Market response for real-time energy balancing – Evidence from three countries

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***Abstract* — This paper highlights and evaluates different approaches how market response is incentivized by local balancing market design to support real-time balancing of electrical energy within an ongoing imbalance settlement period, also known as "passive balancing". Data from the control blocks of the Netherlands, Belgium and Germany are analyzed and the behavior of market parties is evaluated.**

Even though the three countries pursue similar power balancing strategies for the activation of balancing reserves and cost allocation, the incentives for market parties to support transmission system operators in balancing the control block differs. The highest degree of supported market response is found in the Dutch system with real-time publication of imbalance prices, followed by the Belgian system publishing only activated reserves. The German balancing market design does not explicitly incentivize market response for energy balancing in real-time.

***Index Terms* — Passive Balancing, Power Balancing Market Design, EU Regulation**

I. Introduction

The tendency that optimizing dispatch of electric power moves closer to real-time is founded in the transition to fluctuating renewable energies and resulting demand for schedule adaptations. Gate Closure Time (GCT) of intra-day and balancing markets moves closer to the imbalance settlement period (ISP), as an obvious indicator of this development. For some European balancing markets, real-time balancing becomes ever more an interactive task between Transmission System Operators (TSOs) and balance responsible parties (BRPs), where balancing energy prices are supposed to reflect scarcity in real-time to incentivize system supporting behavior by all BRPs besides only activating explicit qualified balancing service providers (BSPs).

The comparison is motivated by the commission regulation, which established a "guideline on electricity balancing" (EBGL) to set the course for harmonized European balancing markets. Amongst other claims, the EBGL aims "to provide incentives for market participants to contribute to solving the system scarcities for which they are responsible" and "efficient balancing rules should be developed" accordingly (EBGL Article (3), [1]). This work aims to research which design parameters are effective to let market participants contribute to solve system scarcities within an ongoing ISP. Therefore this paper is organized as follows. Section II describes the applied analysis method. Section III compares national approaches of how real-time energy balancing and market response is dealt with. In Section IV, results of the data analysis are presented. Section V identifies key market design parameters for efficient market response. Section VI concludes main findings of this paper.

II. Method

The applied method starts with a qualitative comparison of national balancing markets and to which extent market response is incentivized to support the balancing process. The performance of the different approaches is evaluated in a second step by analyzing historical data of the Area Control Error (ACE) and activation of balancing energy from Frequency Restoration Reserves. Goal is to investigate benefits and risks of market response to support real-time energy balancing for TSOs.

A. Comparison of national balancing markets

The balancing market design of the countries The Netherlands (NL), Belgium (BE), and Germany (DE) is compared and evaluated. Investigated design parameters are (i) real-time information, granularity and delay, (ii) settlement of TSO-BSP (metered vs. requested) and (iii) settlement of TSO-BRP (single vs. dual imbalance price).

B. Evaluation of data

Public data from the year 2017 is evaluated. In order to benchmark performance of the different approaches, the mean values (μ) and standard deviation (σ) of ACE and activated balancing energy from automatic Frequency Restoration Reserves (aFRR) and manual Frequency Restoration Reserves (mFRR) are compared. Results are scaled according to local

This paper was developed within the project NEW 4.0 (North German Energy Transition 4.0) which is partly funded by the German Federal Ministry for Economic Affairs and Energy (BMWI). *(sponsors)*

electrical energy consumption. Additionally, occurrence of ISPs with activation of both upward and downward balancing energy within one ISP, so-called “counter-activations”, is evaluated.

III. Balancing and Market Response

Conventionally, the balancing process is described in two separate steps. (A.) BRPs plan their dispatch according to trades and submit their schedules to the TSOs. The schedules have a granularity of 15 minutes, corresponding to the length of an ISP. (B.) By default, this leads to power deviations between load and generation in real-time. The TSOs perform physical power balancing to counterbalance these deviations (MW). Furthermore, energy deviations (MWh) of BRPs over an ISP are also compensated by the responsible TSO. (C.) Market response for real-time energy balancing describes the interaction of these two steps. Table 1 gives an overview of relevant parameters in the three control blocks.

