2018 IEEE 59th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON)

Exploring potential benefits and challenges of European Balancing market: literature review

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***Abstract*— The European balancing market is changing – from national and regional cooperation it has reached the European cooperation level, and common balancing services platforms are being developed according the requirements set in EU legislation. As such cooperation is new experience for all involved stakeholders, it has huge research potential to analyze the benefits and drawbacks of such market integration. This paper presents a literature review from previously conducted studies on potential benefits of cooperation in balancing services exchange. The brief overview and the main principles of the European mFRR platform are given. The main challenges and risks that play a role in the design of the ongoing mFRR platform development are identified and discussed, recommendations for further research are given.**

Keywords — balancing market, frequency restoration reserve, power system balancing, electricity market design

I. Introduction

In a power system, demand should equal supply at all times and each TSO is responsible for the real-time balance in its control area, the balancing mechanism is in place to manage this process. Balancing of the power system is becoming more challenging, as the large, conventional, controllable generation is gradually replaced with distributed, intermittent generation, which leads to higher volatility and decrease of flexibility sources. The need for balancing services is increasing, and it might cause also the price rise and potential operational security risks, if resources are limited within each country's borders.

Currently, the European balancing markets are undergoing the structural changes, as balancing requires more efficient approach, better coordination among transmission system operators (TSOs) and harmonized market model. The Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing [1] (hereafter - Regulation) foresees the integration of the markets for balancing services, focusing on increasing cross-border competition and the overall efficiency of the European balancing system, while ensuring the security of supply, therefore increasing the competition, creating the level playing field and lowering the prices of balancing services. This market serves the purpose to secure economically efficient purchase and in time activation of regulation energy by simultaneously ensuring the financial neutrality of the TSOs. The Regulation requires a certain level of harmonization in both technical requirements and market rules and aligning the key elements such as balancing products, balancing energy pricing and imbalance pricing, which are considered as prerequisites before the markets can be fully integrated, this requires close cooperation of the TSOs on regional and European level. The roles and responsibilities of TSOs, balance service providers (BSPs) and balance responsible parties (BRPs) also need to be harmonized to a large degree to achieve a level playing field for competition in different Member States.

All involved stakeholders are understandably interested to know the size of the benefits of balancing market integration, as market design changes and new IT platform implementations are costly, and for each country could reach tens of millions of euros, therefore we provide general overview on potential benefits of balancing market integration based on available researches, although on the other hand there is no comparable implementation cost estimation to draw relevant conclusions.

The paper concerns very important and current problems in electricity balancing market and its design challenges, as the proper design is extremely important for system operation security and on the other hand provides right market signals and potentially brings financial benefits for market participants. Previous studies cover smaller scale pilot projects and cooperation assumptions, therefore main contribution of this paper is to give brief overview on the current European balancing market development and emphasize the main challenges of such cooperation, which requires further research and analysis. The focus of this paper is available literature review on the given topic, which, currently is quite limited.

In Section II we give brief overview on potential benefits of balancing markets cooperation, based on previously conducted researches. Section III provides general overview on balancing market processes in Europe, while Section IV provides main challenges in the mFRR platform design. Section V gives conclusions of this work.

II. Potential cooperation benefits

In this section we describe the potential benefits of cross-border cooperation in balancing markets.

In literature it can be found that cross border integration of balancing markets provides substantial benefits and increases social welfare, as larger regions reduce the overall demand for balancing and reduce costs for providing balancing services through a broader portfolio of power plants and additional sources for balancing services, and the gains exceed the costs of implementation [2, 3].

The simplest benefit to be gained is the netting of imbalances, in which one side of the border is in deficit and the other side in surplus, so that together they can reduce imbalances on each side. The other obvious benefit is to be derived from procuring

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balancing energy from abroad when it is cheaper. The study [4] found that annual benefits from balancing energy trade between GB and France are potentially of the order of €51 million. The estimated annual savings of integrating the Nordic countries are approximately €221 million compared to individual "stand alone" balancing. In total, balancing benefits estimate might be €1.3 billion/yr or could be as large as €2.7 billion/yr, with proportionate interconnector scaling [4].

