is comprised of energy bids of contracted balancing capacity providers and additional balancing energy bids from other non-contracted prequalified balancing service providers.

Bids for balancing energy include:

- offered quantity,
- direction of activation (upward/downward),
- price,
- location (control area),
- activation type (RR, schedule activated mFRR, directly activated mFRR)

Bidding for balancing energy provision is organized on intraday timeframe, with following proposed gate open and gate closure times:

Balancing service	BSP -> TSO	TSO -> Regional Platform
mFRR	The balancing energy gate closure time for the submission of mFRR energy bids to the connecting TSO by BSPs shall be 25 minutes before the beginning of the next delivery/settlement period for which the BSPs place the respective mFRR energy bids.	The TSO energy bid submission gate closure time for mFRR shall be 25 minutes to 10 minutes before the beginning of the delivery/settlement period for which the BSPs place the respective mFRR energy bids.
RR	The balancing energy gate closure time for the submission of RR energy bids to the connecting TSO by BSPs shall be 55 minutes before the beginning of the next delivery/settlement period for which the BSPs place the respective RR energy bids.	The TSO energy bid submission gate closure time for RR shall be 45 minutes to 36 minutes before the beginning of the delivery/settlement period for which the BSPs place the respective RR energy bids.

Table 3: Balancing energy gate closure times for bids submission

EB GL Article 31 paragraph 2 sets the requirements for the common merit order list:

> *Common merit order lists shall consist of balancing energy bids from standard products. All TSOs shall establish the necessary common merit order lists for the standard products. Upward and downward balancing energy bids shall be separated in different common merit order lists.*

Therefore, on the basis of submitted and verified balancing energy bids, each TSO will create local merit order lists for both upward and downward direction (based on bid prices) which will be forwarded to the regional common activation platform. Local merit order lists will be aggregated in the regional platform to form a Common Merit Order List (one for upward, and one for downward direction) which will include all previous information on bids with additional information of originating control area for each bid.

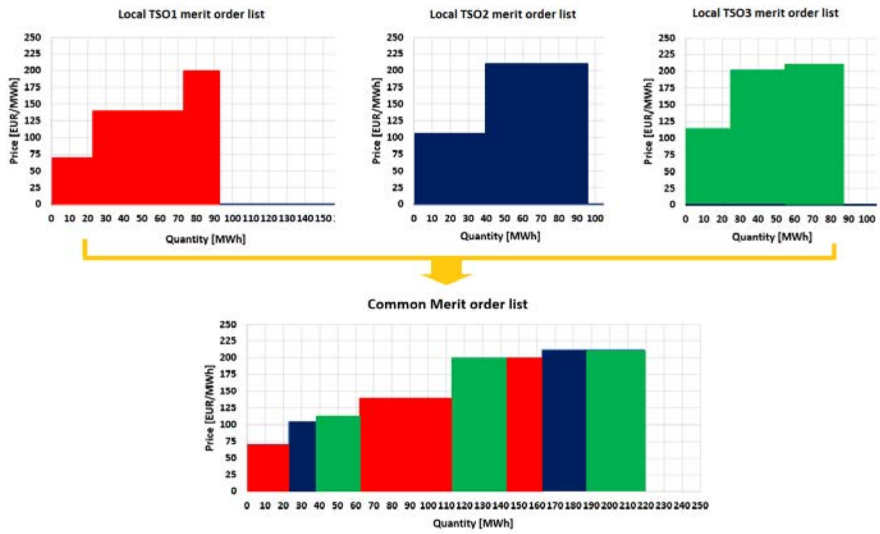


Figure 8: Creation of CMOL

2.4 TSO balancing energy activation requests

The TSOs within the cooperation will submit the balancing energy requests for mFRR & RR activations to the platform.

TSO balancing energy requests include:

- requested quantity,
- direction of activation (upward/downward),
- activation type (RR, schedule activated mFRR or directly activated mFRR)
- location (control area),
- price.

Currently, balancing energy requests in the WB6 members are price inelastic, meaning that TSOs do not define the price limit for which they are willing to active the balancing energy. The rationale behind enabling the elastic price bids is that TSOs can deal with uncertainties about balancing costs taking into consideration alternative measures to solve their imbalances (i.e. opt to rely on imbalance netting and aFRR activations if potential mFRR activation price is too high).

2.5 Usage of Cross Zonal Capacities

Balancing energy cooperation needs to be structured in such way that activated balancing energy bids do not endanger the system's security. Therefore, treatment and determination of CZC must be in line with the following EB GL article (Art. 37):

1. *After the intraday-cross-zonal gate closure time, TSOs shall continuously update the availability of cross-zonal capacity for the exchange of balancing energy or for operating the imbalance netting process. Cross-zonal capacity shall be updated every time a portion of cross-zonal capacity has been used or when cross-zonal capacity has been recalculated.*
2. *Before the implementation of the capacity calculation methodology pursuant to paragraph 3, TSOs shall use the cross-zonal capacity remaining after the intraday cross-zonal gate closure time.*
3. *Five years after entry into force of this Regulation, all TSOs of a capacity calculation region shall develop a methodology for cross-zonal capacity calculation within the balancing timeframe for the exchange of balancing energy or for operating the imbalance netting process. Such methodology shall avoid market distortions and shall be consistent with the cross-zonal capacity calculation methodology applied in the intraday timeframe established under Commission Regulation (EU) 2015/1222.*

Since the methodology for CZC calculation within the balancing timeframe for the exchange of balancing energy or for operating the imbalance netting process will be available by 2022 at the earliest (ENTSO-E level), the available CZC to be considered in the balancing energy exchange process is the capacity remaining after the intraday cross-zonal GCT. With each balancing activation that leads to cross border energy exchange, the available CZC capacities should be updated according to the generated cross border energy exchanges:

<u>*Example:*</u>

Initial ATC value between TSO A and TSO B is 50MW in both directions. Within SA mFRR process, TSO B activated 20MW of SA mFRR, which is delivered by balancing bid connected to TSO A. The remaining capacity for DA mFRR process is now:

TSO A -> TSO B 30 MW (50MW – 20MW)

TSO B -> TSO A 70 MW (50MW + 20MW)

2.6 Activation Optimization Function (AOF)

Optimization function for all processes (RR, SA mFRR, DA mFRR) is defined within this chapter.

For different processes, as described, the optimization occurs in different time,, and different bids and requests are eligible for different services, as depicted in the figure bellow (Figure 9):

- RR process: uses only balancing bids and TSO requests with RR flag
- SA mFRR process: uses balancing bids with SA mFRR and DA mFRR flags, and TSO requests with SA mFRR flag
- DA mFRR process: uses remaining balancing bids after the SA mFRR process that have DA mFRR flag, and TSO requests with DA mFRR flag

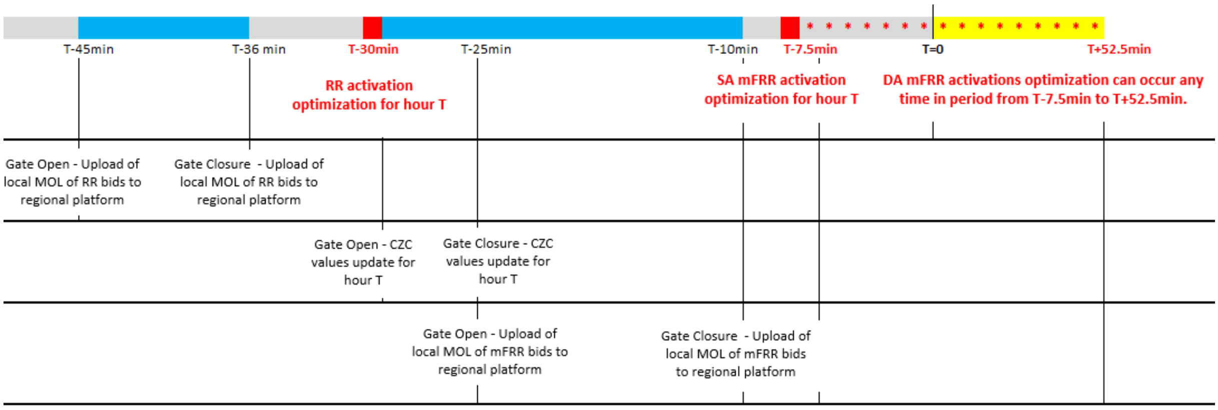


Figure 9: WB6 balancing cooperation – process overview

2.6.1 Objective function

The objective function of the balancing exchange process is based on maximization of the social economic welfare:

$$\max_{\Delta q_{ik}^{\mathrm{up}},\Delta q_{ik}^{\mathrm{down}},\Delta r_{ik}^{short},\Delta r_{ik}^{\mathrm{long}}} \left\{ \sum_{i=1}^{n_{CA}} \sum_{k=1}^{R_i^{\mathrm{short}}} m_{ik}^{\mathrm{short}} \Delta r_{ik}^{\mathrm{short}} - \sum_{i=1}^{n_{CA}}\sum_{k=1}^{R_i^{\mathrm{long}}} m_{ik}^{\mathrm{long}}\Delta r_{ik}^{\mathrm{long}} - \sum_{i=1}^{n_{CA}}\sum_{k=1}^{\mathcal{B}_i^{\mathrm{up}}} c_{ik}^{\mathrm{up}}\Delta q_{ik}^{\mathrm{up}} + \sum_{i=1}^{n_{CA}}\sum_{k=1}^{\mathcal{B}_i^{\mathrm{down}}} c_{ik}^{\mathrm{down}}\Delta q_{ik}^{\mathrm{down}}\right\}$$

Where:

- n_{CA} - is a total number of control areas;
- i=1, 2,.. nCA representing each control area.
- k=1, 2,.. $\mathcal{B}_i^{\mathrm{up}}$ representing each bid within control area i.
- $\mathcal{B}_i^{\mathrm{up}}$, $\mathcal{B}_i^{\mathrm{down}}$ - total number of upward and downward energy bids in ith control area, respectively;
- $\Delta q_{ik}^{\mathrm{up}}$, $\Delta q_{ik}^{\mathrm{down}}$ – optimized/selected quantity of upward and downward balancing energy bids in i-th control area, respectively;

- c_{ik}^{up}, c_{ik}^{down} – submitted price of upward and downward balancing energy bids in i-th control area, respectively;
- $\mathrm{R}_i^{\mathrm{up}}$, $\mathrm{R}_i^{\mathrm{down}}$ - total number of upward and downward energy requests in i-th control area, respectively;
- $\Delta r_{ik}^{\mathrm{short}}$, $\Delta r_{ik}^{\mathrm{long}}$ – optimized/selected quantity of upward (short) and downward (long) balancing energy requests in i-th control area, respectively;
- m_{ik}^{short}, m_{ik}^{long} – submitted price of upward and downward balancing energy requests in i-th control area, respectively;

Sign convention for the bid price is defined as:

Sign convention	Positive price	Negative price
Upward direction	TSO pays to BSP	N/A
Downward direction	BSP pays to TSO	TSO pays to BSP

- Positive price value for upward bids and negative price value for downward bids refer to request of TSO to BSP payment.
- Positive price value for downward bids refer to request of BSP to TSO payment.

