Efficiency Analysis of the Baltic Balancing Market

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***Abstract*—In this paper authors analyze technical and cost efficiency gains from transition from divided balancing model to the common regional balancing market model with centralized balance management. The paper analyses key performance indicators of balancing system, as well as discusses balance responsible parties' (BRPs) incentives to keep their portfolios in balance. Due to rather small sample of statistical data from the Baltic market, we simulate conditions of the common regional balancing market and conclude that it is hard for BRPs to predict the system's imbalance direction, therefore BRPs are incentivized to stay in balance at all times in order to minimize imbalance and balancing costs. Analysis of key performance indicators show that the centralized regional balance management and regionally harmonized balancing market with the single price model delivers more accurate, more efficient system balance management.**

***Index Terms*—balancing market, frequency restoration reserve, power system balancing, electricity market design.**

I. Introduction

Keeping the power system balance between supply and demand 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 whole European power system balancing arrangements are undergoing the structural changes, as balancing requires more efficient approach, better coordination among transmission system operators (TSOs) and harmonized market model.

In order to improve availability of balancing resources and efficiency of power system balance management, and following the requirements included in EU Regulations, TSOs of the Baltic countries from the 1st of January 2018 launched a new regional balancing market. Such market seeks efficient coordination among TSOs, provides harmonized market rules, standardized balancing energy products, common market platform and close to real-time data publishing.

Main contribution of this paper is to provide comparison of two different balancing market models and comprehensive analysis of operational and market data for understanding how the changes in the balancing model affect efficiency of the power system balancing and market participants' behavior.

In Section II we give brief overview of Baltic balancing market's development steps. Section III. Provides overview on balancing market performance criteria, while Section IV. provides comparison of two different balancing market models. We provide readers with description of balancing market simulation and its results in Sections V and VI respectively. Section VII concludes.

II. Baltic Balancing market background

The integration of the Baltic States into EU energy networks has been seen as one of the main objectives that will contribute to the stability and economic growth of the Baltic Sea Region, as stated in Baltic Energy Market Interconnection Plan [1].

In response to the early implementation of the Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing [2], European TSOs initiated a number of pilot-projects, among which was also a "Feasibility study regarding cooperation between the Nordic and the Baltic power systems within the Nordic ENTSO-E pilot project on electricity balancing" [3]. The study concluded, that named cooperation is feasible, however to ease the co-operation between manual frequency restoration reserves (mFRR) balancing markets, Baltic TSOs should create a coordinated balancing area (CoBA) and common mFRR balancing market. Based on provided conclusions, TSOs agreed on harmonization of elements of Baltic balancing market [4], and came up with harmonized balancing market rules [5] and CoBA imbalance settlement rules [6].

III. Balancing market performance criteria

In order to evaluate the effect of different market designs on performance of balancing market, the main performance criteria should be identified. In this paper, we partly use criteria defined in [7] and [8], which are divided in Technical performance and Economical performance criteria.

A. Technical performance: Operational security

Ensuring operational security of the system by means of a market-based mechanism is the main performance criteria of balancing services markets. For Baltic case, it would mean the TSOs' ability to keep the area control error (ACE) close to zero, as the frequency control within IPS/UPS synchronous area is performed by Russian TSO. The Baltic Balancing market objective is to cooperate to maintain balance within CoBA and minimize Baltic ACE [5]. The remaining imbalance after internal Baltic area netting, also called as not netted imbalance, has reduced with new model

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implementation. Not netted imbalance volumes in January 2018 decreased by 34% compared with ones in January 2017. Similar trend was observed in February and March, when Baltic ACE volumes decreased by 35% and 48% on a year-over-year basis respectively. We report that frequency of large imbalances (70+ MWh) in Q1 2018 decreased by more than 3 times compared to similar period of 2017 (Fig. 1). As a result, in 74% of hours CoBA imbalance did not exceed 30 MWh (only in 49% of hours in 2017).