Some studies estimate that integration of balancing markets and the exchanging and sharing of reserves could achieve operational cost savings in the order of €3billion/yr and reduced (up to 40% less) requirements for reserve capacity [3]. Thus, for a total electricity consumption of around 3800 TWh per year by 2030, the potential benefits represent nearly €1/MWh, while other authors claim that integrating balancing markets only present modest gains (€0.1/MWh) [5].

As other benefits, in example of Northern Europe integration study it is identified that system-wide regulating reserve procurement, reduces the necessary redispatch by 40%. The activation of regulating reserves can be reduced by 25% due to system-wide netting of imbalances. The socio-economic benefit of procuring regulating reserves and exchanging balancing energy system-wide, depends on the costs of the regulating reserves. The results show a socio economic benefit of 60–80 million euro per year in reserve procurement and 40–50 million euro per year in system balancing [6]. Similar conclusions are drawn in [7], where the total annual saving is €399 million for both the procurement and the activation of reserves.

The study of cooperation between Baltic and Nordic balancing (mFRR) markets highlight as benefits of such cooperation the higher competition, more robust market to manage deviations in supply and interconnectors, more effective available mFRR resources usage, therefore enhancing the security of supply, and more efficient use of transmission capacity, enabling to even the balancing energy prices and create harmonized conditions for market participants and optimization of power system balancing while avoiding opposite balancing between the separate balancing areas and power systems [8].

The study of pooling the four German control areas into one single control area has also shown that major efficiency gains can be achieved. In particular, three sources of potential cost reductions were identified: less procurement of balancing power, a reduction of activated balancing power and more efficient auctions. In particular study, by netting the area imbalances and by pooling all reserve bids, cost reductions of 162.70 million euro were computed [9]. In addition, studies about so called "German paradox" argue that increasing energy production from VRE did not necessarily require an increase in demand for balancing power [10].

All reviewed studies and reports show, that expansion of the cooperation from national and regional markets towards other European countries is possible and potentially is beneficial to all parties in terms of financial savings and more efficient usage of balancing resources due to imbalance netting. This leads to a logical outcome of common European balancing market platforms, grounded in EU legislation and potentially is beneficial for all involved parties.

III. General overview of balancing processes in Europe

A. Balancing process

Balancing in Europe is organized in up to five steps by using frequency containment reserves (FCR), imbalance netting (IN), frequency restoration reserves with automatic activation (aFRR), frequency restoration reserves with manual activation mFRR and optional replacement reserves (RR) (Fig1.).

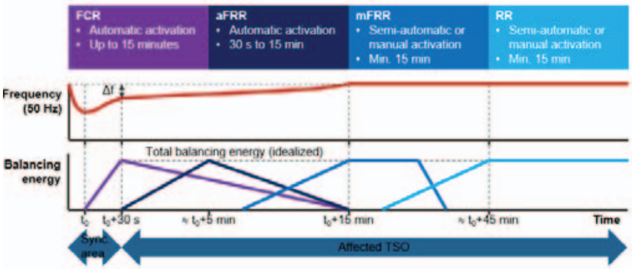

Fig.1. Balancing qualities according to activation time (without imbalance netting). Source: ENTSO-E

The FCR process stabilizes the frequency after the disturbance at a steady-state value within the permissible Maximum Steady-State Frequency Deviation by a joint action of FCR within the whole Synchronous Area. The Frequency Restoration Process (aFRR and mFRR) controls the frequency towards its Setpoint value by activation of FRR and replaces the activated FCR. The RR process replaces the activated FRR and/or supports the FRR activation by activation of RR. The common European platforms for the imbalance netting (IN) process, exchange of balancing energy from aFRR, mFRR and RR are being developed to harmonise the processes in Europe. As processes and structure of these platforms are relatively similar, further on we take a closer look on one of them – mFRR platform.

B. Standard product

In order to facilitate the exchange of balancing energy across borders, the Regulation requires to define a set of standard products for RR, aFRR and mFRR (for direct and scheduled activation) to be exchanged using pan-European platforms (fig.2.).

