EXPLORE

Target model for exchange of frequency restoration reserves

21 October 2016

Executive Summary

Introduction

EXPLORE (**E**uropean **X**-border **P**roject for **LO**ng term **R**eal-time balancing **E**lectricity market design) is an initiative of the Transmission System Operators (TSOs) of the four countries Austria, Belgium, Germany and the Netherlands (all self-dispatch systems) that started at the beginning of 2015. At that time a regional linking of balancing markets was being addressed as a "Coordinated Balancing Area" (CoBA) by the draft Network Code on Electricity Balancing, now being called the Electricity Balancing Guidelines or EBGL. The EXPLORE TSOs intended to study the feasibility of developing such a CoBA among the participating LFC blocks also to achieve future compliance with European regulation. In the version of the EBGL submitted to Member States in June 2016, the concept of regional CoBAs is no longer explicitly included but it is more focused on a European target model. Nevertheless, voluntary regional initiatives as a path towards European integration are still a sound way forward – also within the updated framework of the EBGL. Hence, in the report at hand all functional, operational and governance arrangements to facilitate a regional linking of balancing markets are in sum still addressed as "CoBA".

EXPLORE strives for a consistent balancing market design, taking into account the interaction of spot and balancing markets and investigates the interaction of all balancing processes. EXPLORE TSOs build on some important commonalities. They operate the frequency restoration process with predominantly aFRR and supplementary mFRR. In this they act reactively and no economic optimisation is performed between mFRR and aFRR. The participating countries do not operate a reserve replacement process. The length of the imbalance settlement period (ISP) is 15 minutes.

In a previous Belgium-Dutch-German study[1] a central outcome was that there are "low hanging fruits" in potential cross-border balancing cooperation with high benefits and limited effort – imbalance netting and a common Frequency Containment Reserves (FCR) procurement. There is already a large and successful cooperation for these processes, like International Grid Control Cooperation (IGCC) with 8 countries participating and the common FCR procurement of Austrian Power Grid AG (APG), TenneT TSO B. V. (TenneT NL), the German TSOs, Elia System Operator NV (Elia) and Swissgrid – prospectively RTE will join and further parties are interested or already planning to join. And there are also some "high hanging fruits" with lower or unknown benefit but high complexity, especially regarding the exchange of balancing energy. These are the processes the Electricity Balancing Guideline strives for – the common activation of Balancing Energy bids for the Frequency Restoration Process, both automatic Frequency Restoration Reserves (aFRR) and manual Frequency Restoration Reserves (mFRR).

[1] See "Potential cross-border balancing cooperation between the Belgian, Dutch and German electricity Transmission System Operators" at http://www.elia.be/~/media/files/Elia/users-group/141008_Final_report.pdf

The EXPLORE TSOs have investigated in this project how a Frequency Restoration Reserves (FRR) balancing market design could look like while uniquely at the same time also looking at consistency with other balancing processes and with the spot market. This report describes the results. EXPLORE is currently the only project considering the interactions of aFRR and mFRR by looking at the whole frequency restoration process.

The main aspects of the project are settlement – TSO-Balance Responsible Party (BRP), TSO-Balance Service Provider (BSP) and TSO-TSO -, the design of a mFRR product and an aFRR product as well as related exchange concepts.

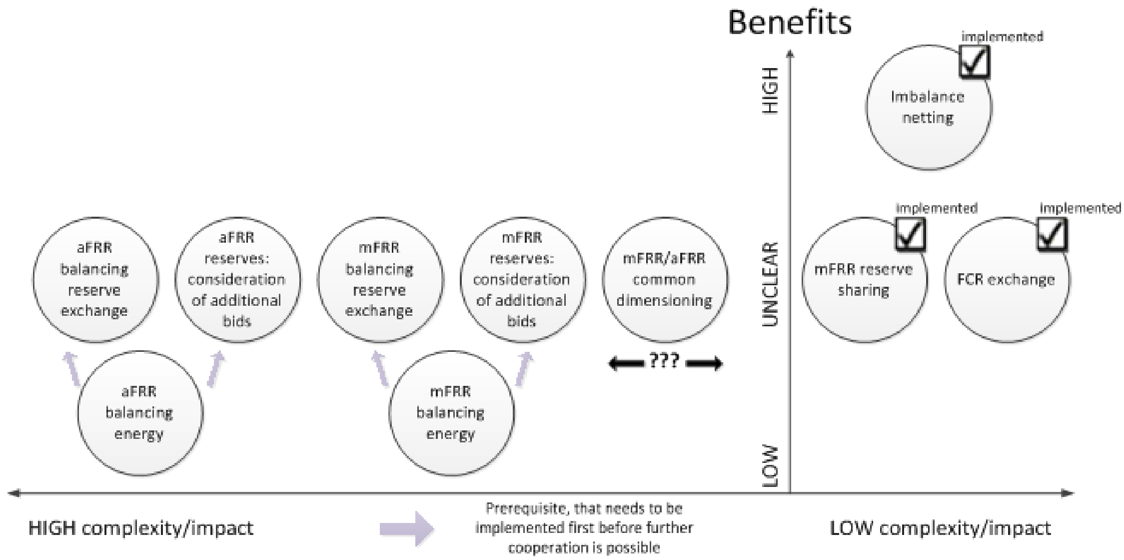

Figure 1: Complexity and impact of balancing cooperation versus expected benefits

Settlement

For **TSO-BRP settlement**, local imbalance pricing is favoured by all involved TSOs. Local means one imbalance settlement price per LFC block, not per bidding zone like imposed by EBGL, shall apply. Even if there is no congestion between two LFC blocks, different imbalance prices shall be possible and allow TSOs (and incentivizes BRPs) to comply with local responsibilities of the TSO (e.g. to regulate the ACE towards zero within the load frequency control (LFC) block) by reflecting the system needs of the particular LFC block. Furthermore, it ensures system security by diminishing the risk that BRPs optimise their dispatch over LFC block borders without capacity allocation. Furthermore, in such a setup small differences between national imbalance settlement schemes can be allowed where required (e.g. due to local regulations, legislation or specific differences in the activation strategy).

For the definition of the local imbalance price all EXPLORE countries will follow the same principles of market based imbalance prices, no possibility for arbitrage with intraday markets and an imbalance price based on local balancing energy demand. Some local differences in the price definition shall remain, such as additional price components or specific links to spot market prices or impact of IGCC imbalance netting. Also the allowance and incentives for BRPs to help the system balance remains a local choice. Finally, all relevant information will be published in time to incentivize and enable correct BRP behaviour.

The choice for local imbalance pricing implies that the effects of the final TSO-BSP and TSO-TSO settlements should be taken into account within the national regulatory framework, specifically in local choices for TSO-BRP settlement.

The EBGL requires marginal pricing by default for TSO-BSP settlement. In auction theory marginal pricing can lead to more efficient auction results, if several preconditions are given as detailed in section 2.3. But there are some doubts and questions with respect to the fulfilment of these preconditions in practice. EXPLORE investigates mainly marginal pricing schemes to respect the EBGL, but keeps pay-as-bid in consideration to give a full and consistent overview of all pricing issues and possibilities and to have a fall-back if marginal pricing is not found superior.

If marginal pricing applies, the main decision is to choose local or cross-border pricing. The cross-border price is the highest activated bid within an uncongested area of the cooperation. In case of congestions, there are marginal prices for each uncongested area where the marginal price is defined by the highest activated bid price per uncongested area. The definition of uncongested area is not obvious in any case, especially in real-time processes like balancing due to changing power flows in real time but settlement only taking place on 15-min energy volumes.

The application of a marginal pricing scheme will influence the balancing energy costs of exporting TSOs. It will then increase the difficulty to give incentives through the imbalance price that allow the TSO to comply with the LFC Block requirements from the System Operations Guideline (SOGL). An imbalance price that incentivises market participants in the desired manner is important for TSOs that activate control power based on observed imbalances (so called reactive balancing). It has therefore been evaluated if a marginal pricing scheme with two different marginal prices within one LFC block (one for local purposes and one for export) can be applied. Because this will influence bidding behaviour and contradict the goal of marginal pricing, this option was discarded. Aside from the pay-as-bid fall-back, an alternative could be to decouple the imbalance price from the activated balancing energy to ensure the desired incentive towards BRPs in all circumstances.

To allow flexibility in the extension of balancing cooperations of different balancing processes, per product pricing rather than cross-product pricing is needed.

The role of the TSO-TSO settlement is to allocate the balancing cost to the TSOs with the activation causing demand. This leads to a distribution of the balancing cost to the LFC blocks that caused the activation and it results in a financial flow between the TSOs. TSOs will not win or lose money from the TSO-TSO-settlement – they act as router for cost-allocation. The TSOs will allocate the cost to BRP or grid user, so financial neutrality is given.

EXPLORE investigated two basically different options, how common activation cost can be allocated: “cost by cause” and “proportional cost sharing”, further explained in section 3.3.

aFRR concept

EXPLORE TSOs predominantly use aFRR within their frequency restoration processes. As the aFRR product is activated continuously and automatically, it is by its nature more deeply integrated within TSO systems, and therefore more technically challenging to implement as a cross-border product than for instance mFRR products.

The technical choices to be made in regard to the aFRR product are not limited to the main issues that are currently discussed within Europe (Full activation time (FAT) and the choice between pro rata and merit order activation). Within EXPLORE other aspects of aFRR have been identified and studied as well, including the signals sent to BSPs, the expectations of BSPs in delivering the requested energy, and the signal to be exchanged between TSOs on the border. Additionally the interaction between the control areas and the AOF (activation optimisation function) was investigated. The technical details and studies performed are explained in more detail in chapter 4.

In the current aFRR processes there are differences between the EXPLORE TSOs (likely between all European TSOs) within their aFRR controllers. These differences can be found both in the signals sent to BSPs as in the controller settings, which are optimised in line with other national arrangements including differing balancing philosophies, LFC block sizes and generation mixes to provide compliancy with ACE quality and dimensioning requirements at LFC block level. Full harmonisation of these settings appears unnecessary and disproportional, however the remaining differences might complicate the final design choices.

The two main aspects of the balancing system affected by choices made in regard to the aFRR product are the liquidity of the aFRR market, both for balancing energy and balancing capacity, and the ACE quality. When considering the EXPLORE design as a possible model for the aFRR market within continental Europe, it should be considered that these choices impact liquidity and frequency quality for this region as a whole.

Currently, many working assumptions for aFRR have been agreed. These concern the allowance of uncontracted bids from a technical perspective, the merit order activation of aFRR and portfolio bidding. In addition, EXPLORE TSOs share the need to harmonize the main prequalification requirements to a proportionate extent, in order to create a level playing field; this is a challenging part on a European level.

Settlement of activated aFRR energy has not yet been extensively studied. It is another important aspect to consider in the market design choices to be made.

To provide for a consistent design that is extendible to other TSOs, with acceptable levels of ACE- and frequency quality and market liquidity, a final choice regarding the aFRR product, its implementation within TSO systems, the interaction between the control areas and AOF, and related aspects will be taken within EXPLORE when further investigations of the impacts on ACE quality and market liquidity have been completed.

mFRR concept

For mFRR there is a common understanding between EXPLORE TSOs in regard to the operational process and product design. EXPLORE TSOs agreed that a 15 minutes FAT could be used if this proves to be fully compliant with the requirement of the TTRF (time to restore frequency; SO GL). If doubts about compliancy remain, a product with a shorter FAT needs to be investigated. Hence, the conclusions given in this report are illustrated for a 15 minutes FAT but are also valid for products with shorter FAT. The product resolution is foreseen to be 15 minutes.

Activation requests are discrete orders rather than continuous ones. Both direct and scheduled activation must be possible from each mFRR bid. Direct activation can take place during a certain time period ahead of the Imbalance Settlement Period (ISP) of the bid while scheduled activation takes place at a fixed point in time ahead of the ISP of the bid. On the combination of direct activation period and point in time of scheduled activation three options were elaborated as can be seen in chapter 5.

Having studied these options, working assumptions were agreed regarding remunerated volumes and imbalance adjustments, valid for all three options. Remunerated volume should be equal to requested power multiplied by the time period between activation and scheduled deactivation and that this is defining the total imbalance adjustment volume, too. This means the settlement includes energy delivered in the ramps. Incentivizing fast reaction and activating close to the ISP of the bid reduces risk for counter-activation, but will also make participation less attractive for BSPs with a slower reaction. Therefore further investigation is needed to conclude on one of the options for a harmonized mFRR product.

For all EXPLORE TSOs that primarily use aFRR for balancing and all deploy a predominantly reactive balancing approach, it is expected that a Common Merit Order List (CMOL) for aFRR balancing energy and imbalance netting will further reduce the need and opportunity for cross-border mFRR balancing energy exchange as long as there is enough aFRR available, and thereby limit the derived economic benefits of this exchange within the Explore TSOs in comparison to the aFRR exchange.

Next steps

The Explore TSOs are willing to discuss the report with interested authorities (NRAs, ACER, EC), in particular the conclusions, and welcome stakeholder feedback. Furthermore, the EXPLORE TSOs aim at discussing the results of EXPLORE with other TSOs, especially those with a different balancing philosophy, to evaluate the extendibility of the conclusions and identify possible ways forward for later implementation project(s).

Table of Contents

1 Introduction

Background

As part of the completion of the Internal Energy Market (IEM), the European Commission and the Agency for the Cooperation for Energy Regulators (ACER) strive for a common market for balancing in Europe. This is challenging due to the close link with system operations and specifically due to the limited cross-zonal capacity available after allocation to market participants in the European electricity spot markets. After years of discussions between the European Network of Transmission System Operators for Electricity (ENTSO-E), ACER and stakeholders the Electricity Balancing Guideline[2] (EBGL) is close to being finalised providing a framework for TSOs under which they can further define the technical concepts and the detailed market design to ensure the development of the common balancing market – something the TSOs have been working on for some time now. The EXPLORE cooperation between the TSOs of Austria, Belgium, Germany and the Netherlands is investigating possibilities to create a consistent common FRR market design, respecting the current draft of the EBGL and limiting the impact on the European wholesale markets.

Up to today the approach for the frequency management of the synchronous system of Central Europe relies on a small margin on the cross-border capacity that is needed for the flows of the FCR. If a big generation outage in one LFC block appears and all FCR within the synchronous area reacts due to the frequency deviation, the flows go into the direction of the outage and do not lead to congestions thanks to this margin. The much larger remainder of the cross-zonal capacity is used for the European Electricity commodity market. It is the task of the TSO to control the overall cross-border exchange of its respective LFC block towards the exchange level scheduled via this electricity commodity market. To achieve this goal, the TSO activates FRR products (upward & downward) to compensate for a lack or surplus of power in its LFC block. The quality of the frequency is the outcome of these balancing processes. The costs are around 1 €/MWh consumption within the EXPLORE LFC blocks – a household with 3,500 kWh electricity demand pays yearly around 3.50 € for this service.

Low hanging fruits

A previous TSO cooperation initiative fitting to the European balancing concept led to the common procurement of FCR in Austria, Belgium, Germany, the Netherlands and Switzerland and will be extended to France in 2017. Further parties have expressed their interest. The prices for FCR for the countries involved converged and stabilised where this market mechanism for FCR procurement was introduced. The implementation effort is limited. For the reallocation of FCR respecting the legal obligations, there is no need of reservation of cross-border capacity and limited impact on TSO processes and system security.

The IGCC (International Grid Control Cooperation), currently between eight countries, uses the remaining cross-zonal capacity after the intraday market to prevent counter activations of FRR.

[2] Any reference or citation from the EBGL refers to the comitology process version submitted to the Member States of 8 June 2016.

If sufficient remaining cross-zonal capacity between LFC blocks is available after intraday trading, negative and positive balancing energy demands are netted and both LFC blocks avoid the activation of balancing resources. This is the lowest hanging fruit of balancing cooperation, as the savings and impacts on operational security (less saturation of reserve activation) are considerable

In a previous study of Belgium, Germany and the Netherlands it was concluded that the balancing processes with the lowest complexity and impact and highest benefits for cooperation are thus already tackled (FCR procurement and imbalance netting) and that the benefits from the balancing processes with the highest complexity and impact for cooperation (FRR exchange) were unclear[3]. These processes are tackled by the EBGL.

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A more challenging step of balancing market integration is the creation of a cross-border balancing market for FRR. The TSOs of Austria, Belgium, Germany and the Netherlands strive to create a consistent cross-border balancing market design for FRR that fits with the envisioned European integrated electricity market, respecting the value of that market particularly regarding the required contribution from liquid markets to the integration of renewable energy sources.

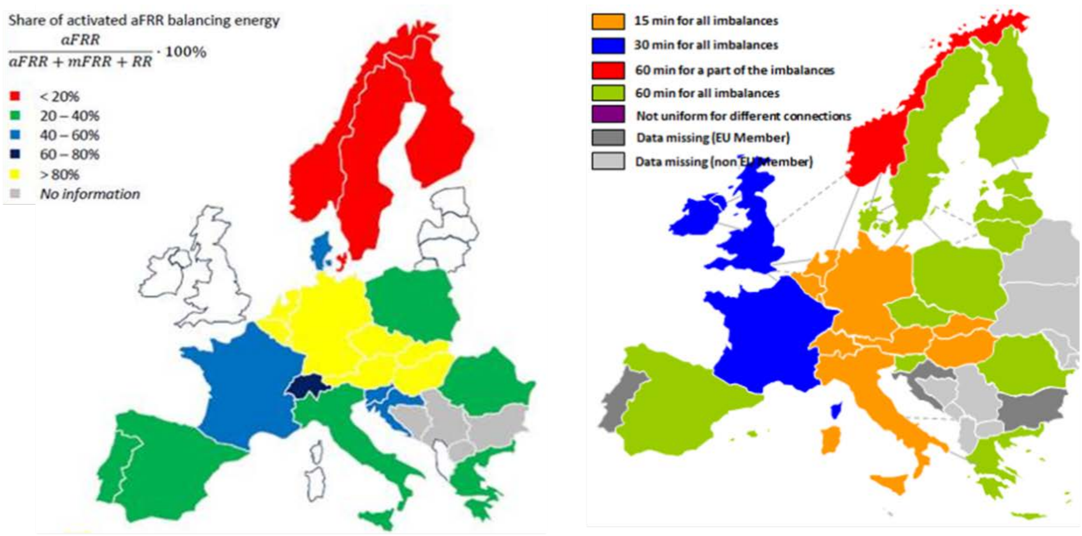


Figure 2: Explore countries are regional partners in balancing (source: ENTSO-E)

With this objective, these TSOs initiated a common study as a first step of a possible further cooperation between the involved TSOs with regard to common balancing market activities

[3] See "Potential cross-border balancing cooperation between the Belgian, Dutch and German electricity Transmission System Operators" at http://www.elia.be/~/media/files/Elia/users-group/141008_Final_report.pdf

under the flag of EXPLORE (European X-border Project for LOng term Real-time balancing Electricity market design). In this report the first results of this study are described in the form of a target model for the exchange of balancing energy for the frequency restoration process.

The countries cooperating in the EXPLORE project are regional partners in balancing since they have common borders and share important main principles of balancing market design. They all have a comparable share of activated aFRR balancing in total balancing energy activation as shown on the left side of Figure 2, they all share the same 15 minute imbalance settlement period (right side of Figure 2) equal to the time to restore frequency (TTRF) and they all support freedom of dispatch. This allows a predominantly reactive balancing strategy and a minimum distortion to market-oriented balancing prices. They also deploy similar activation strategies without economic optimization between FRR products and they all participate in imbalance netting through IGCC. While neighbouring countries differ from the EXPLORE countries in one or more of these key aspects and the EXPLORE target model aims at being extendible, further investigations are required to verify, if these key differences can be bridged.