A. Energy balancing and schedules

Sell and buy orders define the price for electrical energy at different electricity markets (futures, day-ahead, intra-day). BRPs are financially responsible for any energy deviation between submitted schedule and actual dispatch for each ISP. Any deviation is settled and results in an imbalance price. Since all three countries apply in general a single imbalance pricing mechanism, BRPs deviating in the system supporting direction will receive the imbalance price. Germany applies a pure single imbalance price. Belgium applies a dual imbalance price, but the difference in imbalance price between the short position and long position is negligible which means that BRPs with system supporting imbalance can be rewarded. The Netherlands apply in general a single imbalance pricing mechanism, but in case of counter-activations a dual imbalance pricing mechanism is applied, to control and limit market response.

B. Power balancing

The TSOs in the Netherlands, Belgium and Germany pursue similar balancing strategies and use mainly aFRR from a merit order list to counterbalance power imbalances. Activation of balancing reserves leads to costs, channeled to BRPs via the imbalance price. The Netherlands and Germany apply merit order activation of reserves, while Belgium applies pro rata activation. In the Netherlands all called BSPs are rewarded based on request with a marginal price, and the imbalance price is equal to that marginal price (price based). Germany and Belgium apply pay-as-bid for activated reserves resulting in an average price for imbalances (volume based) that is deviated from all costs and available ex post. German BSPs are settled based on measured values.

C. Market response for real-time energy balancing

BRPs can use their assets to support the balancing process the moment it creates a beneficial deviation from their schedule as a consequence of the single imbalance price. By supporting balancing, BRPs can minimize risk and costs and/or maximize revenues, if system information like activated reserves and/or imbalance price is available.

The Netherlands apply the most transparent balancing process. Activated reserves and the imbalance price of the Dutch control block are published real-time with a resolution of one minute and a delay of two to four minutes within each ongoing ISP. Thus, market participants can adjust their dispatch according to this real-time incentive and consequently help balancing the control block. Belgium publishes only activated reserves in real-time, also with a one-minute resolution and delay. The imbalance price is published every 15 minutes at the end of the ISP. German regulation does not foresee active market response in real-time and schedule deviations are not explicitly incentivized. Therefore no real-time information is published.

D. Potential implications of active market response

Besides pure balancing advantages, it must be noted that an active real-time market response also includes some potential implications. These are the necessity of effective price signals based on the prices of balancing energy bids. Furthermore, a strong internal network is required in order to facilitate different flows induced by deviating dispatch. Thirdly, real-time market response remains a voluntary action and TSOs cannot rely on this support likewise from explicit activated BSPs.

TABLE I. Comparison of design parameter in NL, BE and DE.

Design parameter	**Country**		
	The Netherlands	***Belgium***	***Germany***
(i) Real-time information for market response[a,b]	Activated reserves and marginal price in 1 min resolution, delay of 2 - 4 min	Activated reserves in 1 min resolution, delay of 2 - 4 min	No public real-time information
(ii) TSO-BSP settlement and activation of aFRR[c]	Marginal price, merit order activation Full activation time: 15 min	Pay-as-bid, pro-rata activation Full activation time: 7.5 min	Pay-as-bid, merit order activation Full activation time: 5 min
(iii) TSO-BRP and imbalance price settlement[d]	Mainly single and occasionally dual imbalance price Marginal Control Energy Price	Dual imbalance price (differences neglibible) Average Control Energy Price	Single imbalance price Average Control Energy Price

a. https://www.tennet.org/english/operational_management/System_data_relating_implementation/system_balance_information/BalansDeltawithPrices.aspx#PanelTabTable [2]

b. https://www.elia.be/en/grid-data/balancing/current-system-imbalance [3] c. E-Bridge 2016, p.11 [4] d. WGAS Survey 2018, p. 122 [5]

IV. Data Analysis

Table II shows the results of the data analysis. Consumption of electrical energy in the three counties was used to scale the ACE, activated aFRR and activated mFRR accordingly. The μ of the scaled ACE in the Netherlands and Belgium are in a similar range between 2 to 3 MWh imbalance per GWh consumption, while Germany faced μ of 1.6 MWh imbalance per GWh consumption. The σ of 3.3 MWh per GWh consumption shows that the Dutch system was in general the most concentrated around a balanced position, followed by Germany with σ of 6.9 MWh per GWh consumption and Belgium with σ of 15.7 MWh per GWh consumption..