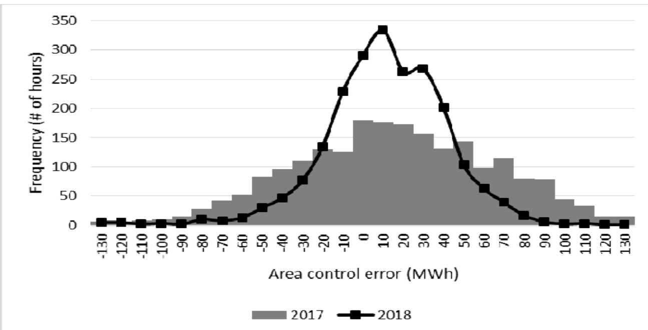

Figure 1. Distribution of not netted imbalance in Baltics, January-March 2018.

In addition, effectiveness of balancing energy markets can be measured by availability and even distribution of resources. As from 2018 all three Baltic TSOs, Finnish and Swedish TSOs combine the available bids in common merit order list, the availability of resources and therefore the competition between balance service providers (BSPs) in the balancing market has raised. Baltic TSOs are balancing the system more actively – in January 2018 balancing energy activations (upward and downward regulation) were made in 75% of hours, while in January 2017 it was only 46% of hours.

B. *Economic performance*

Economically efficient market incentivizes market participants to behave in a way that best serves the general goal of maximizing economic surplus and leads to the globally optimal solution. Economic performance criteria include all the highly interrelated institutional and economic aspects of balancing markets, such as market transparency, market liquidity, balancing services markets efficiency, and non-discrimination [8].

The market transparency in Baltic balancing market has improved, as Baltic TSOs established a common information platform [9], with all the latest market data available, as well as created a level playing field for market participants by developing harmonized rules [5], [6], which is a prerequisite of a competitive and non-discriminatory balancing market. The economic performance of the Baltic balancing market is analyzed in more details in following sections.

IV. Imbalance Settlement Models' Overview

A. *Balancing market arrangements before 2018*

The imbalance settlement arrangements until 2018 were different in Baltic countries, these differences originated from fundamental institutional, technical differences, history, etc. Many traders were active in all 3 Baltic countries, however they had to face difference market designs, and consequently, different imbalance costs in quite similar conditions. For instance, in Lithuania BRPs faced imbalance prices that were less profitable than day-ahead prices – imbalance price for surplus was lower than day-ahead price, while for deficit it was higher than day-ahead price. Effectively, traders in Lithuania had losses from trading in imbalance market. In contrast, dual price model in Latvia and Estonia was not linked to day-ahead prices, thus buying or selling energy in balancing market was often economically reasonable than in day-ahead market. Table 1 shows that in Estonia and Latvia only one direction of imbalance was detrimental for traders.

TABLE I. Average Monthly 1 MWh Imbalance cost in 2017 (EUR/MWh)

	Estonia		**Latvia**		**Lithuania**	
	Surplus	**Deficit**	**Surplus**	**Deficit**	**Surplus**	**Deficit**
Jan	-9.33	6.15	-8.10	6.43	-15.72	-7.12
Feb	-3.44	-1.16	-4.10	2.11	-10.70	-11.62
Mar	-6.29	1.84	-7.28	5.83	-10.42	-10.50
Apr	-7.13	2.59	-3.37	1.63	-10.53	-11.55
May	-2.64	-1.96	2.45	-4.61	-10.12	-15.56
Jun	-1.26	-2.92	1.14	-3.58	-12.43	-12.14
Jul	0.62	-4.59	2.67	-5.08	-11.60	-14.69
Aug	5.23	-9.45	7.01	-9.75	-10.86	-20.32
Sep	1.66	-6.75	0.35	-2.71	-10.93	-17.71
Oct	-5.39	1.43	-4.53	2.73	-11.48	-13.22
Nov	3.15	-7.51	0.80	-3.00	-9.89	-21.22
Dec	2.42	-7.05	1.28	-3.36	-9.91	-18.04

Note: figure with negative sign ("-") means loss/cost, positive figure means profit in imbalance market

Such design caused incentives for BRPs to intentionally create the imbalance in specific direction and capitalize on that. In Fig. 2 we present cumulative cash flows of a hypothetical Latvian BRP, who every hour intentionally plans either 1 MWh of deficit, or 1 MWh of surplus. Even though both strategies result in approximately 9 000 EUR loss, following the trend and changing scheduling strategy allows BRP maximizing its profits.