When EXPLORE started its work at the beginning of 2015 a regional linking of balancing markets was being addressed as a "Coordinated Balancing Area" (CoBA) by the at that time valid draft version of the Network Code on Electricity Balancing, now being called the EBGL. The EXPLORE TSOs intended to study the feasibility of developing such a CoBA among the participating LFC blocks also to achieve future compliance with European regulation. In the version of the EBGL submitted to Member States in June 2016, the concept of regional CoBAs is no longer explicitly included but it is more focused on a European target model. Nevertheless, voluntary regional initiatives as a path towards European integration are still a sound way forward – also within the updated framework of the EBGL. Hence, in the report at hand all functional, operational and governance arrangements to facilitate a regional linking of balancing markets are in sum still addressed as "CoBA".

The target model

As evidenced in this report, EXPLORE is unique in its assessment of the exchange of balancing energy in the wider context of market integration, investigating the consistency of a target model through examining the interactions of the target model design choices with each and the interactions with other markets. In chapter 2 this method of working is further described. This chapter also describes the general market context in a bit more detail, specifically the relationship between balancing markets and intraday markets, and describes some important preconditions for the EXPLORE FRR market: the allowance of voluntary bids, the preference established by the draft EBGL for marginal pricing of balancing energy, and merit order activation of balancing energy bids. Finally, it discussed the gate closure times of balancing energy.

Chapters 3-5 describe the resulting target model. In chapter 3 settlement options are discussed for TSO-BRP settlement, TSO-BSP settlement and finally TSO-TSO settlement. Chapters 4 and 5 discuss the exchange concept and product for respectively aFRR and mFRR.

Finally, in chapter 6, some important conclusions are drawn with relevance to the European debate.

An overview of the working assumptions can be found in the appendix. The appendix also contains a list of abbreviations used within the report.

Next steps

The Explore TSOs are willing to discuss the report with interested authorities (NRAs, ACER, EC), in particular the conclusions, and welcome stakeholder feedback. Furthermore, the EXPLORE TSOs aim at discussing the results of EXPLORE with other TSOs, especially those with a different balancing philosophy, to evaluate the extendibility of the conclusions and identify possible ways forward for later implementation project(s).

2 The EXPLORE FRR target model

2.1 Objective, scope and principles

EXPLORE aims to define a consistent target model for the TSO-TSO exchange of FRR balancing energy. The target model includes a consistent design on settlement covering TSO-BRP, TSO-BSP and TSO-TSO settlement. It also includes a common product design for aFRR and mFRR and other key aspects such as a harmonized gate closure times.

In this stage of the project, implementation issues, exchange of balancing capacity and reservation of cross-zonal capacity for exchange of balancing energy are out of scope. As for cross-zonal capacity, it is assumed that only the capacity remaining after the cross-border intraday gate closure is used.

Throughout the work on EXPLORE, a number of important principles have been guiding. Wholesale markets for electricity are respected and full support of the liquidity of these markets by the EXPLORE model has been strived for. This includes respecting of liquid quarter-hourly (intraday) markets, e.g. for the integration of renewables and a level-playing field for TSOs, BSPs and BRPs to the largest possible extent. All European guidelines are taken into account and where they lead to contradictions, this has been highlighted. Finally, EXPLORE strives for consistent market designs with incentives for desired behaviour.

The EXPLORE members have examined and identified all FRR balancing energy aspects of the target model carefully. An important characteristic that was found in the early stages of investigations was that there are several areas of the target model, for which harmonisation options for each aspect depend on each other. This has led to the identification of several families of interdependent aspects. For these families, consistent and feasible combinations of options on each aspect have been identified and evaluated jointly. One example is the family of pricing and settlement, where interdependencies were identified between TSO-BRP settlement options and TSO-BSP settlement options. There are also interdependencies between the different aspects of product design, and between product design and, for instance, gate closure times. For each family of interdependent aspects, sets of feasible combination of options resulted. Working assumptions are derived for independent aspects.

Working assumptions were concluded on target model aspects, where only one feasible option was identified, one option was perceived as superior to the other identified options at the time or a good compromise could be reached on non-interdependent aspects. Options and working assumptions are elaborated including evaluation considerations and argumentation.

In order to ensure the consistency and feasibility of the final model, working assumptions are not final until the complete target model is defined. An overview of the working assumptions can be found in the annex.

2.2 Energy market interactions

All TSOs of the EXPLORE project emphasize the importance of liquid intraday markets with short gate closure time as an important tool for BRPs to balance their portfolio and react on changing conditions close to real-time (e.g. better forecasts for load or for renewable generation) via the electricity market.

To furthermore allow BRPs to physically react on their own and/or the system balance during real-time, the EXPLORE TSOs (mainly) react on the real-time imbalance. This implies a predominantly reactive balancing approach without extensive use of forecasting. As a consequence, the gate closure time (GCT) for FRR energy bids should be chosen as close to real-time as possible.

BRPs can make commercial transactions in cross-border and local markets (see Figure 3). Net positions of LFC blocks are a result of cross-border transactions and must be scheduled prior to real-time as a necessary input to the TSO control systems for balancing. The administrative alignment of these net positions requires some processing time. For this reason, cross-border gate closure time for ID markets must be ahead of real-time. Transactions within control areas do not change the scheduled control area net positions and can therefore in principle be scheduled up to, or even after real-time. Nevertheless, BRPs must deploy their flexibilities for balancing their portfolio before and during real-time in order to achieve the desired effect on their physical real-time positions and thus the BRP and system imbalance.

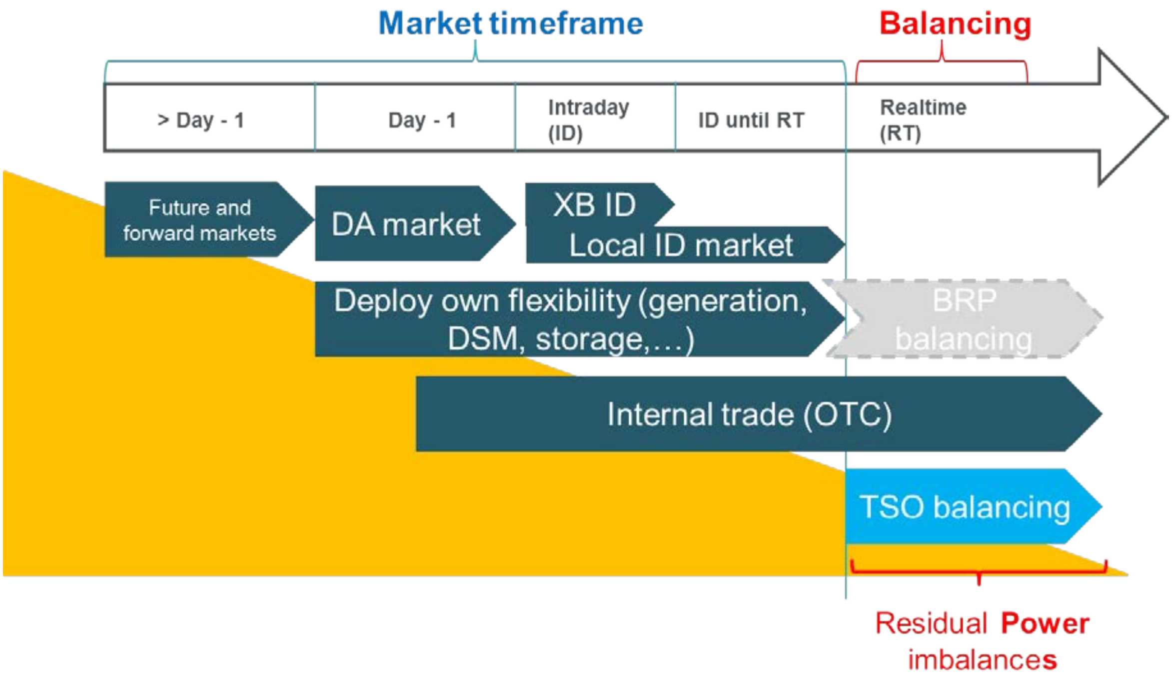


Figure 3: Market time frames and balancing

FRR product design can lead to a distortion of other markets, if product parameters do not consider this, e.g. concerning product duration (validity period), activation period and ramp rate requirements. Market design of the different market segments should channel market liquidity in preferred segments of the market by defining consistent gate closure times and pricing methods. The balancing market should have limited impact on preceding markets (other than providing incentives towards it). A natural boundary for minimizing such impacts is e.g. required time for computing bids ahead of activation. Ambitious gate closure times from preceding markets should not jeopardise system security and should allow sufficient time for well-coordinated balancing processes (e.g. it would be difficult with a local intraday gate closure time of 0 to 15 min before real time to respect this).

In a market design with a high relevance of short term intraday trading (possibly up to real time), e.g. because of a high share of renewables, EXPLORE TSOs found it not feasible to design a balancing market that completely avoids collisions with the intraday market, specifically in regards to gate closure times of the different markets. Balancing energy market gate closure times should be as close to real time as possible.

2.3 Preconditions

Preconditions for the EXPLORE FRR market arise from the Electricity Balancing Guideline and general economic theory. These relate primarily to voluntary bids (allowance for bids without a reserve contract), marginal pricing of balancing energy and energy bid activation order.

Voluntary bids

In accordance with the EBGL any balancing service provider shall have the right to submit to its connecting TSO the balancing energy bids for standard products or specific products or integrated scheduling process bids for which it has passed the prequalification process. In addition, voluntary bids (also known as free bids or non-contracted bids) help prevent unnecessary mark-ups in the balancing energy price. Consequently, voluntary bids should be allowed. Even if voluntary bids may change the merit order in a rather dynamic way, based on analysis so far EXPLORE TSOs have validated that this does not significantly impact the system security before concluding the working assumption that voluntary bids for both aFRR and mFRR are allowed.

BSP energy pricing

EBGL requires marginal pricing per default for balancing energy pricing, but there are some concerns if the expectations will be fulfilled, for instance:

- easy bid setting
  In a "new world" with big portfolios of small units the bidding is not necessarily easier or more difficult with marginal pricing than with pay-as-bid. When placing the bid, the portfolio supplier don't know which unit(s) will deliver the requested balancing energy.
- lower bid prices (marginal cost bidding vs. mark-up of pay-as-bid)
  Mark-ups will be reduced in regard to pay-as-bid, but will not fully disappear. Furthermore, the bidding strategy for balancing energy is more complex than for example for balancing capacity, because the demand is not known beforehand, which also affects the level of mark-ups.

There are several economic preconditions for efficiency of marginal pricing of goods. Some of these were identified and discussed within EXPLORE.

Firstly, the goods shall be homogenous (commodity, balancing energy). Secondly, the supply of goods shall be larger than demand, in other words there must be room for competition. Thirdly, all bid prices are supplied under equal terms and conditions. In regard to the latter there are concerns if the needed level of harmonisation can be reached all over Europe.

The first two preconditions carry additional concerns as detailed below.

Especially for marginal pricing of aFRR some concerns have been raised if precondition 1 applies due to the difference of activation cycle (of few seconds) and the length of the ISP. An activation of few seconds or minutes could be price setting for the whole ISP. The end of the merit order could be high priced because of provider with low capacity, but high energy costs. Depending on the length of the merit order (dimensioning/use of free bids) the activation probability at the end of the merit order influences the bid price calculation (e.g. if fix costs per activation needs to be divided by the expected activation). If such high prices are activated in a pay-as-bid scheme, only for some seconds or minutes, the resulting overall costs are still reasonable. If this price sets the imbalance price for a quarter hour in a marginal pricing scheme, it is questionable if this price reflects the situation of the LFC block well.

The second precondition will partially be fulfilled, if the offered balancing energy is larger than the balancing energy demand either for each individual LFC block or for all LFC blocks in the region as a whole. At regional level, the result is influenced by available cross-zonal capacities that limit either imbalance netting possibilities or the exchange of balancing energy or both. For reaching sufficient supply of balancing energy free bids are needed. But some concerns has been raised if reserving of additional flexibility for the TSO is more beneficial than leaving it for the spot markets.

Before introducing marginal pricing it should be checked if all preconditions are sufficiently fulfilled. Possible negative effects on spot markets should be weighed against positive effects on balancing markets to conclude whether they can be accepted.

Energy bid activation order

For the energy bid activation order, throughout this report a merit order activation is assumed as opposed to pro rata activation. Merit order activation is also prescribed by the EBGL. This leads to the working assumption that energy bids are activated in merit order.

2.4 Gate Closure Time

As a logical consequence of the commonly applied balancing market design principles described in section 2.2, the following GCT principles for EXPLORE are derived.

In order to prevent unnecessary interactions between the liquidity and access to flexibility of intraday and balancing energy markets

- the gate closure time for aFRR and mFRR should be after the cross-border intraday market gate closure time (<60 min),
- the gate closure time for aFRR and mFRR shall respect to the extent possible local intraday markets.

There are no intrinsic reasons why the offered volumes and prices for aFRR and mFRR balancing energy should be established at a different point in time. Therefore, as a working assumption, the gate closure times for aFRR and mFRR shall be the same.

The GCT for balancing energy bids must be before activation, i.e. no later than at the end of the ISP before the ISP where the bid is activated. For mFRR this depends on the exact product definition, although activation will never be further ahead than two ISP before the ISP of the bid. This is further elaborated in section 5.4. Therefore:

- The exact gate closure time for aFRR and mFRR depends on the finalisation of the mFRR product definition.
- There is no need to have a balancing energy GCT further away than two ISPs from real-time.

With this in mind, it is concluded within EXPLORE that the GCT for aFRR and mFRR balancing energy bids should be the same and not prior to thirty minutes before real-time.

3 Pricing and Settlement

This chapter covers all settlement related aspects of activated balancing energy bids in the FRR part of the target model. It relates to the settlement of activated balancing energy between the individual TSOs and their balancing energy service providers (TSO-BSP settlement), between the TSOs for cross-border activated balancing energy (TSO-TSO settlement) and between the individual TSOs and their BRPs for imbalances (TSO-BRP settlement). Throughout this chapter examples are given and elaborated, among others on TSO costs. The term TSO costs is used for simplicity reasons, as eventually any net position of the TSO from TSO-BSP and TSO-TSO settlement is wheeled through the TSO-BRP settlement and/or through the tariffs, depending on the local arrangements, which are out of scope of this analysis. Hence, TSOs are always assumed to be financially neutral. TSO costs are therefore costs to be borne within the respective LFC block.

3.1 TSO-BRP settlement

A common methodology for TSO-BRP settlement with local facets is strived for with the following objectives:

- Give incentives to BRPs to be balanced or support the system balance
- Give (indirect) incentive to BSP to deliver requested balancing energy
- Not make reliance on imbalance energy more attractive than trading in intraday
- Reflect local scarcity (difference between imbalance price and market reference price should increase in the correct direction, dependent on the level and direction of the imbalance of the LFC block, as roughly illustrated by the picture below)

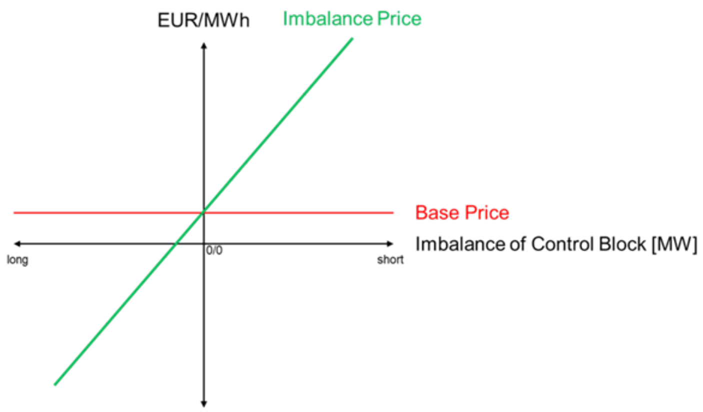


Figure 4: Principle relationship between market reference price (base price) and imbalance price

Options on imbalance pricing

For imbalance pricing, local imbalance pricing and cross-border imbalance pricing have been considered. Both options are in principle compliant with the draft Electricity Balancing Guidelines, although it should be noted that where the acronym XB is used in this the report it refers to “cross-border”, where border relates to a border between LFC blocks as opposed to a border between bidding zones.

In case of local imbalance pricing, the imbalance price is reflecting the imbalance of the local LFC block. In case of cross-border imbalance pricing, the imbalance price is reflecting the imbalance of the cooperation.

The evaluation on these two options is summarized in Table 1.

#	Criterion	Local imbalance pricing	XB imbalance pricing
1	Compliancy with LFC block requirements (SOGL)	YES	NO
2	Responsibility area	LFC BLOCK	CoBA
3	Market participant incentives	LFC BLOCK	CoBA
4	XB capacity use by market parties in balancing timeframe	RESTRICTED	ACTIVELY ALLOWED
5	Harmonisation needs	LOWER	HIGHER
6	Extendibility	EASIER	MORE DIFFICULT

Table 1: Evaluation of imbalance pricing options

The evaluation of the criteria is further explained below.

Criterion 1: Compliancy with System Operations Guideline (SOGL)

The SOGL requires each (TSO of a) LFC block to regulate its ACE towards zero within the TTRF; 15 minutes in continental Europe. This means that regulating the ACE towards zero is a local responsibility of the TSO or TSOs of the LFC block. A local imbalance pricing mechanism allows for local incentives towards BRPs to balance their portfolio (or help the system if allowed by the TSO) within the LFC block and thus to support the TSOs in complying with its responsibilities on LFC block level. Therefore, local imbalance pricing facilitates the role of the TSO(s) to regulate the ACE towards zero within the LFC block.

Criterion 2: Responsibility area

This criterion evaluates the required level of responsibility for determining the imbalance price.

Criterion 3: Market participant incentives

A cross-border imbalance price could under the right circumstances incentivise BRPs to optimise their dispatch over a larger area. Local imbalance prices can help provide the incentives to optimise the dispatch on a geographically contained level (LFC block = imbalance price area)[4].

Criterion 4: XB capacity used by market parties in balancing timeframe & criterion 6: Balancing timeframe XB use of flexibility

In case of a cross-border imbalance price, the BRPs know ex-ante or in real-time that the imbalance price will be equal across multiple LFC blocks (unless there is congestion). Therefore, a market participant that is registered as a BRP in multiple LFC blocks, could optimise the dispatch of its portfolios across LFC blocks without financial risk, thereby using XB capacity without it being allocated or paying for it. In order to achieve consistency with wholesale markets, any cross-zonal capacity used in the balancing timeframe should be allocated, whether it is to activate balancing energy bids or, in the situation of cross-border portfolio optimisation by a market participant, to the given market participant.

As current allocation of capacity is based on administrative rather than physical cross-zonal capacities (remaining capacity after intraday allocation is available for exchange), allocating capacity to market participants who wish to optimise their portfolios cross-border is not possible without first developing a technically complicated solution of recalculating capacity for the balancing timeframe that is closely linked to actually available physical capacity in real-time.

Criterion 5: Harmonisation needs and criterion 6: Extendibility

Local imbalance pricing makes it possible to allow small differences in the imbalance pricing mechanisms between TSOs if required due to local regulations, legislation or specific differences in the activation strategy, while still being sufficiently harmonized to fulfil the requirements of the EBGL. A cross-border pricing mechanism cannot take these specificities into account, which also makes the extendibility to other LFC blocks (with perhaps an even more different activation philosophy) more difficult.

Overall, a local imbalance pricing mechanism allows TSOs (and incentivizes BRPs) to comply with local responsibilities, ensure system security and allow small differences, where required. Going in the direction of XB imbalance pricing questions the responsibility of each TSO as defined in SO GL.

Following the design objectives for TSO-BRP pricing and the above evaluation, the EXPLORE TSOs appreciate commonly local imbalance pricing. For the definition of the local imbalance price, all EXPLORE countries follow the same design principles of market-based imbalance prices, e.g. avoid arbitrage with intraday markets and imbalance prices based on local balancing energy demand. Local differences in the imbalance price definition shall however remain, such as additional price components or specific links to intraday prices. Furthermore, it remains a local choice to allow BRPs to support the system balance or not. In any case, all necessary information according to the local choice will be published timely.