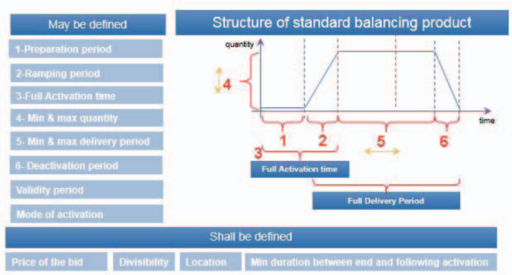

Fig. 2: Characteristics of standard product. Source: ENTSO-E

The list of standard products may set out at least the following characteristics of a standard product bid: (1) preparation period, (2) ramping period, (3) full activation time, (4) minimum and maximum quantity, (5) minimum and maximum duration of delivery period, (6) deactivation period, validity period and the mode of activation. The list of standard products shall set out at least the following variable characteristics of a standard product to be determined by the BSPs: the price of a bid, its divisibility, location and minimal duration between the end of one activation and the following one.

C. European mFRR balancing energy platform

The development of the mFRR platform is organized by the involved TSOs via the implementation project MARI (Manually Activated Reserves Initiative), which aims to implement and make operational the European platform, where all standard mFRR balancing energy product bids shall be submitted and the exchange of balancing energy from mFRR shall be performed [11]. The process is based on the TSO-TSO model, where market participants provide their mFRR balancing energy bids to the TSOs, which, consequently provides received mFRR bids, the available cross-border capacity and its TSO mFRR need (if any) to the mFRR platform. The activation optimization function performs the mFRR market clearing and chooses the mFRR balancing energy bids to be activated to satisfy the mFRR need. The full process of mFRR activation through platform is organized as follows (Fig.3):

1. TSOs receive bids from BSPs in their imbalance area;
2. TSOs forward standard mFRR balancing energy product bids to the mFRR platform;
3. TSOs communicate the available cross-zonal capacities (CZC) and any other relevant network constraints as well HVDC constraints;
4. TSOs communicate their mFRR balancing energy demands;
5. Optimization of the clearing of mFRR balancing energy demands against BSPs' bids;
6. Communication of the accepted bids, satisfied demands and prices to the local TSOs as well as the resulting cross-border (XB) schedules;
7. Calculation of the commercial flows between imbalance areas and settlement of the expenditure and revenues between TSOs;
8. Remaining CZC are sent to the TSOs.

As the core of the platform can be considered the activation optimization function algorithm that chooses the most cost efficient mFRR balancing energy bids to be activated in order to meet the TSOs' needs, respecting the technical and economic constraints and considering the possibility of netting TSOs needs.

D. Activation optimisation function

The activation optimization function (AOF) is based on the maximization of the social welfare, and the minimization of manual frequency restoration power exchange on borders which is effective in case the maximization of the social welfare provides multiple optimal solutions.

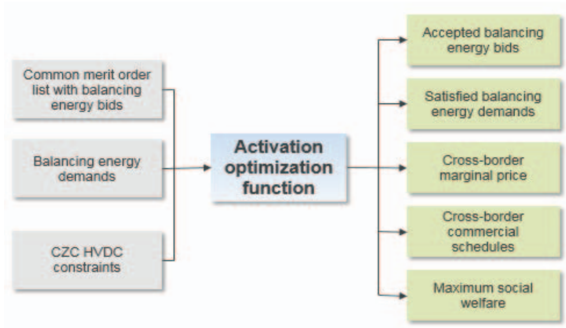

Fig.4. Scheme and outcome of the Activation Optimization Function [11]

A scheme of the optimization model is presented in Fig.4. As illustrated in this figure, the optimization model uses as input the common merit order lists (CMOL) with the balancing energy bids submitted by the BSPs, the balancing energy demands submitted by the TSOs, as well as network information, i.e. cross-zonal capacities (CZC) or HVDC constraints. The AOF creates a cost curve consisting of the TSO balancing energy demands and the CMOLs of all bids, and based on this curve as well as on all defined constraints, it provides the optimal social welfare (see fig.5), the satisfied demands, the accepted bids, the cross-border marginal prices