The social welfare is the total surplus of all TSOs participating in the Regional Balancing Platform obtained from satisfying their balancing requests and the total surplus of BSPs resulting from the activation of their associated balancing bids, as illustrated in Figure 10. *The curve consisting of positive TSO balancing requests and downward BSP balancing bids constitutes the consumer curve (based on economic theory), and therefore indicates what price consumers (TSOs and BSPs) are prepared to pay for consuming balancing energy, based on their expectations of private costs and benefits. On the other hand, the curve consisting of negative TSO balancing requests and upward BSP balancing bids constitutes the producer curve (based on economic theory), and therefore shows the price they are prepared to receive for supplying balancing energy. Social welfare, also known as economic welfare, is the total benefit available to society from an economic transaction, and therefore is made up of the red area in which is the sum of the consumer and the producer surplus (5).*

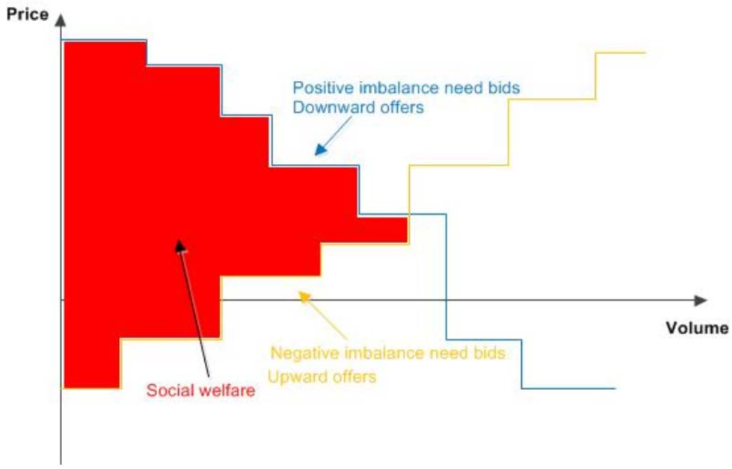


Figure 10: Balancing market - Social Economic Welfare

2.6.2 Constraints of the optimization algorithm

Bids & requests constraints

Since bids and requests are defined as divisible (smallest amount is 1 MW), for all balancing energy bids and requested (“upward“ and “downward“) lower/upper bounds are determined as (0 means that bid is not activated):

$0 \le \Delta q_{ik}^{down} \le q_{ik}^{down}$ (q_{ik}^{down} – max downward bid quantity)

$0 \le \Delta q_{ik}^{up} \le q_{ik}^{up}$ (q_{ik}^{up} – max upward bid quantity)

$0 \le \Delta r_{ik}^{short} \le r_{ik}^{short}$ (r_{ik}^{short} - upward request)

$0 \le \Delta r_{ik}^{long} \le r_{ik}^{long}$ (r_{ik}^{long} – downward request)

Power balance constraint

Bid selection is performed in such manner that level of outgoing/incoming cross border exchanges through all borders of a control area corresponds to the level of export/import of balancing energy. Therefore, equality constraint for power balance of each control area is defined as:

For all control areas $i = 1, 2, \cdots, n_{CA}$ are:

$$\sum_{k=1}^{R_i^{long}} \Delta r_{ik}^{long} + \sum_{k=1}^{\mathcal{B}_i^{up}} \Delta q_{ik}^{up} - \sum_{k=1}^{\mathcal{B}_i^{down}} \Delta q_{ik}^{down} - \sum_{k=1}^{R_i^{short}} \Delta r_{ik}^{short} = \sum_{\ell \in \Omega_i} P_\ell$$

Also, balance of the whole system in cooperation is defined as:

$$\sum_{i=1}^{n_{CA}} \sum_{k=1}^{\mathcal{B}_i^{up}} \Delta q_{ik}^{up} - \sum_{i=1}^{n_{CA}} \sum_{k=1}^{\mathcal{B}_i^{down}} \Delta q_{ik}^{down} = \sum_{i=1}^{n_{CA}} \sum_{k=1}^{R_i^{short}} \Delta r_{ik}^{short} - \sum_{i=1}^{n_{CA}} \sum_{k=1}^{\mathcal{B}_i^{long}} \Delta r_{ik}^{long}$$

Where:

- P_l – cross border balancing energy exchange over border l. It could be both positive and negative, with positive sign defining the flow in reference direction
- Ω_i - is set of borders/CZCs of the i-th control area with neighbouring areas, i.e. $\sum_{\ell\in\Omega_i} P_\ell$ represents a sum of outgoing/incoming cross border exchanges over all borders of control area i.

ATC-based constraints

Each cross border exchange must meet the network limits (CZCs), therefore inequality network constraints are defined.

In the case that CZCs are defined with ATC values for each border and direction, lower/upper bounds for energy flow (P_ℓ) are defined as:

$$-ATC_\ell^{\text{a\_f}} \le P_\ell \le ATC_\ell^{\text{w\_f}};\ \ell = 1, 2, \cdots, t_\ell$$

Where:

- $ATC_\ell^{\text{w\_f}}, ATC_\ell^{\text{a\_f}}$ – defined ATC values for border l and directions respectively;
- t_l – is total number of borders.

The summary of the optimization inputs and outputs is presented in the figure bellow.

Figure 11: Optimization inputs & outputs

2.7 Pricing and Settlement

This Chapter defines ex-post activities related to remuneration of volume of exchanged balancing energy, pricing of energy, as well as TSO-BSP and TSO-TSO settlement.

2.7.1 Imbalance settlement period

Current imbalance settlement period in WB6 parties is 60min, and as mentioned in previous chapters, the proposed design for current WB6 cooperation envisages 60min imbalance settlement period before the TSOs switch to target[3] 15min ISP.

2.7.2 Balancing energy volume

Each TSO within cooperation will settle the activated volume of mFRR and RR balancing energy with the BSPs connected at that TSO's control area, regardless of where a certain volume of balancing energy is requested. The energy volumes relevant to the remuneration of deployed mFRR and RR balancing energy will be calculated for each bid of each BSP and for each imbalance settlement period. Separate settlement of upward and downward activation will be implemented. For each BSP, only one TSO will be responsible for settlement and accounting (connecting TSO).

For the TSO-TSO volume settlement of exchanged balancing energy, the Study proposal for WB6 cooperation model assumes that exchanged balancing energy is settled within the main hour T, as integral of power over time:

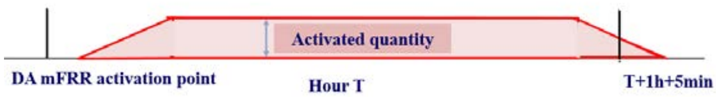
TSO-TSO exchange profile	Illustration
RR - Rectangular shape	
SA mFRR - Trapezoid profile with 10min ramps and 50min duration of activated quantity	
DA mFRR - Trapezoid profile with 10min ramps and duration of activated quantity depending on the activation point	

Table 4: TSO-TSO exchange profile

[3] EB GL Art.53, paragraph 1, defines that ISP of 15min should be implemented three years after the EB GL entry into force. However, the paragraphs 2 and 3 define that TSOs can jointly request an exemption supported by cost-benefit analysis concerning the harmonisation of the imbalance settlement period.

2.7.3 Balancing energy pricing and TSO-TSO settlement

Two options, marginal pricing and pay-as-bid pricing, were analysed for the WB6 balancing cooperation pricing mechanism.

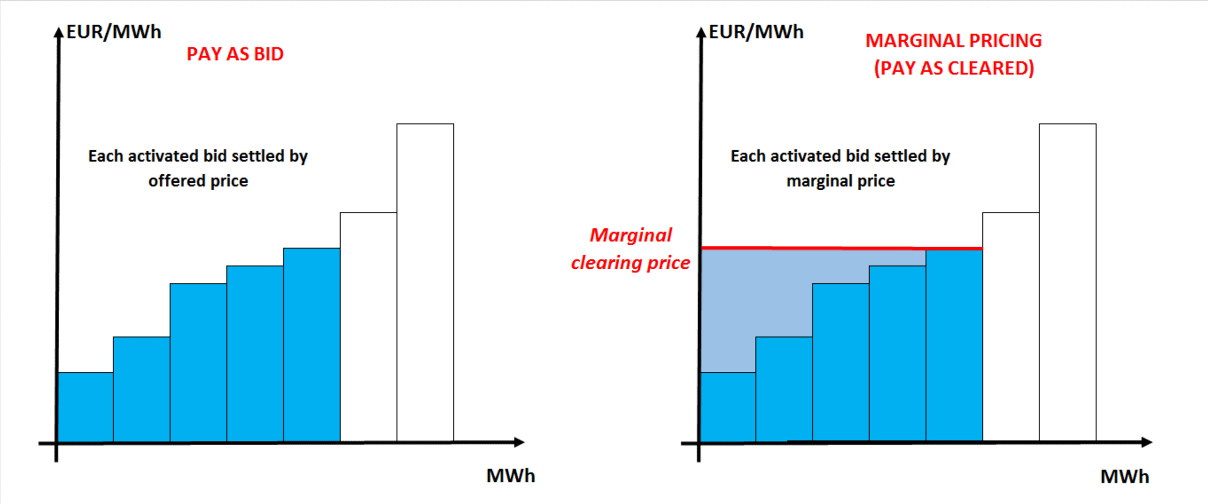


Figure 12: Pricing mechanisms: pay-as-bid & marginal pricing

The EB GL defines that all TSOs shall harmonise their pricing methods. It also defines that mechanism shall be based on marginal pricing (pay-as-cleared), unless TSOs complement the proposal with a detailed analysis demonstrating that a different pricing method is more efficient for European-wide implementation.

Currently, where national merit order list is applied (EMS, NOSBiH), the balancing pricing is based on pay as bid method. The rationale behind the implementation of pay-as-bid method is that to some extent, it shields the TSOs against occurrence of excessive balancing energy costs in the highly concentrated markets with low level of competition.

However, if sufficient competition is present, marginal pricing produces numerous potential benefits:

- incentives for participants to bid at short run marginal costs
- more efficient dispatch
- it is easier to prepare bids and therefore better for smaller providers (DR & DG)
- Provides stronger incentives to BSPs to invest in balancing capacity and BRPs to be balanced/support the system balance

The proposal for the WB6 cooperation model is implementation of cross-border marginal pricing, which is in line with EB GL. Also, in case there is a lack of market liquidity on national level, creation of regional balancing energy exchange cooperation will contribute to the increase of competition and to the decrease of possible exercise of market power.