[4] The current draft of the Electricity Balancing Guidelines requires the imbalance price area to be equal to the bidding zone.

3.2 TSO-BSP settlement

Balancing energy pricing deals with the price that BSPs receive for activated balancing energy (TSO-BSP settlement – balancing energy price).

For the balancing energy prices to be applied in TSO-BSP settlement the options shown in Figure 5 were investigated.

Figure 5: TSO-BSP settlement options

Marginal pricing methods are attractive from a market theory point of view, but require specific market conditions as elaborated in section 2.3.

Cross-border marginal pricing poses a challenge with regards to close to real-time calculation (and publication) of imbalance prices from TSO-BSP settlement if no congestions apply. In addition, for uncongested situations balancing energy prices under this option will become equal in all concerned LFC blocks. A solution would need to be found to be able to continue to guarantee a local imbalance price to provide the local means to comply with the LFC block level requirements from the SOGL as described in section 3.1 dealing with TSO-BRP settlement, e.g. a high imbalance price may result whereas the local demand is low and vice versa.

Cross-border and local marginal pricing might impact balancing costs (and hence imbalance costs for BRPs and/or tariffs) of structurally exporting LFC blocks as exported balancing energy increases the local balancing energy price. Initial assessments show that under local marginal pricing this may be rather limited, but the exact scope of this limitation requires further analysis.

In the search for options, one consideration was to differentiate between options that influence the costs for exporting TSOs and those that do not ("exporting bid scheme"). If an LFC block within the cooperation structurally has the lowest balancing energy prices, it will export the most balancing energy. For this reason EXPLORE TSOs have been also looking for settlement schemes where the export of balancing energy does not increase the costs for the exporting LFC block. In case of cross-border marginal pricing all LFC blocks are influenced by every activation per definition. For pay-as-bid pricing it would not be natural that exporting TSOs take parts of the costs of the exported bids – so there is no reason that exports influence the cost of the exporting TSO.

Below the options are described in detail. All figures in this description demonstrate the option for an example of two LFC blocks A and B forming one FRR cooperation. The left side of the figure shows the local Merit Order, the local balancing energy demand (d_A and d_B) and the corresponding marginal price (MP_A and MP_B). The right side shows the situation after integration on the upper right side for the uncongested case and on the lower right side for the congested case.

Cross-border marginal pricing

- All BSPs in a non-congested area[5] receive the same marginal price.
- The marginal price is the price of the most expensive bid activated in the non-congested area.
- With congestions the marginal price is the highest activated bid per uncongested area within the cooperation (at least one LFC block).

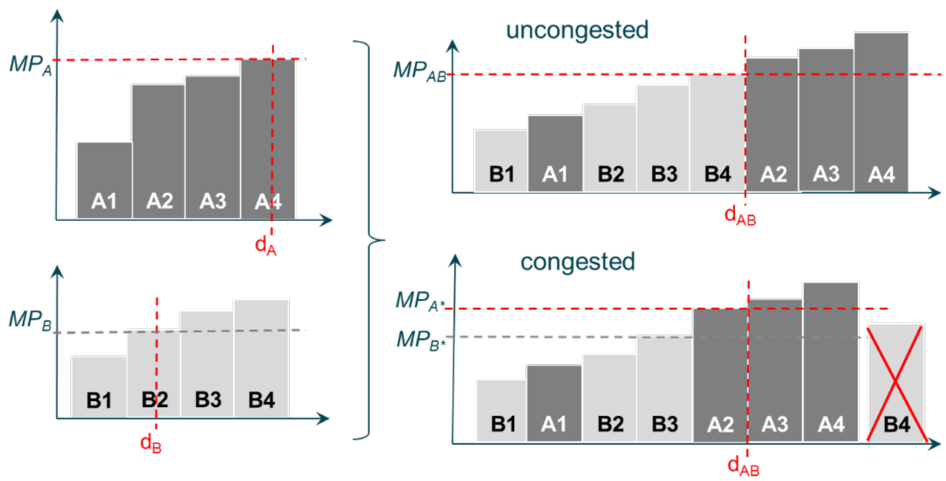


Figure 6: XB marginal pricing

In the uncongested example all bids receive MP_{AB}. In the congested example all bids of A receive MP_{A*} and all bids of B receive MP_{B*}. Bid B4 is unavailable for export because of limited cross-border capacity.

The definition of congested and uncongested areas is high relevant for cross-border marginal pricing schemes. There will hardly be any quarter hour without any congested borders. The way of defining the congested area and their collateral impact on the marginal price will become even more complex when considering that the congestion situation can change within an ISP.

[5] Subset of one or more LFC blocks that have no congestions between them. Can be as small as a single LFC block.

Local marginal pricing, marginal price influenced by exporting bids.

- All BSPs in a LFC block receive the same marginal price.
- The marginal price is the price of the most expensive bid activated in one LFC block (including exporting bids).
- This leads to a different price per LFC block (except by coincidence).

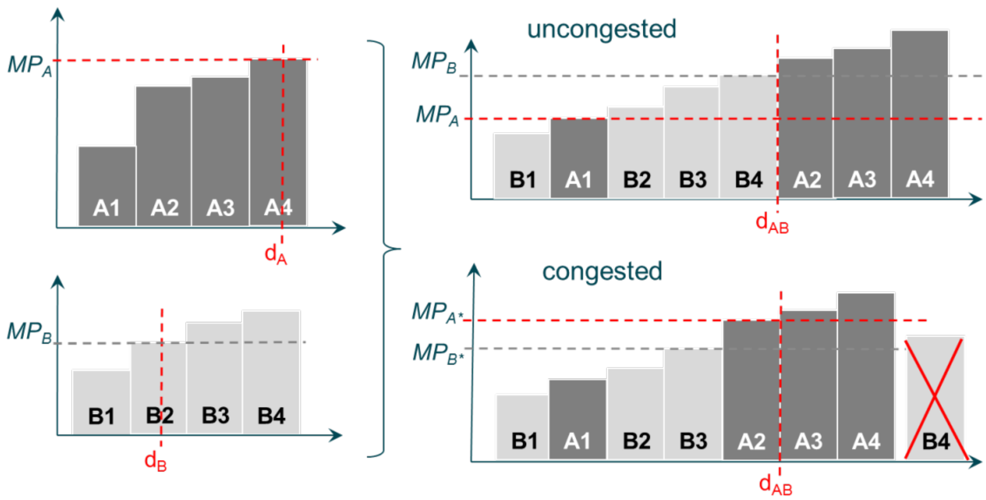


Figure 7: Local marginal pricing, marginal price influenced by exporting bids

In the congested and in the uncongested example all bids receive the local marginal price ($MP_{A(*)}$ and $MP_{B(*)}$).

Local marginal pricing, marginal price not influenced by exporting bids

- All BSPs in one LFC block activated for local demand receive the same (local) marginal price.
- The local marginal price is the price of the most expensive bid activated for local purposes in each LFC block.
- Prices for exporting bids are determined differently with the goal to keep the local balancing cost on local level. There are different options, e.g. exported bids receive marginal price of importing TSO, their bid price, marginal price of all exported bids of the cooperation or the marginal price of exported bids within each LFC block.
- Prices for exporting bids are defined by the marginal price of the LFC block they are exported to. It needs to be identified which LFC block imports which bid. This is challenging if more than two LFC blocks cooperate.
- This leads to two different prices for BSPs in the exporting LFC blocks: one for bids needed for the local demand, one for exporting bids.
- The marginal price of the exporting TSO and therefore the cost need to be covered locally, is not influenced by exporting bids.

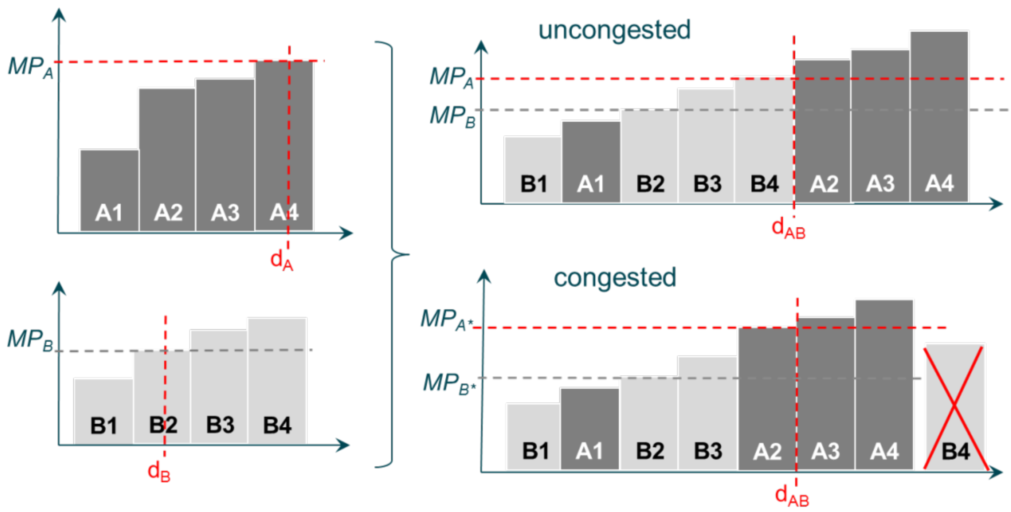


Figure 8: Local marginal pricing, marginal price not influenced by exporting bid, exporting bid receives marginal price from the importing LFC block

In the uncongested example B1 and half of B2 receive MP_B, A1, B3, B4 and the other half of B2 receive MP_A. In the congested example B1 and half of B2 receive MP_B, A1, A2, B3 and the other half of B2 receive MP_A.

All options that lead to different marginal prices within one LFC block (local prices not influenced by exported bids) were discarded by EXPLORE. Different marginal prices might lead to gaming and therefore contradict the idea of marginal pricing – especially easy bid setting at marginal cost. There is an incentive to bid a price level increasing the probability to be exported and receive a higher price. The option where exported bids receive their bid prices is discarded, too. Mixing marginal pricing and pay-as-bid leads to strategic bidding behaviour, because the risk of receiving only the bid price might lead to different bidding behaviour than in pure marginal pricing schemes.

<u>TSO-BSP settlement - per product or cross-product pricing</u>

EXPLORE strives for one single aFRR product and one single mFRR product for balancing energy. This aspect is therefore about whether aFRR and mFRR balancing energy should be priced separately or whether they should be priced jointly. In case of a pay-as-bid settlement, the products are priced separately and there is no choice. Therefore, this question is only relevant in case of a marginal pricing scheme.

For a marginal pricing scheme for TSO-BSP settlement the following options have been considered:

- TSO-BSP settlement price that is the same for aFRR and mFRR,
- TSO-BSP settlement price that is different for aFRR and mFRR and
- a local choice in whether the prices for aFRR and mFRR should be the same.

An argument in favour of per-product pricing is that aFRR and mFRR balancing energy products are not comparable enough to warrant the same value, which raises a concern of overpaying mFRR providers. Furthermore, there will be no possibility to have the same price for aFRR and mFRR in case the geographical scope of the mFRR cooperation is different from the aFRR cooperation unless an exchange of mFRR across several regions that are in sum consistent with the aFRR region, can be implemented.

Cross-product pricing has the advantage of consistency of pricing between the different means by which energy is injected and withdrawn from the system in the balancing timeframe, which helps to prevent gaming and provides helpful incentives, specifically in systems that allow BRPs to support the system balance in real time.

Making cross-product pricing a local choice is not considered to be an option, as it could lead to a different bidding behaviour in each LFC block and it could lead to an exchange of identical products with incomparable competition on pricing (e.g. mFRR exchange with the clearing price set by aFRR on one side and set by mFRR on the other side).

Pay-as-bid

In this case each activated bid receives its bid price for the activated volume of the bid. With pay-as-bid there is no influence of exporting bids on the local balancing prices, so LFC blocks with structural low bid prices (due to generation mix) and low demand will keep the cost low even a lot of balancing energy is going to be exported. Pay-as-bid is well known and used by most of the European TSOs but not favoured by EBGL.

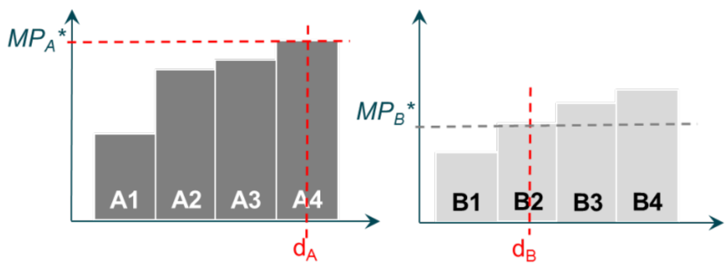
3.3 TSO-TSO settlement

The role of the TSO-TSO settlement is to allocate the balancing cost to the TSOs with the activation causing demand. The TSOs will allocate the cost to BRP or grid user, so financial neutrality is given. This leads to a distribution of the balancing cost to the load frequency control (LFC) blocks that caused the activation and it results in a financial flow between the TSOs. TSOs will not win or lose money from the TSO-TSO-settlement – they act as router for cost-allocation.

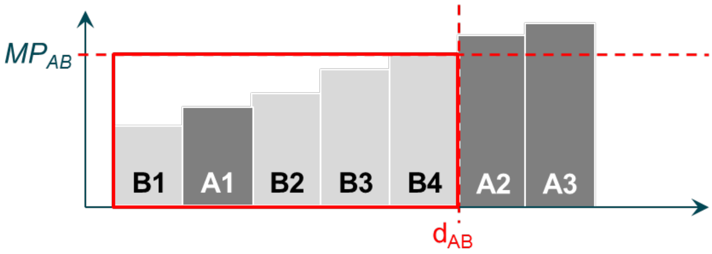
EXPLORE investigated two basically different options, how common activation cost can be allocated: "proportional sharing of costs" and "cost by cause".

proportional sharing of costs

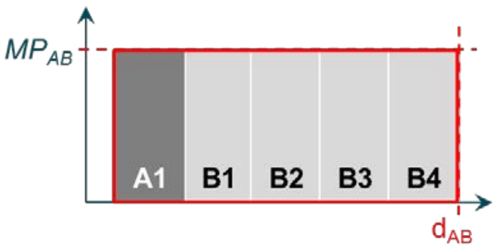
The basic idea is that the costs of the common activation are shared proportional to the individual demand of each LFC block. The following example with **cross-border marginal pricing** BSP settlement **without congestions** demonstrates the way proportional cost sharing works.



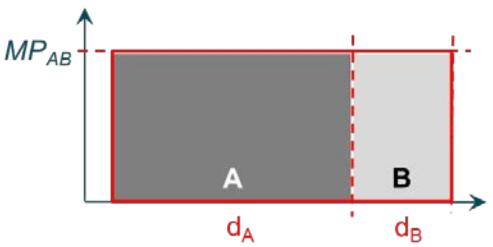
The demand of LFC block A (d_A) is 3,5 and the demand of LFC block B (d_B) is 1,5. The resulting local marginal prices without cooperation would be MP_A* = price of bid A4 and MP_B* = price of bid B2.



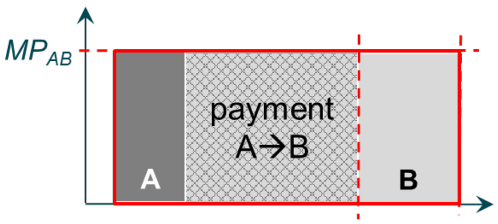
The activation of the common demand (d_{AB}) from the common Merit Order list leads to a different dispatch and a TSO-BSP price (MP_{AB}) of B4. The total activation costs are highlighted with the red rectangle.



Every BSP receives the marginal price of the cooperation (B4). Every TSO pays the local activated bids with the settlement price (MP_{AB}).

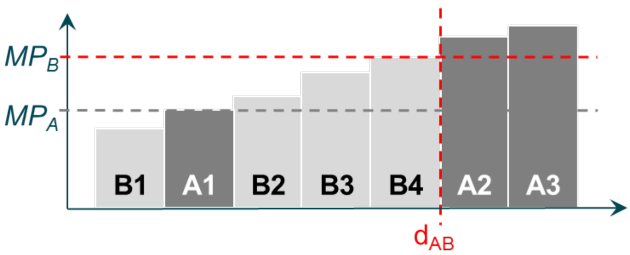


The target cost of each LFC block are the product of local demand (d_A and d_B) and the TSO-BSP-price (MP_{AB}).

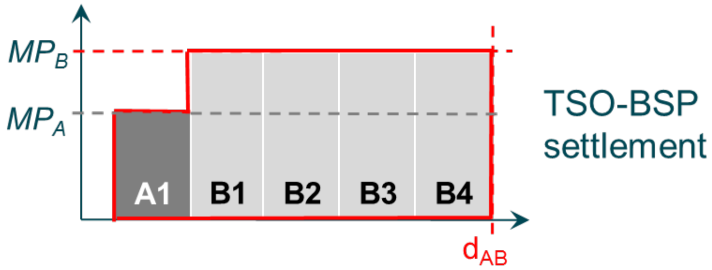


The difference between the costs the TSO pays to the local BSP and the target cost needs to be shared by TSO-TSO settlement.

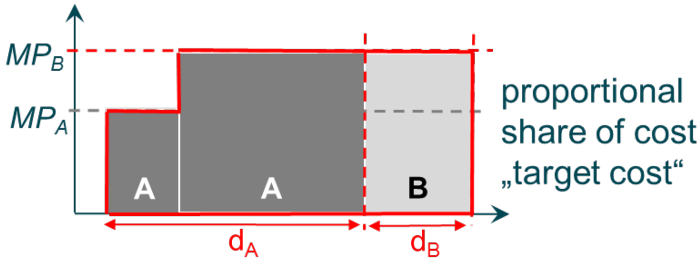
This way of TSO-TSO settlement works for local marginal pricing without congestion, too. In the following example the local demand and MOLs are the same as in the previous example, but local marginal pricing occurs.



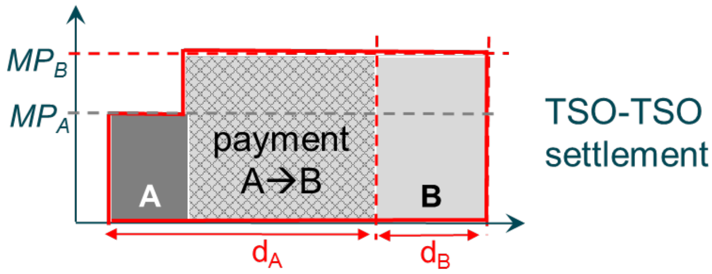
The activation of the common demand (d_{AB}) and the local marginal pricing leads to the different local marginal prices (MP_A and MP_B).



Every BSP of LFC block A receives the marginal price of A (MP_A) and every BSP of LFC block B the marginal price of B (MP_B). The total activation costs are highlighted with the red rectangle.

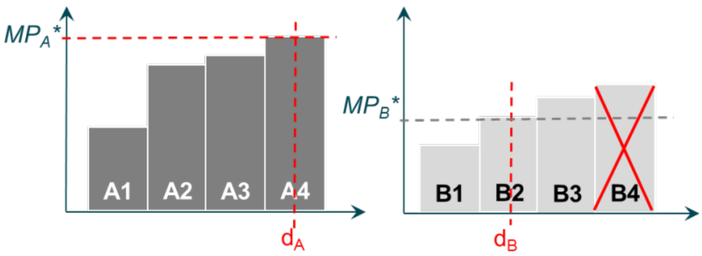


The target cost of each LFC block are the product of local demand (d_A and d_B) and the respective TSO-BSP-price (MP_A and MP_B).

