Justification and Specification of Maximum and Minimum Balancing Energy Prices

Report
Prepared by the order of ENTSO-E

28 May 2021

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List of abbreviations

- ACER Agency for the Cooperation of Energy Regulators
- aFRR automatic Frequency Restoration Reserves
- BRP Balance Responsible Party
- BSP Balancing Service Provider
- ENTSO-E European Network of Transmission System Operators for Electricity
- mFRR manual Frequency Restoration Reserves
- MTU Market Time Unit
- VoLL Value of Lost Load

1. Introduction

To support the efficient functioning of the balancing energy market, harmonised maximum and minimum balancing energy prices can be introduced in the markets for upward and downward balancing energy pursuant to Article 30(2) of the Commission Regulation (EU) 2017/2195 (henceforth referred to as the "EB Regulation"). This report aims at a justification and specification of harmonised maximum and minimum balancing energy prices on the European platforms for the exchange of balancing energy.

Maximum and minimum balancing energy prices are enforced by limit prices for balancing energy bids. A limit price is a maximum (minimum) price that balancing energy bids must not exceed (undercut).[1]

Since the arguments for limit prices for downward balancing energy are similar to those for limit prices for upward balancing energy, most of the arguments in this report are stated only in terms of upward balancing energy and limit prices that determine a maximum balancing energy price.

To specify limit prices for balancing energy bids, this report proceeds in three steps. First, the limit price is assessed by an economic evaluation based on auction and game theory. Second, based on legal requirements and conditions as well as results of empirical studies, upper and lower bounds for a limit price are determined taking into account the maximum and minimum clearing price for day-ahead and intraday markets and the Value of Lost Load (VoLL). Third, taking into account the trade-offs set forth in the first step, the range for a limit price is narrowed down to arrive at a proposal for maximum and minimum balancing energy prices.

The structure of the report is as follows. Section 2 describes the determination of balancing energy prices, the roles they play in the electricity markets, and risks and consequences of distorted balancing prices. Section 3 justifies a limit price by providing auction-theoretic findings and discussing positive and negative effects of a limit price. Section 4 derives lower and upper bounds on the range of limit prices for balancing energy bids. Section 5 derives a proposal for specifying limit prices for balancing energy bids and concludes.

2. Balancing energy prices

This section sets the stage for the arguments in the next sections by describing some basic relationships.

2.1 Determination of balancing energy prices

Balancing energy prices are determined in an auction, in which BSPs submit bids that specify (among other things) a volume and a price bid for energy for a validity period of bids of 15 minutes (ACER 02-2020 I, Article 7, ACER 03-2020 I, Article 7). In the merit order, the bids are ranked in ascending order of the price bids (in case of upward balancing energy) and are awarded up to the capacity put out to tender (taking further constraints into account). In case of a realised demand for balancing energy within the validity period of the bids, the awarded bids are activated according to the merit order. Whenever a bid is activated, the BSP is paid a price equal to the highest activated bid in the Market Time Unit (MTU). The MTU is either equal to the time period of the optimisation cycle of the Activation Optimisation Function (aFRR MTU), which might be four seconds, or equal to 15 minutes, i.e., equal to the validity period of bids (mFRR MTU) (ACER 02-2020 I, Article 2, ACER 03-2020 I, Article 2). That is,

[1] Limit prices are commonly applied in auctions in the public sector, such as spectrum auctions or auctions for the renewable energy support (BNetzA, 2018; EEG 2017).

the auctions apply variations of marginal pricing (pay-as-cleared uniform pricing) to determine the price for balancing energy, as prescribed by EB Regulation, Article 30(1)(a).

BSPs are paid only if their bids are activated, which occurs less frequently the higher the bid in the merit order. High balancing energy prices (at the upper end of the range of feasible bids) result if many high bids are awarded and a sufficiently high demand for balancing energy realises.