Cross-border marginal pricing defines that the most expensive bid activated in a non-congested area determinates the price within all zones in this non-congested area. This means that all balancing energy that results from the activation of balancing energy bids (under one process – RR, SA mFRR, DA mFRR) within an uncongested area is remunerated with the same marginal price for providing the same service. In case of cross-zonal capacity limitations between adjacent areas, a price split can occur meaning that in each uncongested area the highest selected bid sets the marginal price for the respective area. The price for cross-zonal capacity corresponds to the price difference between the adjacent uncongested areas (i.e. the CZC price is determined in the implicit manner).

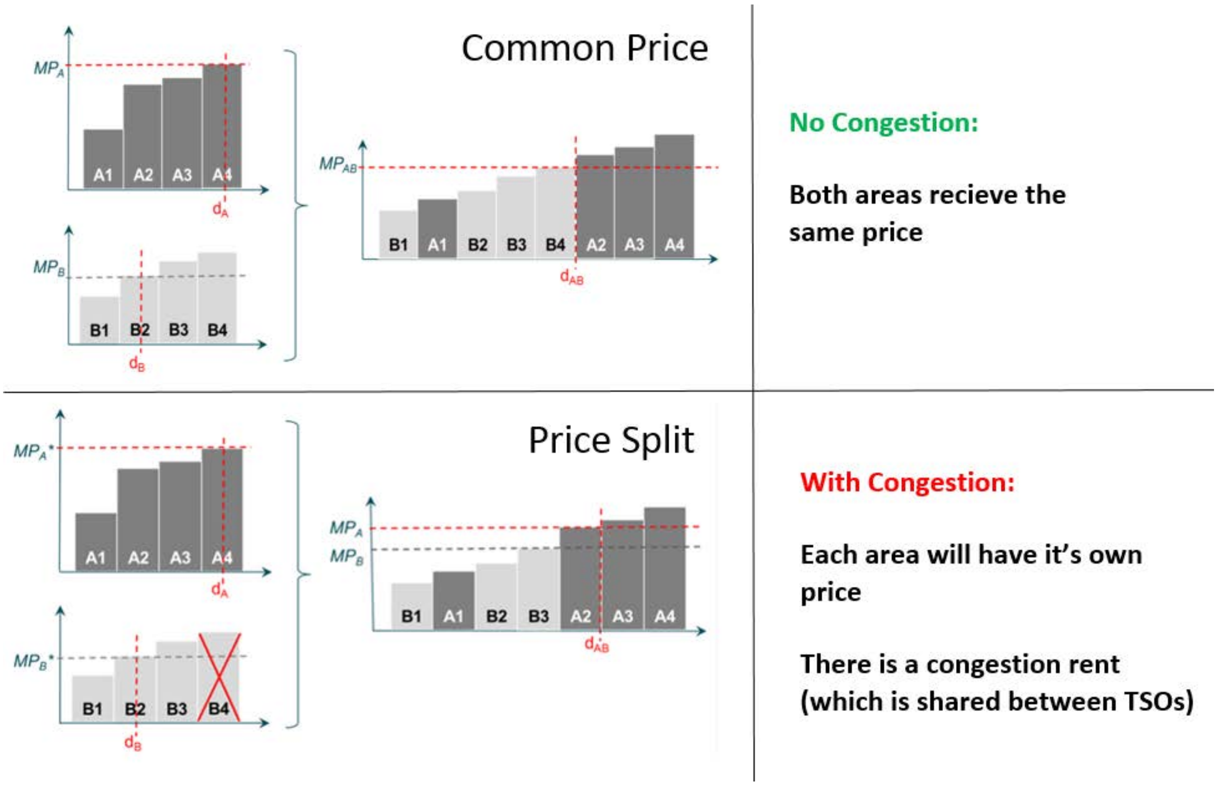


Figure 13: Cross-border pricing mechanism

The above described principle is already applied within day-ahead market coupling, as well as proposed for mFRR energy exchange, under the MARI project (4)(5).

On the basis of determined cross-zonal marginal prices, as well as exchanged energy volumes, the payment flow between the TSOs (TSO-TSO settlement) for the observed ISP is defined separately[4] for RR auction, mFRR auction, as well as for each DA mFRR activation.

[4] The requirement to perform the optimisations (i.e. market clearings) separately results directly from the different activation processes (scheduled and direct activation). For RR and mFRR with scheduled activation, the necessity for separated clearings results from different product parameters (such as full activation time, gate

The TSO-TSO settlement is calculated through value of exchanged energy and congestion rent. The first component (value of exchanged energy) is defined as a difference of:

- Costs of activated bids: costs of activated upward & downward balancing energy within ISP and the TSO control area (i.e. due to the “connecting TSO” principle, in each control area, BSPs can be activated both for the needs of the local TSO, as well as for the cross border exchange, which produces the difference between costs of activated bids and costs of activated requests).
- Costs of activated requests: costs of the activated upward & downward balancing energy requests from TSOs, and corresponding cross-zonal marginal price (pay-as-cleared) for upward & downward balancing energy.

The second component represents the congestion rent. The congestion rent is calculated as a product of price difference and exchanged balancing energy between two bidding zones (the calculation is performed for each activation cycle – one RR cycle per ISP one SA mFRR cycle per ISP; up to the number of DA activations per ISP).

The first component can be positive (TSO exports balancing energy), negative (TSO imports balancing energy) or zero (TSO is not exporting/importing balancing energy). The second component is always non-negative, i.e. if there is a congestion on some of TSO borders, it is positive, otherwise it is zero. The sum of these two components, defines compensation payments that each TSO has to settle or receive.

closure times). mFRR with direct activation is required to fulfil the requirement of Time To Restore Frequency (TTRF) arising from SOGL as many TSOs use mFRR to cover their dimensioning incident.

Example:

The balancing energy cooperation between the two TSOs is analysed for one ISP and activation of SA mFRR (input bids, requests, and available CZC is presented in the table below).

Bids	TSO	Direction	Quantity [MW]	Price [EUR/MWh]
Bid_1	TSO A	Upward	50	55
Bid_2	TSO A	Upward	60	70
Bid_3	TSO A	Upward	40	60
Bid_4	TSO B	Upward	30	100
Bid_5	TSO B	Upward	20	30
Requests	**TSO**	**Direction**	**Quantity [MW]**	**Price [EUR/MWh]**
Request_1	TSO A	Upward	90	65
Request_2	TSO B	Upward	40	80
CZC	**From [MW]**	**To [MW]**		
TSO A - TSO B	10	10		

Table 5: Pricing example- inputs

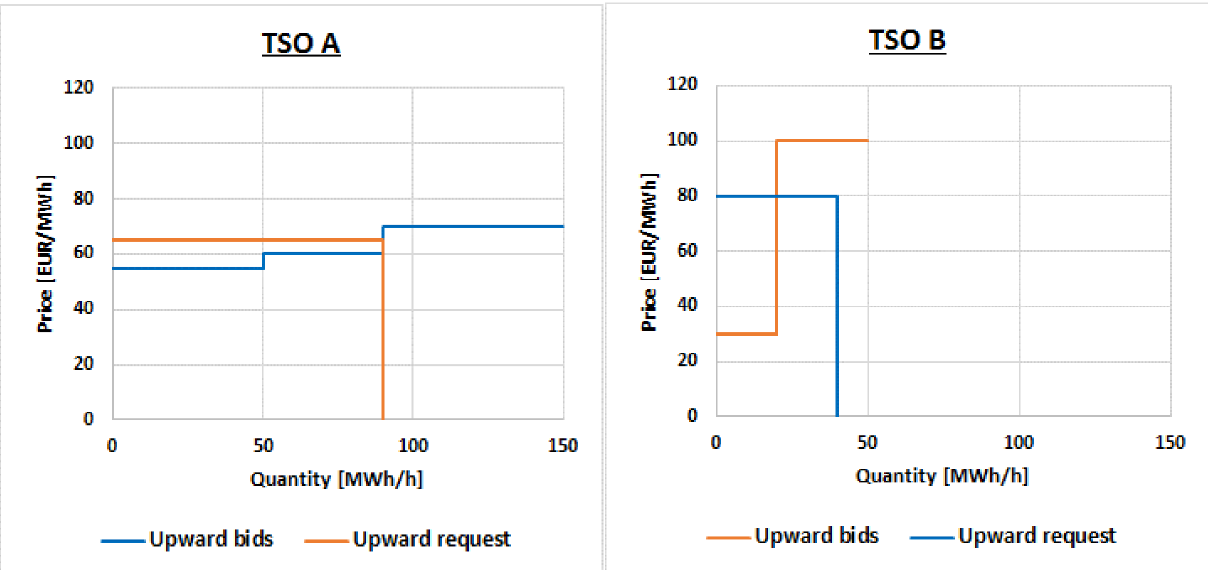


Figure 14: *Pricing example- inputs*

The Activation Optimization Function (AOF) determines the following optimal result for SA mFRR activation:

Bids	TSO	Direction	Activated Quantity [MWh/h]	Settled Price [EUR/MWh]
Bid_1	TSO A	Upward	50	65
Bid_2	TSO A	Upward	0	65
Bid_3	TSO A	Upward	40	65
Bid_4	TSO B	Upward	0	80
Bid_5	TSO B	Upward	20	80
Requests	**TSO**	**Direction**	**Activated Quantity [MWh/h]**	**Settled Price [EUR/MWh]**
Request_1	TSO A	Upward	80	65
Request_2	TSO B	Upward	30	80
Energy Exchange	**From [MW]**	**To [MW]**		
TSO A - TSO B	10	-10		

Table 6: Pricing example- results

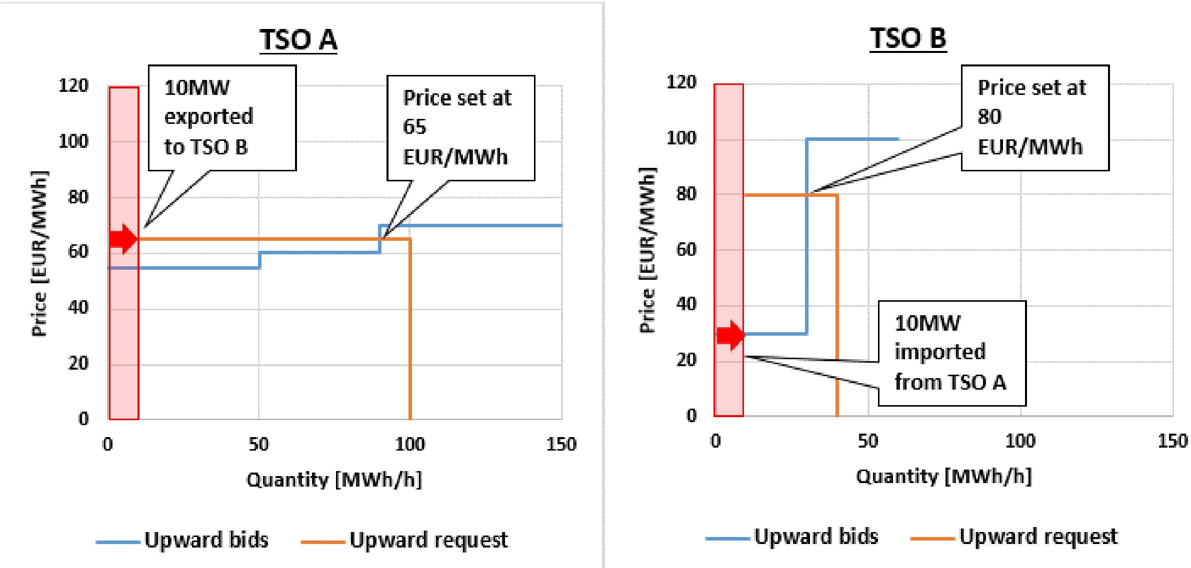


Figure 15: *Pricing example- results*

The bid prices are lower in TSO A control area, and therefore the TSO A exports the balancing energy to TSO B. Since there is only 10MW of available CZC, and the need for cheaper balancing energy import of TSO B is higher than that, the congestion occurs. The Request 1 sets the marginal price in TSO A area (65 EUR/MWh), while the Request 2 sets the marginal price in TSO B area (80 EUR/MWh).