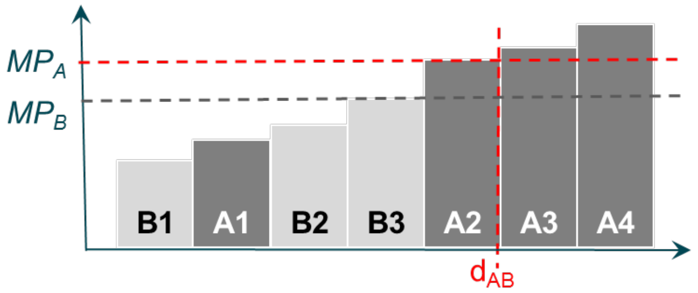


The difference between the costs the TSO pays to the local BSP and the target costs needs to be shared by TSO-TSO settlement.

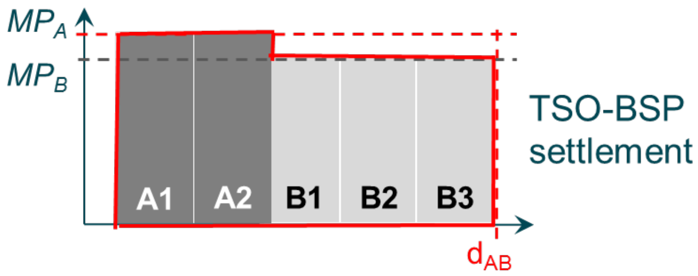
In case of congestions different marginal prices occur even in cross-border marginal pricing (for local marginal pricing anyway). In case of two cooperating TSOs, the options (cross-border and local) do not differ anymore if congestions apply and therefore one common example is given below. The local demand and MOLs are the same like in the previous example. Bid B4 is not available because of a congestion.



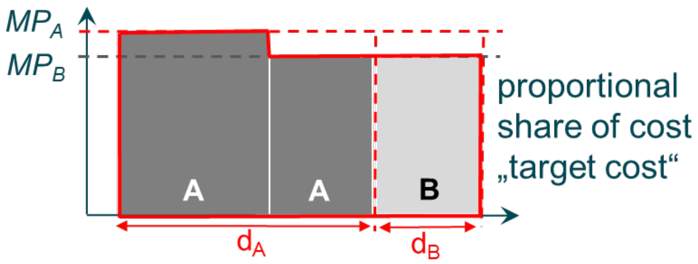
The demand of LFC block A (d_A) is 3,5 and the demand of LFC block B (d_B) is 1,5. The resulting local marginal prices without cooperation would be MP_A* = price of bid A4 and MP_B* = price of bid B2.



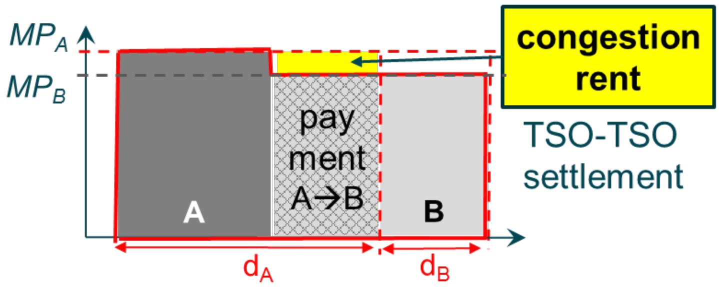
The activation of the common demand (d_{AB}) and the congestion leads to the different prices (MP_A and MP_B).



Every BSP of LFC block A receives the marginal price of A (MP_A) and every BSP of LFC block B the marginal price of B (MP_B). The total activation cost are highlighted with the red rectangle



The target cost of each LFC block are the product of local demand (d_A and d_B) and the respective TSO-BSP-price (MP_A and MP_B).



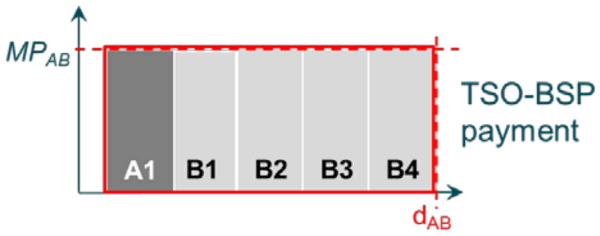
The difference between the costs the TSO pays to the local BSP and the target costs needs to be balanced by TSO-TSO settlement.

Due to the congestion, congestion rent can be calculated and shared additionally. This is not part of the described TSO-TSO settlement schemes.

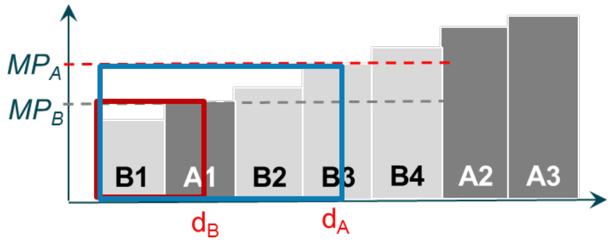
<u>cost by cause</u>

The basic idea of cost by cause is, that every TSO should first take the costs that would occur if only one TSO have activated balancing energy from the common Merit Order List. So every TSO receives the cheapest bids in a first step. Of course real activation costs will be higher if more than one TSO activates balancing energy. The additional costs need to be shared in a second settlement step.

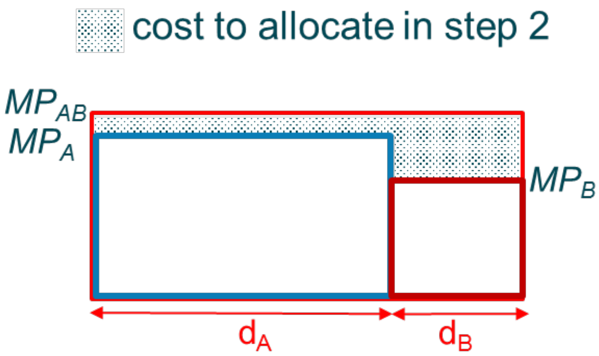
The following example demonstrates the cost by cause settlement with **cross-border marginal pricing without congestions**.



The activation of the common demand (d_{AB}) from the common Merit Order list leads this dispatch and a TSO-BSP price (MP_{AB}) of B4. The total activation cost are highlighted with the red rectangle. Every BSP is remunerated with MP_{AB}.

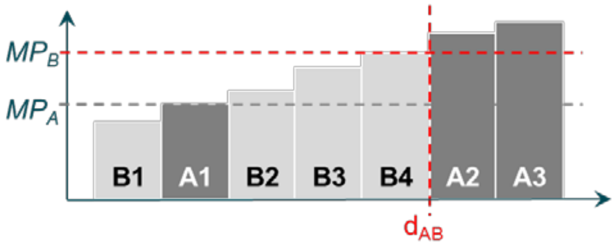


In step 1 TSO A and B take the local activation costs from the common Merit Order without regarding the activation of the other TSO. The dark red rectangle show the step1-costs of TSO B and the blue rectangle show the step1-costs of TSO A.

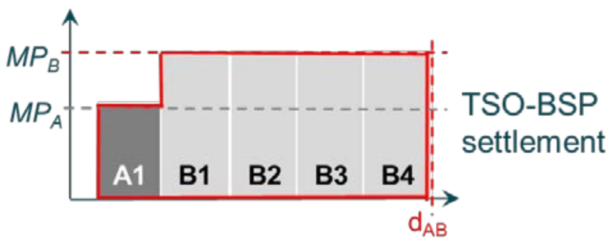


In step 2 the residual cost need to be shared by TSOs. This can be done differently, e.g. proportional to the respective demand. The sum of step1 cost and step2 cost are the respective target costs of each TSO. The difference between the local costs from BSP payment and target costs need to be settled by TSO-TSO settlement.

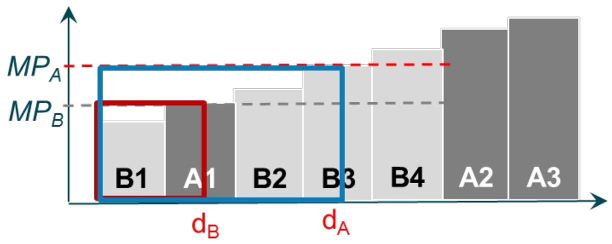
For the choice of local marginal pricing without congestions for TSO-BSP settlement this TSO-TSO settlement option works similar.



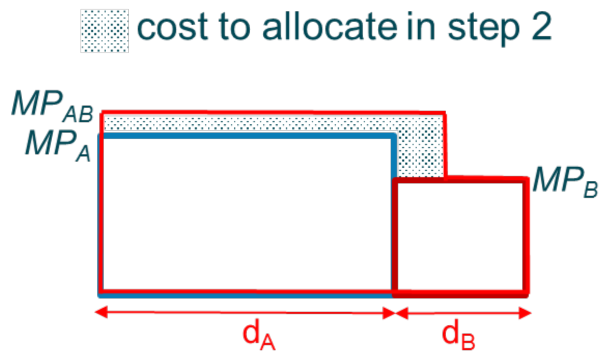
The activation of the common demand (d_{AB}) leads to the local marginal prices MP_A and MP_B.



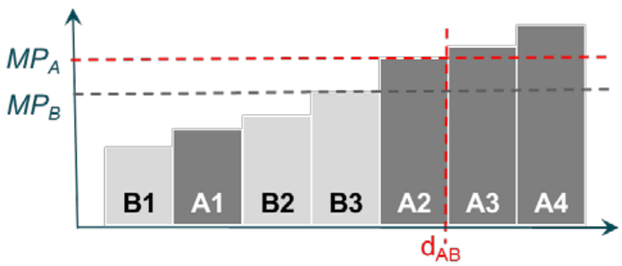
Every BSP of LFC block A receives the marginal price of A (MP_A) and every BSP of LFC block B the marginal price of B (MP_B). The total activation cost are highlighted with the red rectangle.



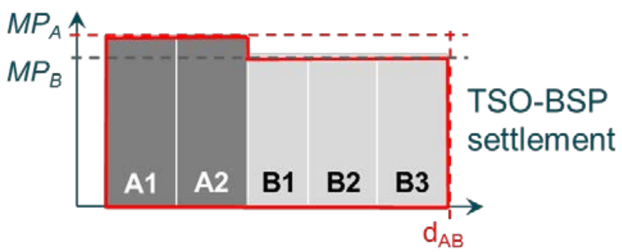
Step 1 and step 2 are identical for local and cross-border marginal pricing.



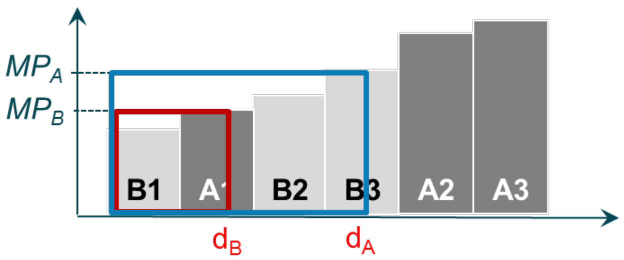
In case of **congestions** different marginal prices occur even in cross-border marginal pricing (for local marginal pricing anyway). In case of two cooperating TSOs, the **options (cross-border and local) do not differ anymore if congestions apply** and therefore one common example is given below. The local demand and MOLs are the same like in the previous example. Bid B4 is not available because of congestion.



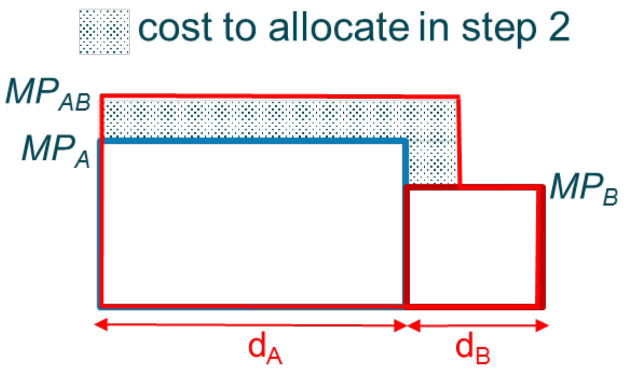
The activation of the common demand (d_{AB}) leads to the local marginal prices MP_A and MP_B. B4 is not available due to congestions and therefore A2 is activated in replacement.



Every BSP of LFC block A receives the marginal price of A (MP_A) and every BSP of LFC block B the marginal price of B (MP_B). The total activation cost are highlighted with the red rectangle.



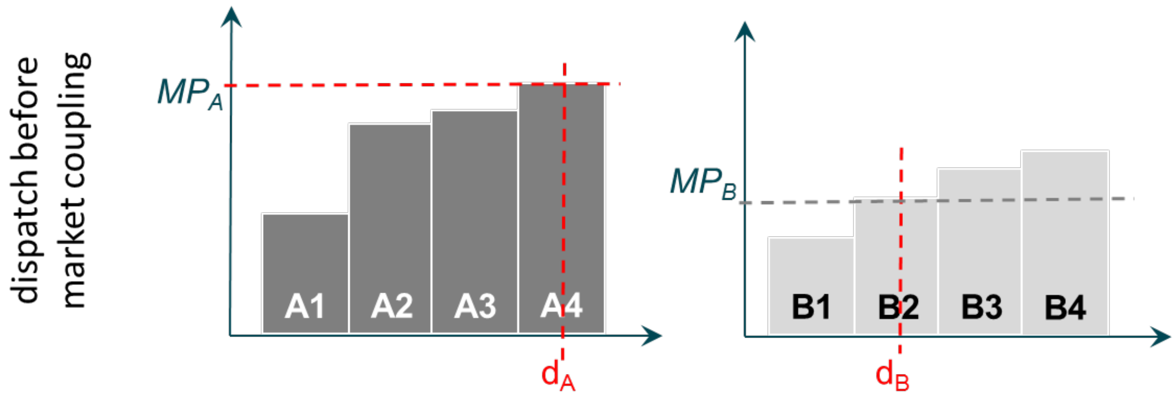
Step 1 and step 2 are identical for local and cross-border marginal pricing.



Due to the congestion, congestion rent can be calculated and shared additionally. This is not part of the described TSO-TSO settlement schemes.

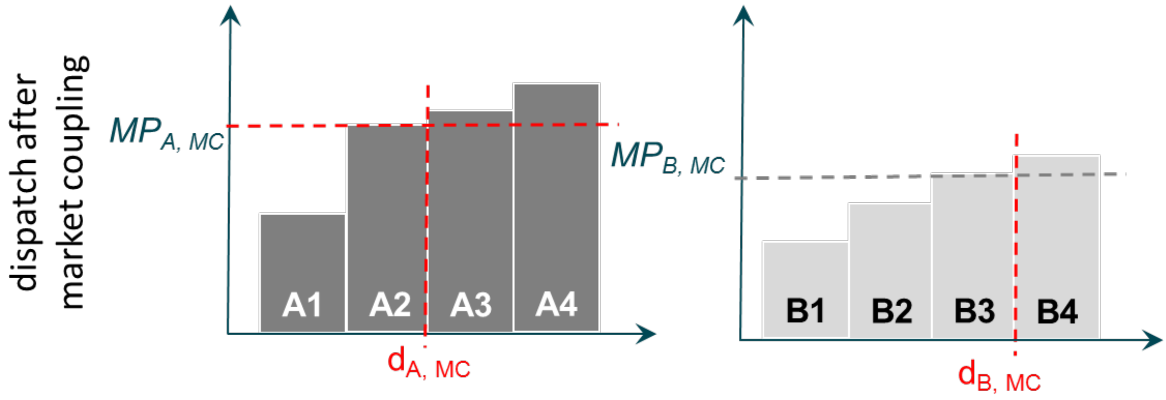
3.4 Financial neutrality

No TSO should have financial interest at the balancing process. But keeping local incentives at the balancing energy price by having coupled markets for balancing energy is hard to achieve. The following simple example presents one possibility:



TSO A and B have the demand d_A and d_B and each 4 bids at the local Merit Order. The TSO-BSP marginal prices are the correct incentivising imbalance prices (MP_A and MP_B).

Now both are activating from a common Merit Order. A new dispatch applies with different TSO-BSP prices.



The new TSO-BSP prices are not reflecting the local situation anymore.

If the imbalance prices are defined without regarding the integration costs and income do not match for this quarter hour.

However, it is not necessary for costs and income for the TSO to be exactly equal in each quarter hour to achieve financial neutrality. Basically there will be losing and winning quarter hours for each TSO. If this is balanced on a weekly, monthly or yearly basis, financial neutrality can still be achieved by using an incentivising imbalance price based on local demand and local bid prices. If the balance cannot be achieved within the respective timeline, other regulatory arrangements such as additional components on the imbalance price are able to provide the financial neutrality to the TSO.

3.5 Summary

Local imbalance pricing is favoured by EXPLORE in order to provide TSOs the means of performing incentive-based balancing at LFC block level through the imbalance price (not applied by all EXPLORE-TSOs).

EXPLORE investigated possibilities to take the risk from structural exporting LFC blocks by implementing exporting bid schemes (exports do not increase local costs). With marginal pricing such a scheme cannot be implemented without contradicting the principles of marginal pricing. With pay-as-bid implementing exporting bids is natural. However, pay-as-bid has its own drawbacks, and is not favoured by EBGL. For cross-border marginal pricing the definition of congested and uncongested areas is necessary, but not obviously in bigger geographical scopes. The congestion situation can change within an ISP or the direction of the balancing demand might change within an ISP. In both cases it is unclear which BSP receive the (cross-border) marginal price and which BSP receive the local marginal price. Further a local marginal price is more reflective of the local imbalance, which can help to fulfil the local TSO requirements stemming from SOGL.

Two basically different TSO-TSO settlement schemes have been described. Proportional cost sharing is easier to calculate and makes the congestion rent transparent. Cost-by-cause might be better reflecting the local situation, but might be hard to calculate in real-time.

It is hard to keep an imbalance price with correct local incentives by integrating balancing energy markets. One possibility has been shown where financial neutrality can be kept in a longer time scale.

There might be not the perfect combination of options for every LFC block in Europe. That is why at least the imbalance pricing needs to be up to each TSO and the respective regulatory authority ensuring correct local incentives and financial neutrality.

4 aFRR design

Integration of aFRR balancing energy markets is highly complex and has significant impact on operational processes[6]. There are good underlying technical and economic reasons (e.g. size of LFC block, generation structure, load behaviour, market liquidity) for the many local differences in aFRR control concepts, differences which need to be levelled out to a large extent for an integrated aFRR balancing energy market. There were limited requirements for technical harmonisation and no requirements for market harmonisation so far, contributing to these local differences. This does not only concern the aFRR product design, but also the aFRR control concept. This chapter describes the status quo followed by an exploration of combination of options for aFRR prequalification requirements (including FAT) and the aFRR CoBA control concept. Next, aFRR product design aspects that do not impact ACE quality are covered, followed by a summary on aFRR CoBA design. The main criteria used to evaluate the options are market liquidity and ACE or frequency quality.

4.1 Status quo in aFRR product design and control concept

Designing an aFRR CoBA product and a CoBA control concept requires understanding of the differences in product design and control concept and how they work together between the countries involved and how they work out under different choices for an aFRR CoBA concept and FAT.

In the following section, options on aFRR CoBA control concept and aFRR FAT will be investigated as well as the impact on ACE quality and potential aFRR market liquidity. Besides on FAT and control concept, this section elaborates other important differences between the EXPLORE countries in this respect.

Figure 9 shows the high level functional architecture of the control concept that applies. Each control cycle, the TSO control system observes the Area Control Error which represents the TSO system imbalance, calculates the required contribution from each BSP and sends that as a control request to the BSP. The subsequent reaction of the BSPs influences the observed ACE for the next control cycles, where there can be a delay in reaction caused by ramping limitations in the generator(s) underlying the activated BSP aFRR bids.

