Market Information on the Cost-Benefit-Analysis for Allocation of Cross-Zonal Capacity for the Exchange of Automatic Frequency Restoration Reserves between Germany and Austria

21/09/2018

DISCLAIMER

This document is released on behalf of the TSOs from Austria and Germany solely for the purpose of a stakeholder information. This document constitutes the current proposal for the Cost-Benefit-Analysis for the allocation of cross-zonal capacity for the exchange of automatic Frequency Restoration Reserves between Germany and Austria, currently being approved by the Austrian and German National Regulatory Authorities. The market information is not in any case a legal binding document and/or provides any right for the reader to legally object the content of this document nor to comment or interact with regard to the content in any other way. All information is without guarantee for accuracy, completeness and correctness and the Austrian and German TSOs assume no responsibility or liability thereof.

1 Table of Contents

2 Introduction

The transmission system operators (TSOs) of Germany (DE) and Austria (AT) are exchanging automatic Frequency Restoration Reserves (aFRR) balancing energy since July 2016[1]. In a further step the cooperating TSOs agreed to intensify the existing cooperation to an exchange of aFRR balancing capacity based on a TSO-TSO model and respecting the requirements arising from the Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing (henceforth EBGL).

According to EBGL, TSOs who exchange Frequency Restoration Reserve (FRR) shall make sure that the necessary cross-zonal capacity (CZC) for the exchange of balancing capacity is available. Hence, CZC between the bidding zones of Germany and Austria must be allocated in order to enable the cross-border exchange of aFRR balancing capacity. The cooperating TSOs agreed that the maximum allocated CZC for the exchange aFRR balancing capacity shall not be higher than 280 MW and be determined based on a cost-benefit-analysis (CBA).

In order to fulfill the requirements of EBGL as well as of market participants, the cooperating TSOs agreed on developing a method for the CBA to be able to determine the allocation of CZC. This method is based on a comparison of the market values for CZC in the balancing and in the day-ahead market. If the CBA results indicate a higher expected market value using CZC on the day-ahead market, the CZC would be allocated to the day-ahead market. CZC that was re-assigned to the day-ahead market can then be used again as part of the daily capacity for the day-ahead market coupling.

This market information is supposed to give insight to stakeholders into the method and to foster the understanding of the proposed CBA methodology. Furthermore, first results for the allocation form a prototype of the CBA are included in the market information.

3 Methodology

The CBA is based on a comparison of the market value of CZC on the day-ahead market versus its market value on the balancing market. The CZC should be allocated to the market where it generates the highest value. The following subsections focus on the calculation of these values. Afterwards an overview of the comparison of the market value is presented including a high-level description of the algorithm used in the CBA.

[1] More information on the aFRR balancing energy cooperation between DE and AT can be found here.

3.1 Calculation of the Market Value of CZC on the Balancing Market

The market value of CZC on the balancing market results from the difference of expected costs when aFRR capacity is selected based on a common merit order list (CMOL) compared to two separate local merit order lists (LMOLs) for DE and AT. The calculation of the market value is based on the current procurement algorithm for accepting bids in the two control blocks. To determine the market value the expected costs for aFRR balancing capacity as well as the expected costs of aFRR balancing energy are considered.

As the CBA is performed before the gate for aFRR balancing capacity closes (see Section 5), the CMOLs for aFRR balancing capacity and energy need to be created on the basis of expectations and forecasts. Hence, average CMOLs for each delivery day as well as for each activation direction (positive and negative aFRR) must be derived. For this purpose the final CMOLs for aFRR balancing capacity as well as for aFRR balancing energy of the 4 weeks prior to the delivery week for which the CBA is conducted are used.

The expected costs for aFRR balancing capacity are based on expected prices and quantities of bids on the CMOL. Within the expected costs for aFRR balancing capacity the expected costs of aFRR balancing energy are considered and are calculated based on the corresponding CMOL for aFRR balancing energy. In order to approximate the probability of activation for aFRR balancing energy bids, the aFRR balancing energy bid prices are weighted by a probability of being activated. By assigning probabilities of activation to each aFRR balancing energy bid the CBA avoids a potential inefficient use of CZC. The described method for the determination of expected balancing capacity costs resembles the proposed procurement algorithm for aFRR balancing capacity.

The market value of the CZC allocated for the balancing market is then derived by the sum over differences between the most expensive bids avoided locally minus the cheapest bids that can be procured cross-border in the cooperating control block. As the CBA calculates avoided costs for aFRR, the market value of CZC on the balancing market can also be interpreted as the sum of avoided costs for aFRR.

3.2 Calculation of the Market Value of CZC on the Day-Ahead Market

The market value of CZC on the day-ahead market corresponds to the expected day-ahead price difference between the two bidding zones of Germany and Austria, multiplied by the expected scheduled energy exchanged in each direction. Since the CBA needs to be done before the results of the day-ahead market coupling are available (see Section 5), the expected price difference needs to be calculated accordingly.