In the Table 7, the summary of costs for activated requests, costs for activated bids, congestion revenue, and overall TSO-TSO settlement position is presented:

TSO	Costs of activated requests [EUR]	Costs of activated bids [EUR]	Congestion revenue [EUR]	TSO-TSO Settlement [EUR]
TSO A	5200	5850	75	725
TSO B	2400	1600	75	-725

Table 7: Pricing example- TSO-TSO settlement

The difference between the marginal prices observed in area A and area B, multiplied by energy flow, determine the congestion rent. The total congestion rent corresponds also to the difference between costs of activated requests and costs of activated bids.

Overall, it can be concluded that TSO B needs to compensate TSO A for 725EUR.

2.8 IT requirements and data exchange

Regarding IT and data exchange requirements, all TSOs should establish new electronic interfaces between mFRR&RR platform and national MMS (market management systems) and SCADA/EMS (energy management systems), as well as shall update existing electronic interfaces between SCADA/EMS and local BSP unit's controllers.

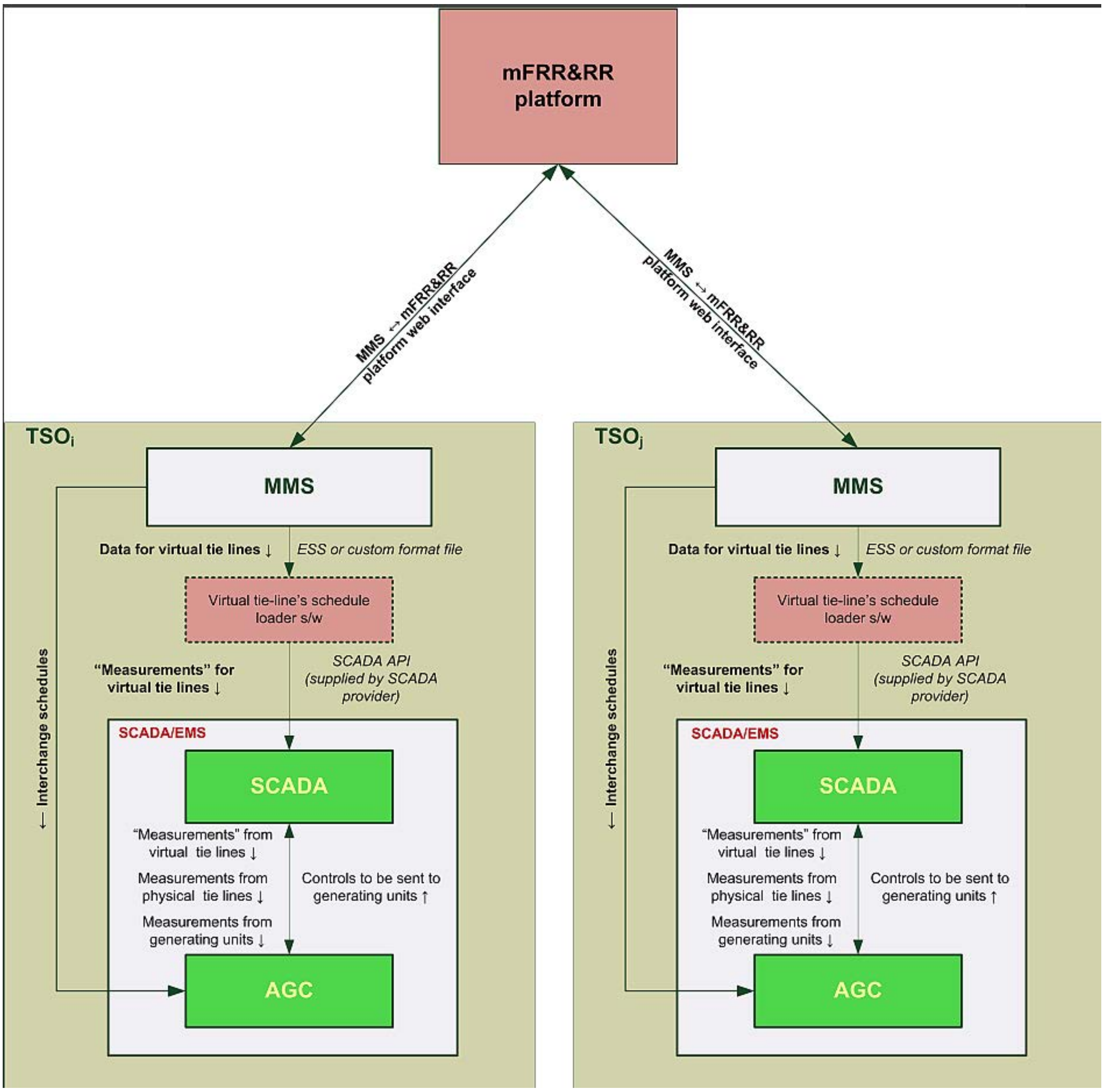


Figure 16: IT structure

Firstly, WB6 TSOs should enable usage of virtual tie lines in their SCADA/EMS systems as an addition to physical tie lines that are currently used to calculate Frequency Restoration Control Error (FRCE) within AGC module of SCADA/EMS systems. For all virtual tie lines, the corresponding EIC codes[5] shall be defined. Further, mFRR&RR platform must be able to produce and send corresponding XML files to market management systems (ESS platforms) of each TSO that will update the energy exchange values on each virtual tie line as a result of activation optimization function process. National ESS platforms of each TSO should automatically create the updated "SCADA/EMS" file that will contain a new value of control program (net position) that AGC module shall follow. The new energy-exchange values on virtual tie lines between participating TSOs shall be implemented in AGC module in such a way to comply with proposed shape of mFRR&RR standard product in terms of ramping period.

The interfaces between TSOs' SCADA/EMS and local BSP units' SCADA systems for activation of mFRR&RR balancing energy should be updated to allow sending of the activation signals by using standard protocols.

[5] The Energy Identification Coding Scheme (EIC) is a 16-character coding scheme used in Europe to uniquely identify entities and objects related to the electricity, standardized and maintained by ENTSO-E

3. mFRR & RR PLATFORM: SOFTWARE DESCRIPTION

3.1 Functional design

The functional design of the platform, consisting of three inputs processing modules (Bids, Requests, CZC) and two output processing modules (Results, Settlement), is presented in the figure below. .