[6] See "Potential cross-border balancing cooperation between the Belgian, Dutch and German electricity Transmission System Operators" at http://www.elia.be/~/media/files/Elia/users-group/141008_Final_report.pdf

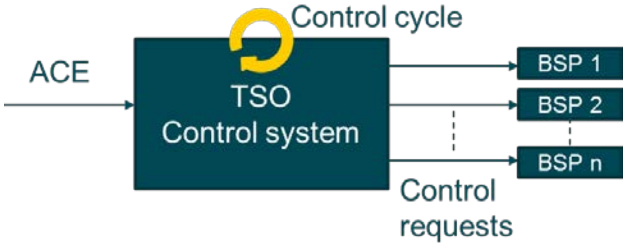


Figure 9: High level functional diagram of TSO control system

Differences between EXPLORE TSOs exist on the following aFRR aspects:

- BSP ramping limitations can be taken into account when calculating the control request or not. If they are not, the delta in control request between subsequent control cycles can be higher than the ramp requirement for the BSP.
- Bids that are actively controlled (selected to participate in the control) can be activated pro-rata (all aFRR bids receive a delta control request but the delta of each bid is relative to the bid size) or in merit order (only the cheapest bids receive a delta control request).
- Control cycle. This is the time difference between each calculation and submission of control requests.
- Generator scope of bid, where bids can be per generating unit or per portfolio of generating units
- The FAT

Table 2 shows the differences.

TSO	Consideration of ramping rate in control request calculation	Way of activation	Cycle control signal	FAT
APG	no ramping rate	Merit-order	2 s	5 min
ELIA	ramping rate defined on FAT and bid size	Pro-rata	8 s	7.5 min
TTG	Depending on BSP	Merit-order	4 s	5 min
TTN	Depending on ramp rate defined by BSP	Merit-order	4 s	15 min
AMP	Depending on BSP	Merit-order	3 s	5 min
TNG	Depending on BSP	Merit-order	4 s	5 min
50Hz	Depending on BSP	Merit-order	2 s	5 min

Table 2: Differences in aFRR design between EXPLORE TSOs

Section 4.3 will deal with working assumptions on order of activation, portfolio or unit based bidding and allowance of voluntary bids.

Another important difference is about requirements to follow the control request (=setpoint), where there are two families of variants. To understand the figures demonstrating the differences, Figure 10 shows the control demand, control target and control request signals in the local control concept. The control target signal is the direct output of the secondary controller before filtering it to the control requests for the BSPs. The control demand signal is the sum of the ACE that goes into the secondary controller and the actual BSP responses. The control demand signal represents the disturbance in the system after mFRR activation and is also called the open loop ACE. The box right to the secondary controller shows the filtering of the control target to the BSP control requests. This filtering involves the distribution of the control target over all participating BSPs and may include a ramp rate limiter (per BSP or over all BSPs) or not. Next right to the control target filter is the box representing the secondary control power activation resulting from the control request to the BSP.

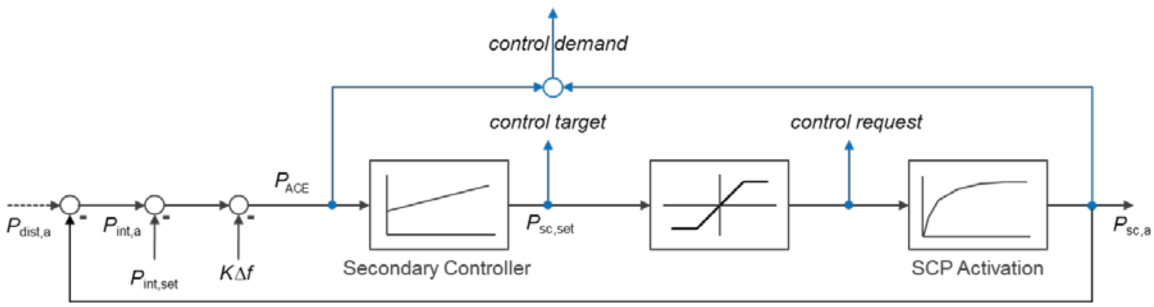


Figure 10: Control demand and control target signals from the local controller

The two families of variants on requirements to follow the control request are:

A. <u>FAT product, i.e. in setpoint following, BSPs must respect the FAT (see Figure 11):</u>

- BSPs must deliver the power requested at the latest after a delay equal to the FAT.
- The change in control request from one control cycle to the next are in general not limited and the evolution of control requests can in certain circumstances be a large step change (Figure 11 shows an example where the change in control request is not limited and Figure 12 shows an example where the change in control request is limited by a ramp rate).
- With this product, BSPs can react faster than the minimum requirements. BSPs have a large compliancy area which translates in an uncertainty area for the TSO.

B. <u>setpoint product, i.e. aFRR must follow the control request:</u>

- BSPs must closely follow the signal sent by the TSO (control requests are limited by the BSP ramp rate), within a given small power margin (see Figure 13).

- FAT is used to derive a fixed ramp rate by linear interpolation considering no preparation period.
- The evolutions of the signal sent to the BSPs by the TSO (delta of the control request) are limited by this fixed ramp rate. With this product, BSPs cannot react faster than the signal sent and have a smallest compliancy area. The uncertainty for the TSO is reduced.

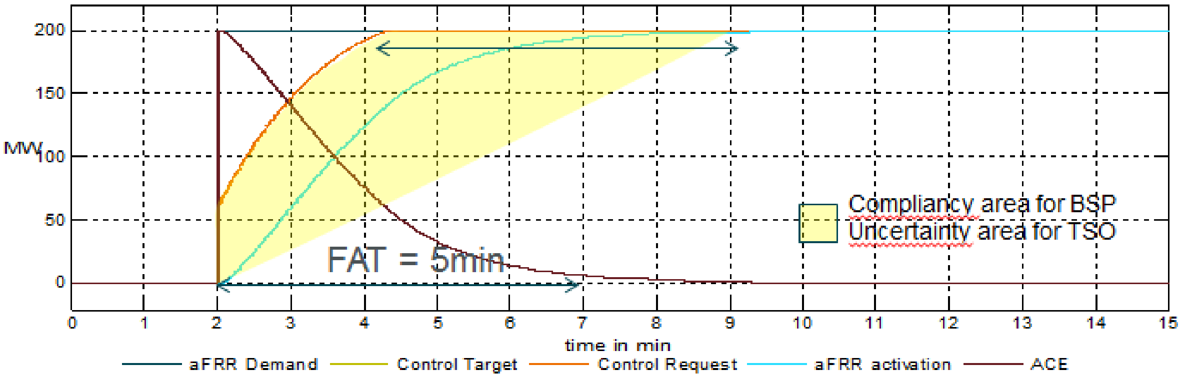


Figure 11: ACE step response when BSP must deliver requested power within FAT without ramp limitation – control target and control request are superimposed. Ramp rate of the output of the controller is not limited. BSP expected to follow signal within FAT and with a minimal reaction based on prequalification (e.g. linear ramping rate).

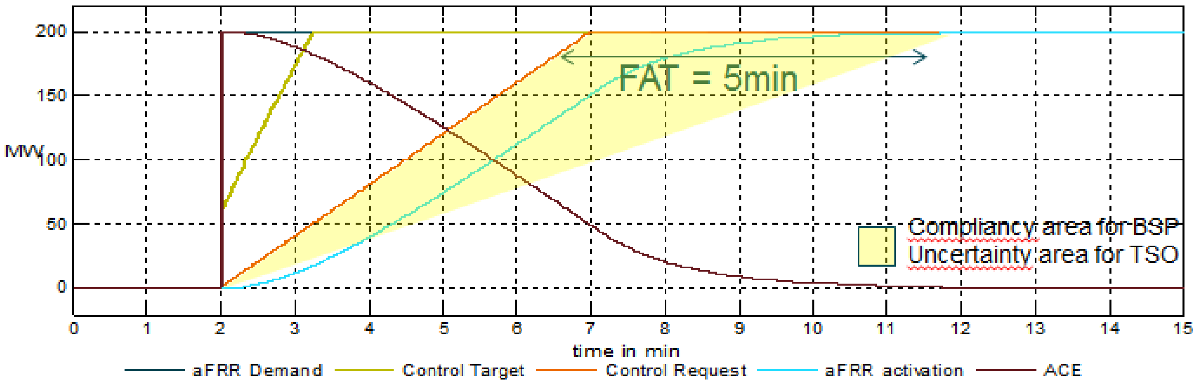


Figure 12: ACE step response when BSP must deliver requested power within FAT and where a ramp limitation is inserted in the controller. The control request is limited. A delay in the reaction of the BSP is not explicitly prohibited but the BSP is incentivized to follow the control request through the imbalance adjustment.

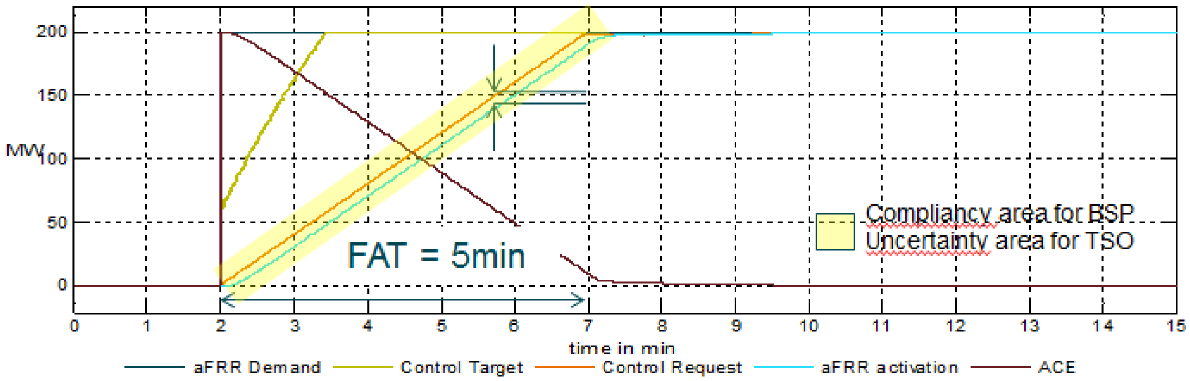


Figure 13: ACE step response when BSP must deliver requested power within a fixed margin. Signal from the controller to BSP is limited based on a linear ramping rate derived from FAT. BSPs are requested to closely follow signal within a limited power and/or time band.

4.2 aFRR CoBA product design and control concept

aFRR product design and the aFRR CoBA control concept together impact aFRR market liquidity and ACE quality. Hence, options on aFRR product design parameters as described in section 4.1 above must be analysed together and in combination with the options on the aFRR CoBA control concept. The analysis of the EXPLORE TSOs has so far studied ACE quality and potential aFRR market liquidity for different options of FAT and aFRR CoBA control concept. This section describes the options and presents the preliminary results.

4.2.1 aFRR CoBA control concept

EXPLORE TSOs considered two different control concepts for the aFRR CoBA. In the first concept the input to the AOF are the control demand signals of the local control areas. The output of the AOF are correction values added to the ACE of the individual TSOs. This concept is called hereinafter control demand concept. In the second concept the input to the AOF are the control target signals of the local controllers. Output of the AOF are correction values added to the ACE of the individual TSOs and the control request signals transferred via the TSOs to the connected BSPs. This concept is called hereinafter control request concept.

<u>Control demand concept for aFRR CoBA AOF</u>

The control demand represents the disturbance within a control area. In a control demand concept for the aFRR CoBA, the AOF receives the local control demands. Based on the common CMOL and available transmission capacities the correction of the local demand is calculated which leads to an optimal distribution of the demand. The correction value is sent back to the local controller and added to the local ACE. This is shown in Figure 14. In this concept, the local controller remains calculating the control requests and the control demand (AOF input) and the correction signal (AOF output) are exchanged. The natural choice for this concept is the FAT product.

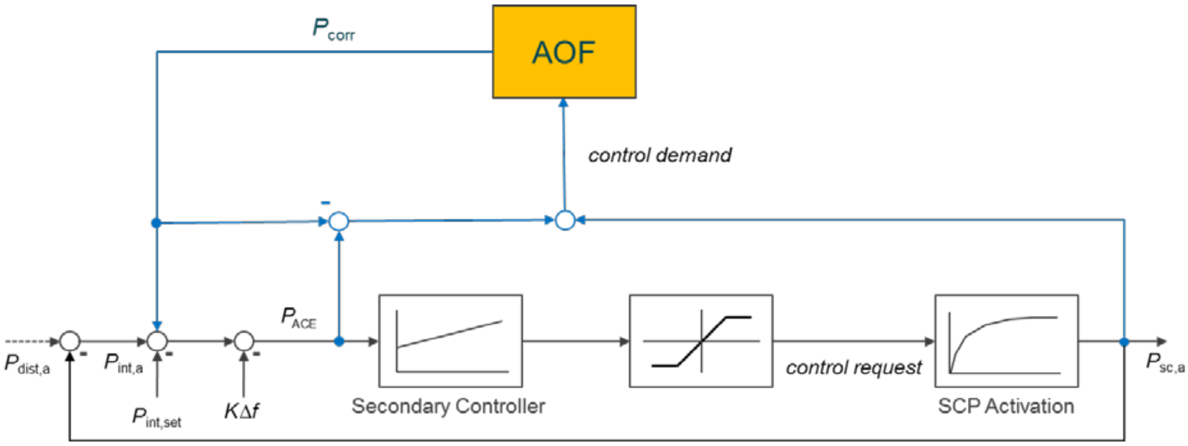


Figure 14: aFRR CoBA AOF based on local control demands

Control request concept for aFRR CoBA AOF

A second aFRR CoBA control concept is building on the control target signals from the local controllers. The basic idea for this concept is that the exchanged aFRR balancing energy equals the sum of what is locally activated aFRR for another TSO. For this concept, an aFRR setpoint product has been assumed as it is a natural choice. In this case the local control targets are netted in the AOF, taking available transmission capacities into account and the AOF uses the CMOL and the information on available transmission capacities to select the bids to be activated. Based on this and the information of BSP ramp limitations, the AOF calculates the control requests for the bids. The control requests are passed on to the BSPs via the TSOs. The filter function of the local controllers is replaced by the filter function in the AOF (which still could be specific depending on the LFC block of the bid including a ramp limiter). The control request concept for the aFRR CoBA AOF is shown in Figure 15. In this concept, the control target (AOF input), the control request and the correction signal (both AOF output) are exchanged.

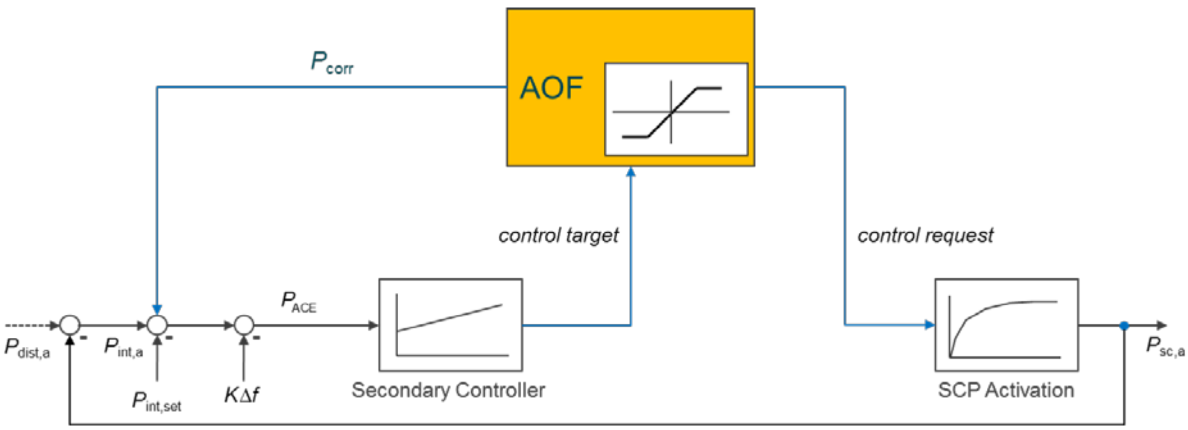


Figure 15: aFRR CoBA AOF based on local control targets

Examples

A simple example demonstrates the difference in functioning of both concepts.

Let us assume two LFC blocks A and B that form the following common merit order:

MOL-Position	A [MW]	B [MW]
1	50	-
2	-	50
3	-	50

Let us further assume a step aFRR demand of 100 MW in LFC block A and aFRR demand of 0 in LFC block B. Bid 1 and bid 2 have to be activated to cover the overall imbalance.

Using the same secondary control configuration in both LFC blocks and for both control concepts and applying the same filtering (local controllers in case of control demand, AOF in case of control target), Figure 16 demonstrates the control signals following from a control demand AOF concept and Figure 17 demonstrates the control signals following from a control request AOF concept.

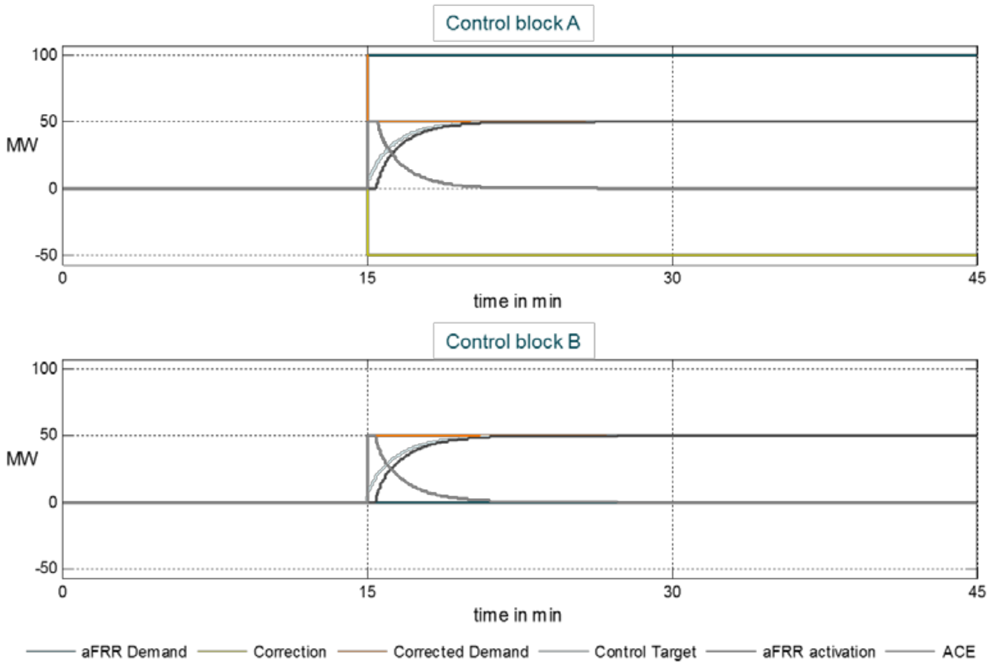


Figure 16: Example of aFRR AOF control demand concept

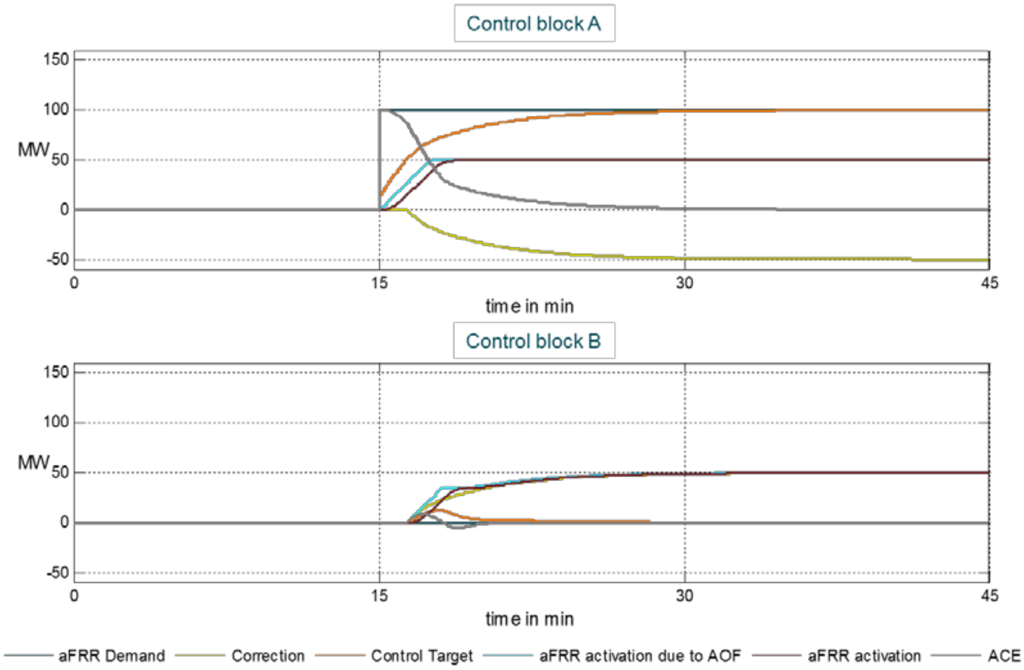


Figure 17: Example of aFRR AOF control request concept

What can be observed from this particular example is that the two concepts lead to different local and overall ACE quality following a step disturbance. In the control demand concept, the overall control demand is distributed by the CMOL to the local controllers. Hence, the exporting TSO (LFC block B) imports part of the ACE from the importing TSO (LFC block A). In the control request concept, where aFRR must be a setpoint product, the aFRR activation is limited by the respective ramping requirements. If these ramping requirements are limitative in comparison with the technical capabilities of the BSP, the overall ACE quality is reduced. The exporting TSO hardly imports any ACE. It may be concluded that the combined choice of product requirement and control concept is a trade-off between XB impact on ACE and local impact on ACE. The ACE impact may eventually have many impacts, e.g. system frequency and the dimensioning of the reserve needs for each TSO and should be evaluated carefully.