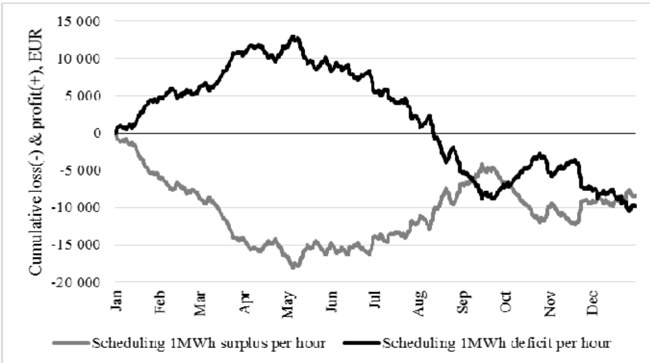

Figure 2. Cummulative loss/profit from scheduling imbalance in Latvia, price conditions of year 2017.

For instance, from Table 1 we conclude that Latvian traders, who scheduled deficit from January to April, were profiting from buying energy from imbalance market rather than Nord Pool exchange. In summer months (May-September), selling electricity in imbalance market was more profitable than in day-ahead market. In markets as Latvian or Estonian, which are highly dependent on dominant traders and producers, it is possible to predict such profit opportunities.

Moreover, differences in market designs created additional administrative costs for international electricity traders. Table 2 summarizes the main imbalance settlement parameters and provides an overall comparison for the imbalance settlement arrangements in the Baltic countries before 2018 [4].

TABLE II. IMBALANCE SETTLEMENT IN BALTICS UNTIL 2018

	Estonia	*Latvia*	*Lithuania*
Number of imbalance portfolios	*Single*	*Single*	*Triple (consumption, production, cross-border trade)*
Imbalance price determination	*Average cost-based (pay-as-bid)*		*Partly (average) cost-based (pay-as-bid), partly reference price*
Imbalance pricing model	*Dual-price*		
Imbalance price methodology: main component for price	*Aggravating: Weighted average price + marginal; Reducing: Weighted average price – marginal*	*Aggravating: Weighted average control energy price x coefficient (3%); Reducing: Weighted average control energy price x coefficient (3%)*	*Aggravating: Weighted average control energy price x coefficient (2%); Reducing: Day-ahead market price x coefficient (2%)*
Price methodology for system open supply price (ACE)	*Netted imbalance is priced at the average EE, LV and LT NP Elspot price Not netted imbalance volumes are settled at prices provided by open balance provider*		
Balance obligation for RES	*BRP*	*BRP*	*TSO*

In Estonia and Latvia, settlement of imbalances was based on a single portfolio - all injections and offtakes of energy in the transmission grid of each market participant were accounted algebraically into a single account, which finally reported a net position for each market participant. The methodology of imbalance dual pricing was cost-based - the price is based on the volume-weighted average of the pay-as-bid balancing cost in a national merit order and system ACE cost, multiplied by specific coefficient. Lithuanian imbalance settlement utilised three portfolios (consumption, production, and cross-border trade.

In addition, each TSO was responsible to balance its own system within the predefined limits, and imbalance netting within Baltics was performed post factum, before settlement with open balance provider. As for balancing purposes mostly the local resources and resources of open balance provider were used, the model did not foster the competition between Baltic BSPs.

B. *Harmonised Baltic Balancing market arrangements*

Since 1st of January 2018, Baltic TSOs on rotational basis appoint one nominated TSO, who is in charge of balancing the CoBA, instead of each country, which implies real-time imbalance netting during operational hour, therefore balancing resources are used more efficiently, avoiding the balancing energy activations in opposite direction.

In order to harmonise the different market arrangements in Baltic countries, from 2018 Baltic TSOs have established the single price and single portfolio model [10], the overview of the main building blocks is summarized in table 3.