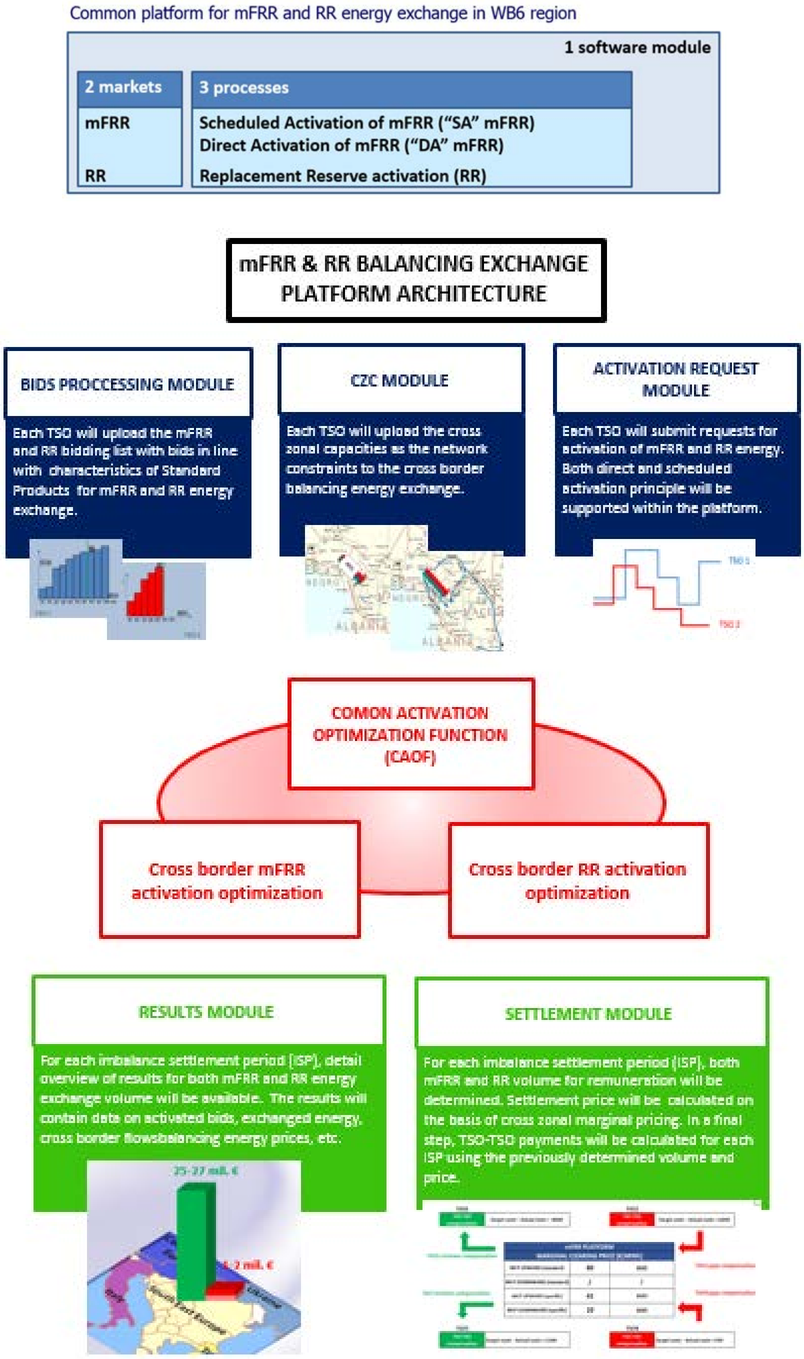


Figure 17: mFRR & RR platform – functional design

3.2 Software description

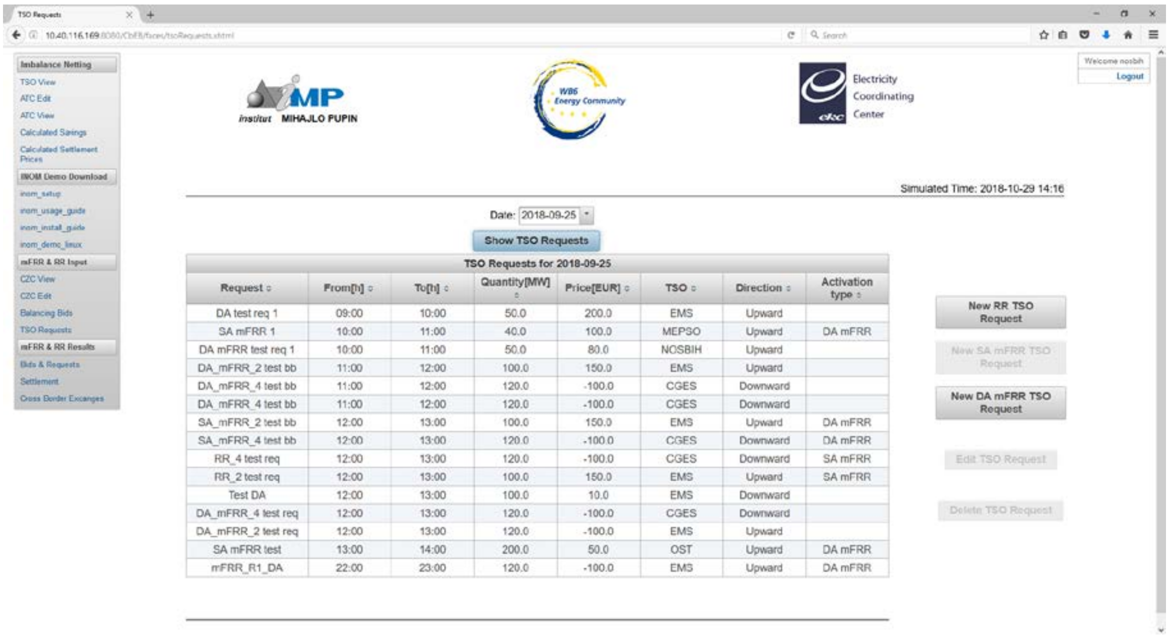
In this chapter, the software implementation of Regional mFRR & RR Balancing Platform is described.

The Regional mFRR & RR Balancing Platform is accessed from the link:

http://147.91.50.48:8181/CbEB

Within the platform, supported processes include Replacement Reserve activation (RR), Scheduled Activation of manual Frequency Restoration Reserve (SA mFRR) and Direct Activation of manual Frequency Restoration Reserve (DA mFRR).

The platform is running in simulated time, and this time is set by administrator. Simulated time is displayed at the top-left part of each page. Input data can be entered through the web user interface. It consists of Cross Zonal Capacities (CZC), Balancing Bids and TSO Energy Requests. There is a predefined timeframe for each type of input data (according to the target model for WB6 cooperation defined in Chapter 2). The Platform supports this by enabling and disabling data entry for CZCs and each activation type, both bids and requests.



TSO Requests for 2018-09-25

Request	From[h]	To[h]	Quantity[MW]	Price[EUR]	TSO	Direction	Activation type
DA test req 1	09:00	10:00	50.0	200.0	EMS	Upward	
SA mFRR 1	10:00	11:00	40.0	100.0	MEPSO	Upward	DA mFRR
DA mFRR test req 1	10:00	11:00	50.0	80.0	NOSBIH	Upward	
DA_mFRR_2 test bb	11:00	12:00	100.0	150.0	EMS	Upward	
DA_mFRR_4 test bb	11:00	12:00	120.0	-100.0	CGES	Downward	
DA_mFRR_4 test bb	11:00	12:00	120.0	-100.0	CGES	Downward	
SA_mFRR_2 test bb	12:00	13:00	100.0	150.0	EMS	Upward	DA mFRR
SA_mFRR_4 test bb	12:00	13:00	120.0	-100.0	CGES	Downward	DA mFRR
RR_4 test req	12:00	13:00	120.0	-100.0	CGES	Downward	SA mFRR
RR_2 test req	12:00	13:00	100.0	150.0	EMS	Upward	SA mFRR
Test DA	12:00	13:00	100.0	10.0	EMS	Downward	
DA_mFRR_4 test req	12:00	13:00	120.0	-100.0	CGES	Downward	
DA_mFRR_2 test req	12:00	13:00	120.0	-100.0	EMS	Upward	
SA mFRR test	13:00	14:00	200.0	50.0	OST	Upward	DA mFRR
mFRR_R1_DA	22:00	23:00	120.0	-100.0	EMS	Upward	DA mFRR

Figure 18: TSOs Energy Requests Page

Above figure shows TSO Requests page. Existing requests are displayed in table, which can be organized by TSO, time, price or quantity of the request, as well as activation type. At the right side of the page, there are buttons for new request entry, one for each activation type. Also, there are buttons for editing and deleting existing requests from the table. Buttons turn active or passive, minding the current simulation time and the ability to enter/edit/delete given request at that time.

After clicking on "New RR TSO Request", dialog for data entry is displayed (Figure 19):

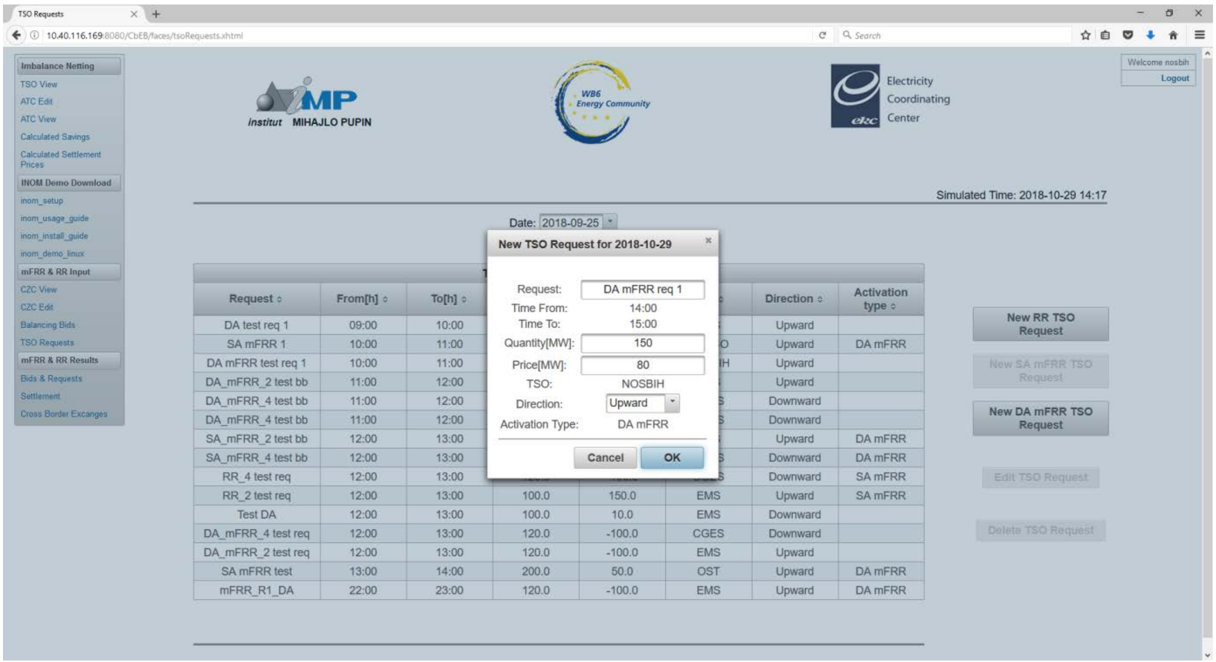


Figure 19: TSOs Energy Requests Page

CZC and Balancing Bids Input Pages can be seen on the Figure 20.

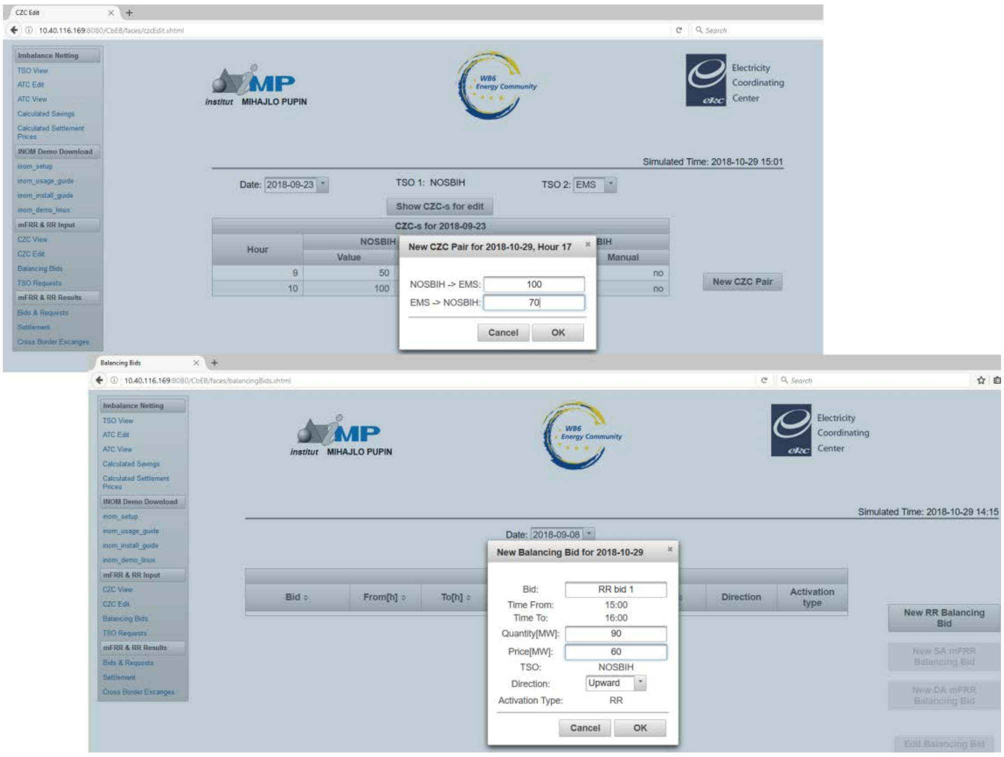


Figure 20: *CZC and Balancing Bids Input Pages*

For entered CZCs, bids and requests, the software calculates and executes simulated activations. Results are displayed in the table form at the Bids and Requests page (Figure 21). We can choose date and hour (or "Whole day"), as well as sort date according to the available bid characteristics (hour, TSO, price, type, etc.) Data entries and activations are done in simulated real-time but all results are placed in the archives, so they can be accessed at any time later.