2.2 The relationship between balancing energy prices and imbalance prices: incentives and risks

Balancing energy prices are used to determine the imbalance prices that BRPs have to pay for their imbalances. For each imbalance settlement period of 15 minutes, an imbalance price is derived either by the weighted average or the maximum price approach based on the prices for activated balancing energy and the respective volumes (ACER 18-2020 I, Article 9). Thus, high balancing energy prices cause high imbalance prices.

The connection between balancing energy prices and imbalance prices incentivises BRPs to support the system's balance in an efficient way (as requested in Recital 17 EB Regulation). BRPs can reduce their expected payment for their imbalances and the probability of high imbalance prices by increasing their efforts to keep their imbalance low. If a BRP reduces its imbalance, it thereby, first, directly decreases the amount it has to pay for its imbalance, and, second, decreases the demand for balancing energy in the system which reduces the balancing energy price. Therefore, imbalance prices can appropriately incentivise BRPs to adjust their efforts to avoid imbalances.[2] Nevertheless, due to the limited predictability of imbalances, a BRP cannot prevent every imbalance.[3] Therefore, BRPs always face the risk of unexpected imbalances, which may translate into large imbalance payments if there are high bids in the merit order and the imbalance is sufficiently large.

According to Recital 17 EB Regulation imbalance prices are intended to reflect the real-time value of energy. This requirement implies that high imbalance prices, and thus, high balancing energy prices, are acceptable if they correspond to the real-time value of energy. A possible definition of the real-time value of energy is the current cost for providing the marginal unit of energy. Whether balancing energy prices correspond to the real-time value of energy depends on whether the marginal activated bid corresponds to the cost for providing the marginal unit of energy. In Section 3, we analyse reasons for strong deviations of balancing energy bids from energy provision costs. We call the resulting high bids exaggeratedly high bids.

Exaggeratedly high bids for balancing energy can result in exaggeratedly high balancing energy prices, which do not generate the correct price signals and incentives to market participants required by EB Regulation, Article 30(1)(d). Furthermore, exaggeratedly high balancing energy prices result in exaggeratedly high imbalance prices.[4] These induce economically unjustified high financial risks for BRPs (up to bankruptcy), especially for small BRPs, which they cannot escape even by planning to minimise imbalances. Thus, exaggerated balancing energy prices endanger both overall efficiency and low costs for involved parties, violating the principle in EB Regulation, Article 3(2)(c).

[2] The empirical analysis of Eicke et al. (2021) supports the hypothesis that an expected increase of the imbalance price reduces the system imbalance.

[3] If the sets of BRPs and BSPs are largely identical, BSPs' incentives to achieve high prices at the balancing energy market are mitigated by the resulting high imbalance prices they might have to pay themselves.

[4] Those incentivise BRPs to reduce imbalances. However, one may argue extremely high imbalance prices induce BRPs to increase their efforts to avoid imbalances to a level that is not economically meaningful.

3. Auction-theoretical assessment of a limit price for balancing energy bids

In this section, we adopt an auction-theoretic view. First, we analyse the determination of balancing energy bids with the focus on exaggeratedly high bids that are much higher than the energy provision costs. Second, we analyse and assess the effects of a limit price on balancing energy bids.

3.1 Reasons for high and exaggeratedly high balancing energy bids

Before discussing strategic reasons for exaggeratedly high balancing energy bids, we set the stage for the arguments used in that discussion and clarify some further reasons for high energy bids.

Balancing energy auctions do not incentivise truthful bidding. Truthful bidding means that the bids are equal to the costs of energy provision. An auction with marginal pricing incentivises truthful bidding only if several conditions are fulfilled: lowest-rejected-bid marginal pricing (i.e., uniform pricing where the lowest rejected (non-activated) bid determines the price), single-unit-supply bidders (i.e., bidders who submit only one bid), homogeneous goods (i.e., bidders are indifferent between the goods at auction), and the auction is a one-shot game (Krishna, 2009; Haufe and Ehrhart, 2018). Under these conditions, the BSPs are incentivised to submit truthful bids, independent of their beliefs about their competitors' bids. However, in the balancing energy auctions under consideration, none of these conditions is satisfied (Ocker et al., 2018a; Ehrhart and Ocker, 2021). The auctions apply pay-as-cleared marginal pricing (i.e., uniform pricing where the highest activated bid determines the price). Bidders submit multiple bids. The different positions in the merit order offer different (activation probabilities and) profit opportunities, which makes the auctioned goods heterogeneous.[5] The balancing energy auctions will take place repeatedly, once every 15 minutes, with mostly the same set of bidders and similar volumes put out to tender. The auctions thus constitute a repeated game rather than a one-shot game between the bidders, which has an influence on incentives and expected outcomes.