TABLE II. Data Analysis of the Balancing Performance in 2017

Data from 2017[a,b]	**Control Block of**		
	The Netherlands	***Belgium***	***Germany***
Energy consumption	115.4 TWh in total μ = 3 293 MWh per ISP	84.8 TWh in total μ = 2 408 MWh per ISP	538.7 TWh in total μ = 15 373 MWh per ISP
Area Control Error (ACE)	μ = 9.5 MWh per ISP σ = 10.9 MWh per ISP	μ = 5.8 MWh per ISP σ = 37.9 MWh per ISP	μ = 24.9 MWh per ISP σ = 106.3 MWh per ISP
ACE scaled to local energy consumption	μ = 2.88 MWh per GWh cons. σ = 3.31 MWh per GWh cons.	μ = 2.41 MWh per GWh cons. σ = 15.73 MWh per GWh cons.	μ = 1.62 MWh per GWh cons. σ = 6.91 MWh per GWh cons.
Counter-activations of aFRR upward and downward	Occurrence in 9.1 % of all ISPs	Occurrence in 66.8 % of all ISPs	Occurrence in 97.3 % of all ISPs
Activation of aFRR upward or downward	Occurrence in 71.4 % of all ISPs	Occurrence in 29.2 % of all ISPs	Occurrence in 2.7 % of all ISPs
No activation of aFRR	Occurrence in 19.5 % of all ISPs	Occurrence in 4.0 % of all ISPs	Occurrence in 0.0 % of all ISPs
Activated aFRR upward	μ = 5.9 MWh per ISP σ = 13.0 MWh per ISP	μ = 11.6 MWh per ISP σ = 13.3 MWh per ISP	μ = 107.5 MWh per ISP σ = 183.6 MWh per ISP
Activated aFRR upward scaled to local energy consumption	μ = 1.79 MWh per GWh cons. σ = 3.95 MWh per GWh cons.	μ = 4.82 MWh per GWh cons. σ = 5.52 MWh per GWh cons.	μ = 6.99 MWh per GWh cons. σ = 11.94 MWh per GWh cons.
Activated aFRR downward	μ = 7.6 MWh per ISP σ = 13.9 MWh per ISP	μ = 15.0 MWh per ISP σ = 15.0 MWh per ISP	μ = 100.7 MWh per ISP σ = 177.4 MWh per ISP
Activated aFRR downward scaled to local energy consumption	μ = 2.31 MWh per GWh cons. σ = 4.22 MWh per GWh cons.	μ = 6.23 MWh per GWh cons. σ = 6.23 MWh per GWh cons.	μ = 6.55 MWh per GWh cons. σ = 11.54 MWh per GWh cons.
Activated mFRR upward	μ = 0.0 MWh per ISP σ = 0.7 MWh per ISP	μ = 2.6 MWh per ISP σ = 12.2 MWh per ISP	μ = 15.3 MWh per ISP σ = 92.9 MWh per ISP
Activated mFRR upward scaled to local energy consumption	μ = 0.00 MWh per GWh cons. σ = 0.21 MWh per GWh cons.	μ = 1.08 MWh per GWh cons. σ = 5.07 MWh per GWh cons.	μ = 1.00 MWh per GWh cons. σ = 6.04 MWh per GWh cons.
Activated mFRR downward	μ = 0.0 MWh per ISP σ = 0.3 MWh per ISP	μ = 2.0 MWh per ISP σ = 9.6 MWh per ISP	μ = 8.1 MWh per ISP σ = 69.0 MWh per ISP
Activated mFRR downward scaled to local energy consumption	μ = 0.01 MWh per GWh cons. σ = 0.09 MWh per GWh cons.	μ = 0.91 MWh per GWh cons. σ = 3.99 MWh per GWh cons.	μ = 0.53 MWh per GWh cons. σ = 4.49 MWh per GWh cons.

a. ENTSO-E Statistical Factsheet 2017 [6] b.Data from ENTSO-E Transparency platform, https://transparency.entsoe.eu/ [7]