The results include:

<u>Bids and Requests tab</u> – with the status of each submitted bid and request

Date: 2018-10-25 Time From: 15 Simulated Time: 2018-11-08 16:34

Show Bids And Requests

Accepted Bids for 2018-10-25, Hour 15

Bid	Type	From [h]	To [h]	Activated [h]	TSO	Direction	Offered Quantity [MW]	Activated Quantity [MW]	Offered Price [€/MWh]	Settled Price [€/MWh]	Energy Volume [MWh]	Bid Revenue [€]
RR 1	RR	14:00	15:00	13:30	EMS	Upward	50.00	50.00	55.00	65.00	50.00	3,250.00
RR 3	RR	14:00	15:00	13:30	EMS	Upward	40.00	40.00	60.00	65.00	40.00	2,600.00
RR 6	RR	14:00	15:00	13:30	CGES	Upward	20.00	20.00	30.00	80.00	20.00	1,600.00
RR 2	RR	14:00	15:00	13:30	EMS	Upward	60.00	0.00	70.00	65.00	0.00	0.00
RR 5	RR	14:00	15:00	13:30	CGES	Upward	30.00	0.00	100.00	80.00	0.00	0.00

Accepted Requests for 2018-10-25, Hour 15

Request	Type	From[h]	To[h]	Served [h]	TSO	Direction	Requested Quantity [MW]	Received Quantity [MW]	Offered Price [€/MWh]	Settled Price [€/MWh]	Energy Volume [MWh]	Request Cost [€]
RR req 4	RR	14:00	15:00	13:30	EMS	Upward	90.00	80.00	65.00	65.00	80.00	5,200.00
RR 7	RR	14:00	15:00	13:30	CGES	Upward	40.00	30.00	80.00	80.00	30.00	2,400.00

Figure 21: Bids and Requests Tab

<u>Cross border exchanges tab</u>

Simulated Time: 2018-11-08 16:35

Date: 2018-10-25 TSO 1: EMS TSO 2: CGES

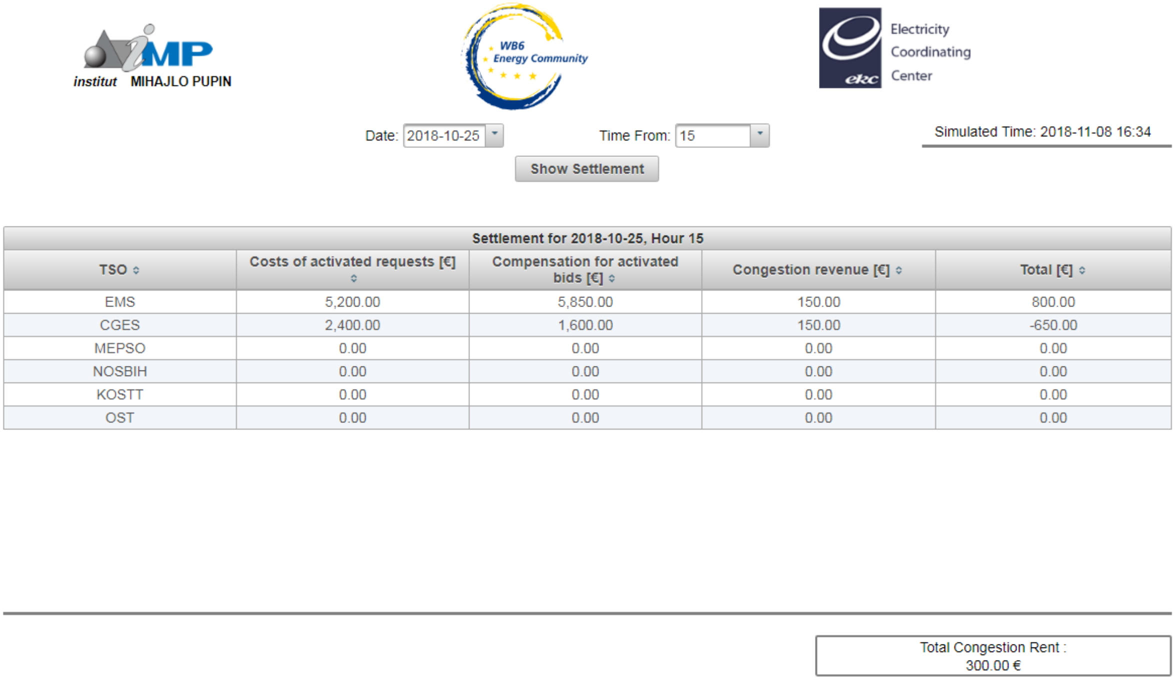
Show Cross Border Excanges

Cross Border Excanges for 2018-10-25

Hour	EMS -> CGES	CGES -> EMS
14	0	0
15	10	-10

Figure 22: Cross border exchanges tab

Settlement tab



Settlement for 2018-10-25, Hour 15				
TSO	Costs of activated requests [€]	Compensation for activated bids [€]	Congestion revenue [€]	Total [€]
EMS	5,200.00	5,850.00	150.00	800.00
CGES	2,400.00	1,600.00	150.00	-650.00
MEPSO	0.00	0.00	0.00	0.00
NOSBIH	0.00	0.00	0.00	0.00
KOSTT	0.00	0.00	0.00	0.00
OST	0.00	0.00	0.00	0.00

Figure 23: Settlement tab

4. DRY RUNS, PILOT TESTS AND BENEFITS ASSESSMENT

4.1 *Dry runs and benefit assessment*

This Chapter provides an overview of performed dry runs of WB6 balancing energy cooperation for mFRR & RR exchange, as well as an assessment of economic benefits resulting from its implementation. The analysis is performed on the basis of TSOs' data for period 16th -22nd of July 2018, using the developed Regional Balancing Platform described in Chapter 3.

The preformed assessment of benefits is based on the current bidding strategies and observed balancing prices in the WB6 parties, which are still not fully market based, as identified and described in the Task 1. Also, in order to perform economic benefits evaluation, certain necessary assumptions are made mainly due to the lack of data. Therefore, these analyses and consequent numerical results can only be treated as indicative, providing an estimation of the potential savings under regional balancing cooperation.

4.1.1 Input data

In order to conduct the dry runs, following data was collected and processed:

- <u>mFRR & RR activation requests (volume + activation time + duration):</u>
  Since all WB6 parties currently apply the old balancing services categorization ("tertiary energy"), the recorded activations are treated as mFRR (with dominant direct activation mode).
- <u>mFRR & RR bids (volume + price):</u>
  Similar to the treatment of activation requests, the obtained tertiary energy bids are treated as mFRR bids.
- <u>Cross Zonal Capacities</u>:
  In form of the remaining intraday ATC values.

The summary of the input data for each TSO is provided in the *Table 8*. It should be noted that currently, KOSTT is not keeping balancing reserve[6] or activating mFRR & RR balancing energy. Therefore, the dry runs were related to the cooperation of five other TSOs.

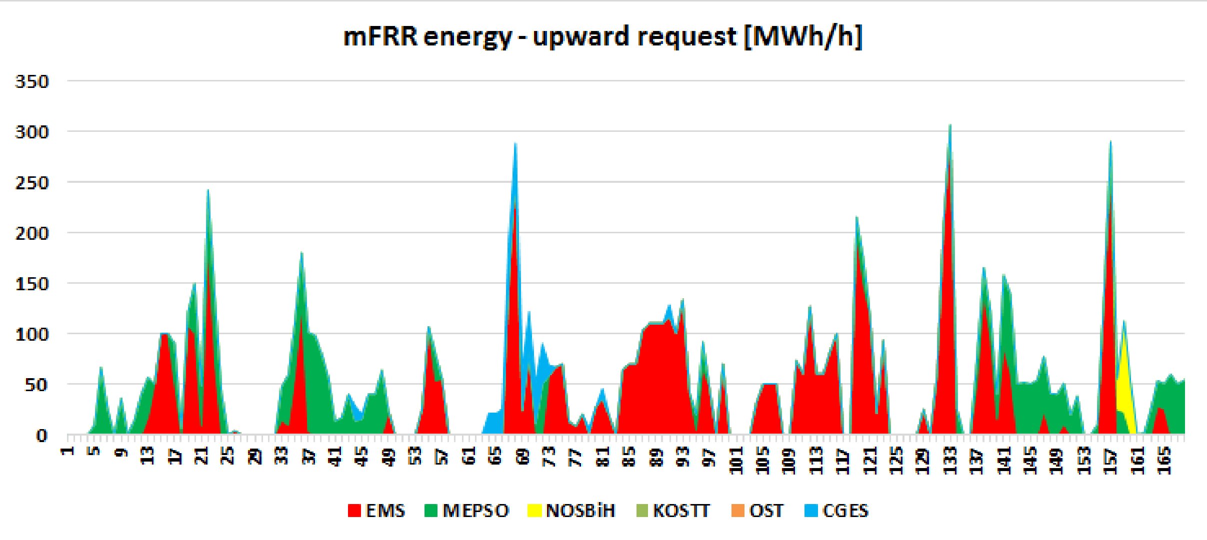
[6] Current needs for tertiary reserve are 260 MW, but, in the absence of flexible units, Kosovo's power system has no generating unit that can provide tertiary regulation.

TSO	Balancing Energy (mFRR, RR) Activation Requests data	Balancing Energy (mFRR, RR) Bids data	CZC (ATC) data
CGES	Data collected.	Data collected.	Data collected.
EMS	Data collected.	Data collected. Explicit bids were not available, only activated quantities and settled prices. Average settlement prices for tertiary energy for each observed day and direction (upward, downward) were used for bid prices. The contracted reserve size for each direction (upward, downward) was used for bid quantities.	Data collected.
KOSTT	Data collected (no activations).	Data collected (no bids).	Data collected.
MEPSO	Data collected.	Data collected. Explicit bids were not available, since the new balancing mechanism is yet to be implemented. The considered bid quantity corresponds to available hourly reserve (upward, downward). The bid prices were correlated with HUPX price (1.3 upward, 0.3 downward).	Data collected.
NOSBIH	Data collected.	Data collected. Explicit bids were available for the hours in which NOSBIH activated tertiary energy. For the rest of the hours, the considered bid quantity corresponds to required tertiary reserve size (upward, downward). The bid prices correspond to average settlement price of activated upward and downward tertiary energy in July.	Data collected.
OST	Data collected.	Data collected. Explicit bids were not available. The considered bid quantity corresponds to available hourly reserve (upward, downward). The bid prices were correlated with HUPX price (1.2 upward, 0.05 downward).	Data collected.