Therefore, unlike sometimes stated (e.g., Recital 48 ACER 01-2020), marginal pricing (as stipulated by EB Regulation for the balancing energy markets) per se does not ensure correct price signals and incentives to market participants. Instead, it leaves room for a wide range of plausible bids, which will be discussed in the paragraph on rational motives for exaggeratedly high balancing energy bids.

Bids are belief-dependent. The heterogeneity of the merit-order positions of the awarded bids and the application of pay-as-cleared marginal pricing are two factors that impede truthful bidding and cause BSPs' optimal energy bids to depend on their beliefs about their competitors' bids and about the distribution of demand. Since the energy auctions are frequently repeated under similar conditions with the same participants, these beliefs may be determined by the BSPs' knowledge about their competitors and about the level of demand acquired by observing and experiencing former balancing energy auctions. Bidders may then optimise against these beliefs or learn over time to adjust their bidding (Hortaçsu and Puller, 2008).

Even for a BSP that takes only variable costs into account, bids that optimise against such beliefs may exceed the costs. However, the size of these deviations is not to be expected to result in extremely high bids (that fall out of the range determined in Section 4). For example, Ehrhart et al. (2021) present such an optimisation approach, in which the representative BSP's beliefs about the competitors' bids and the activation probability at each merit order position are given by an empirically based monthly average bid distribution and monthly average activation curve of a balancing energy market. Using data from auctions for upward aFRR in Germany in November 2020, this yields an exponential bid distribution up to 48,000 Euro/MWh and an exponentially decreasing activation function. In this

[5] BSPs will take not only their energy provision costs but also the activation probabilities at different positions in the merit order into account when calculating their bid.

model, the BPS determines its optimal bid *b** by maximizing its expected profit $\pi(b,c) = a(b)\cdot(b - c)$ with respect to its bid *b*, given its variable costs *c* of its generation unit and its beliefs *a*(*b*) about the activation probability depending on *b*. Concretely, *a*(*b*) is the expected percentage of activation in the considered validity period for the bid *b*. As the most striking result, the optimal bid *b** is far below the highest bids in the bid distribution. Examples for the optimal bid *b** for different variable costs *c* in this setting are: *b** = 650 Euro/MWh for *c* = 0 Euro/MWh, *b** = 950 Euro/MWh for *c* = 100 Euro/MWh, and *b** = 1200 Euro/MWh for *c* = 200 Euro/MWh. Thus, even if a BSP expects that several competitors submit very high bids, the BSP's best-reply-bid lies in a moderate range.[6] Indeed, the optimal bids are higher than the corresponding variable costs, but they are far below 10,000 Euro/MWh.

The fact that much higher bids[7] (up to the maximum price of 99,999.99 Euro/MWh) than the optimal bids *b** derived above have been observed in the German balancing energy auctions indicates that BSPs' bid calculation is not only determined by the optimal bid for a single generation unit in the current auction, based on the unit's physical costs of energy provision.