Points that require further investigations on the control demand concept are:

- The stepwise exchange does not reflect the local activation and therefore affects the local ACE, depending on CMOL structure and overall demand. It does not influence the overall ACE
- Additional measures necessary to prevent CMOL deviations due to local dynamic behaviour of the local control loop (delay of corrected input controller, overshoot controller or no reaction of BSPs, which results in activation based on local MOL)
- Can lead to parallel activation of two or more bids with different costs, however only bids will be activated which are needed for covering the current demand.

Points to be further investigated on the control request concept are:

- The local responsibility and governance regarding BSP activation is questioned.
- TSOs with procurement of fast local BSPs might import slow activation of external units and impact on local ACE.
- The concept is currently not developed in detail nor implemented (stability not proven).
- Impact on global ACE quality and feasibility of mitigation measures.

aFRR FAT and AOF control concept

Six different combinations of FAT and AOF control concept from three different FAT options (5 min, 7.5 min and 10 min) and two AOF control concept options (control demand and control request) have been simulated for 1 day of operation (i.e. 1 January 2016) of the 7 EXPLORE control areas on ACE quality. Input to the simulations was the real aFRR demand for each local controller for that day. The settings of the local controllers were harmonised and adjusted to the respective control concept. The local filters for calculating the control request out of the control target (see Figure 10) were copied to the AOF in case of the control request concept. Figure 18 shows the histogram of resulting ACEs in MW with a histogram category size of 10 MW. The Y-axis shows the rate of occurrence of ACEs within each category, i.e. an ACE between -5 and + 5 MW occurred during 3.5 % of the time.

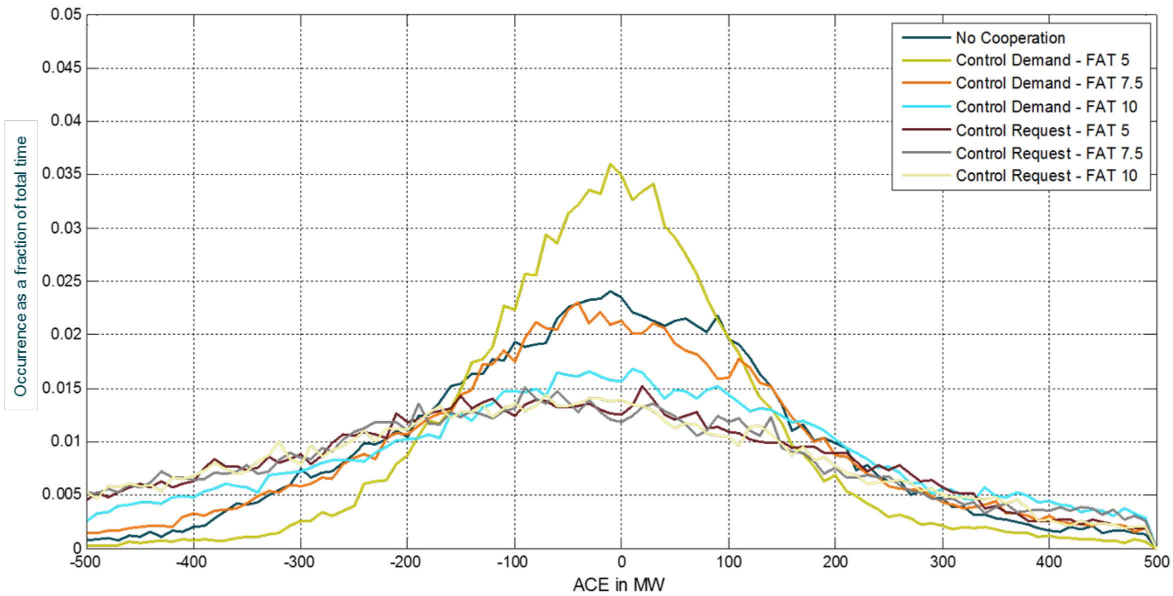


Figure 18: Simulated ACE quality for different combinations of aFRR FAT and AOF control concept

The results of this example indicate that an AOF based on control demand outperforms an AOF based on control request regarding overall ACE quality. This can be (partially) explained by the faster activation that was simulated in the control demand concept because the historically observed activation reactions were applied rather than an activation according to the minimum ramping requirements. It can also be observed that for this particular day, in case of an AOF based on control request, overall ACE quality seems less sensitive to the FAT.

The results cannot be conclusive to the best combination of options at this stage of investigation. Possibility to allow BSP to nominate their physical ramp rate to mitigate the ACE impact in the control request approach were not analysed either.

This demonstrates that further investigations are required to find the best combination of FAT, aFRR setpoint following requirements, AOF concept, local controller and filter setting. Making a selection based on the best performing combination of FAT and control scheme for ACE quality might not lead to the most efficient result, given that the FAT also has an impact on the aFRR market liquidity.

It can be concluded that local prequalification requirements differ in important details, that FAT is not necessarily the only important product parameter that requires harmonisation and that precise aFRR harmonisation requirements require further investigations.

4.3 Other aFRR CoBA product design aspects

4.3.1 Order of bid activation

The draft EBGL requires the European integration model for frequency restoration reserves with automatic activation to respect merit order activation. Previous versions were mentioning that the principles of a merit order activation has to be respected. This wording is much more appropriate for aFRR as a parallel activation of some bids is needed in order to solve quickly large imbalance. Within EXPLORE merit order activation of aFRR bids is assumed.

4.3.2 Voluntary bids and product time granularity

Allowing for voluntary bids requires changes to the market interfaces in the TSO business processes where currently voluntary bids are not allowed. For example, in case the aFRR capacity is not contracted, there is still a certain technical interface required to activate the bid plus to monitor that the bid follows the control signal according to the same product requirements.

Furthermore, the time granularity of the bid parameters might have an impact on ACE quality or operational feasibility. Based on current investigations, these parameters do not have an impact on control quality so harmonisation to the most flexible option is assumed to allow maximum liquidity of aFRR balancing energy. From a technical perspective, voluntary bids are possible.

4.3.3 Portfolio or unit-based bids

The choice between portfolio and unit-based bidding is assumed to not have an impact on control quality, so harmonisation to the most flexible option is assumed to allow maximum liquidity of aFRR balancing energy. Within EXPLORE the working assumption is therefore portfolio-based bidding.

4.4 Summary

Historical local choices in the aFRR design lead to local differences in control concepts and aFRR products. This has also been demonstrated for EXPLORE. As a consequence of these differences, further investigations on requirements to follow the control request (FAT or setpoint product), on the CoBA aFRR control concept (control demand or control request based) and on the definition and requirements of the FAT (ramping requirements) are required before a working assumption can be found for the combination of these choices. Aside from the technical criteria, the design of the TSO-TSO settlement for both concepts must also be further investigated. For other aspects, which do not necessarily impact ACE quality and security of supply, working assumptions have been agreed. This concerns the allowance of uncontracted bids from a technical perspective, the merit order activation of aFRR bids and portfolio bidding. In addition, EXPLORE TSOs share the need to harmonize the prequalification definitions and requirements on FAT to a proportionate extent, in order to create a level playing field.

5 mFRR design

This chapter deals with all mFRR product design aspects not related to pricing. Covered here are FAT, activation trigger, volume divisibility, activation request time, remunerated volume, imbalance adjustments and TSO-BSP settlement price for requested mFRR energy outside the main ISP of the bid.

5.1 Full Activation Time

FAT is the maximum time allowed between TSO activation request and start of delivery period (delivery period starting when the full requested power is delivered, as define in EB GL). Throughout this document it is assumed that preparation time for the BSP is a BSP choice, as long as the BSP respects the FAT requirement. FAT is hence defined as the time between when the BSP receives the activation request until the delivery of the full requested power, including no further restriction on how this is performed.

Whereas with an ISP of 15 minutes and a TTRF of also 15 minutes an mFRR FAT of 15 minutes seems to be an obvious choice, but compliancy of this option with the frequency control and frequency quality requirements as laid down in the System Operations Guideline is not so obvious, depending on the interpretation. Therefore, in order to arrive at a working assumption on mFRR FAT, EXPLORE TSOs have requested clarification on the interpretation from ENTSO-E.

5.2 Activation trigger for mFRR

Although activation strategies are preferably a local choice, current triggers are based on local depletion of aFRR, and there are cross-border effects of different activation strategies in cross-border balancing markets, which suggests review and coordination may be necessary. This section analyses this possible necessity in more detail.

Description of options

mFRR activation triggers in the EXPLORE countries are based on aFRR control parameters. In a CoBA situation, there are local parameters (taken from the local controller) and global parameters (generated by the aFRR CoBA AOF) available to trigger mFRR activation.

The options for aFRR parameters that can be used for a cross-border mFRR activation trigger are:

A. mFRR activation trigger based on local values:

1. aFRR demand
2. Corrected aFRR demand
3. Activated aFRR

B. mFRR activation trigger based on global values:

1. Activated aFRR

2. Netted aFRR demand

Analysis

A.1 mFRR activation trigger based on local aFRR demand

In this case mFRR activation is triggered when the local aFRR demand reaches a certain threshold (aFRR band). This could lead to activation of more mFRR than the netted aFRR demand from the CoBA. This could also lead to counter activation of aFRR and mFRR. Both are illustrated in Table 3.

CBC	Unit	A	B	Global
aFRR Band	[MW]	±200	±600	±800
Demand	[MW]	+200	-200	0
aFRR Activation before mFRR activation	[MW]	0	0	0
mFRR Request due to activation strategy	[MW]	100	0	100
(XB) mFRR Activation	[MW]	0	100	100
Residual Demand	[MW]	100	-200	-100
aFRR activation after mFRR activation	[MW]	0	-100	-100

Table 3: Example of mFRR activation trigger based on local aFRR demand

A.2 mFRR activation trigger based on corrected local aFRR demand

If the local corrected demand is used as activation trigger for mFRR, it can happen that a LFC block without own demand (in this example TSO A), activates for other LFC blocks all of its aFRR. Because the local (corrected) demand is high, the activation trigger for mFRR applies and the exporting TSO activates mFRR.

CB	Unit	A	B	Global
aFRR Band	[MW]	±200	±600	±800
Demand	[MW]	0	200	0
aFRR Activation without mFRR activation	[MW]	200	0	0
mFRR Request due to activation strategy	[MW]	100	0	100
mFRR Activation	[MW]	0	100	100
Residual Demand	[MW]	0	100	-100
aFRR activation after mFRR activation	[MW]	0	100	-100

Table 4: Example of mFRR activation trigger based on corrected local aFRR demand

In this example the cheapest mFRR is located in the LFC block B, so the mFRR of B is activated, although all of the aFRR of B is available. This is a contradiction to the reactive balancing approach.

A.3 mFRR activation trigger based on local activated aFRR

In this option the locally activated aFRR (including cross-border activated aFRR) is used as the trigger for mFRR activation. This option prevents counter-activation under netting, which may occur under option 1. This is demonstrated in Table 5.

CB	Unit	A	B	Global
aFRR Band	[MW]	±200	±600	±800
Demand	[MW]	+200	-200	0
aFRR Activation without mFRR activation	[MW]	0	0	0
mFRR Request due to activation strategy	[MW]	0	0	0
mFRR Activation	[MW]	0	0	0
Residual Demand	[MW]	0	0	0
aFRR activation after mFRR activation	[MW]	0	0	0

Table 5: Example of mFRR activation trigger based on local activated aFRR

The example in Table 6 demonstrates how this mFRR trigger activates mFRR for another TSO (cross-border activation). In this example it is assumed that mFRR is triggered to free aFRR, because the aFRR band is reached. It is also assumed that there are only cross-border activations (A activates aFRR for B, B activates mFRR for A).

CB	Unit	A	B	Global
aFRR Band	[MW]	±200	±600	±800
Demand	[MW]	0	200	200
aFRR Activation before mFRR activation	[MW]	200	0	200
mFRR Request due to activation strategy	[MW]	100	0	100
mFRR Activation	[MW]	0	100	100
Residual Demand	[MW]	-100	0	-100
aFRR activation after mFRR activation	[MW]	-100	0	-100

Table 6: mFRR activation trigger based on local activated aFRR - XB activation

But the mFRR in LFC block B is not needed, there is sufficient aFRR left.

The example in Table 7 demonstrates how IGCC netting prevents mFRR activation even if local demand is higher than the aFRR band. But the fact that the balancing energy demand is higher than the allocated aFRR should trigger TSO activities. It is not ensured that the netting is available for the duration of the balancing need of the TSO. It depends on the demand of other LFC blocks and the availability of cross-border capacity. Both can change every second. In cases of sudden change of netting availability, this activation trigger is not sufficient to prevent risks for the LFC block – especially if the netted demand is even bigger than in this example.

		CoBA		IGCC	
CB	Unit	A	B	C	Global
aFRR Band	[MW]	±200	±600		±800
Demand	[MW]	300	700	-1200	-200
aFRR Activation without mFRR activation	[MW]	0	0	-200	200
mFRR Request due to activation strategy	[MW]	0	0		0

Table 7: mFRR trigger based on local activated aFRR - example with IGCC netting

B.1 mFRR activation trigger based on global activated aFRR

The activation based on global activated aFRR takes into account netting like shown in Table 5. It leads not to an mFRR activation that is needed by the CoBA (cf. Table 6). The global need for mFRR is determined, if a defined volume of aFRR is used. The common mFRR need is going to be activated from the common MOL. A way of distributing the activated energy to the LFC blocks has to be found, basically every TSO with a demand in the direction of activated mFRR (e.g. upward energy) is part of the reason why mFRR is activated.

But this option is also not taking into account demands that are higher than the allocated local aFRR and the associated risk of suddenly not available netting (cf. Table 7).

B.2 mFRR activation trigger based on global netted aFRR demand

In this option, the global netted aFRR demand is used as a trigger for mFRR activation. mFRR is only activated, if the global netted aFRR demand reaches a certain threshold (e.g. 70% of global aFRR band).

This option is comparable to option B.1 but the netted aFRR demand would be mostly higher than the activated aFRR, hence the trigger threshold has to be adjusted accordingly. This is an implementation issue, which is not covered in this report.

Evaluation

A summary of the possible activation triggers and their effects for cross-border activation of mFRR is provided in Table 8.

Based on Local Values	Based on Global Values
Demand ➢ might lead to a counteractivation of aFRR and mFRR ➢ although full demand can be netted, mFRR would be activated	**Activated aFRR** ➢ Global demand does not respect local scarcity situations ➢ mFRR might be activated in a Control Block with an opposite (netted) demand ➢ Not activating mFRR because of netted aFRR while having high demand might be disadvantageous in case of congestions
Corrected Demand ➢ Exporting TSO would activate mFRR without own demand ➢ Not activating mFRR because of netted aFRR while having high demand might be disadvantageous in case of congestions	**netted Demand** ➢ Might lead to mFRR activation while aFRR activation is very low due to netting ➢ mFRR might be activated in a Control Block with an opposite (netted) demand ➢ Not activating mFRR because of netted aFRR while having high demand might be disadvantageous in case of congestions
Activated aFRR ➢ By activation for other TSO without own demand, mFRR would be activated ➢ Not activating mFRR because of netted aFRR while having high demand might be disadvantageous in case of congestions	

Table 8: Possible mFRR activation triggers and effects

Proposed solution

Reactive balancing systems, like exploited by EXPLORE TSOs, predominantly use aFRR to restore frequency. Underlying the assumption, that every TSO has full access to the cMOL according to the conditions of EBGL, mFRR activation will mainly occur in case of local aFRR shortage and shortage of cross-zonal capacity for cross-border activation. Hence, in reactive balancing systems, the main driver for mFRR activation remains the local imbalance and local shortage of aFRR. Cross-border activation of mFRR requires coordination, but will rarely occur. The main activation of mFRR will be local to reduce the local demand to a limit that decreases the risk of suddenly disappearing netting or aFRR exchange to an acceptable limit.

Explore TSOs highlight that the opportunities for mFRR balancing energy exchange and the derived economic benefits for primarily reactive systems are expected to be limited.

A proportionate solution including impact of extension to TSOs with a pro-active balancing concept needs to be further investigated.

For reactive TSOs a cross-border mFRR activation will rarely occur. The probability is very low that most of the aFRR of all TSOs of the CoBA will be used into the same direction at the same time and there is additional cross-border-capacity for mFRR exchange. Hence, the current working assumption of EXPLORE is to apply local activation triggers for mFRR.

5.3 Volume divisibility in relation to maximum bid size

mFRR bids in EXPLORE countries have different minimum and maximum bid sizes. While the harmonisation of the bid size limits is not considered imperative, large indivisible bids may lead to a limitation of cross-border activation possibilities.

Indivisibility of bids without bid size restriction may lead to bids that are too large to be activated or can only be activated with a counter-activation of aFRR or smaller mFRR bids in opposite direction. Therefore, efficiency of balancing requires a limitation in size of indivisible bids. Within EXPLORE It is assumed that volume indivisible bids will be allowed up to a to be determined maximum bid size.

5.4 Activation request time

Direct activated and schedule activated mFRR

The main difference between a direct and a schedule activated mFRR bid is the TSO activation request time relative to the main ISP of the bid (this is the ISP for which the bid was offered). For a direct activated (DA) bid, this time may vary within a specified time period, for a schedule activated (SA) bid, this time is fixed. With DA bids, TSOs have the ability of immediate reaction to sudden outages but there is no potential for netting of DA requests (as the requests are by definition not synchronized), whereas with SA bids, activation request time is synchronized, which allows for netting of SA requests.

A second distinction is related to the ISPs for which balancing energy is requested. For a schedule activated bid, balancing energy is only requested for the main ISP of the bid. For a DA bid, balancing energy can also be requested outside the main ISP of the bid[7].

Both types of activation are applied in the EXPLORE countries. If some TSOs decide to allow only either direct activated bids or schedule activated bids, XB exchange possibilities will be limited as DA can then only be activated by TSOs who need to apply direct activation and SA bids only by TSOs who want to apply scheduled activation. So a working assumption was agreed that forecloses a liquidity split and therefore loss of potential efficiency gains of an mFRR CoBA.

Within EXPLORE it is concluded that direct activation and scheduled activation of mFRR must both be supported and combined in one product.