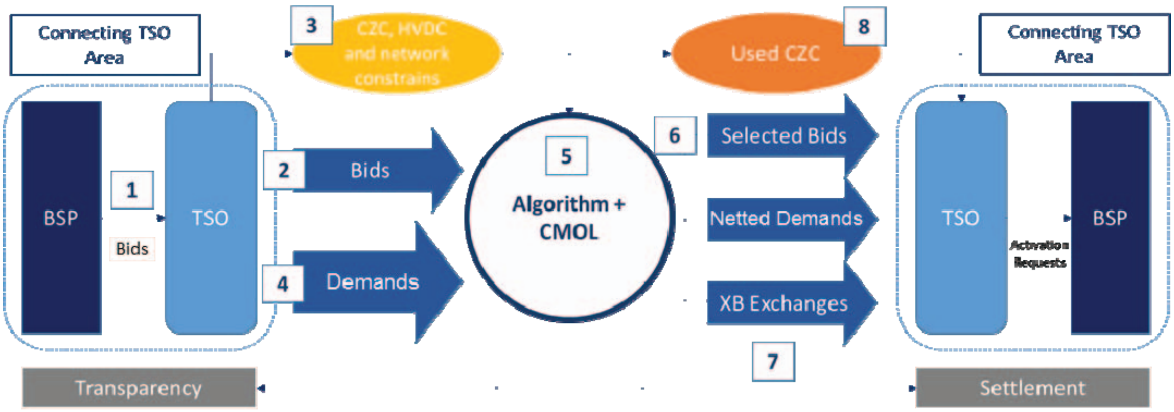

Fig.3. General Process of mFRR Activation [11]

and the cross-border commercial schedules [11].

IV. Main mFRR platform market design challenges

Some in previous years made studies [12], [13], [14], [15], [16] identify already several balancing market design challenges, provide different design variables and balancing market performance criteria, and suggestions to policy makers on balancing market design, based on some national and regional TSOs cooperation assumptions. However, currently European balancing market is already in the development phase, the balancing market design issues and challenges have reached more detailed level and several design options are already proposed for review and feedback of market participants and involved stakeholders through public consultations [17], [11]. Therefore, we provide brief overview of the current challenges that concerns products and processes, AOF algorithm, settlement, several constraints, and harmonization, that in our opinion should be emphasized and carefully analyzed further in mFRR platform development phases.

A. Products and processes

a) Bid Linking

There is possibility to link bids for economic reasons and for technical reasons:

- Technical linking: links between bids in consecutive quarter-hours needed to avoid the underlying asset of a bid being activated twice;
- Economical linking: links between bids with the purpose of economic optimization, allowing BSPs to offer more flexibility and to maximize the opportunity of being activated.

The mFRR platform currently considers two types of "smart bids":

- Linked bid orders: the acceptance of a subsequent bid (child) can be made dependent on the acceptance of the preceding bids (parent);
- Exclusive group orders: only one bid can be accepted from a list of mutually exclusive bids.

"Smart bids" could allow BSPs to offer more flexibility, maximize the opportunity to be activated by fitting with TSO needs, reduce costs of balancing, reduce counter activations and contribute to an efficient and competitive balancing market. The links between bids in different consecutive imbalance settlement periods are needed to avoid infeasible overlapping activations of the same bid. However smart bids generate complexity for the algorithms of the different activation optimization functions, prolong the computation time and system costs, therefore further analysis is needed on added value they generate (flexibility, lower costs etc.) as well as exploring the possibilities of linking bids between different platforms. There should be limits to the possibilities of linking (e.g. maximum number of linked bids). A methodology to link bids over different imbalance settlement periods in order to avoid overlapping activation of the same bid in different imbalance settlement periods (i.e. linking for technical reasons) is required.

b) Divisibility of bids

Divisibility refers to a parameter of the bid specifying whether the bid can be partially activated or not. Most TSOs allow indivisible bids, however some limits inside the mFRR platform should be set. Divisibility options in power volume are following:

- divisible,
- divisible with a technical minimum that has to be activated,
- indivisible (the total bid has to be either fully activated or not at all activated).