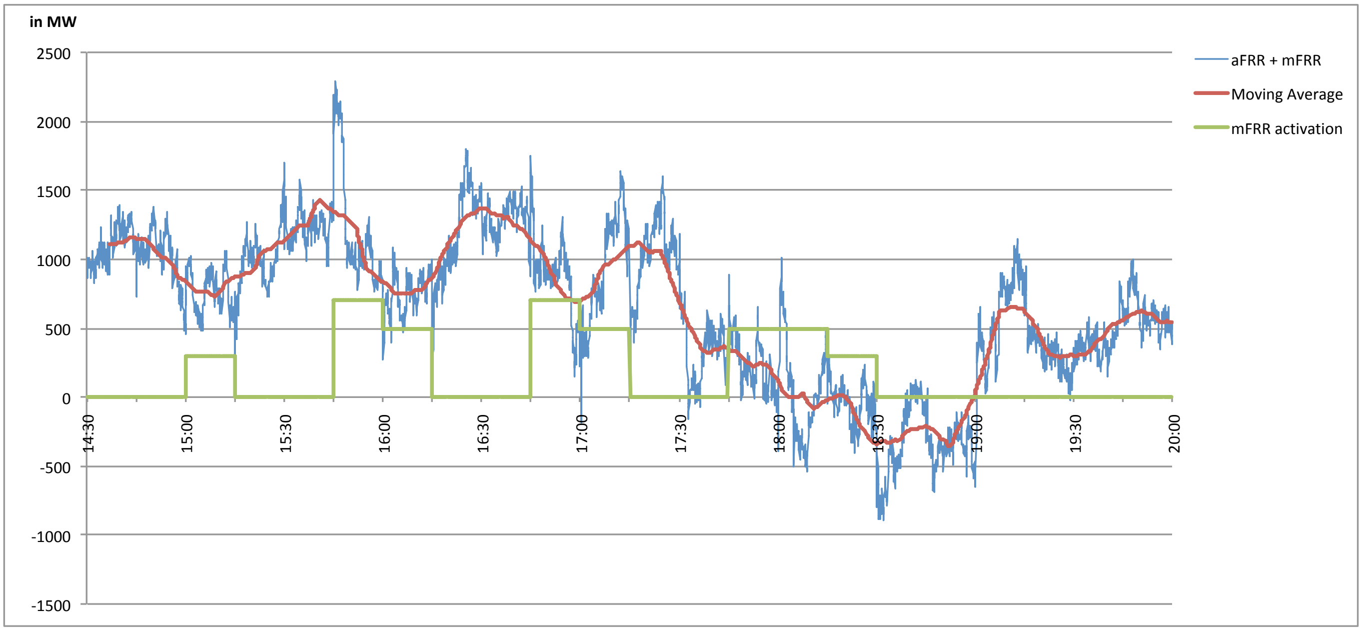

FIGURE I. EVIDENCE OF MARKET RESPONSE TO ACTIVATION OF MFRR IN GERMANY, DATA FROM TENNET TSO GMBH.

Consistent with the ACE, also the scaled activation of all reserve types is comparatively small in the Netherlands. Germany was confronted with the highest scaled activation of aFRR upward and downward, followed by Belgium. Remarkable is the activation of mFRR in the Netherlands, which is close to zero. The low demand for mFRR in the Netherlands indicates a well functioning market response, as the system imbalance is real-time compensated by market response reducing need for high volumes of reserves. Thus, solving system scarcity with schedule deviations seems to be beneficial for the BRPs in the Netherlands and makes mFRR only a tool for scarce system needs. This occurrence is a strong indication that market response is apparently a cost-effective market-based measure for balancing market designs to support real-time power balancing.

The scaled μ of activated mFRR upward and downward in Belgium is slightly higher than in Germany, but the σ is higher in Germany. Apparently, the missing price component in Belgium leads to less effective market response than in the Netherlands, as the comparatively high demand for mFRR indicates. Inquiry at market parties confirms this observation.

Occasionally, some German BRPs respond to system scarcity, even though the German system does not foresee it. Figure I shows that the demand for reserves declines after activation of mFRR which can be explained by market response. The call for mFRR activation is transmitted to the executing BSPs latest 7.5 minutes before the beginning of an ISP and in principle only known by the TSOs and the called BSPs [8]. Nevertheless, the presented evidence shows three cycles of an oscillation between mFRR activation of 300 to 700 MW and market response of roughly several hundreds of MWs in addition. The first call for mFRR activation is submitted between 14.45 and 14.52´30s for the ISP starting at 15 hrs. The demand for reserves starts declining during that time window. The same pattern can be observed before the ISPs starting at 15.45 and 17.45 hrs. The activation signal of mFRR leads to a financial incentive for dispatch deviations and is known by some market parties and in this particular example has led to a system supporting behavior.

Where the Dutch system experiences counter-activations in only 9.1 % of all ISPs and 66.8 % of all ISPs in Belgium, Germany experienced this in 97.3 % of all ISPs. Nevertheless, for the German case, these results are somehow misleading, since the aFRR balancing energy activation in the counter direction quite often relates to very small volumes. Table III shows how the share of ISPs with counter-activations in Germany decreases when neglecting a rising amount of aFRR balancing energy activation.

TABLE III. COUNTER-ACTIVATIONS IN GERMANY.

Data from 2017[a]	**Neglect aFRR activation of**					
	1 MWh	***2 MWh***	***3 MWh***	***4 MWh***	***5 MWh***	***10 MWh***
ISPs with counter-activations	83 %	68 %	56 %	49 %	43 %	26 %

a. Data from ENTSO-E Transparency platform, https://transparency.entsoe.eu/ [7]

The high share of ISPs with rather small aFRR counter-activation in Germany results mainly from German BSPs with aFRR delivery without TSO aFRR activation request, and settlement based on measured values (with tolerance band) instead of request settlement. In this case, the small amount of aFRR activation does not relate to a physical need of balancing energy and should be disregarded when analyzing German data of balancing energy activation from aFRR and counter-activation influencing real-time price incentives.

In addition, the Netherlands experienced 19.5 % of all ISPs without aFRR activation at all. This circumstance occurred in 4.0 % of all ISPs in Belgium and in 0.0 % of all ISPs in Germany. This occurrence is only possible because of the International Grid Control Cooperation (IGCC) that performs imbalance netting between the control blocks of Austria, Belgium, Switzerland, Czech Republic, Germany, Denmark, France and the Netherlands [9]. IGCC is an optimization system for the avoidance of counter-activation of aFRR between countries, respecting available cross-zonal capacity.

V. Efficient market response for energy balancing

The Dutch TSO supports market response with information about power scarcity and costs. BRPs can evaluate their marginal costs for deviations from dispatch and compare it to the imbalance price. Additionally, the information about energy scarcity indicates the risk of not being awarded in case of a counter-activation when the dual imbalance price applies. Therefore, BRPs can take data-based decisions resulting in a system supporting market response which made mFRR mainly redundant. An example of the effectiveness of passive balancing in the Dutch power system is elaborated in [10]. High transparency about energy scarcity and costs in combination with a penalization for overreaction results to be the best approach for efficient market response. The low share of ISPs with counter-activation and the low scaled ACE are the benchmarks that indicate the presence of controllable interaction between TSOs balancing efforts and market response without a nervous behaving system.

The Belgian TSO supports market response with information about energy scarcity without prices. Counter-activations are not penalized which might lead to overreaction due to market response. The sign and magnitude of the imbalance price can be derived from the available information, but the market response is limited by the uncertainty about potential revenues.

From the German observation in this work it is concluded that incomplete system information still contributes to participation of market response (passive balancing) due to single imbalance pricing, however the effectiveness and potential is limited. A clear mechanism to prevent overreaction is currently also not provided.

VI. Conclusion

The comparison of the three countries shows evidence that the ACE open loop and resulting activation of Frequency Restoration Reserves decline with a rising degree of transparency that allows market response real-time (passive balancing), subject to correct price incentives. This conclusion is based on the very similar power balancing approaches of the TSOs differing mainly in the transparency about real-time system information. The high occurrence of counter-activations in Belgium and Germany shows potential for improvement. Imperfect information occasionally leads to overreaction of market response, since a pure single price is applied and physics and market incentives are less coherent.

The Dutch approach seems to work best in this case, considering the low occurrence of counter-activations of aFRR upward and downward and, especially, the comparatively small deviation of the scaled ACE. Therefore, an additional mechanism to prevent overreaction of market participants, like the Dutch approach of changing from single to dual price in case of counter-activations, is advisable as a component for an efficient market response in real-time.

The presented evidence in Germany (Figure I) shows some consequences of applying a single imbalance price for schedule deviation without full transparency of system and market information real-time. The appliance of a single imbalance price is inherently the incentive for BRPs to have to a certain degree a system supporting schedule deviation, but they can only react correctly in case of sufficient real-time information. This information consists of (expected) imbalance price as the motivation for market response and TSO's activated reserves as risk management for market response. The majority of potential market response remains inactive due to ambivalent information and financial risks.

These results should be considered when developing common European balancing rules by power balancing TSOs aiming to use the potential of real-time market flexibility in addition to pre-qualified BSPs only. However, it must be noted that networks must be able to facilitate changes in dispatch and balancing energy prices must be correct in order to set efficient incentives. As described, identified design parameters are real-time information granularity and delay, pricing settlement (marginal imbalance pricing, single and dual), aFRR controller set-up, and full activation time of reserves. The effectiveness of market response is strongly determined by the interaction of these design parameters and should be considered as a package deal rather than stand-alone options.

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