Table 8: mFRR & RR – status of input data

4.1.2 Dry run results

The TSOs mFRR energy activation requests are presented in the figure bellow (Figure 24).



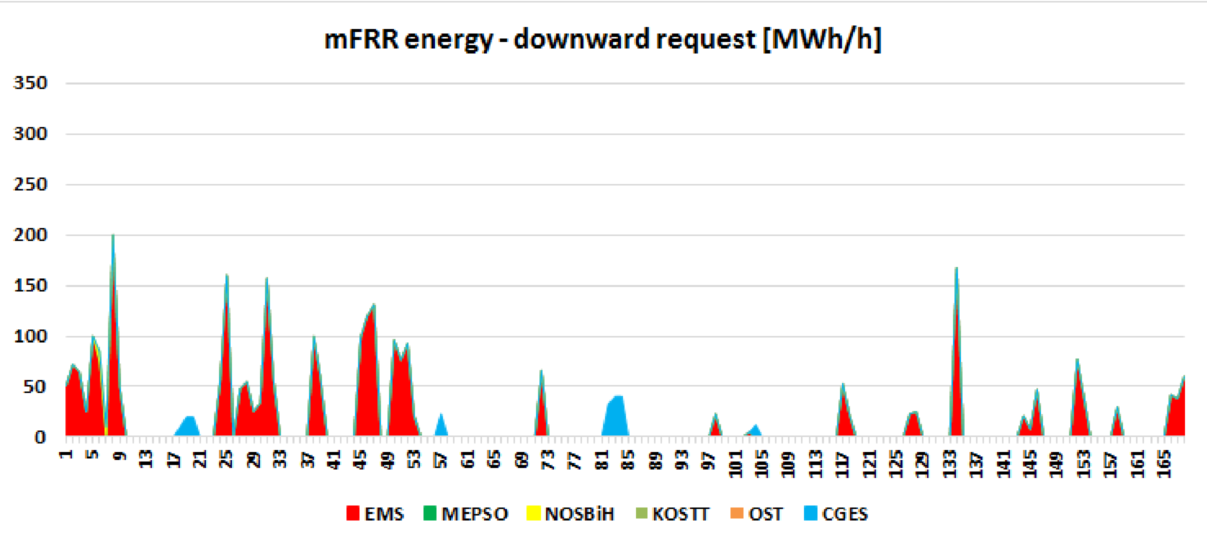
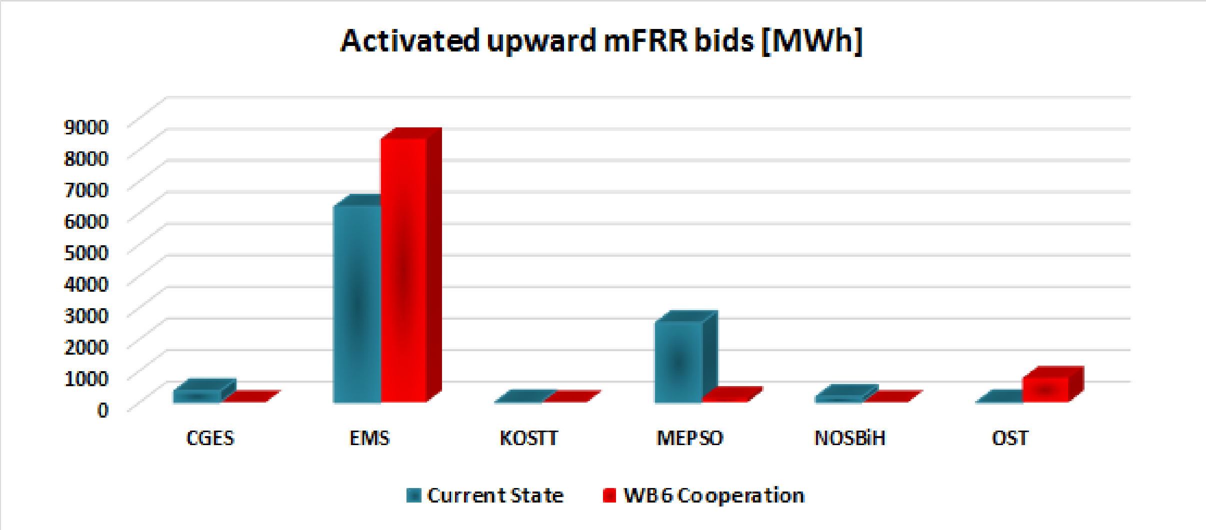


Figure 24: TSOs mFRR activation requests

The total requested mFRR energy in the observed week was at a level of 12,212 MWh (76% in upward direction, 24% in downward direction). It can be noted that EMS has the highest volume of requested mFRR energy in the region.

The activated upward mFRR bids (per TSO) are presented in the figure bellow, for the current state and the case with established WB6 cooperation.



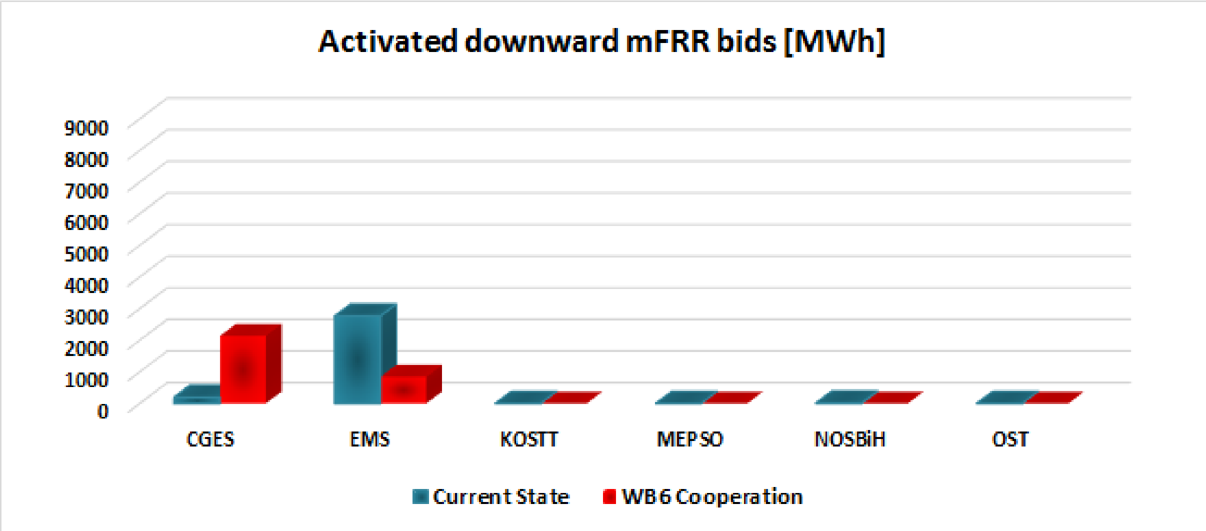


Figure 25: Activated mFRR bids

The results show following share in balancing energy provision with implementation of regional cooperation: EMS (75.2%), CGES (17.5%), OST (6.3%) and MEPSO (1%). The BSP bids in the NOSBIH control area were not activated during the observed week, due to the higher prices compared to the others. In the upward direction, the most competitive bids are the ones from EMS and OST, while for the downward direction the most competitive bids are from the BSPs of CGES and EMS.

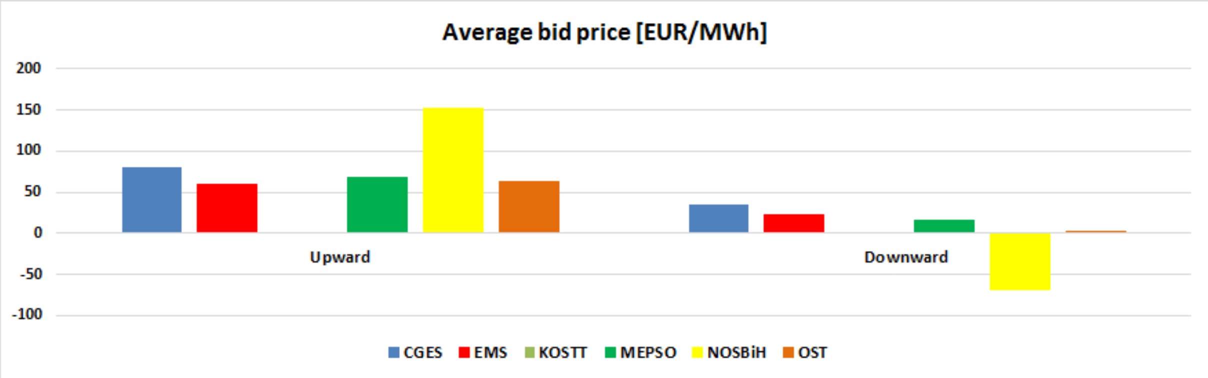


Figure 26: Average bid price per TSO

The Social Economic Welfare is used as an indicator for quantification of economic benefits produced by WB6 balancing cooperation. The Social Economic Welfare is comprised of:

- Producer Surplus (in this case BSPs' surplus)
- Consumer Surplus (in this case TSOs' surplus (implicitly BRPs' surplus))
- Congestion Revenue

The overview of Social Economic Welfare and participating TSOs is presented in the figure below (Figure 27).