Costs for capacity provision (including costs for must run, ramping costs, and anticipated opportunity costs due to other energy markets[8]) may cause high energy bids if a bidder (with this unit) does not participate in the balancing capacity market. Such a bidder will incorporate the costs for capacity provision in the energy bid, which may lead to high bids, in particular if the expected demand for balancing energy (activation probability) is small. To illustrate, consider anticipated opportunity costs due to other energy markets, e.g. the intraday market. If a BSP, at the time of the submission of the balancing energy bid, expects a positive profit from participating in the intraday market in case the balancing energy bid is rejected,[9] this BSP will incorporate the value of this fall-back option (the expected profit from the intraday market) into the calculation of the optimal bid. The optimal bid increases in the value of the fall-back option. Whereas the profit stream from the intraday market covers the whole validity period of the bids, a profit from the balancing energy market realises only when the bid is activated. The result of such an optimisation may be a very high energy bid. Such a BSP with opportunity costs might prefer to participate in the balancing capacity market over participating only in the balancing energy market to recover its costs of capacity provision. A BSP that participates in the balancing capacity market will incorporate its capacity costs into the capacity bid, and will base its energy bid only on the variable costs (Ocker et al. 2018 a, b).

The next paragraph discusses strategic motives that influence a BSP's optimal bid.

[6] In the German balancing energy auctions in November 2020, pay-as-bid pricing was applied (regelleistung.net). This pricing rule induces the BSPs to submit energy bids with a competition-dependent mark-up on their costs. This also holds for the scheduled application of pay-as-cleared marginal pricing with MTUs equal to the optimisation cycle, although to a lesser extent (Ehrhart and Ocker, 2021). This analogy allows the transfer of the insight about the approximate level of bids with a mark-up on costs from the German example to the scheduled European design.

[7] Those exaggerated bids generate a background risk of exaggeratedly high balancing energy prices and, thus, also of exaggeratedly high imbalance prices. This is given by the specific (typical) shape of the BSPs' offer curve and, thus, merit order of awarded energy bids (as, e.g., observed in the German balancing energy auctions; Ehrhart et al., 2021): the merit order starts with low bid prices and shows a moderate increase in the lower and medium range, followed by a steep rise up to very high bids in the upper range of the merit order. Hence, if the demand (activation level) is not too high, the price will be determined by the moderate bids. However, if the activation exceeds a certain level, the price will soar.

[8] Note, the shorter the validity period of bids, the less attractive is the opportunity of the intraday market.

[9] Such participation options in the intraday market after being rejected at the balancing energy market may be limited due to the timing in some European countries.

Rational motives for exaggeratedly high balancing energy bids exist. We identify two main reasons for incentives to submit exaggeratedly high energy bids.

(1) **Multi-unit-supply BSPs**. BSPs that participate with multiple generation units have an incentive to exaggerate in their bids the costs of their more expensive generation units to increase the marginal price.[10] This particularly applies to powerful multi-unit BSPs with a large market share (Ehrhart et al., 2021, sections 3.3 and 4.3.6; Haufe and Ehrhart, 2018; Ausubel et al., 2014). Because the incentive to exaggerate differs in a BSP's units' costs of energy provision, this bidding behaviour promotes inefficiency (Noussair, 1995; Engelbrecht-Wiggans and Kahn, 1998).[11]

(2) **Regular repetition of the balancing energy auctions under similar conditions, with similar bidders, and with short validity periods of bids**. These factors incentivise tacit collusion, that is, the submission of high bids in order to coordinate the regularly participating BSPs on a high bid level and, thus, to reach a high price level.[12] This is supported by the short validity period of 15 minutes because the negative effect on the BSP if the high bid is not awarded or is not/rarely activated is weaker than with a long validity period (Berninghaus and Ehrhart, 1998; Ehrhart et al., 2021, sections 3.4 and 3.5).

The incentives in (1) and (2) are particularly strong in small markets or markets with little competition, or if the set of participating bidders (and their generation units) remains largely unchanged over time. Both conditions, particularly the second one, apply to the balancing energy markets.

A possible design element is the **release of non-awarded energy bids** for energy bids belonging to bids awarded in the balancing capacity auction.[13] If this design element is used, it creates incentives to increase the energy bids for BSPs with infra-marginal generation units[14] that have the opportunity to sell their energy on, e.g., the intraday market (Ehrhart et al., 2021, Section 3.2).

3.2 Effects of mitigating exaggerated bids for balancing energy by a limit price

A limit price can have positive and negative effects (e.g., Myerson, 1981).