TABLE III. IMBALANCE SETTLEMENT IN BALTICS AFTER 2018

	Estonia, Latvia, Lithuania
Settlement model	*Single portfolio model*
Imbalance pricing model	*Single price*
mFRR reference price	*Marginal mFRR or local Elspot when no mFRR was activated within the operational hour*
Imbalance price formula	*mFRR reference price +/- targeted component (c)*
Reference for short/long position	*Baltic's total imbalance position*
ACE cost recovery model	*Included via (actual) targeted component, monthly average component*
Targeted component (EUR/MWh) formula	$\frac{\text{TSO's net cost or revenue due to balancing trades (EUR)}}{\sum \text{absolute volumes of hourly Baltic CoBA imbalance positions (MWh)}}$
Balance responsibility	*100% BRP*

The Baltic TSOs adopted a single portfolio model meaning that both production and consumption are dealt within the same portfolio. Imbalances in this model are settled in each direction. The single price model means that BRPs shall receive exactly the same price regardless whether their imbalance position is at a surplus or deficit. The imbalance price is determined based on the direction of the Baltic ACE and the mFRR balancing activations carried out to minimize Baltic ACE or the day-ahead price, in case there were no mFRR activations. The targeted component will be aimed at capturing the full cost of balancing, and calculated taking into account the actual ACE and other costs/revenues related with trade of balancing energy.

V. Simulation Methodology and Data

The main goal of the simulation is to find, whether new CoBA model creates incentives for BRPs to schedule their consumption and generation accurately. In order to answer this question, we have to find the imbalance costs BRPs face in different states of Baltic power system. We simulate three key variables of CoBA model: 1) CoBA's imbalance direction; 2) single balancing and imbalance price; 3) imbalance volumes for some BRP. The settlement period in Baltics is one month and imbalance settlement period (ISP) is 1 hour. Thus, each simulation is based on 744 data points, which represent one month of hourly data.

We start with CoBA's imbalance direction. 220 scenarios of system's hourly imbalance directions are simulated (table 3) – we begin with 20 scenarios, where 100% of hours in a particular scenario are defined as deficit hours. In our model, Baltic TSOs in deficit hours are using upward regulation, the price of which becomes a reference for imbalance price in CoBA. We continue by increasing a proportion of surplus hours by 10% in each 20 scenarios. Thus, in scenarios 41-60 (inclusive), 80% of hours are defined as deficit hours and remaining hours are surplus hours. Within the specific scenario, hours are marked as deficit or surplus in a random manner.

TABLE IV. CoBA's Imalance Scenarios

Scenario #	1-20	…	181-200	201-220
% deficit hours & upward regulation	100%	…	10%	0%
% surplus hours & downward regulation	0%	…	90%	100%

Next, each deficit hour is assigned the imbalance price, which is equal to marginal upward balancing price in that hour. Similarly, marginal downward balancing prices become a reference for imbalance prices in surplus hours. We simulate marginal balancing prices taking into account publicly available marginal balancing prices in January and February 2018. We find that difference of balancing and Elspot prices in deficit hours is following F-distribution, while distribution of Elspot and balancing price difference in surplus hours is close to normal. We use properties of these distributions to simulate hourly price differences, m_h, which could be viewed as profit margins for BSPs above/ below spot price ($Spot_h$). As input for Elspot price, we use Nord Pool reported hourly day-ahead price for Latvia in January 2018. In each of 220 scenarios imbalance price, *IP*, in hour h is defined as:

$$IP_h = Spot_h * (1+m_h), \text{ where } \begin{cases} \begin{cases} m_h \leq 0 \\ m_h \sim N \\ \text{in a deficit hours} \end{cases} \\ \begin{cases} m_h \geq 0 \\ m_h \sim F \\ \text{in a surplus hour} \end{cases} \end{cases} \quad (1)$$

We present distribution of simulated imbalance prices in system with 80% deficit hours compared to day-ahead prices in Fig. 3.

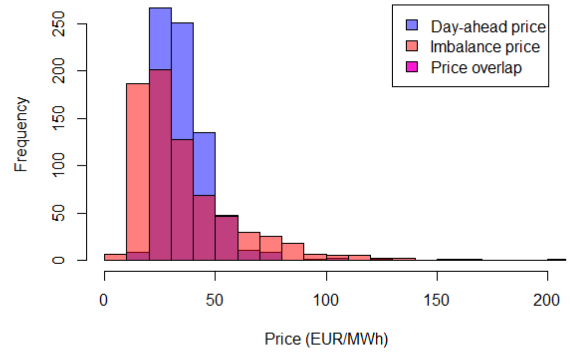

Figure 3. Distribution of imbalance prices in system with 80% deficit hours.