In order to keep this process as transparent and comprehensible as possible, the day-ahead prices for both bidding zones of the according delivery day of the previous week shall be used. This approach is assumed to be sufficiently accurate for predicting the day-ahead prices of the delivery period. However, if initial operational experience shows that the accuracy of the forecast can be improved e.g. by introducing additional time-lags and/or exogenous variables like wind forecasts or by introducing additional binary variables or fixed effects e.g. for holidays or single days between holidays and weekends, the TSOs of DE and AT will consider an improvement of the proposed methodology.

3.3 Comparison of Market Values for CZC (Cost-Benefit Analysis)

To derive the optimal amount of CZC, to be allocated to the balancing market, the derived market values of CZC on the balancing and day-ahead market need be compared. The optimal CZC to be allocated is defined by the amount of CZC where the marginal value of an additional MW CZC for the balancing market is exactly equal to the marginal value of an additional MW CZC for the day-ahead market. This follows the basic intuition that if 1 MW of CZC generates more value e.g. in the day-ahead market than in the balancing market it is allocated to the former as the market value of CZC is higher in the day-ahead market. An illustration of the comparison performed by the CBA is depicted in Figure 1 below.

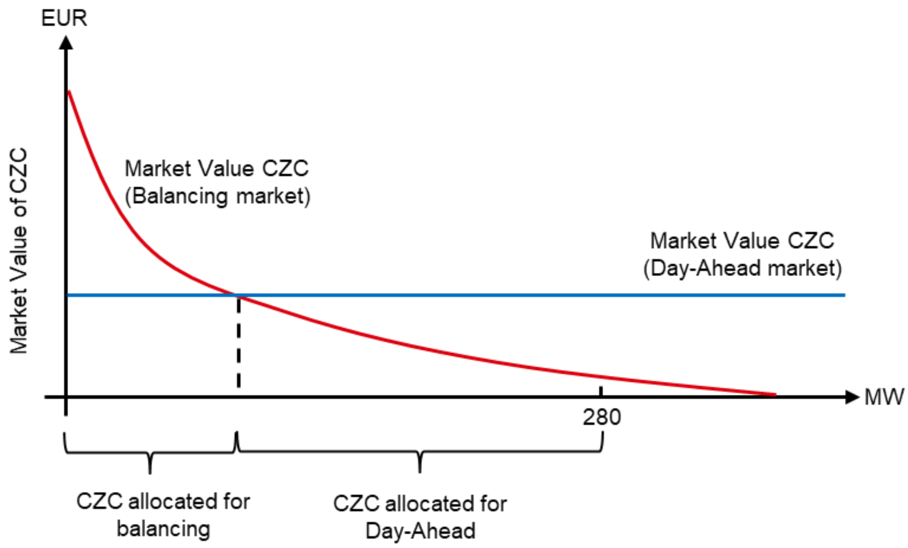


Figure 1: Optimal Allocation of CZC

3.4 Optimization and Constraints

To model the above described comparison of market values the TSOs of DE and AT decided to formulate an optimization problem. The optimization problem aims at maximizing the total economic advantage by allocating CZC to the balancing and/or the day-ahead market. In other words, the objective function firstly (a) identifies the economic advantage arising from a common procurement of aFRR balancing capacity and secondly (b) compares the economic advantage to the economic (dis)advantage on the day-ahead market arising from the allocation of CZC to the balancing market. Economic advantage increases by the amount of (lower priced) bids that can be accepted in the other country, due to a higher allocation of CZC for aFRR. This, however, decreases the CZC that may be allocated to the day-ahead market, $\boldsymbol{capacity_{d,h,p}^{DA}}$, which on the other hand reduces the economic advantage in the overall optimization problem.

Hence, the optimization is formulated as a maximization problem with two main components. The objective function as well as the most important constraints are described below in formulas (1) to (5).

$$\mathbf{max} \sum_c \sum_d \sum_h \sum_p \left(\begin{array}{c} \left(\boldsymbol{aFRR_{cap}}{}_{\boldsymbol{c,d,h,p}}^{\boldsymbol{max}} * \boldsymbol{aFRR_{cap_p}}{}_{\boldsymbol{c,d,h,p}}^{\boldsymbol{max}} \right) - \sum_{\boldsymbol{b}} \left(\boldsymbol{aFRR_{cap}}{}_{\boldsymbol{c,d,h,p,b}} * \boldsymbol{aFRR_{cap_p}}{}_{\boldsymbol{c,d,h,p,b}} \right) \\ + \left(\boldsymbol{capacity_{c,d,h,p}^{DA}} * \boldsymbol{spread_{c,d,h,p}^{DA}} \right) \end{array} \right) \tag{1}$$

$$\mathbf{s.t.}$$

(only the most important constraints are displayed)

$$capacity_{DE\to AT,d,h}^{aFRR} = \max(energy_{DE\to AT,d,h}^{aFRR\ pos}, energy_{AT\to DE,d,h}^{aFRR\ neg}) \tag{2}$$

$$capacity_{DE\to AT,d,h}^{aFRR} \leq 280 \tag{3}$$

$$capacity_{DE\to AT,d,h}^{DA} + capacity_{DE\to AT,d,h}^{aFRR} \leq 4900 \tag{4}$$

$$\sum_{c,b} aFRR_{cap}{}_{c,d,p,b}^{max} = \sum_c \left(aFRR_{cap}{}_{c,d}^{required,pos} + aFRR_{cap}{}_{c,d}^{required,neg} \right) \tag{5}$$

$$\boldsymbol{where}$$
$$c \in \{AT, DE\}$$
$$d \in days$$
$$h \in \{00-04; 04-08; 08-12; 12-16; 16-20; 20-24\}$$
$$p \in \{positive,\ negative\}$$
$$b \in bids$$

3.4.1 Component 1: Economic advantage on aFRR balancing market (line 1)

The definition of economic advantage in a market with perfectly inelastic demand is not straightforward, as there is per definition no upper limit that constrains the optimization problem. Therefore the TSOs elaborated an approach for the CBA that is illustrated in **Fehler! Verweisquelle konnte nicht gefunden werden.**. In the approach the economic advantage in the aFRR balancing capacity and energy markets is defined as the maximum bid that is accepted by the auctioneer, $\boldsymbol{aFRR_{cap}}{}_{\boldsymbol{c,d,h,p}}^{\boldsymbol{max}}$, times the price of this bid, $\boldsymbol{aFRR_{cap_p}}{}_{\boldsymbol{c,d,h,p}}^{\boldsymbol{max}}$, minus the area of the merit order as the sum of each bid's quantity, $\boldsymbol{aFRR_{cap}}_{\boldsymbol{c,d,h,p,b}}$, times its respective price, $\boldsymbol{aFRR_{cap_p}}_{\boldsymbol{c,d,h,p,b}}$, up to this highest priced bid (p_{max}).

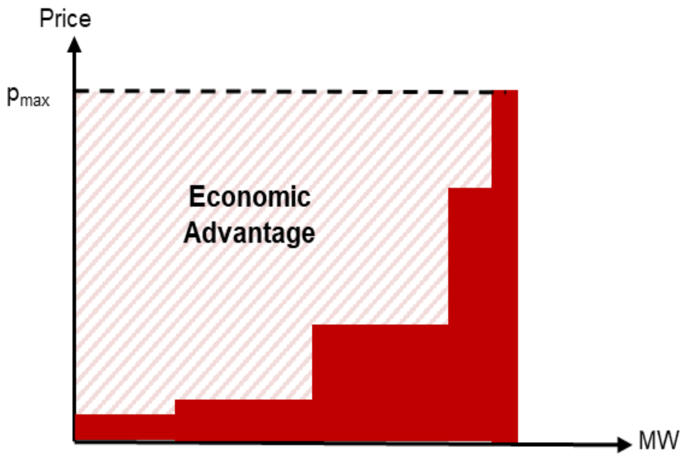


Figure 2: Economic Advantage in aFRR

3.4.2 Component 2: Economic (dis)advantage on the day-ahead market (line 2)

The economic (dis)advantage on the day-ahead market is derived by multiplying the transmission capacity that is allocated to the day-ahead market, $\boldsymbol{capacity^{DA}_{c,d,h,p}}$, by the price difference between the two bidding zones, i.e. by the spread, $\boldsymbol{spread^{DA}_{c,d,h,p}}$.

3.4.3 Constraints

The maximum CZC that can be allocated for the exchange of aFRR balancing capacity, i.e. 280 MW, enters the optimization algorithm via constraints (2) and (3): positive aFRR allocated in Germany for Austria, $\boldsymbol{energy^{aFRR\ pos}_{DE \to AT,d,h}}$, leads to energy flows in the same direction, whereas negative aFRR allocated in Austria for Germany, $\boldsymbol{energy^{aFRR\ neg}_{AT \to DE,d,h}}$, also leads to energy flows in this direction. The maximum of these energy flows in each direction, i.e. $\boldsymbol{capacity^{aFRR}_{DE \to AT,d,h}}$ for energy flows from Germany to Austria, may not exceed the limit of 280 MW.

Constraint (4) introduces the limit of 4900 MW on overall energy flows that may appear on both the day-ahead market and the aFRR market together. The constraint is included for both directions, i.e. for DE to AT and AT to DE. The last constraint (5) ensures that the demand for positive and negative aFRR balancing capacity must be fulfilled at all times in DE and AT. For the sake of simplicity and since the objective function is also only stated in a simplified version, only the most important constraints are displayed in this document.

3.5 Determination of CZC for Monthly Capacity Auctions

In order to make CZC available for the allocation to the balancing market, a certain amount of CZC needs to be deducted from the monthly capacity auctions. To determine this amount of

CZC the CBA results of the 4 weeks prior to the monthly auctions shall serve as the basis. Based on the previous 4 weekly CBA results an amount of CZC is derived that is ex-ante allocated for the balancing market and correspondingly reduces the tradable amount in the monthly auctions. However, this ex-ante allocated CZC for balancing will be adjusted on a weekly basis based on the CBA outlined in chapter 3.

4 Data basis for the CZC allocation

As mentioned in the previous chapters, the main task of the CBA is to derive expected market values of CZC on the balancing and day-ahead market and to compare them against each other given certain constraints. This chapter summarizes the necessary data basis for the calculation of expected market values of CZC for the balancing and day-ahead market.

4.1 Balancing Market Merit Order Lists

As mentioned in Section 3.1 above, the necessary merit order lists for aFRR balancing capacity and balancing energy are derived using the MOLs for each delivery day, delivery period, and direction from the previous *n* weeks. I.e. for example, for the MOLs of a given Monday in delivery week W and positive aFRR for the delivery period from 00:00 to 04:00, the according MOLs of the previous 4 Mondays and delivery period (from 00:00 to 04:00) are used, i.e. W-1, W-2, W-3, and W-4.

More precisely, the available CMOLs are decomposed to derive the LMOLs for DE and AT. To make the MOLs comparable across weeks the LMOLs should be of equal length. This is achieved by discretizing them with 1 MW increments and by inserting missing data via (the nearest-neighbor) interpolation, i.e. using the price of the previous step. A weighted average of these LMOLs is derived, where more recent data is awarded with larger weights assuming they have a higher predictive power than less recent data. Using previous MOLs thus serve as a viable approximation of expected bidders' behavior and strategies. The resulting LMOLs for Germany and Austria are then recombined and sorted by bid prices in ascending order to again derive a predictive CMOL. Examples are shown in Figure 3 below for positive aFRR balancing capacity as well as positive aFRR balancing energy for DE and AT.

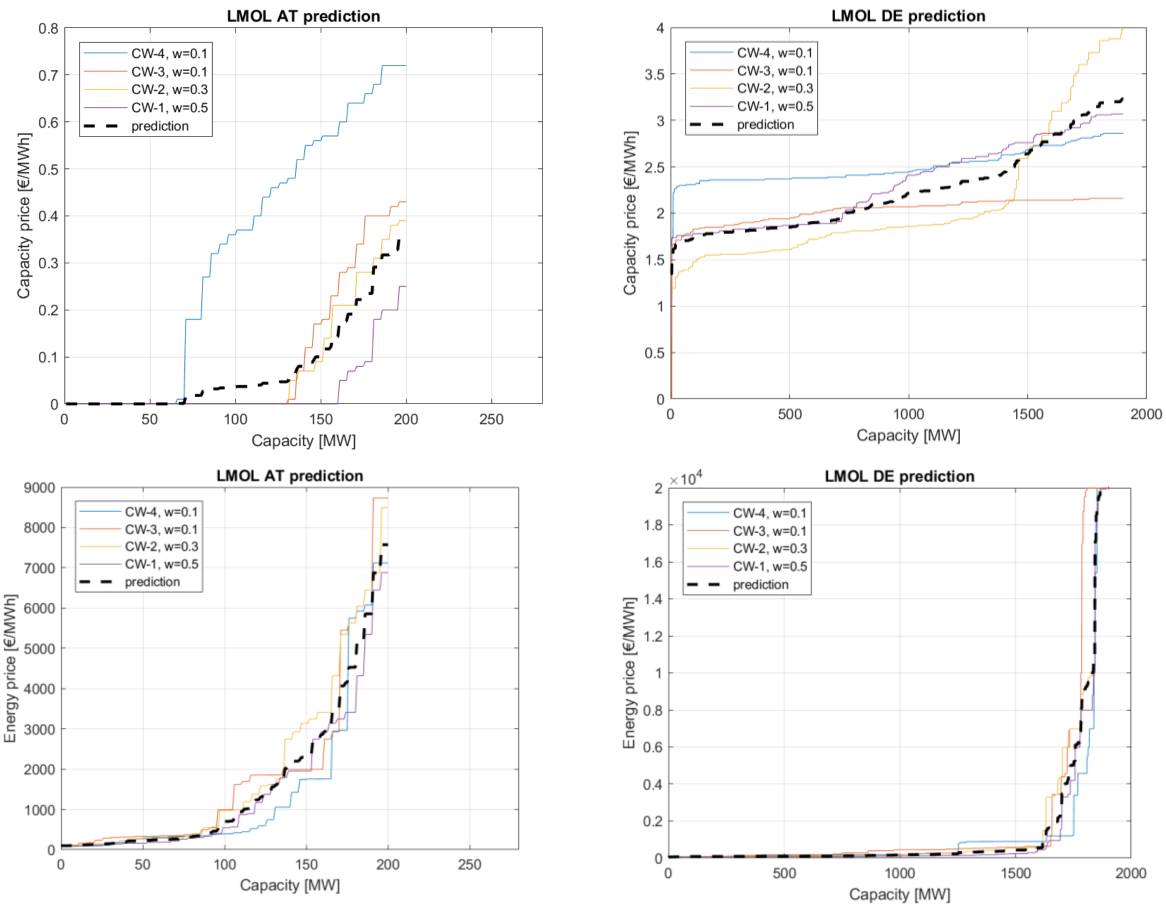


Figure 3: *Week ahead prediction of Local Merit Order Lists (LMOL) based on the weighted average of preceding LMOLs - for aFRR Capacity and Energy. The capacity and the energy CMOLs are combined linearly, resulting in a mixed price CMOL, which is the basis for further optimization purposes.*

The CMOLs for capacity allocation as well as for energy activation are combined linearly, including the activation probability α and thus resulting in mixed price CMOLs (see equation () below and the following paragraph for more information). As described in 3.1 these serve as the basis for the CBA and resemble the proposed procurement algorithm for aFRR balancing capacity.

$$CMOL_{MP} = CMOL_{CAP} + \alpha CMOL_{ENERGY} \tag{6}$$

4.2 Probability of Being Activated

Every bid accepted in the MOL for aFRR balancing capacity is eligible for being activated later on according to the MOL for aFRR balancing energy. As this depends on the demand for aFRR energy at a given point in time, each bid must be combined with its probability of being activated to derive the expected costs for the TSO.

Currently, the probability is assumed to be constant for all bids and it is calculated as the ratio of the sum of activated aFRR balancing energy to the sum of accepted aFRR balancing capacity. The underlying data are CMOLs of Germany and Austria for the 12 months prior to the

CBA. This method of determining the probability of being activated is in line with the methodology proposed by the German regulator Bundesnetzagentur for the procurement process of aFRR balancing capacity.

5 Description of the Process for the CZC Allocation

In this chapter the process and necessary steps until the final allocation of CZC for the balancing market is described. The process starts with the computation of CZC that can be allocated for the balancing market before the monthly auction. Afterwards the timing and frequency of the CBA is illustrated.

5.1 Procedure for the Allocation of CZC for the balancing market

In order to make CZC available for the allocation to the balancing market, a certain amount of CZC needs to be deducted from the monthly capacity auctions. To determine this amount of CZC the CBA results of the 4 weeks prior to the monthly auctions shall serve as the basis. Based on the previous weekly CBA results an amount of CZC is derived that reduces the tradable amount of CZC in the monthly auctions. This process will run before each monthly auction. Within the weekly CBA the previously outlined comparison of market values for CZC will be performed potentially leading to CZC that will be reallocated to the day-ahead market. This reallocated CZC will again be available for the day-ahead market coupling process. Figure 4 shows the intended process from the long-term CZC allocation until the evaluation of CZC in the weekly CBA. Based on the optimization run performed in the CBA, the CZC determined before the monthly auction can again (partially or fully) be reallocated to the day-ahead market.

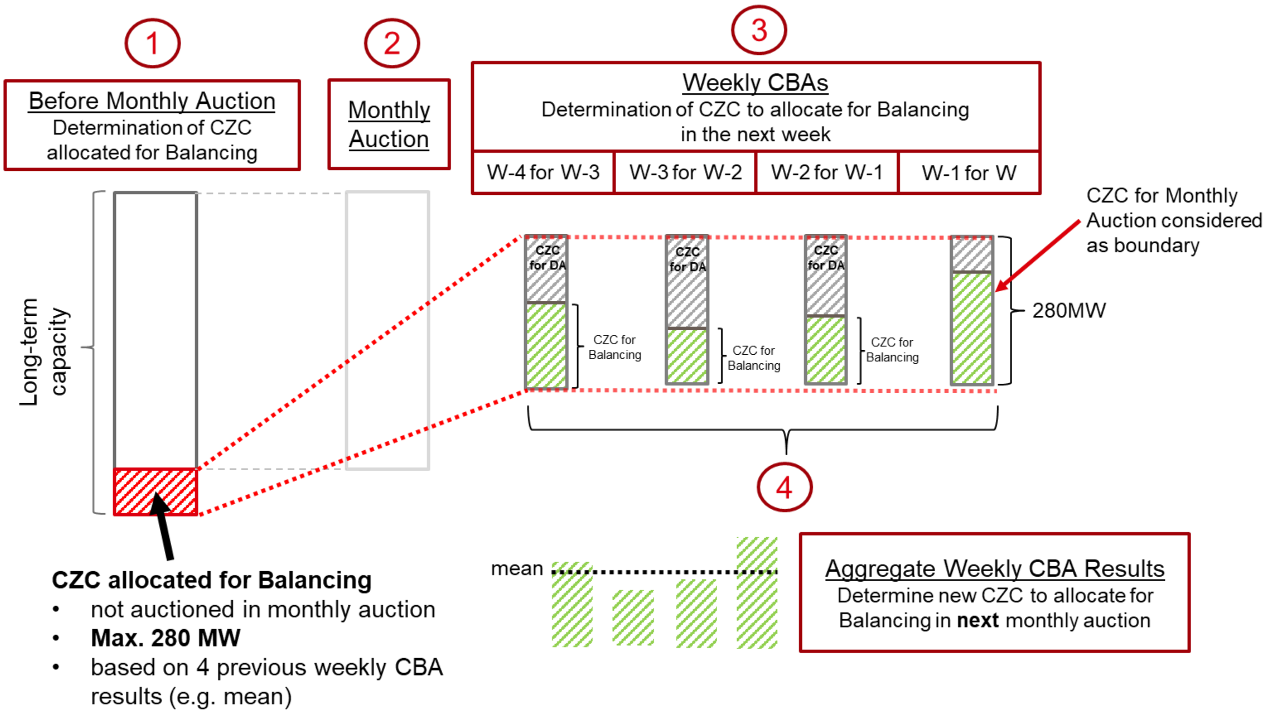


Figure 4: Process for the allocation of CZC for the balancing market

5.1.1 Frequency and Timing of the CBA run

Due to operational constraints and the compatibility with the flow-based process for capacity calculation, the TSOs of DE and AT decided to determine the CZC allocated to the balancing market on a weekly basis. Hence, in each week before the actual delivery week starts, a CBA-run will be performed to determine the CZC allocated for balancing. For each delivery week (W) the CBA will provide an optimal allocation of CZC for the balancing market in each flow direction (i.e. from DE to AT and from AT to DE). These values will then be included in the corresponding (daily) auctions for aFRR balancing capacity.

The determination of allocated CZC for the balancing market will be timed such that market participants can include the information in their bidding strategies in the aFRR balancing capacity as well as the day-ahead energy market.

Currently TSOs foresee a weekly CBA-run on Monday (W-1) before the gate closure of the aFRR capacity market for Monday in the upcoming delivery week (W). The results of the CBA will be valid for one week, i.e. from Monday to Sunday. For the next delivery week (W+1) a new optimal allocation will be derived based on a CBA-run in week (W).

Figure 5 summarizes the intendent process for the CZC allocation. The process starts with the determination of CZC that is allocated for the balancing market before the gate opening of the monthly long-term capacity auction (based on the previously performed 4-weekly CBAs). In a next step the ex-ante allocated CZC is again re-evaluated in the CBA, where the expected market value of CZC on the balancing and day-ahead market is compared. Based on this comparison the final amount of allocated CZC for the balancing market for delivery week W is determined. The result of the CBA is subsequently used in the daily aFRR balancing capacity procurement process for delivery week W. Before the start of delivery week W+1 a new CBA-run will be performed, determining the allocated CZC for the balancing market in delivery week W+1. Again the basis for the allocation is the ex-ante allocated CZC before the monthly long-term auction.

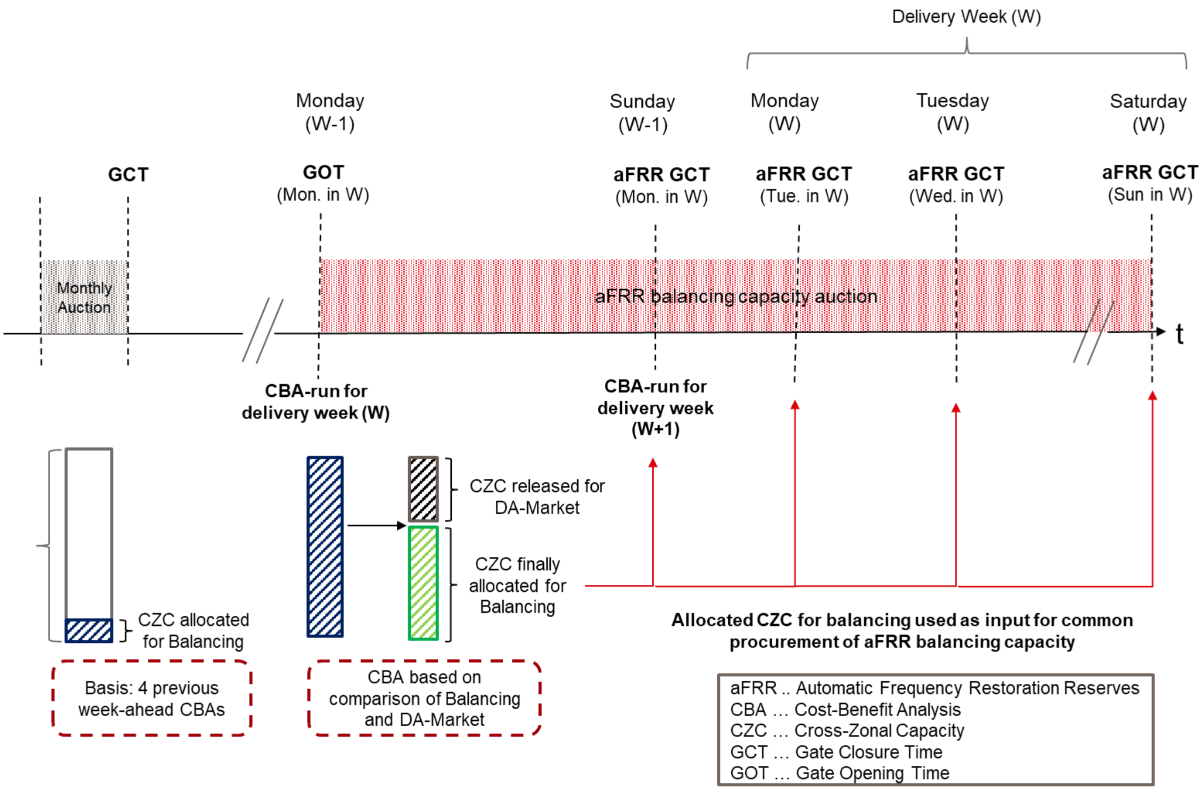


Figure 5: Overview of process and timing for CZC allocation for balancing

5.2 Publication of Results

The amount of CZC that is allocated for balancing markets influences the bidding strategies of market participants on the day-ahead energy market as well as on the aFRR balancing market. Hence, in order to inform the participants as soon as possible, the CBA results will be published on the homepage of Austrian Power Grid as well as on the homepages of the German TSOs. In addition, the CZC is planned to be published in the auction details before the gate for the daily aFRR balancing capacity auctions opens.

6 Preliminary Results

In order to test the CBA, a dry-run based on real-time data has been performed. This section summarizes the assumptions for the dry-run and provides a comprehensive overview of the preliminary results that were obtained during the dry-run simulations.

6.1 Assumptions

6.1.1 Period

For the dry-run the period between 1st January 2018 and 30th June 2018 was considered. In addition to this period the last four calendar weeks of 2017 have been considered in order to determine the MOLs for the balancing market in accordance with chapter 4.1. In total results for 26 weeks were obtained in the dry-run.

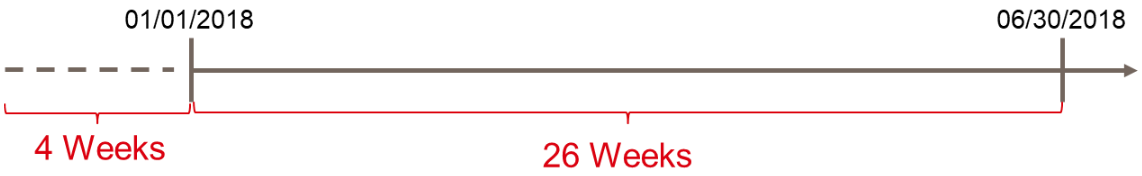


Figure 6: Period considered in dry-run

The considered period offers some advantages. Firstly the data in regards to the balancing market have been available. Moreover, the process for awarding balancing capacity bids in AT an DE has been the same for the whole period under consideration.

6.1.2 aFRR Balancing Merit Order Lists

As described in chapter 4.1 the MOLs for aFRR balancing energy and capacity were determined based on the tendering results of the previous 4 weeks. However, for the dry-run a slight deviation from the outlined process was necessary. Until 12th July 2018 the aFRR balancing capacity products in AT and DE have been peak and off-peak products procured on a weekly basis. For the simulations, the weekly peak and off-peak products were mapped to daily 4-hour products. As of 12th July 2018 the aFRR balancing capacity product has been changed to a 4-hour-product that is procured on a daily basis.

6.1.3 Day-Ahead Market Spread

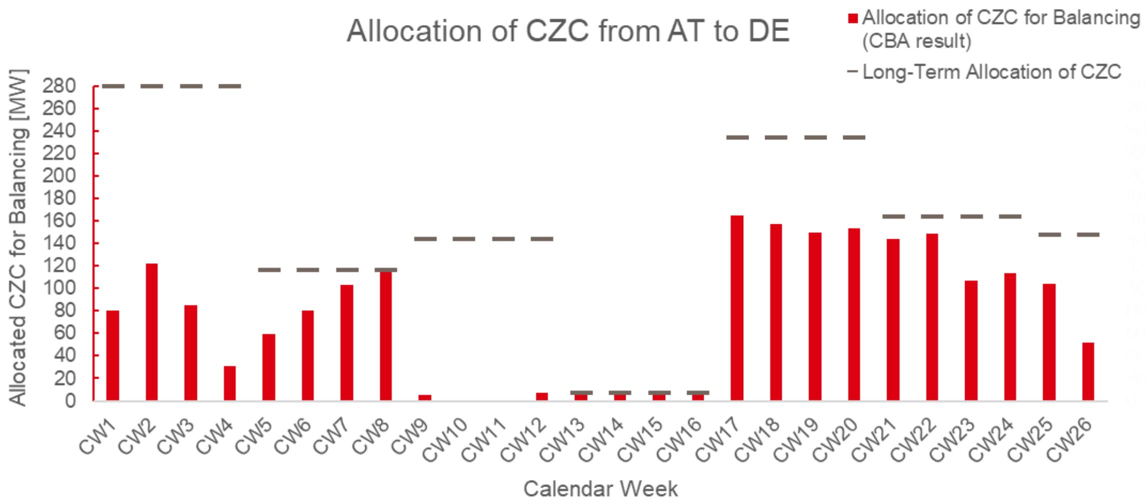
Since for the dry-run, AT and DE still form a common bidding zone no historical market spread is available. Therefore it is assumed that the market spread is equivalent to 2.5 EUR/MWh for the direction from DE to AT. For the opposite direction a market spread of 0 EUR/MWh is assumed. From current perspective this market spread is the best market forecast based on a comparison of monthly futures.

6.1.4 CZC for Monthly Capacity Auctions

In chapter 5.1 the process for the allocation of CZC before the monthly auction is described. In order to simulate its effect on the weekly CBA results it is assumed that before each monthly auction the 95% quantile of the 4 previously received CBA runs is used to determine the amount of CZC that is ex-ante allocated for balancing. Note that this is an assumption taken for the dry-run simulations.

6.2 Dry-Run Results

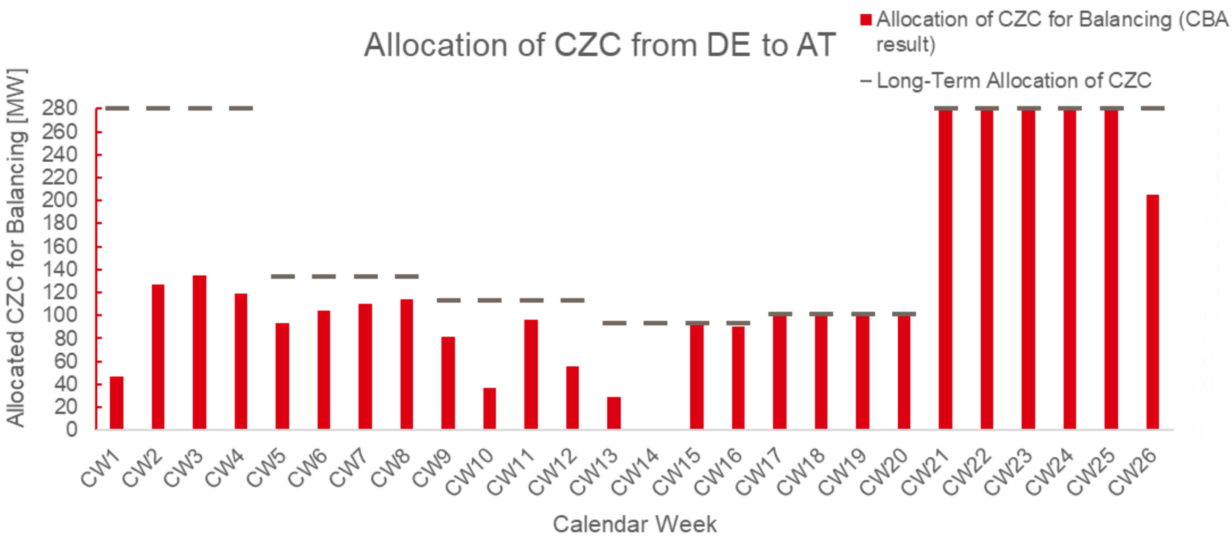
In accordance with the outlined methodology and taking into account the assumptions taken, a dry-run based on historical data has been performed. In the following figures the allocated CZC for the exchange of aFRR balancing services per calendar week is shown separated by the energy flow direction (i.e. from AT to DE and vice versa). The CZC allocated before the monthly capacity auction (grey horizontal bar) determines the upper bound for the weekly allocations (red bar). In each week the difference in allocated CZC between the upper bound and the weekly CBA result would be reassigned to the day-ahead market.



	MIN	MAX	MEAN
AT to DE [MW]	0	165	77

Figure 7: Dry-Run results for the allocation of CZC from AT to DE for balancing per calendar week

Figure 7 shows the amount of allocated CZC for the flow direction from AT to DE. As can be seen from the figure, there is clearly some variation from a minimum of 0 to a maximum of 165 MW. The average allocation for this flow direction would approximately be 77 MW. Moreover, the maximum available CZC of 280 MW is never reached, which means that in each week, some CZC could be re-assigned to the day-ahead market.



	MIN	*MAX*	*MEAN*
DE to AT [MW]	*0*	*280*	*128*

Figure 8: Dry-Run results for the allocation of CZC from DE to AT for balancing per calendar week

Figure 8 shows the amount of allocated CZC for the flow direction from DE to AT. Similar to the opposite flow direction the results vary between the weeks with a minimum allocation of 0 to a maximum of 280 MW. The average allocation for this flow direction would approximately be 128 MW. Only for the calendar weeks 21 to 25 the maximum amount of 280 MW is reached in each week.

6.3 Conclusion

In chapter 6.2 preliminary results from a dry-run for the period of 1st January 2018 until 30th June 2018 are shown. As can be seen from the results there is potential for the allocation of CZC for the exchange of balancing services between AT and DE based on the optimization of the overall economic advantage. Moreover, almost in each calendar week an allocation of CZC would be performed in both flow directions implying that balancing markets in both control blocks of AT and DE would benefit significantly from the allocation. However, since the development of the CBA is a continuous process and the go-live for the CZC allocation is currently planned for January 2019, the presented results are still preliminary and do not provide a reliant forecast for further allocations of CZC. Furthermore, since the aFRR balancing capacity products and the tendering period changed as of 12th July 2019 the TSOs of AT and DE plan to perform an additional dry-run in course of 2018 taking into account the new products.