Description of options on activation request time

For direct activation, the following options have been studied for the TSO activation request time ahead of the ISP of the bid (ISP of the bid is called the main ISP) with t = start of the main ISP:

1. DA request time is between t-22,5 min and t-7,5 min;
2. DA request time is between t-15 min and t-0 min.

For scheduled activation, the following options for TSO activation request time are evaluated:

a. Schedule Activated (SA) activation request time is at t-7,5 min.
b. SA request time is at t-0 min (or rather: as close to the start of the ISP as IT-technically possible).

In case of scheduled activation, early activation request time facilitates effective delivery by slower BSPs as they will have more time to prepare (ramp-up) to deliver the energy during the ISP of transaction and late activation facilitates efficient activation for the TSO, assuming that in case of an early activation request delivery will not start until start of ISP (see figure below).

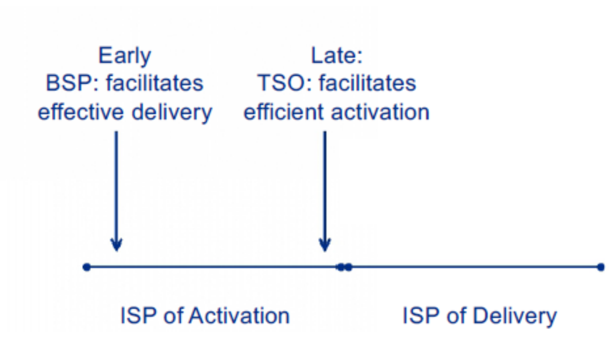


Figure 19: Schedule activated mFRR

[7] See Figure 3 and Table 3 in: "Potential cross-border balancing cooperation between the Belgian, Dutch and German electricity Transmission System Operators" at http://www.elia.be/~/media/files/Elia/users-group/141008_Final_report.pdf

Not all combinations of direct and schedule activation are considered useful. There is a preference to avoid that a request for scheduled activation within an ISP is earlier than a corresponding request for direct activation, as this could lead to over-fulfilment.

Figure 20 illustrates the possible combinations of DA and SA options. Time is on the X-axis while power is on the Y-axis. All options show a minimum assumed power profile delivery starting at the point of scheduled activation, ramping up to full power output during a time period equal to FAT and then immediately ramping down to zero during a second time period equal to FAT. In the example FAT is equal to the ISP and the ISPs are separated by vertical lines. Note that with a FAT smaller than the ISP, assumed start of deactivation period will be later according to the difference (ISP-FAT).

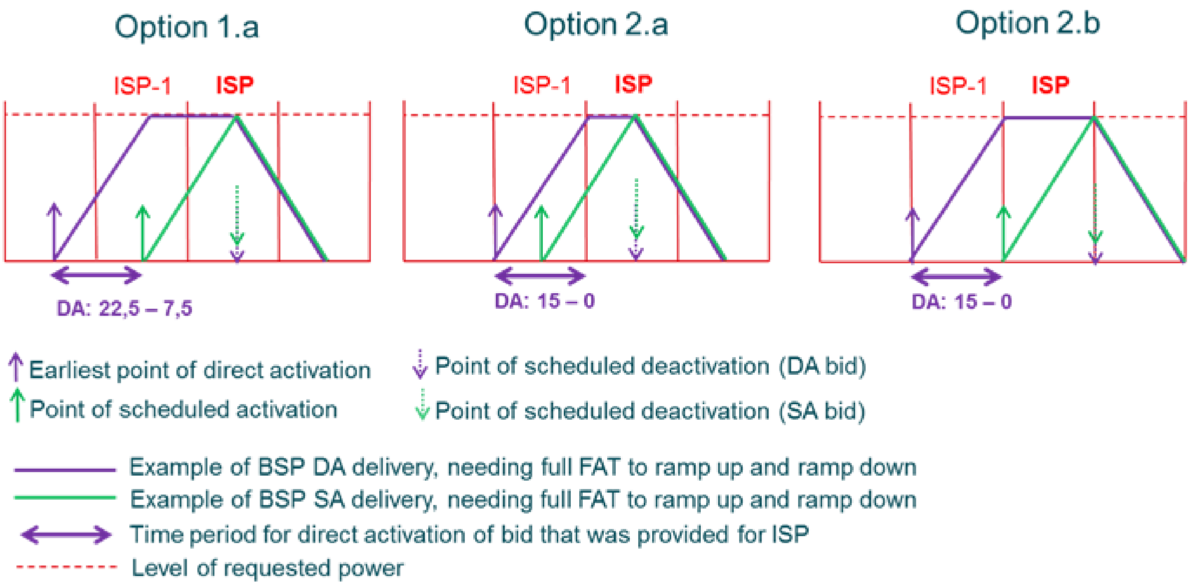


Figure 20: Visualisation of combinations of options for the mFRR activation request times

In option 1.a, the TSO activation request time for DA bids is between 22,5 and 7,5 minutes before start of the ISP of the bid and the TSO activation request time for SA bids is at 7,5 minutes before start of the ISP of the bid.

In option 2.a, the TSO activation request time for DA bids is between 15 and 0 minutes before start of the ISP of the bid and the TSO activation request time for SA bids is at 7,5 minutes before start of the ISP of the bid.

In option 2.b, the TSO activation request time for DA bids is between 15 and 0 minutes before start of the ISP of the bid and the TSO activation request time for SA bids is at 0 minutes before start of the ISP of the bid (meaning as late as IT-technically possible before start of the ISP of the bid).

Evaluation of options for activation request time

The three combinations of options for activation request time for DA and SA activated bids have been evaluated on the following criteria:

- Criterion 1: Allows for a GCT of mFRR energy bidding as late as possible
  Obviously, activation of mFRR bids cannot be before gate closure of the mFRR energy bidding process. The earliest activation time therefore sets the scoring on this criterion. Options 2 and 3 allow a GCT of one ISP before the ISP of the bid or earlier, while option 1 requires a GCT of 1.5 ISPs before the ISP of the bid or earlier.
- Criterion 2: BSP ability to bid mFRR in ISP where the underlying capacity already has been traded in the previous ISP
  If the activation of the bid can take place before the ISP of the bid, this undermines the ability for the BSP to trade the bid in the spot market for the ISP before.

Criteria 1 and 2 collapse to a main criterion that interaction with other markets should be minimal, but can be interpreted in 2 different ways:

1. mFRR is considered to deliver full power at a certain point in time

   If the earliest point of activation is more than 15 minutes before the main ISP, full power delivery from mFRR bid is already expected in the ISP before the ISP for which the bid is offered. This expectation cannot be met if the ISP before the main ISP has already been traded in ID market as it would result in a double marketing. Consequently, when moving an asset from the ID market to the mFRR market, there is one 'lost' ISP that cannot be offered in any market. This is illustrated for all three options in the figure below.

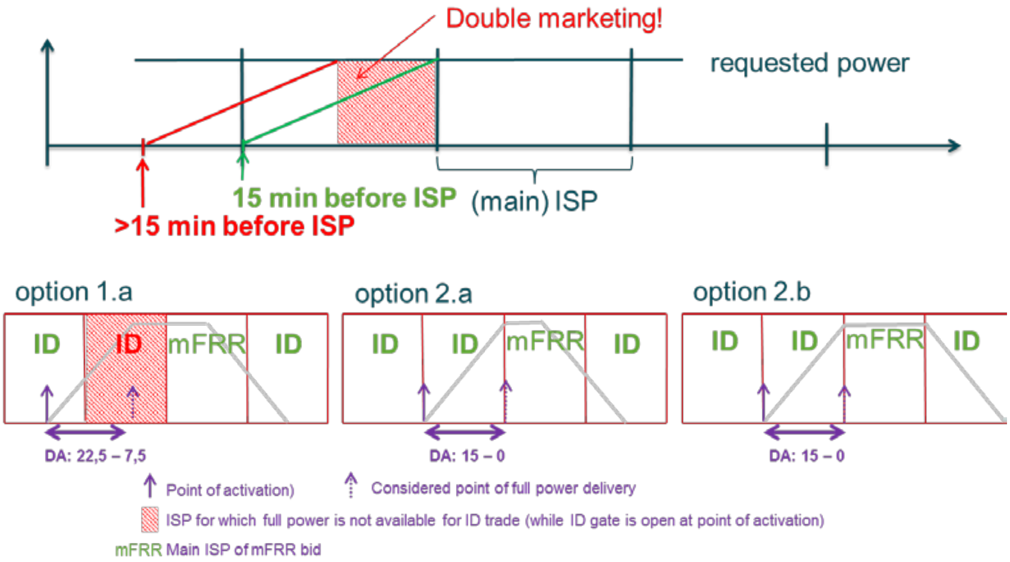


Figure 21: ISP-1 not available for ID trade if full power is considered to be delivered at a certain point in time in ISP-1

2. mFRR is considered to deliver a fixed amount of energy in a certain timeframe

If the imbalance adjustment incentivizes the BSPs to deliver the requested energy in the main ISP and ISP-1, for all 3 options the energy incentivized to be delivered in ISP-1 is unavailable for ID market participation.

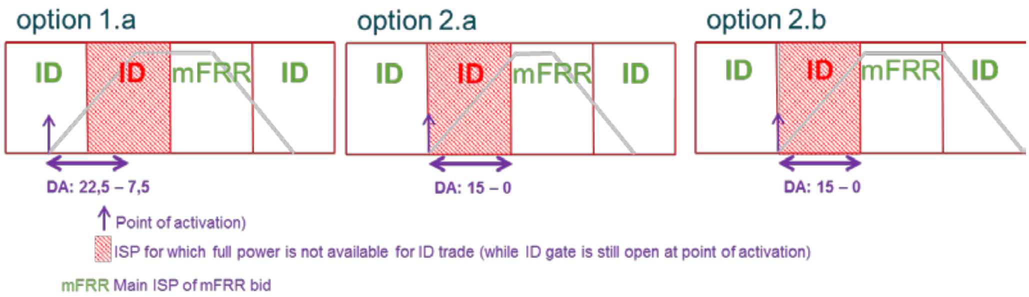


Figure 22: ISP-1 is not available for ID trade if fixed amount of energy delivery is considered for ISP-1

- Criterion 3: Activation request time as close as possible to ISP of bid
  An activation request time as close as possible to the ISP of the bid helps prevent counter-activations, as the latest point in time energy is delivered from the bid is closer to the activation request, and less uncertainties remain. Figure 23 shows a practical example of how counter-activations could be prevented. An additional advantage is that an activation closer to the ISP of the bid allows better reflection of the system state in that ISP in the price, which is especially relevant when BRPs are allowed to support the system balance in real time.

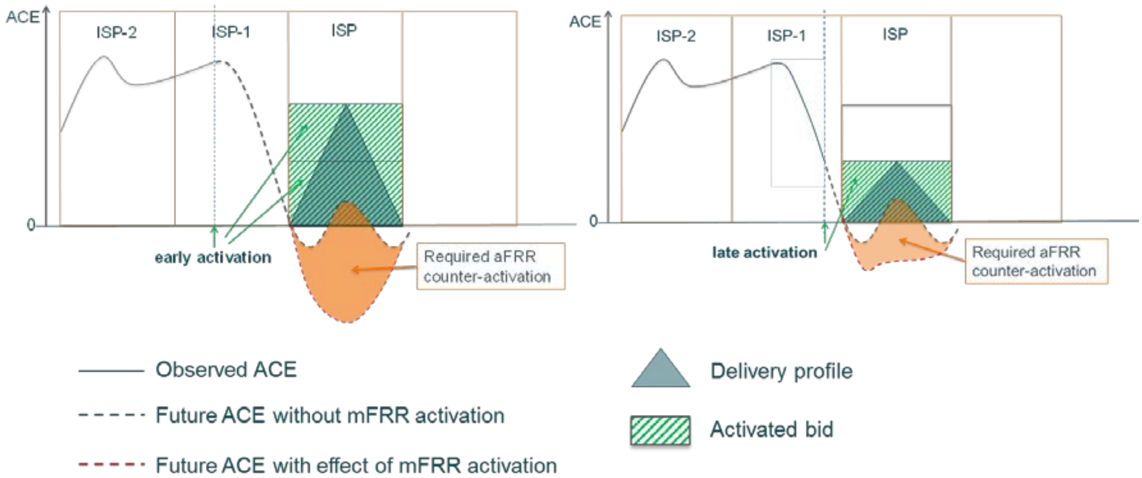


Figure 23: Risk of counter-activation with early activation request time (left) and late activation request time (right)

- Criterion 4: Prevents over-fulfilment
  In case of direct activation of a bid of one ISP and scheduled activation of another bid for the next ISP, both of the same volume, the minimum expected power delivery during the combined activation period should not be higher than the maximum expected power delivery of either bid.

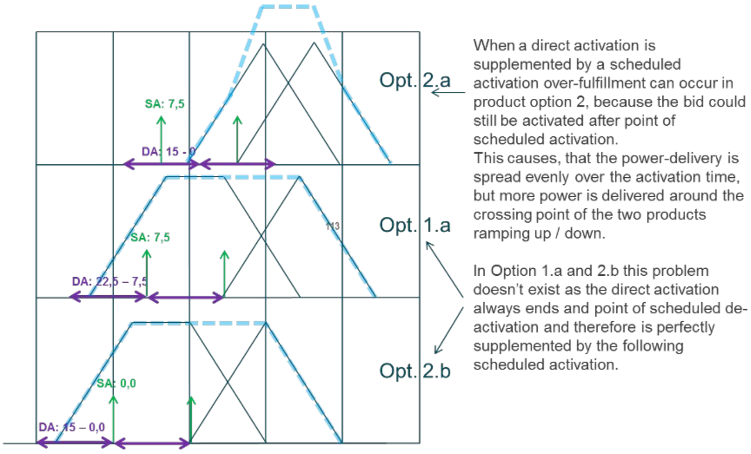


Figure 24: Criterion 4: Prevent over-fulfillment

- Criterion 5: Maximum expected energy in ISP of bid
  According to the imbalance adjustment, which is in the main ISP and in ISP-1 an incentive is given to the BSPs to deliver most of the energy in the main ISP and the remaining part in ISP-1. But depending on the expected minimum power profile, slow BSPs are not always able to fulfil this incentivised behaviour. Depending on the option there are cases with only half of the energy provided in the main ISP if the BSP needs the complete full activation time to deliver the bid.

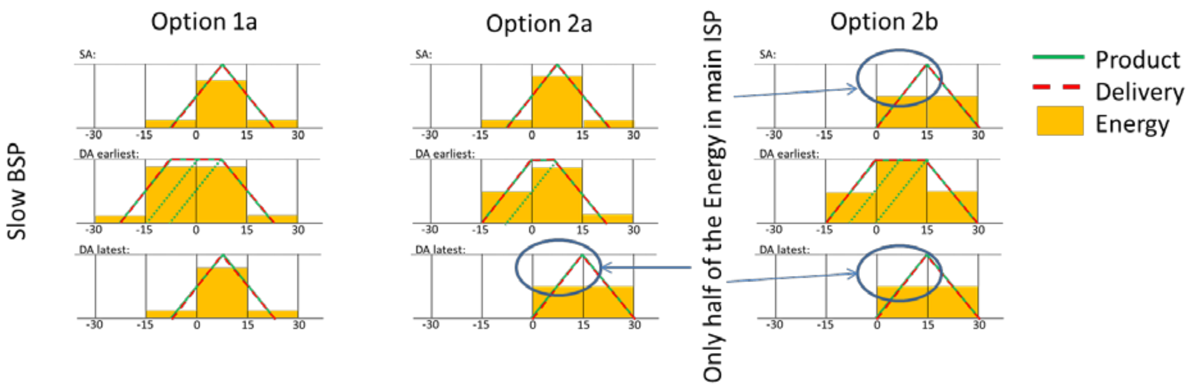


Figure 25: Expected energy deliveries from slow BSPs

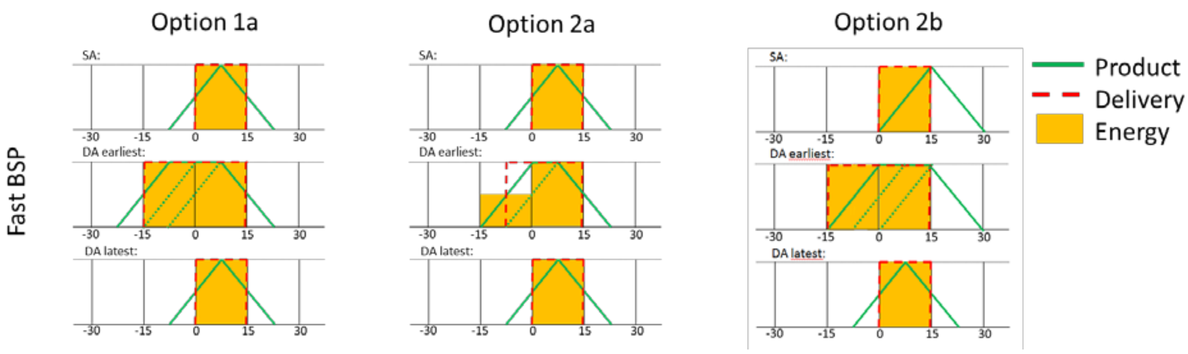


Figure 26: Expected energy deliveries from fast BSPs

- **Criterion 6: Minimum TSO imbalance as a result of the XB exchange profile**
  This criterion relates to the difference between the imbalance adjustment of a XB activated bid and the exchanged energy volumes corresponding to the XB exchange profile. This must then be resolved by additional aFRR activation. Therefore, a smaller difference leads to a smaller TSO imbalance. Depending on the incentive to follow the power delivery profile, which is induced by the imbalance volume adjustment dealt with in 5.5, this may lead to more efficient balancing. Figure 27 demonstrates the effect of a 10 min ramp on the XB exchange profile and the assumed reaction of a slow BSP needing the full FAT to ramp-up and down.
  With the finding that mFRR will be predominantly used local in reactive balancing design, the cross-border exchange has a limited importance. The cross-border exchange can further be adapted if it is necessary.

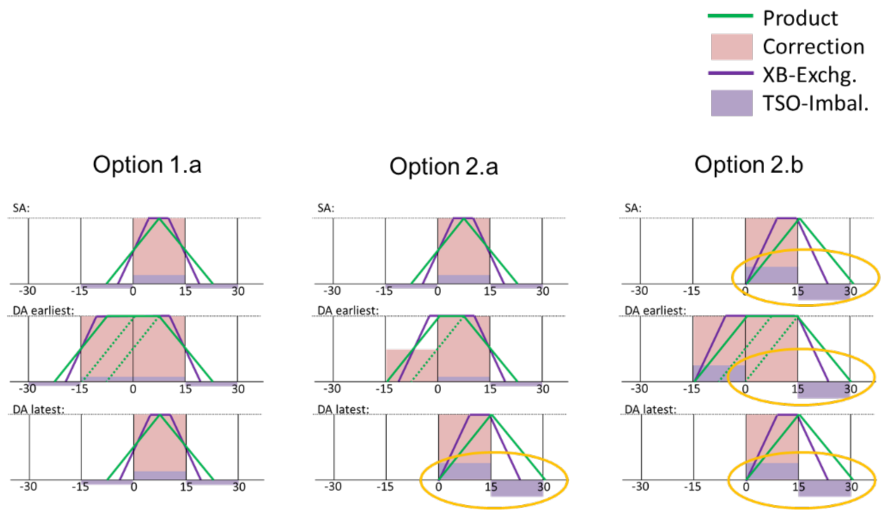


Figure 27: Example of system imbalances of exporting TSO as a result of difference between mFRR product ramping and XB exchange ramping

In order to evaluate the options for some of these criteria, remunerated volumes and imbalance adjustment volumes must be considered. For that, the principles on remunerated volumes and imbalance adjustment volumes for mFRR according to section 5.5 were applied.

Table 9 shows how each of the options are evaluated on these criteria.

Proposed solution

A balanced weighting of the scores is required to come to a working assumption on mFRR activation request time. This requires further investigations, including extendibility to areas with a different ISP or a pro-active rather than a reactive balancing concept. The assessments so far lead to the following principles:

- Minimal interaction with other markets
  - The later the earliest possible activation, the later the possible GCT for balancing energy from mFRR.