We consider the following **positive effects** of a limit price for energy bids as particularly relevant:

- It reduces incentives to raise bids far above costs of energy provision, and thus may push prices towards the real-time value of energy. Its bid-reducing effect applies not only to bids that would be above the limit price if it was not there but also to bids that would then be below the limit price.
- A limit price reduces the financial risk for the BRPs (see Section 2.2) by limiting imbalance prices.

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[10] The BSP's lowest bid (for its cheapest unit) may determine the price for this unit; its second-lowest bid may determine the price for two of its units, its third-lowest bid may determine the price for three of its units, and so on. Thus, there is an incentive for higher mark-ups on the costs for more expensive units of the BSP because if the bid for a more expensive unit determines the price, then this price applies to more units of the BSP than if a bid for a cheaper unit determines the price. This incentive is in balancing energy auctions enhanced by the fact that the bids for the more expensive units have a less attractive merit order position due to the lower activation probability and, therefore, the loss in case the bid is not awarded is lower.

[11] This inefficiency occurs if the bids in the merit order are not ordered according to the size of the underlying costs. If mark-ups on costs do not only depend on costs but differ in the rank of the respective unit in the BSP's set of units (see Footnote 10), this may cause such an inefficiency.

[12] In game-theoretic wording, by tacit collusion, the players (the BSPs) try to coordinate on an equilibrium in the repeated game (the regularly repeated auction) that does not constitute an equilibrium in the one-shot game (one-shot auction) and that yields a higher payoff (profit) for the players than the equilibrium in the one-shot game (Fudenberg and Maskin, 1986; van Damme, 1991).

[13] This feature is, for example, implemented in the German balancing energy auctions (regelleistung.net, 2021).

[14] A generation unit is denoted infra-marginal (extra-marginal) if the variable generation cost are below (above) the price on the alternative energy market, e.g., the intraday market (Müsgens et al., 2014).

- A limit price is an appropriate means to impede tacit collusion and the exertion of market power because limit prices prevent high bids and prices and, thus, reduce gains from successful coordination.
- Thereby, a limit price contributes to giving correct price signals and incentives to market participants and can have a positive influence on efficiency (as required by EB Regulation, Article 30(2) and (1)(d)). The positive effect on efficiency realises if inefficiencies caused by non-monotonic distortions of bids relative to the underlying costs are reduced (Bresky, 2013).
- Additionally, a (temporary) limit price may help to alleviate transition problems of the new balancing energy markets by providing a security against the negative effects. Examples include:
    - IT problems when determining and implementing the merit order, resulting in a loss or replacement of bids in the merit order.
    - Outage of generation units that should be activated.
    - Exaggeratedly high bids submitted by inexperienced bidders (Hortaçsu and Puller, 2008).

The potential **negative effect** of a limit price for balancing energy bids is that it may reduce participation by BSPs that instead make use of their outside option of participating in a different market, which applies only to infra-marginal generation units, or that stay out of all markets. To the extent that the capacity put out to tender cannot be fully awarded, this can decrease efficiency. However, this risk is considered to be low for the following two reasons:

- Very high bids are unlikely to be due to high physical costs of energy provision. Thus, non-participation by BSP with low capacity provision costs like extra-marginal generation units, which do not have opportunity costs, is not to be expected.
- The risk of having low participation in the balancing energy market is mitigated by the existence of balancing capacity markets. If high bids in the balancing energy market are due to a large share of BSPs with high capacity provision costs (such as opportunity costs), these BSPs should participate in the balancing capacity market, which is better suited for the remuneration of capacity provision (Ocker et al., 2018a, b). BSPs whose capacity bids in the balancing capacity market are awarded have to submit an energy bid, which can assure sufficient participation in the balancing energy market.