Estimated benefits - mFRR & RR cooperation [EUR]							
Horizon	CGES	EMS	KOSTT	MEPSO	NOSBiH	OST	Sum
Dry run week	22,630	11,450	-	26,805	18,892	2,061	81,838
Annual estimation (WB6 region)							4,267,262

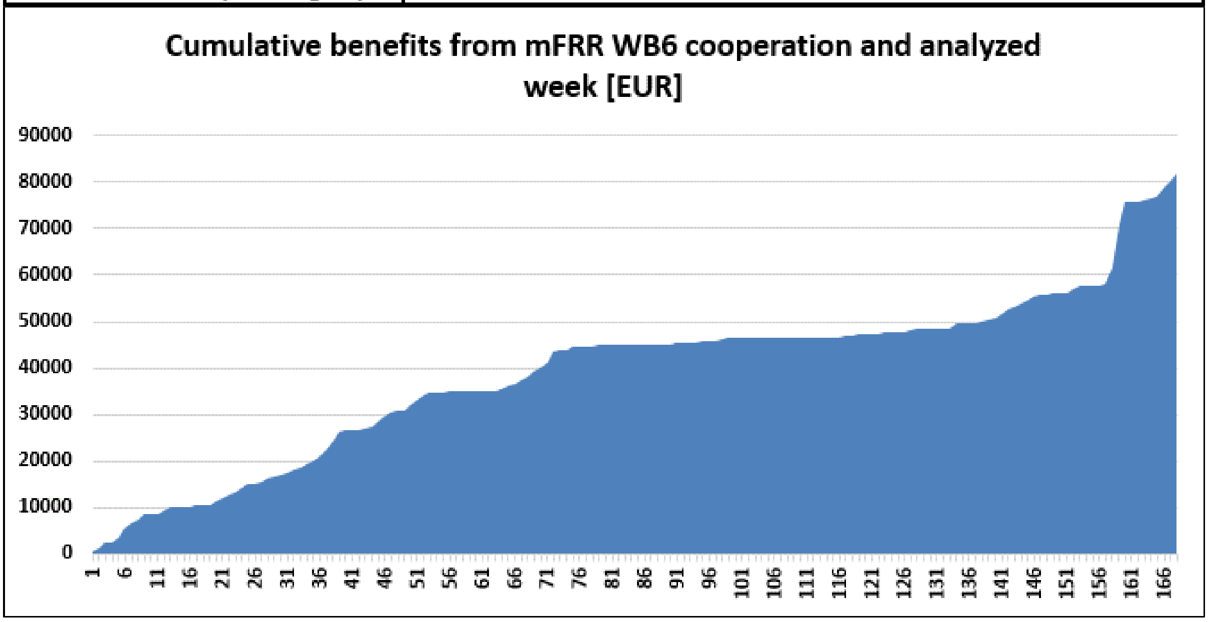


Figure 27: mFRR cooperation benefits

On the basis of the conducted dry runs, tentative estimation of annual benefits from introduction of mFRR & RR cooperation in WB6 region can be estimated at a level of EUR 4.3 million per year. The overall per TSO benefit distribution on annual level is not expected to fully correspond to the "dry runs" benefit breakdown, due to the variable pattern of activation requests. However, performed dry runs provide good insight on expected market dynamics under the regional balancing market cooperation, and obtained estimation based on dry runs (EUR 4.3 million/year), gives the order of magnitude of analysed benefits.

In addition to Social Economic Welfare, the comparison of weighted average price of activated mFRR balancing energy for the current state and the case with the WB6 regional cooperation implemented, is presented in the figure below (Figure 28).

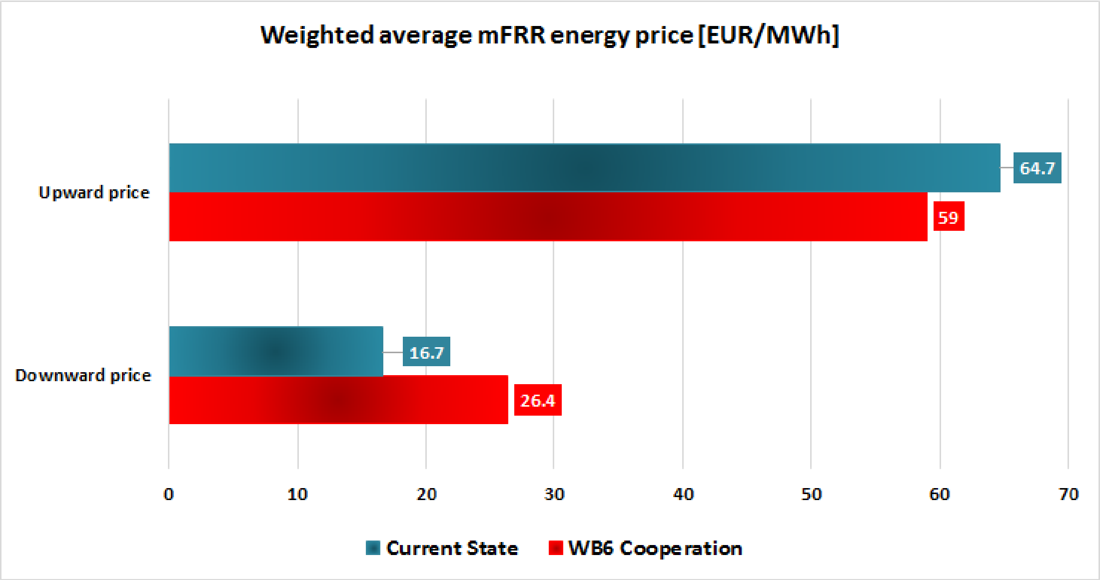


Figure 28: Weighted average mFRR energy price

It can be noted that mFRR balancing energy price decreases for 5.7 EUR/MWh in upward direction, and increases 9.7 EUR/MWh in downward (increase in downward direction reflects BSP->TSO payment, therefore it can be interpreted as positive indicator).

It can be concluded that implementation of regional mFRR & RR balancing energy exchange cooperation based on TSO-TSO model with common merit order list ensures that cheapest balancing energy bids are used first, thus increasing the overall economic efficiency of balancing process in WB6 parties. Beside benefits that can be monetised, it is important to emphasize that introduction of regional balancing market provides decrease in market concentration and increase in competition among balancing services providers, which is especially important in the region in which there is a rather small number of BSPs per control area.

4.2 Pilot tests

In addition to dry runs performed on the historical data, the Regional Balancing Platform (described in the Chapter 3 3) was made available for the TSOs for the purpose of pilot testing in real time "mirror" environment. The tests enabled TSOs to familiarize with the process of balancing energy exchange on the basis of above described cooperation model (Chapter 2). The tests were conducted in a form of simulated training, that incorporated "simulated" mFRR & RR activations that correspond to the real time balancing energy activations performed in the TSOs' dispatching centres. The ECS and NRAs were provided with the observer roles, with possibility to monitor the process.

The overview of pilot tests is presented below:

Pilot Tests – schedule & organization	
Monday 5th of November, 13:00 – 15:00 trial test	EKC&EIMP as tests Administrators
Tuesday 6th of November, 0:00 – 16:00 guided test	EKC&EIMP as tests Administrators
Wednesday 7th of November, 10:00 – 16:00 guided test	EKC&EIMP as tests Administrators
Thursday 8th of November, 10:00 – 16:00 guided test	EKC&EIMP as tests Administrators
Friday 9th of Nov – onwards: 24/7 unguided tests	Platform was made available for the TSOs 24/7 to perform additional pilot tests

Table 9: Pilot tests - overview

During the tests, 40 balancing requests were served, with 3095MW of activated bids.

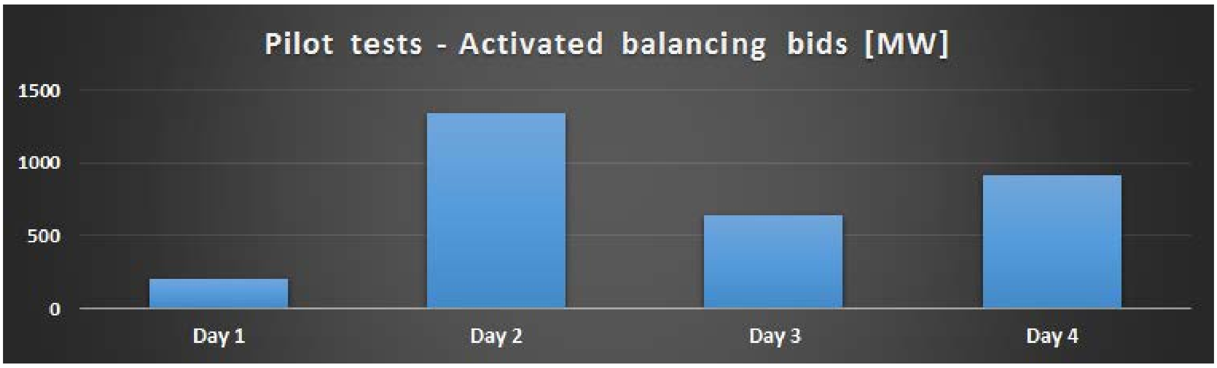


Table 10: Pilot tests – statistical data

Settlement for 2018-11-06, Hour 14				
TSO	Costs of activated requests [€]	Compensation for activated bids [€]	Congestion revenue [€]	Total [€]
EMS	0.00	4,503.99	0.00	4,503.99
CGES	-426.27	3,412.11	0.00	3,838.38
MEPSO	0.00	-426.27	0.00	-426.27
NOSBIH	0.00	0.00	0.00	0.00
KOSTT	9,553.91	0.00	0.00	-9,553.91
OST	0.00	1,637.81	0.00	1,637.81

Table 11: Pilot tests – sample output

5. Conclusions and recommendations

This task provides analysis and definition of suitable models for the processes of exchange of balancing energy from frequency restoration reserves with manual activation (mFRR) and exchange of balancing energy from replacement reserve (RR) in the WB6 region.

On the basis of the current state of balancing markets in the WB6 region, and following the European target projects MARI (mFRR) and TERRE (RR), the selection of applicable cooperation on the level of exchange of balancing energy (mFRR, RR) is given:

- Each WB6 member, when market ready and compliant with the European process, should apply to join the relevant European platform for the balancing energy exchange (aFRR – Picasso, mFRR – MARI, RR – TERRE (optional))
- In a meantime, as intermediate step, implementation of regional cooperation could be beneficial for both technical and economic reasons compared to national balancing market operation only. This would accommodate transformation of current practice with bilateral agreements for "tertiary energy" exchange into multilateral regional balancing cooperation, which would boost the efficiency of balancing energy deployment, as well as overall balancing market welfare. In addition, this interim solution would provide smother transition and harmonization with EB GL.
- Therefore, the design of regional mFRR & RR balancing cooperation described in this (Task 4) report is tailored to address key requirements defined by EBGL and relevant draft Implementation Frameworks (MFRRIF, RRIF), as well as to take into account the specific characteristics of WB6 region.

The detail elaboration of the proposed roadmap is provided within the Task 5 of the Study.

In addition, the conducted dry runs based on the recorded data (activations, bids, prices), provide tentative estimation of annual benefits at a level of EUR 4.3 million per year, from introduction of mFRR & RR cooperation in the WB6 region.

6. REFERENCES

(1) ENTSO-E Operational Handbook, Policy 1, Policy 2

(2) Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a Guideline on Electricity Balancing (EB GL)

(3) Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a Guideline on Electricity Transmission System Operation (SO GL)

(4) mFRRIF: 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, May 2018

(5) 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, May 2018

(6) The proposal of all Transmission System Operators performing the reserve replacement for the implementation framework for the exchange of balancing energy from Replacement Reserves in accordance with Article 19 of Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing, February 2018

(7) ENTSO-E response to the public consultation on "All TSOs' performing the replacement reserve process as defined in the EBGL regulation for the implementation framework for the exchange of balancing energy from Replacement Reserves in accordance with Article 19 of Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing", June 2018

(8) Explanatory Document to all TSOs' proposal for a methodology to determine prices for the balancing energy and cross-zonal capacity used for exchange of balancing energy or for operating the imbalance netting process in accordance with Article 30 of Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing