Comparison of European power balancing markets – Barriers to integration

Felix Röben
University of applied sciences HAW Hamburg
Competence Center
für Erneuerbare Energien und Energieeffizienz (CC4E)
Hamburg, Germany
felix.roeben@haw-hamburg.de

***Abstract* — The European power balancing markets undergo disruptive changes due to the new European regulations. The commission regulation "establishing a guideline for electricity balancing" (GLEB) gives guidance to integrate markets in Europe. Intermediate harmonization of products for balancing services is scheduled already in 2018.**

The situation for concerned system operators, balance service providers and balance responsible parties in Europe will change. This paper presents an investigation of current differences in national power balancing markets and potential barriers for the integration. A systematic comparison of market designs and reserve controller set-ups with the predefined choices of the upcoming guideline took place. Identified barriers for the harmonization are differences in reserve controller set-ups and activation strategies. The task is to agree on common power balancing products, full activation time of all reserve types, prequalification requirements for service provider and rules for cross-border balancing.

***Index Terms* — EU winter package, European integration, Guideline for Electricity Balancing, NEW 4.0, Power Balancing Markets**

I. INTRODUCTION

This investigation is part of a broad research project on energy systems and markets. An alliance of regulators, industrial partners and universities work together on the transition to renewable energy sources in the project Norddeutsche Energiewende (NEW 4.0). The results of this paper will help developing models to answer identified research questions.

Motivation behind looking at balancing markets is security of electricity supply and cost efficiency. Mainly the latter is reason for the implementation of common markets.

Draft roadmaps for the integration of balancing markets are requested from all system operators latest by end 2019. Intermediate steps of harmonization are scheduled already in 2018 [1]. A profound understanding of the interrelations of market design parameter is crucial for the consultation process. The consideration of potential risks at an early stage is important.

Systematic literature review led to a dataset of applied balancing market designs and controller set-ups in Europe. The systematic review was followed by qualitative evaluation of the measures resulting from the commission regulation "establishing a guideline for electricity balancing" (GLEB).

Section II pictures the applied method. Section III presents the literature review and depicts the ongoing integration of balancing markets. In Section IV, the measures of harmonizing balancing markets are evaluated. Section V identifies barriers for the implementation of common European power balancing markets. Section VI concludes the main findings of this paper.

II. METHOD

The applied method starts with a literature review on the current situation and scheduled integration process. The following data analysis is focusing on technical and financial interrelations. The research question is:

What are barriers for the harmonization of balancing markets and products?

A. Literature review

At first, the current design of national balancing markets and the set-ups of reserve controller are listed and grouped.

The European Network of Transmission System Operators for Electricity (ENTSO-E) is in the scope. This organization represents all European transmission system operators (TSO). Balance responsible parties (BRP) agree on generation and consumption of electricity on spot markets. Prequalified BRP who offer reserve capacity via bids on balancing markets are balance service provider (BSP). National regulators define the legal frame in a country in which TSO, BRP and BSP interact.

NEW 4.0 "North-German transition towards renewable energy", several partners from industry and public institutions work on IT pilot schemes in the federal states Hamburg and Schleswig-Holstein. NEW 4.0 started in December 2016. See www.new4-0.de for details. *(sponsors)*

Data of the ENTSO-E members operating in the following countries is cumulated and considered:

Austria (AT); Belgium (BE); Bosnia and Herzegovina (BA); Croatia (HR); Czech Republic (CZ); Denmark (DK); Estonia (EE); Finland (FI); France (FR); Germany (DE); Greece (GR); Hungary (HU); Ireland (IE); Italy (IT); Latvia (LV); Lithuania (LT); the Netherlands (NL) Norway (NO); Poland (PL); Portugal (PT); Romania (RO); Serbia (RS); Slovak Republic (SK); Slovenia (SI); Spain (ES); Sweden (SE); Switzerland (CH); United Kingdom (UK)

A substantial design frame to describe balancing markets with 23 parameters exists in the literature [2]. A reduced design frame is used, but technical parameters of reserves are highlighted in comparison to the reference model.

B. European regulation

The identification of mandatory actions enacted by the GLEB takes place. The measures are put in the context of an incremental integration process. ENTSO-E proposals are considered.

C. Evaluating difficulty of measures

The scheduled actions are evaluated by their impact on EU member states with a systematic comparison, based on the difficulty of harmonization. The difficulty is rated in a systematic procedure. The procedure takes the number of applied design choices in Europe into account and evaluates the difficulty of reaching a common solution in a qualitative way.

III. REVIEW

In general, the TSOs organize the balancing process, coordinate the markets for balancing products and oversee cost settlement. BSP perform power balancing and the costs for this service are transferred to BRP. National regulators do not play an active role in power balancing, but define the market frame and aim at improving cost efficiency. Besides these relations, the design of markets, products and cost settlement varies among European countries.

A. Transmission System Operator (TSO)

Transmission system operator can be differentiated by their pro-active (DK, FR, UK) or reactive behavior (AT, BE, DE, NL) [4]. Passive balancing is a unique approach in the Dutch TSO. Publishing price signals for the BRP has the potential of cutting costs for balancing energy. Thus, a TSO limits reserve activation by providing BRPs with incentives to have an imbalance being in opposition to the system imbalance [5].

B. Classification of reserve types

The GLEB describes four reserve types: Frequency Containment Reserves (FCR), automatic Frequency Restoration Reserves (aFRR), manual Frequency Restoration Reserves (mFRR) and Replacement Reserves (RR). National balancing markets typically include three reserve types, which will be reassigned to the GLEB reserve types for the integration [1].

C. Gate Closure Time (GCT)

The GCT of markets is the point in time, when the submission or the update of bids is no longer permitted. The merit order list is finalized and the bidders are notified about the results of procurement in a next step. Not awarded reserve capacity bids can be offered on a different market, if the notification takes place before the GCT. Table I gives an overview about applied GCT und upcoming changes.

TABLE I. REVIEW ON GATE CLOSURE TIME (GCT)

Design variable	**Applied designs and evaluation of roadmap**		
	Examples [a]	***GLEB*** [b]	***Pilot Projects*** [c,d]
GCT of intra-day spot market	No intra-day market (Czech Republic, Serbia), 250 minutes (IT), 195 minutes (ES, PT) to 5 minutes (Belgium) [11]	max. 8 hours before real-time (b article 24.5 b)	
GCT of balancing market Capacity FCR	hours (Tschechien, Slovakei, HU, DK, Greece), day (DE, NL, CH, AT) to year (BEL, Irland) (a s. 10)		D-2 15.00 by 26.11.18 and D-1 8.00 by 27.11.2020 (c article 4)
GCT of balancing market aFRR Capacity	day (PG, ES, DE, CH, Finnland, Sweden, Greece) to year (NL, Croatia, Serbia) (a s. 31)	TSO proposal requested by 18.12.2018 (b article 21.1 & 21.3 h)	
GCT of balancing market mFRR Capacity	hour (DE, DK, Tschechien, Slovakei) to year (FR, NL, BEL, Finnland, Croatia etc.) s. 52 entso-e survey (a s. 52)	TSO proposal requested by 18.12.2018 (b article 20.1 & 20.3 h)	
GCT of balancing market RR Capacity	day (ES, GB, CH, Slovakei, HU) to year (Litauen, CR, Serbia) (a s. 76)	TSO proposal requested by 18.06.2018 (b article 19.1 & 19.3 h)	60 to 55 min before period (d article 7)

a. Entso-E survey: Survey on Ancillary services procurement, Balancing market design 2014 (January 2015) [6]; b. EU Commission regulation 2017 establishing a guideline on electricity balancing [1]
c. ENTSO-E Draft Proposal for common rules and processes for exchange and procurement of FCR (January 2018), applied by TSOs of AT, BL, CH, DE, DK, FR, NL [7]
d. ENTSO-E draft proposal for the implementation framework for the exchange of RR (February 2018) [8]

The GCT is crucial for volatile renewable energy sources, as the weather forecast error is reduced significantly over time. Therefore, trading of renewable power is more accurate, as closer the GCT is to the physical delivery.

D. Frequency Containment Reserves (FCR)

FCR is the most homogeneous reserve type. The awarded BSP follows a harmonized activation strategy, which is based on the system frequency. FCR starts within seconds after the frequency deviation exceeds 20 mHz as a joint action of all contracted BSPs in the synchronous area. The total FCR capacity is defined to be 3000 MW in the synchronous area, based on operational generation units and their reliability. Each TSO holds available a share of FCR, which is proportional to the share of energy consumption in the area. The full activation time (FAT) is 30 seconds in case of a frequency deviation of 200 mHz or more. As the reserves react directly to the frequency without central coordinating, all FCR within a synchronous area are activated in parallel [9].

While a common activation strategy is applied, the market design differs a lot. Products, procurement process and cost settlement vary among countries. Table II gives an overview about the applied designs.

Some countries apply a symmetric FCR product without clearing of energy costs. Therefore, only one FCR market exists and the bid consists of a power value and a capacity price. In this case it is assumed that positive and negative activation is equalized. Another approach is unsymmetrical products and applying an additional energy price. Thus, two markets exist (for positive and for negative FCR) and the bid consists of a power value, capacity price and energy price.

The cost settlement for capacity price is performed either pay as bid, with a marginal price or a regulated price. Countries applying the energy price use marginal pricing or a regulated price for the settlement. As all reserves are activated in parallel, all awarded capacity bids will lead to costs for energy.

TABLE II. REVIEW ON FREQUENCY CONTAINMENT RESERVES (FCR)

Design variable	**Applied designs and evaluation of roadmap**		
	Examples [a]	***GLEB*** [b]	***Pilot Project*** [c]
FCR Full Activation Time (FAT)	30 seconds (for 3000 MW, 15 seconds for 1500 MW) [9]		
Scoring rule for FCR Capacity		Activation optimisation function (b article 31)	Common Merit Order list by 01.07.2019 (c article 8, 11)
FCR capacity as symmetrical product	symmetric and not symmetric (GB, IE, BE, DK, HU, GR) (a s. 12)		Symmetric by 26.11.2018 (c article 5, 11)
FCR capacity product resolution in time	from year (IE, BE) to hour (DK, SE, NO, FI, CZ, SK, GR) (a s. 9)		24 h product by 26.11.2018 and 4 h product by 01.04.2020 (c article 5, 11)
FCR energy product resolution in time	30 min (FR, IE), hour (PL), week (DE) (a s. 20)		
FCR capacity product resolution in MW	1 MW (FR, BE, DE, DK, PL etc.) to 5 MW (NL, AT, TR) (a s. 8)		1 MW by 01.07.2019 (c article 4, 11)
FCR energy product resolution in MW	no minimum bid size (PG, DK, SI, BA) to 10 MW (GB) (a s. 19)		
FCR capacity settlement rule	pay as bid (DE, GB, NL, BE, CH, AT, CR, SK, HU, SE), marginal price (DK, GR, NO, FI) or regulated price (FR, IE, PL) (a s. 13)		Marginal price by 01.07.2019 (c article 8, 11)
FCR energy settlement rule	no energy bid at all (DE, NL, DK, CH, AT, PT, ES), pay as bid (GB), marginal pricing (PL, NO, SE, FI) or regulated price (FR, IT, SK) (a s. 23)	Separate price for positve and negative balancing energy (b article 46.2)	
FCR energy activation strategy	pro-rata, therefore all contracted reserves are "activated"		

a. Entso-E survey: Survey on Ancillary services procurement, Balancing market design 2014 (January 2015) [6] b. EU Commission regulation 2017 establishing a guideline on electricity balancing [1]
c. ENTSO-E Draft Proposal for common rules and processes for exchange and procurement of FCR (January 2018), applied by TSOs of AT, BL, CH, DE, DK, FR, NL [7]

E. automatic Frequency Restoration Reserves (aFRR)

After FCR, aFRR is the second fastest reserve type, but its activation is organized separately by each TSO. The control target is to deal with power deviations and to replace activated FCR. The power deviation is calculated by adding power generation (positive value), power consumption (negative value) and scheduled power exchange to other control areas (positive or negative). In an intermediate step, the measured frequency is used to calculate activated FCR (positive or negative). The FCR must be concerned, because it is part of the measured power flows. The calculated FCR of the TSO is added to the calculated power deviation. The result is called area control error (ACE), which than starts the activation of aFRR in corresponding size. A single controller per TSO performs this task. Maximum permissible FAT of aFRR is 15 minutes [9].

Besides these universal relations, the aFRR is procured in national balancing markets. The scoring, price and activation rules are crucial, looking at the BSP bidding strategies. Some countries contract BSP based on their capacity price, others on the energy price and a third group considers a combination of capacity and energy price. Pay as bid and marginal (single) prices are applied. [14]

The period, over which aFRR reserves are contracted vary from hours to weeks, the minimum size varies from no minimum to a minimum of 10 MW per bid. Symmetrical and unsymmetrical products exist. Different combinations of these settlement rules are applied [6].

From a technical perspective, also the aFRR controller work in different manners. Maximum permissible FAT of aFRR is 15 minutes, but a FAT of 5 to 15 minutes is applied. Some controllers send the ACE signal as continuous ramp with signals (at least every 10 seconds). Other controllers apply a stepwise activation and the BSP oversee the full activation of their aFRR within the FAT [10].

F. manuel Frequency Restoration Reserves (mFRR)

The mFRR are manually activated by the TSO to replace FCR and aFRR in case of a consistent power deviation. The product characteristics, product procurement process and settlement vary in a similar manner as aFRR [6].

G. Replacement Reserves (RR)

The fourth reserve type is RR, which is not used by all TSOs. RR is applied in 16 countries [11]. Table III gives an overview about the applied design of RR markets and a proposal for an integrated market (pilot project) of 10 TSOs performing RR.

TABLE III. REVIEW ON REPLACEMENT RESERVES (RR)

Design variable	**Applied designs and evaluation of roadmap**		
	Examples [a]	***GLEB*** [b]	***Pilot Project*** [c]
TSOs applying the Replacement Reserve Implementation Framework (RR IF)	16 countries in Europe use RR[d], 10 are RR IF members; BU, CH, ES, FR, GB, HU, IT PL, PT, and RO. Potential: CR, DK, HR,NW, FL and SW.		
RR Full Activation Time (FAT)		TSO proposal requested by 18.06.2018 (b article 19.1 & 19.3 i)	30 min (c article.9)
RR capacity product resolution in time	hours (ES, PL, SK, HU, RO) to year (FR, CR, RS, LT, LV) (a s. 75)	TSO proposal requested by 18.06.2018 (b article 19.1 & 19.3 i)	
RR energy product resolution in time	15 min (BE, IT) to hour (PT, ES, NL, CH, PL etc) (a s. 86)	TSO proposal requested by 18.06.2018 (b article 19.1 & 19.3 i)	min 15 minutes and max 60 minutes (c article 11)
RR capacity product resolution in MW	no minimum size (PT, CR) to min 10 MW (ES, LV) (a s. 74)	TSO proposal requested by 18.06.2018 (b article 19.1 & 19.3 i)	1 MW (c article 11)
RR capacity procurement scheme	mandatory offers (HU), Mandatory provision without reservation (PL, GR), bilateral market, organised market (FR, CH, SK, RO), hybrid (ES) (a s. 73)	Market with common merit order list (b acticle 19.2)	
RR energy activation strategy	mandatory offers (PL, HU, IT, PT), organised market (ES, NL, CH, CZ, SI, RO) (a s. 84)	Activation optimisation function (b acticle 19.2)	Optimisation algorithm (c article 8)
RR capacity settlement rule	Pay-as-bid (FR, GB, SK, HU), regulated price (PO, LT, RO, RS) or marginal price (ES, LT) (a s. 78)	Marginal price (b article 30.1 a)	cross-zonal marginal price (c article 13)

a. Entso-E survey: Survey on Ancillary services procurement, Balancing market design 2014 (January 2015) [6] b. EU Commission regulation 2017 establishing a guideline on electricity balancing [1]
c. ENTSO-E draft proposal for the implementation framework for the exchange of RR (February 2018) [8] d. https://www.entsoe.eu/network_codes/eb/terre [11]

IV. MEASURES FOR INTEGRATION

The listed harmonization measures are an extract of the GLEB. Table I, Table II and Table III outline some harmonization process, enforced by the GLEB. The tables also put draft roadmaps of ENTSO-E members into the context. The planned European integration and identified measures are described hereafter.

A. Harmonisation of products

The main purpose of the GLEB is the establishment of common principles for the procurement and the settlement of FCR, aFRR, mFRR and RR (article 1). All TSOs shall develop proposals for aFRR, mFRR and RR standard products within two years. Therefore, by 18.12.2019 (article 25.2).

B. Harmonisation of GCT

The GCT of bids for at least one integrated scheduling process is defined to be no longer than eight hours before real-time. (article 24.5 b) The GCT of all balancing markets are set to be later in time. Thus, within eight hours before real time. (article 24.5)

C. Common merit order list and optimisation function

All TSOs shall submit the energy bids of BSP and a common merit order list is created based on the bids (article 29). The activation of FCR, aFRR, mFRR and RR is than executed by an optimization function (article 31). The consultation process is ongoing and all TSOs shall submit a proposal for classifying the activation purposes by 18.12.2018 (article 31.1).

D. "Free" energy bids

All BSP shall have the right to submit energy bids (article 16.5), entering into force by 18.12.2018 (article 65.2). Therefore, not awarded (no price for capacity is paid) BSP can submit energy bids in the capacity procurement process.

E. Cost settlement

The common imbalance settlement period is defined to be 15 minutes, implemented latest by 18.12.2019 (article 53). BRP pay the price for their imbalance and a single price shall be applied, but dual price is possible (article 55.3 c). TSO proposals of harmonization roadmaps are requested by 18.12.2018 (article 52.2 c).

While processes are harmonized and markets integrated, the imbalance price stays heterogeneous (article 55.3). Thus, it is still calculated separately in control areas and settled by the TSOs.

V. EVALUATION OF BARRIERS

Barrier for the harmonization of balancing markets and products is the variety of applied balancing strategies.

First, the differences in controller set-ups (e.g. signal and activation strategy) should be considered. If a technical issue prevents the integration, the deadline for implementation could be scheduled accordingly late. IT-Security is crucial to guarantee security of supply and should be designed accordingly.

The indicated balancing energy market design choices (single price, common merit order list, settlement period of 15 minutes and 1 MW power bid) are internationally applied and functional [3, 12]. Nevertheless, the cost efficiency of these design choices is part of scientific debates.

The cost benefits compared to dual price (or a combination of single and dual) and "pay as bid" pricing is unclear, according to the literature [13]. The reduction of the settlement period and minimum power bid to values under 15 minutes and 1 MW could cut costs further, according to the literature [13]. Thus, the interrelations of activation strategy, clearing and settlement should be examined in greater detail. In this context, the FAT of reserves should be considered. Also, passive balancing of BRP could cut costs for balancing. The interrelation of FAT and passive balancing should be investigated.

The different balancing approaches were developed to cope with individual power generation portfolios of each region. Therefore, other barriers to integration of the power balancing markets might exist.

VI. CONCLUSION

The GLEB implies the harmonization of all tradable power balancing products, of the FAT of all reserve types, of the prequalification requirements for service provider and common rules for cross-border balancing. Proposals and roadmaps for the integration are requested from all TSOs latest by December 2019. The GLEB makes allowance for a step-by-step integration. It allows groups of TSOs to perform pilot projects (e.g. FCR and RR markets, see Table II and Table III).

Barrier for a fast integration is the diversity of balancing approaches. Potential harmful interrelations of all national characteristics with harmonized balancing procedures are difficult to rule out. The European regulators counter this risk by involving all stakeholders and ask for proposals from the industry.

To enable "free bids" (see chapter IV.D) is a new approach that bears the chance of increasing market competition. It may complicate collusive behavior on markets, according to the literature [14].

The targets of the GLEB are ambitious, but the harmonization is accompanied by the operating industry. The process is promising, if it can involve all stakeholder.

The identified research questions for future investigations: How does the market set up (interrelations of activation strategy, clearing and settlement) interact with the full activation time? How does passive balancing influence power balancing?

REFERENCES

Standards:

[1] The European Commission, "COMMISSION REGULATION (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing", Official Journal of the European Union

Periodicals:

[2] Reinier van der Veen, Rudi A. Hakvoort, "The electricity balancing market: Exploring the design challenge", *Utilites Policy*, vol. 43, pp. 186-194, November 2016

[3] Tom Brijs, Cedric De Jonghe, Benjamin F. Hobbs, Ronnie Belmans, "Interactions between the design of short-term electricity markets in the CWE region and power system flexibility", Applied Energy, vol. 195, pp.36-51, March 2017

Dissertations:

[4] Jerom E.S. de Haan "Cross-border balancing in Europe: ensuring frequency quality within the constraints of the interconnected transmission system", Technische Universiteit Eindhoven, the Netherlands, 2016.

Papers Accepted for Publication (but not yet published):

[5] Felix Röben, Hans Schäfers, „Integration of power balancing markets - transparancy as design variable," 41th IAEE conference, Transforming Energy Markets, Groningen, June 2018

Technical Reports:

[6] TSOs from Austria, Belgium, Denmark, France, Germany, the Netherlands and Switzerland, "Proposal for the establishment of common and harmonized rules and processes for the exchange and procurement of Frequency Containment Reserve (FCR) in accordance with Art. 33 of COMMISSION REGULATION (EU) 2017/2195 establishing a guideline on electricity balancing", FCR Cooperation – Draft Proposal, 15 January 2018

[7] ENTSO-E, "The proposal of all Transmission System Operators performing the reserve replacement for the implementation framework for the exchange of balancing energy from Replacement Reserves in accordance with Article 19 of Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing", 21 February 2018

[8] ENTSO-E WGAS, "Survey on Ancillary services procurement, Balancing market design 2014", January 2015

[9] ENTSO-E Operational Handbook, "Policy 1: Load-Frequency Control and Performance", approved in March 2009

[10] E-Bridge, IAEW, "Study assessment of aFRR products. For Balancing Stakeholders Group workshop", 15. January 2016

Papers from Conference Proceedings (Published):

[11] Fabian Ocker, Sebastian Braun, Christian Will, "Design of European Balancing Power Markets", *13th IEEE International Conference on the European Energy Market* (EEM) 2016

[12] Bo Jie, Takao Tsuji, Kenko Uchida, "An Analysis of Market Mechanism and Bidding Strategy for Power Balancing Market Mixed by Conventional and Renewable Energy", *14th IEEE International Conference on the European Energy Market* (EEM) 2017

[13] Bettina Burgholzer, "Evaluation of different Balancing Market Designs with the EDisOn+Balancing model", *13th IEEE International Conference on the European Energy Market* (EEM) 2016

[14] Fabian Ocker, "Design and Performance of European Balancing Power Auctions", *14th IEEE International Conference on the European Energy Market* (EEM) 2017