To summarise, the **trade-offs** that have to be taken into account when determining a limit price are, on the one hand, that a limit price mitigates incentives and limits opportunities for exaggeratedly high and distorted bids, thus preventing extreme price peaks, protecting BRPs from extreme payments, and potentially promoting efficiency. On the other hand, a limit price may reduce participation (which affects efficiency if bids do not cover the volume put out to tender) and, if set too low, may prevent justified price peaks in times of scarcity.[15]

4. Bounds for maximum and minimum balancing energy prices

The task of this section is to establish bounds for the choice of limit prices that determine the maximum and minimum balancing energy prices. Our analysis and argumentation are geared to the regulatory guidelines and specific technical and economic conditions of the electricity supply system.

According to EB Regulation, Article 30(2), "harmonised maximum and minimum balancing energy prices shall take into account the maximum and minimum clearing price for day-ahead and intraday

[15] The positive effect of a lowered limit price on efficiency is that it reduces the probability of satisfying demand not with the least-cost energy, which has been called the misallocation effect, whereas the negative effect is that it increases the probability of not satisfying demand, called the demand restriction effect (Bresky, 2013).

timeframes". In the decision on the technical limit prices, ACER states "price limits in the balancing timeframe should not be lower than the limits imposed within the day-ahead and intraday timeframes and should not restrict price formation" (Recital 71 ACER 01-2020).

This determines the **lower bound** for (the absolute values of) a limit price for balancing energy bids: the limit price at the balancing energy markets should be set at least at the level of the limit prices at the day-ahead market (–500 Euro/MWh and 3000 Euro/MWh, ACER 04-2017 I, Article 3) and the intraday market (+/–9,999 Euro/MWh, ACER 05-2017 I, Article 3). Thus, the maximum and minimum balancing energy prices for upward and downward balancing energy should be above 9,999.99 Euro/MWh and below –9,999 Euro/MWh, respectively.[16]

An appropriate criterion to determine the **upper bound** for (the absolute values of) a limit price for balancing energy bids is provided by the VoLL. This is because the price for the satisfied balancing energy demand determines the imbalance price (ACER 18-2020 I, Article 9(3)). The imbalance price imposed on the BRPs should not exceed the "maximum electricity price that customers are willing to pay to avoid an outage", i.e., the VoLL as defined in Electricity Regulation 2(9). Thus, the VoLL can be taken as an upper limit on the balancing energy price.

The VoLL is to be determined and made publicly available for each bidding zone at least every five years according to Electricity Regulation, Article 11, but these values are not yet available. A recent study by VVA et al. (2018) estimates the average VoLL in European countries to 5,000–10,000 Euro/MWh for households and to 20,000–30,000 Euro/MWh for the industry. A study by CEPA (2018) reports similar values.

Thus, based on available estimates of the range of the average VoLL in the European Union, and the limit prices at day-ahead and intraday markets, we suggest the range of 10,000 Euro/MWh to 25,000 Euro/MWh for maximum balancing energy prices and –25,000 Euro/MWh to –10,000 Euro/MWh for minimum balancing energy prices.

5. Conclusion and recommendation

In theory and practice of auctions, a limit price is an established means to implement the principle of optimisation between overall efficiency and lowest total cost, which is mandated in EB Regulation, Article 3(2)(c). In Section 4, a range for a limit price in balancing energy auctions is derived based on the maximum and minimum clearing price for day-ahead and intraday markets and the VoLL (+/– 10,000 Euro/MWh to +/– 25,000 Euro/MWh). For the reasons and considerations on the trade-offs given in Section 3, the positive effects of an ambitious limit price within this range appear to outweigh the risks that the negative effects may materialise. Therefore, a limit price between 10,000 Euro/MWh and 17,500 Euro/MWh for upward balancing energy and a limit price between –10,000 Euro/MWh and –17,500 Euro/MWh for downward balancing energy are suggested for the implementation of harmonised maximum and minimum balancing energy prices in the markets for upward and downward balancing energy.

[16] Note that these maximum and minimum clearing prices for day-ahead and intraday timeframes may be adjusted according to automated adjustment mechanisms (ACER 04-2017 I, Article 4, ACER 05-2017 I, Article 4), which needs to be taken into account when requiring that the maximum and minimum prices for balancing energy are above and below these prices, respectively.

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