The not allowing the indivisible bids might lower the market liquidity, however on the other side allowing them might incentivize market abuse, deviations from actual TSOs needs and not incentivize BSPs to be more flexible. Therefore, a compromise should be found, that limits maximum indivisible bid size and creates specific products to allow for a relatively low number of specific units with a higher size to still participate in the market. Also the firmness and reliability of the bids shall be ensured.

c) TSO balancing need

The TSO balancing need is related to the operational security. A TSO may have a larger balancing need than the bids made available for the platform, therefore in a non-emergency situation balancing needs exceeding the volume of submitted bids should be limited or restricted as proposed in [17].
A TSO can balance their area with several balancing products. When the TSO has alternative measures to manage an imbalance, the ability to specify a limit on the price will remove uncertainties and allow the TSO to utilize available resources cost efficiently. It may also lead to more needs submitted to the platform, since it removes the incentive for the TSO not to submit needs due to the expectation of alternative measures being less costly. Therefore, mFRR platform will take the possibility of elastic demands and include into design the price dependencies:

- Inelastic: not priced (the volume is absolutely required by the TSO);
- Elastic: One or more request levels with volume and max/min price they are willing to accept for up-/down activation.

If the TSO is using proactive balancing strategy, they base their needs on imbalance forecasts and can submit their needs in advance, or use different solutions, therefore reducing the balancing costs. Contrary, TSOs using reactive balancing strategy, will pay higher (any) price in inelastic demand case, if no other solution is available within their decision perimeter, or if the realization of imbalance is certain (such as in the case of outages). These situations have been taken into account through the concept of elastic needs for the scheduled activations. Any TSO can submit an elastic demand that reflects the price they are ready to pay on the platform, regarding the cost of the available alternative solutions and its expectation of the demand and therefore its risk exposure on the demand uncertainty. The elastic demand concept is expected to increase the mFRR needs volume submitted by TSOs to be satisfied through the mFRR platform, since it will allow TSOs to better consider the uncertainty of the imbalance and the alternative solutions within their decision perimeter. For direct activation, only inelastic needs are allowed, since direct activation is expected to be used in the case of outages, when the imbalances are certain and balancing energy is needed as soon as possible.

B. Algorithm

There are possible two types of activation - direct activation and scheduled activation. Direct activation in continuous manner implies fast running algorithm and immediate activation, whenever demand is submitted to platform. There are several risks that direct activation in a continuous manner might exceed the required time limits (15min) from submission of a need until bid is fully activated due to following factors:

- the management of HVDC cables will require a delay from one activation until the next one;
- direct activation is directly influenced by the communication times (TSO-mFRR platform and TSO-BSP information exchange);
- due to significant data amount and constant CZC and bid availability updates, the significant computation time of the algorithm will affect the frequency of direct activations and cause additional waiting time. In addition, fast-performing data processing might significantly raise the costs of foreseen mFRR platform.

As an alternative [17] propose direct activations in cycles, which allow bids and needs to be gathered and optimized with respect to network constraints and netting possibilities, although there is no clear proposal on the cycle length. Such solution might ease the algorithm and computation time, however it might raise the system operation security risks, as it will involve waiting time until the need is proceed, however in some cases, like N-1 incidents, TSOs need to resolve large imbalances within short time and need to have the ability to activate mFRR bids at any point in time.

Furthermore, in [17] TSOs discuss several principles of the optimization algorithm which are related to the efficiency of the algorithm in terms of TSO need satisfaction, optimal usage of available transmission capacity and resulting cross-border mFRR flows, balancing costs efficiency and mFRR balancing energy prices formation, but also to the complexity of the algorithm. Such principles are:

a) Economic Objective of the algorithm: Social Welfare Maximization (Fig. 5).
b) Optimization algorithm in 1 or 2 optimization steps for the schedule activation:
    - One step approach: netting of TSO needs and activation of cost-efficient mFRR bids at the same time, considering the upward TSO mFRR needs, the downward TSO mFRR bids the downward TSO mFRR needs and upward mFRR bids at the same time.
    - Two steps approach: first step netting of TSO needs; second step activation of cost-efficient mFRR bids separately for upward and downward regulation.
c) Scheduled counteractivations: In one step optimization, depending on the mFRR bids prices, there may be cases that mFRR bids in opposite directions can be matched for increasing the social welfare.
d) Direct activation: upward and downward demands are satisfied separately, i.e. the bids of only one direction together with the respective TSO needs are inputted to the algorithm.