We finish by simulating 210 BRP's hourly imbalance profiles. Each 10 scenarios are associated with specific average hourly imbalance volume, *IV*, within a scenario:

TABLE V. BRP's Imalance Scenarios

Scenario #	1-10	…	191-200	201-210
Imbalance range, MWh	[-200;0]	…	[-20;180]	[0;200]
Average hourly imbalance, MWh	-100	…	90	100

In the final step, we calculate monthly statistics for each of 46 200 combinations of 220 imbalance price scenarios and 210 imbalance volume scenarios. For imbalance price scenario *i* and imbalance volume scenario *j* we calculate monthly average cost of imbalance $IC_{i,j}$ expressed in € per imbalance MWh:

$$IC_{i,j} = \frac{\sum_{h=1}^{744} |IV_{h,j} * (IP_{h,i} - Spot_h)|}{\sum_{h=1}^{744} |IV_{h,j}|} \quad (2)$$

VI. Results

From table 6 we draw two conclusions:

1. If the whole system 60% of hours is in surplus, cost of imbalance is almost 0EUR per imbalance MWh, which makes BRPs indifferent of their scheduling accuracy;
2. The lower is BRP's intentional imbalance, the lower are BRP's costs per imbalance MWh and less dependent from the system's state it is.

We find that current balancing model makes it possible to eliminate balancing costs for BRPs, if the whole system is, on average, 60% of time in surplus. Results show that BRPs face almost 0.00 EUR/imbalance MWh costs, if 60% of hours during the month are surplus hours and remaining are deficit hours. Such result is influenced by the structure of BSPs' marginal balancing bids. Upward regulation bids are positively skewed and virtually have no limit. Average margin (difference between balancing price and Elspot price) for upward regulation was 57% above spot price at the beginning of 2018. Maximum margin was 364%. In contrast, downward regulation bids in practice have lower limit of 0.00 EUR/MWh. Even though, negative prices are allowed in CoBA, no one used them so far. Average margin for downward regulation was 38% below spot price. Maximum margin was 88%, which is considerably lower than for upward regulation. This is explained by the fact that downward regulation is usually associated with lower costs for BSPs, in in contrast to upward regulation, when BSPs have to activate ineffective production units.

Our conclusion that BRPs can be indifferent of their scheduling accuracy (Table 5), if system in 60% of hours is in surplus, cannot be easily exploited by BRPs – deviation from such ratio results in large costs for BRPs. If BRPs decide not to schedule their consumption and production accurately, and choose to submit biased schedules, they are likely to end up in the situation, when the system is not 60% of hours in surplus. High number of BRPs in three Baltic states makes it practically impossible to predict, whether the specific hour will be a surplus or deficit one. This leads us to a conclusion that it is irrational for BRPs to hope that in 60% of hours the system will be in surplus and it is costless to have intentionally scheduled biased imbalance significantly different form 0 MWh.

The second conclusion extends the abovementioned arguments. If the proportion of surplus to deficit hours is different from 60-40, BRPs may find profitable to plan imbalance of either direction. For instance, if Baltic power grid is 80% of hours in deficit, BRPs with average hourly surplus of 40 MWh earn 0.68 EUR/imbalance MWh in the balancing market. In contrast, BRPs with average hourly deficit of 40 MWh in such system state faces 0.77 EUR loss per 1 MWh of imbalance. While BRPs with surplus scheduled are favoring from their scheduling bias, any rational BRP in deficit should be willing either to reduce its imbalance close to 0, which is associated with almost 0.00 EUR/imbalance MWh costs indifferent of system state, or to plan surplus instead of deficit (assuming that its actions will not change the imbalance direction of the whole system). Both decisions, ceteris paribus, will negatively affect the first group of BRPs – system in surplus is no longer financially attractive for BRPs in surplus. If such logics is applied, no BRPs should be motivated to plan intentional imbalance. Even though, it is practically impossible to plan consumption or generation 100% precisely, being unbiased and very close to the balance is risk-free strategy for BRPs.