- If a balancing energy GCT is feasible after the GCT of the spot markets, less interactions are foreseen.

	Option 1.a DA period: 22,5-7,5 min before ISP of bid SA time: 7,5 min before ISP of bid	Option 2.a DA period: 15,0-0 min before ISP of bid SA time: 7,5 min before ISP of bid	Option 2.b DA period: 15,0-0 min before ISP of bid SA time: as close as possible to start of ISP of bid
Allow for latest GCT	No	Yes	Yes
Ability to bid for ISP when bid already traded for ISP-1 in ID	No	Yes (power product) No (energy product)	Yes (power product) No (energy product)
Prevents over-fulfilment	Yes	No	Yes
Activation request time closest to ISP of bid	No	No	Yes
Maximum expected energy delivery in ISP of bid	Yes	Depends on BSP reaction	Depends on BSP reaction
XB activation profile follows XB exchange profile	Yes	Depends on XB exchange profile	Depends on XB exchange profile

Table 9: Evaluation of options for mFRR activation request times on specified criteria

- Minimal over-fulfillment
  - e.g. if deactivation of direct activated bid and activation of schedule activated bid is not at the same point in time, sequential direct and scheduled activation leads to expected power over-fulfilment.
- Minimal risk of aFRR counter-activation
  - The later the TSO decision, the lower the risk of counter activations with aFRR and the easier to control in which ISP main energy is delivered; however, an incentive to react faster (through the imbalance adjustments) leads to a disadvantage for the BRP of slower BSPs.
  - The closer the SA request to the start of the ISP, the lower the uncertainty on the volume of mFRR to be activated.

5.5 Remunerated volume and imbalance adjustment

Description of options

Options on remunerated volume relate to how the TSOs determine the total volume to be remunerated, based on parameters available to the TSO and to the BSP. Options on imbalance adjustments relate to whether total imbalance adjustment volume can deviate from the total remunerated volume or not and to the split of the total imbalance volume adjustment over the main ISP of the bid and surrounding ISPs as an incentive for the desired spread of balancing energy delivery over the desired ISPs.

Proposed solution

Foremost, efficiency requires that the total imbalance volume adjustment is the same as the remunerated volume.

Then the remunerated volume should be determined according to the required balancing energy to be delivered according to the product specification, in particular the FAT. With an ISP of 15 minutes and assuming a FAT of 15 minutes, the required balancing energy to be delivered depends on the activation method (direct or schedule activated) and time of activation request.

For imbalance volume adjustments, the spread of imbalance volume adjustments should follow the desired spread of balancing energy delivery.

Applying these principles leads to different results for the combination of options of DA and SA request time that were assessed in section 5.4. The figures below demonstrate how this works out for the different options where in case of DA the earliest point of activation is elaborated.

Again, in the pictures, the horizontal line represents the timeline and the vertical line represents power. The vertical lines represent ISP boundaries. On the left side a scheduled activation is shown, on the right side a direct activation, where it is assumed that the time of activation request is at the start of the DA activation request period. On the top side, the remunerated volume is shown and on the bottom side the imbalance adjustments. Note that although remunerated volume is shown relative to ISPs, it is remunerated at the same price in all ISPs. This is not the case for imbalance adjustments as they will be subject to the imbalance price of the ISP concerned.

Note that the black solid line represents the slowest acceptable BSP power delivery profile. In this assumed profile, scheduled activation is the assumed point in time where the BSP reaction starts and time of scheduled deactivation is the assumed point in time where the BSP starts ramping down from full activation. Requested power is the point of maximum power on this profile.

In case of example option 1.a (Figure 28: DA request at t-22.5, SA request at t-7,5), the direct activated bid is assumed to deliver power not only in the ISP of the bid, but also in one ISP before. While the remunerated volume and imbalance adjustment volumes are equal to the area under this profile, the imbalance volume adjustment is allocated to incentivize balancing energy delivery distribution over the ISPs as most desired: in ISP-1 and ISP.

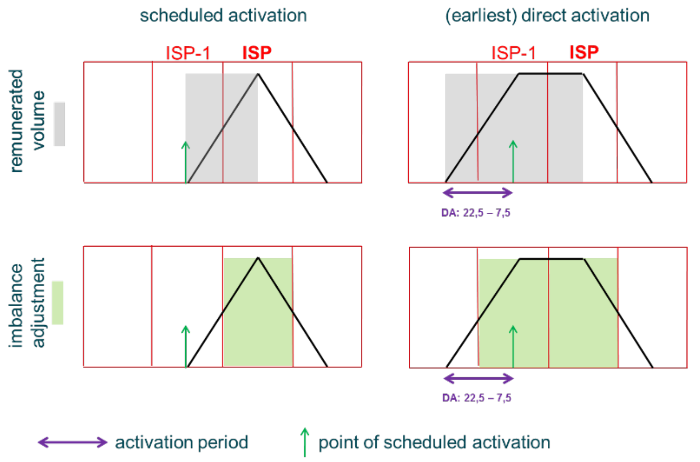


Figure 28: Remunerated volume and imbalance volume for option 1.a

In case of example option 2.a (Figure 29: DA activation at t-15, SA at t-7,5), the direct activated bid is assumed to deliver power in the ISP of the bid but also in the ISP before. While the remunerated volume and imbalance adjustment volumes are equal to the area under this profile, the imbalance volume adjustment is allocated to incentivize balancing energy delivery distribution as most desired: in the ISP of the bid.

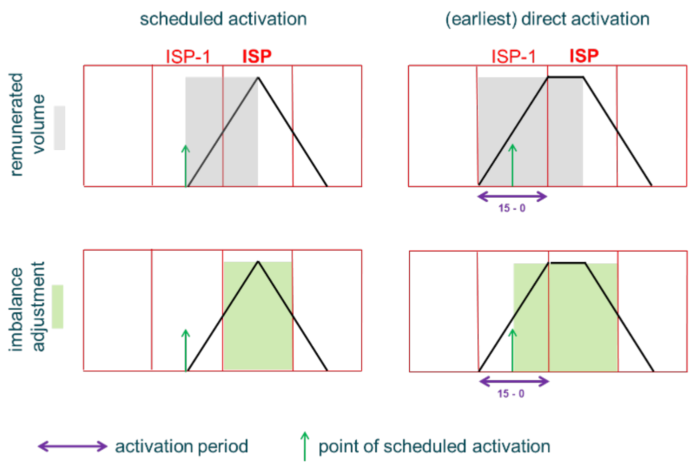


Figure 29: Remunerated volume and imbalance volume for option 2.a

For option 2.b illustrated in Figure 30, the calculation of remunerated volume works as in the other options.

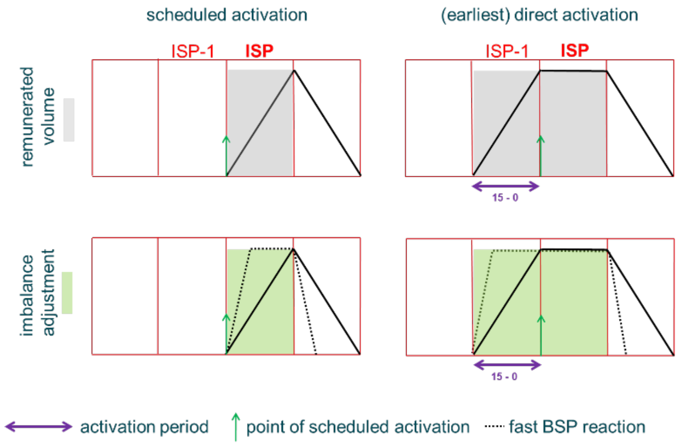


Figure 30: Remunerated volume and imbalance correction for option 2.b

Note that these are only examples of earliest point of DA. However, the same principles apply to a later DA request times within the activation request time period that belongs to each option.

Principles on mFRR remunerated volume and imbalance adjustments

This leads to the following principles for determination of remuneration volume, imbalance adjustment volume, and allocation of imbalance adjustment volumes to ISPs:

- Remunerated volume and imbalance adjustment volume shall be the same
- Remunerated volume = requested power * time between activation and scheduled deactivation
- Imbalance adjustment volume allocation is done in a way that energy delivery is incentivized in the ISPs where it is most desired

The precise imbalance volume adjustment allocation under each option should be specified in a later stage.

5.6 TSO-BSP settlement price for requested mFRR energy outside the main ISP of the bid

Description of options

For balancing energy that is requested outside the main ISP, it must be determined what price should be used for remuneration of that energy. A related question is if - in case of marginal pricing - that price should then set the remuneration price for all of the activated balancing energy in the relevant ISP or not. For SA bids, this aspect is not relevant as all energy that is requested is limited to the ISP of the bid.

A key consideration is that all energy activated from a bid should be remunerated according to the TSO-BSP balancing energy price in the main ISP of the bid. For balancing energy activated outside the ISP of the bid, it was not concluded if the remunerated price should set the balancing energy price outside the ISP of the bid or not.

Proposed solution

All energy delivered from mFRR bids should be remunerated according to the balancing energy price for the main ISP of the bid. Whether this should influence the price for energy activated in other ISPs or not was not concluded.

5.7 Summary

EXPLORE TSOs have developed the following principles for a standard mFRR balancing energy product design:

- The product is on a time granularity basis of 15 minutes, equal to TTRF.
- The FAT will be 15 minutes or less, depending on the ENTSO-E approval of compliancy of a 15 min FAT versus TTRF (section 5.1).
- All bids must allow direct activation as well as scheduled activation within a 15 minutes activation period before the ISP of the bid; point of direct activation can vary within activation period; point of scheduled activation is fixed within activation period; preparation time of TSO is not part of the product design and shall be as short as possible; preparation time of BSP is up to the BSP and part of the FAT (section 5.4).
- Remunerated volume equals requested power times time between activation and scheduled deactivation (section 5.5).
- Volume of imbalance adjustments equals remunerated volume, imbalance adjustments per ISP will be set according to required incentives to deliver (section 5.5).
- Price of remunerated volume is the balancing energy price in the main ISP of the bid (section 5.5).
- TSO cross-border exchange adjustment will be based on a realistic average BSP reaction, minimizing impact on LFC block imbalance resulting from exchanged mFRR.
- mFRR activation trigger:
  Reactive balancing systems, like exploited by EXPLORE TSOs, predominantly use aFRR to restore frequency. Underlying the assumption, that every TSO has full access to the cMOL according to the conditions of EBGL, mFRR activation will mainly occur in case of local aFRR shortage and shortage of cross-zonal capacity for cross-border activation. Hence, in reactive balancing systems, the main driver for mFRR activation remains the local imbalance and local shortage of aFRR.

Further investigations are needed to come to a specified working assumption on the following aspects:

- TSO activation request time + Validity period (time during which a bid can be activated) + Earliest point of activation:
  Three DA/SA options have been specified and remain after extensive elaboration.

6 Conclusions

While the executive summary describes the main conclusions of EXPLORE regarding settlement options, and the aFRR design and the mFRR design, this part of the report aims more at focusing on learnings of EXPLORE with regard to the ongoing Electricity Balancing Guideline process. Several learnings of EXPLORE have a direct link to it and give valuable input for the comitology process.

The EXPLORE TSOs are willing to discuss the report with interested authorities (NRAs, ACER, EC), in particular the conclusions and welcome stakeholder feedback.

Implementation timeline of balancing cooperation

Previous versions of EBGL aimed at implementation of regional balancing cooperations (CoBAs) to exchange balancing energy. EXPLORE TSOs evaluated that they are good partners for such regional cooperation thanks to the similarities between their market designs and their balancing philosophy. Consequently the EXPLORE TSOs engaged in a study project to identify a complete consistent market design to exchange aFRR and mFRR energy in early 2015, with a particularly intensive work during the first eight months of 2016 with project management support.

While working assumptions could be agreed on many topics, other points are still open due to its high level of inter-linkage between themselves and due to different legislative and regulatory framework. This is illustrative of the complexity of the work to integrate different balancing markets which have been developed in isolation during a long period with limited requirements for technical harmonisation and no requirement for market design harmonisation.

In the new context of European platforms, where not only four LFC blocks (EXPLORE TSOs) will have to agree on options but all European TSOs, the challenge ahead can be appreciated, in particular when a solution is sought with a high level of consistency between the design choices. This raises a concern about the practical feasibility to comply with the short timelines (four years after entry into force) to implement European platforms for all balancing processes. As this depends greatly on the possibility of finding a common design, the deadline for definition of the design (one year after entry into force) is similarly challenging.

In summary, there is a natural trade-off between the geographical extend of the balancing cooperation and the timeline for implementation, which is not correctly taken into account for the deadlines defined in the current version of EBGL.

Depth of harmonisation

EXPLORE is seeking at developing a market design as consistent as possible between the different aspects, with a good convergence of the national framework in order to ensure a good level-playing field. That means that not only the EBGL mandatory provisions were considered during the project. This depth of harmonisation was something identified as possible in a regional cooperation of TSOs with a similar design and balancing philosophy as a starting point.

In the context of the European platform it is more challenging to reach the level of harmonisation required for a consistent market model and especially considering the tight deadlines as discussed above. With the current draft of EBGL, the level of harmonisation that was sought in EXPLORE seems infeasible EU wide. In other words, the size of the cooperation and the depth of harmonisation can be seen as a trade-off in the current context.

EXPLORE has shown that harmonisation and integration are both important to reach a consistent market design and necessary to prevent market distortions. EXPLORE TSOs therefore advocate to reconsider regional integration where needed to allow better consideration of harmonisation together with integration to achieve an efficient balancing market.

Applicability of marginal pricing

Several concerns have been raised in EXPLORE regarding marginal pricing with respect to cross border cooperation. Both cross border marginal pricing for balancing energy as well as local marginal pricing create complications which are not obvious at first sight. Depending on local markets and other market design aspects, blindly applying cross border marginal pricing may lead to unnecessarily high prices not brought on by scarcity. Furthermore, it is difficult to match the influence of exported bids on the balancing energy prices with the local responsibilities on ACE defined in the SOGL when defining the imbalance price.

Local marginal pricing can create similar problems with local responsibilities. Though these seem to appear in a smaller extent and could be further mitigated by not including exported bids in the determination of the marginal price, this would lead to the situation where BSPs within one LFC block would not receive the same price, affecting a level-playing field with consistent bidding strategies by BSPs.

These identified complications need to be properly taken into account when determining the best way forward with regards to the pricing method for balancing energy. The pros and cons of marginal pricing need to be properly weighed against those of pay-as-bid, and for this reason pay-as-bid is maintained as an option within EXPLORE.

Imbalance price settlement

EBGL requires that the settlement principles shall establish adequate economic signals which reflect the imbalance situation. EXPLORE TSOs fully agree with this principle which is consistent with the provisions of System Operation Guidelines. The adequate economic signals allow the TSO (which activates control power based on observed imbalances - so called reactive balancing) to share the responsibility of being balanced with the BRPs active within their LFC block. Adequate economic signals particularly get important and relevant for TSOs with an incentive-based balancing philosophy, where BRPs actively support to counteract the system imbalance.

At the same time, EBGL requires that imbalances are settled at a price reflecting the value of activated energy bids. As shown in chapter 3, if a marginal pricing scheme is applied, the price of balancing energy bids will be influenced by the need for balancing energy expressed by other LFC blocks. This is aggravated in case activation strategies differ significantly, for instance due to differing balancing philosophies.

As the solution to this issue is not yet fully identified, EXPLORE TSOs advocate to keep flexibility toward the imbalance price within EBGL to explore further options to achieve the best design for adequate economic signals, which is seen as the primary objective.

APPENDIX

A. Overview of working assumptions

B. Abbreviations

A. Overview of working assumptions

This annex provides an overview of the results on all aspects of the EXPLORE target model as well as the open design choices. They are sorted by the chapters in which they are described.

Chapter 1

Although not part of the target model, for completeness the commonalities of EXPLORE TSOs are included here.

- Imbalance settlement period is equal to 15 minutes
- Operation of frequency restoration process with predominantly aFRR and supplementary mFRR
- Predominantly reactive balancing approach
- No economic optimisation between mFRR and aFRR
- No reserve replacement process in place
- Common imbalance netting through IGCC

Chapter 2

- Only cross-zonal capacity available after intraday gate closure is used for balancing energy exchange. Other options out of scope.
- Voluntary bids for aFRR and mFRR are allowed
- Energy bids shall be activated in merit order
- The gate closure times for aFRR and mFRR shall be the same and no more than 30 minutes before real-time

Chapter 3

- Local imbalance pricing
- Local choice to allow BRP support of the system in real-time
- Publication of all necessary information in accordance with local choice for BRP system support
- Three TSO-BSP settlement options remaining:
  - Cross-border marginal pricing
  - Local marginal pricing influenced by exported bids
  - Pay-as-bid
- In case of marginal pricing, there is a separate price for aFRR and for mFRR (per-product pricing)
- Two TSO-TSO settlement options remaining:
  - Proportional sharing of costs
  - Cost by cause

Chapter 4

- Three interlinked choices for the aFRR concept remain open:

    - Requirements to follow the control request
        - FAT product
        - Setpoint product
        - Local choice
    - CoBA aFRR control concept
        - Control demand
        - Control request
    - FAT
- Portfolio bidding and prequalification of aFRR is assumed
- EXPLORE TSOs agree on proportionate harmonisation of prequalification definitions and requirements on FAT for aFRR

Chapter 5

- mFRR product resolution is 15 minutes
- mFRR FAT is 15 minutes conditional to compliancy with TTRF requirements
- Both direct and scheduled activation must be possible from each mFRR bid
- Three options of combinations of direct activation period and point in time of scheduled activation remain:
    - Earliest direct activation 22.5 minutes before ISP of bid, scheduled activation 7.5 minutes before ISP of bid.
    - Earliest direct activation 15 minutes before ISP of bid, scheduled activation 7.5 minutes before ISP of bid.
    - Earliest direct activation 15 minutes before ISP of bid, scheduled activation 0 minutes before ISP of bid.
- Remunerated volume is equal to requested power multiplied by the time period between activation and scheduled deactivation. This means energy delivered in the ramps is settled
- Volume of imbalance adjustments equals remunerated volume. Imbalance adjustments per ISP will be set according to required incentives to deliver.
- Price of remunerated volume is the balancing energy price in the main ISP of the bid
- TSO cross-border exchange adjustment will be based on a realistic average BSP reaction, minimizing impact on LFC block imbalance resulting from exchanged mFRR.
- Further harmonisation of activation strategies for mFRR is not necessary between EXPLORE TSOs. Activation triggers remain local.
- Volume indivisible mFRR bids will be allowed up to a maximum size.

B. Abbreviations

ACE	Area Control Error
ACER	Agency for the Cooperation of Energy Regulators
APG	Austrian Power Grid AG
aFRR	Automatic Frequency Restoration Reserves
AOF	Activation Optimization Function
BRP	Balance Responsible Party
BSP	Balance Service Provider
CMOL	Common Merit Order List
CoBA	Coordinated Balancing Area
DA	Direct Activated
EBGL	Electricity Balancing Guideline
EC	European Commission
Elia	Elia System Operator NV
ENTSO-E	European Network of Transmission System Operators for Electricity
EXPLORE	European cross-border project for long term real-time balancing electricity balancing market design
FAT	Full Activation Time
FCR	Frequency Containment Reserves
FRR	Frequency Restoration Reserves
GCT	Gate Closure Time
ID	Intra Day
IEM	Internal Energy Market
IGCC	International Grid Control Cooperation
ISP	Imbalance Settlement Period

LFC	Load-frequency control
MOL	Merit Order List
mFRR	Manual Frequency Restoration Reserves
NRA	National Regulatory Authority
SA	Schedule Activated
SOGL	System Operations Guidelines
TenneT NL	TenneT TSO B.V.
TSO	Transmission System Operator
TTRF	Time to restore frequency
XB	Cross-border