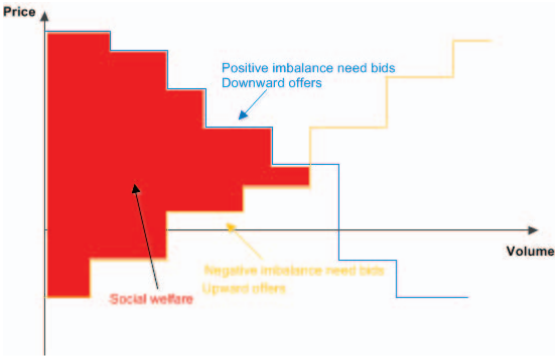

Fig. 5: Social Welfare maximization in mFRR platform

Social welfare in the context of AOF means, the total surplus of the participating TSOs that is obtained from satisfying their mFRR demand submitted to the mFRR Platform and the total surplus of BSPs resulting from the activation of their associated submitted standard mFRR balancing energy product bids.

C. Settlement

It is proposed to use cross-border marginal price between TSOs in the mFRR platform. The cross border marginal price is the price of the last bid of the mFRR standard product which has been activated to cover the energy need for balancing purposes within an uncongested area. Therefore, it defines the value where the selling curve and the buying curve meet. Differences in prices occur in congested situations. As settlement is very broad topic, it is not further evaluated in this paper, however it has a great influence on mFRR platform design as it involves the financial outcomes of the involved stakeholders and requires more detailed analysis.

D. Congestion management and constraints

Constraints are the criteria and conditions that must be respected by the algorithm.

a) Power Balance Constraints

In the power balance constraint, netting of the TSO demands inherently occurs. The netting of the TSO demands occurs as long as it results in a higher social welfare and it does respect other technical constraints, e.g. power flow constraints. The total activated upward bids and satisfied negative demands must be equal to the total activated downward bids and satisfied positive demands.

b) HVDC Constraints

HVDC constraints means that there are limits on the power that could flow through HVDC lines. However, the losses in HVDC lines shall be considered. The HVDC losses as well as HVDC dynamic constraints shall also be considered in the algorithm. Because of HVDC losses, for each settlement period, the energy volume sent from an exporting area A may differ from the received energy in the importing area B. This will also have an impact on the prices, and hence there will be a price difference between these two areas.

c) Power Flow Constraints

The power flow constraints guarantee that the accepted offers respect the transmission capacity limits set by the TSOs.

All constraints shall be respected and included in the algorithm, as they have great influence on power system operation security.

E. Harmonization

Harmonization of balancing market arrangements across Europe is a very challenging task, considering the variety of different balancing energy products and balancing market rules. It is essential that all involved TSOs harmonize the market design elements that are key to creating a level playing field for balancing market participants. And on the other hand, developers should take into account the national market specifics to a certain level.

CONCLUSIONS

From literature review we conclude that cross border integration of balancing markets potentially can bring financial benefits, increase social welfare, use balancing resources more efficiently and contribute to the power system operation security. However, due to lack of information about the costs of European mFRR platform (and other balancing services platforms) implementation, and potential losses of the areas with cheap balancing energy resources, it is hard to evaluate the net financial benefits and platform pay-back time (if any). In our view the financial aspects become secondary, and at the first place the cooperation should be seen as beneficial from market development and improved system operation aspects.

From the identified mFRR platform design challenges we conclude that further analytical analysis is needed to evaluate and choose the potentially most beneficial balancing market design options to gain maximum social welfare and simultaneously contribute to the more efficient power system operation. This paper functions as a foundation for a further research towards design of balancing services markets and provides the basis for our next detailed research step towards evaluating and solving the mentioned in this paper challenges.

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https://doi.org/10.1109/RTUCON.2018.8659855

Electronic ISBN: 978-1-5386-6903-7.

USB ISBN: 978-1-5386-6902-0.

Print on Demand (PoD) ISBN: 978-1-5386-6904-4.