TABLE VI. BRP'S COST OF IMBALANCE (€ PER IMBALANCE MWH)

% of surplus hours	Average hourly imbalance of a BRP (MWh)																		
	-90	**-80**	**-70**	**-60**	**-50**	**-40**	**-30**	**-20**	**-10**	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
10%	-1.64	-1.55	-1.21	-1.00	-1.33	-1.01	-0.63	-0.33	-0.51	0.04	0.67	0.27	0.96	0.70	1.11	1.90	2.10	2.09	2.17
20%	-1.57	-1.27	-0.81	-0.65	-0.93	-0.77	-0.50	-0.31	-0.36	0.13	0.47	0.25	0.95	0.68	1.08	1.81	1.96	2.02	2.08
30%	-1.35	-1.11	-0.71	-0.48	-0.57	-0.39	-0.24	-0.17	-0.22	0.10	0.49	0.23	0.53	0.47	0.91	1.18	1.61	1.66	1.81
40%	-1.24	-0.85	-0.54	-0.46	-0.42	-0.31	-0.11	-0.09	-0.24	-0.01	0.19	0.12	0.40	0.22	0.54	1.04	1.14	1.31	1.40
50%	-0.62	-0.57	-0.40	-0.19	-0.20	-0.15	-0.08	-0.08	-0.04	0.00	0.06	0.06	0.19	0.19	0.13	0.55	0.46	0.51	0.76
60%	0.01	-0.01	0.04	-0.01	0.04	-0.02	-0.07	-0.03	-0.01	0.03	0.03	-0.01	-0.01	0.00	0.02	0.03	0.03	-0.05	-0.06
70%	0.65	0.54	0.38	0.22	0.40	0.31	0.12	0.04	0.05	-0.01	-0.10	-0.03	-0.10	-0.07	-0.18	-0.30	-0.35	-0.45	-0.58
80%	1.16	1.07	0.81	0.77	0.81	0.55	0.23	0.20	0.15	-0.03	-0.27	-0.10	-0.19	-0.09	-0.29	-0.47	-0.64	-0.77	-0.95
90%	1.56	1.47	1.12	0.90	1.18	0.86	0.51	0.26	0.27	-0.02	-0.33	-0.16	-0.46	-0.39	-0.50	-0.73	-0.85	-0.92	-1.24

VII. CONCLUSIONS

Transition to the common regional balancing market model with centralized balance management improves efficiency and accuracy of system balance management.

The technical performance of the Baltic power balance management has improved, the mFRR resources are used more efficiently and simultaneous balancing reserve activations in opposite directions are avoided. The transparency of the balancing market, the competition and liquidity has improved, providing BSPs access to wider market and lower balancing costs to BRPs. The new model has created level playing field for all Baltic market participants.

Under the new balancing market model BRPs are better incentivized to stay in balance. Wider market, higher number of BRPs and electricity producers make it riskier to gamble against the balancing market. As long as there is no dominant electricity producer, whose production volumes are seasonally dependent, the ambiguity of system's imbalance direction within the certain timeframe remains high.

Our simulation results indicate that in the single price model with the Baltic statistical price pattern from Q1 2018 larger BRPs with a dominant size of portfolio that are in most of the situations incentivized to stay in balance. Only if surplus balance in CoBA is about 60% of time, incentives to stay in balance are reduced to minimum. Nevertheless, it is practically impossible for BRPs to predict when such state of balancing in CoBA is achieved, and thus BRPs are expected to stay incentivized to stay in balance at all times to minimize balancing costs. In contrast, the balancing model, which was previously used in Baltics, allowed dominant BRPs to predict state of system balance and portfolio balance form maximum economic gain rather than minimum energy imbalance.

The previous dual pricing drives inefficiency in balancing by over-incentivising parties to balance. Under a single price model at a regional level BRPs benefit from lower balancing costs and economic netting of imbalances among portfolios in different Baltic states.

As the new model has been implemented very recently we recommend to analyse the Baltic balancing market performance in the longer time period, as the first months might be considered as transitional period and the market participants and TSOs are still forming their experience within new arrangements.

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