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ENERGINET POSITION ON FULL COST BALANCING. A POLLUTER-PAYS ZERO-SUM-GAME, TO AVOID AN UNFAIR DISTRIBUTION OF COSTS SOCIALISED TO ELECTRICITY CONSUMERS.

1 March 2024

Table of contents

This discussion paper will elaborate the initial concept, that Energinet sees relevant for *Full cost balancing,* based on the demand and resulting costs for balancing reserves procurement, which is directly introduced because of imbalances. It also elaborates the reasoning behind introducing such a polluter-pays zero sum game, shifting part of the financing of the balancing reserve from the system tariff to an imbalance fee.

The discussion paper also briefly discusses if a second principle concerning price elastic procurement of balancing reserves is to be introduced. Meaning that it is considered if the full dimensioned balancing capacity is to be procured or not, based on an assessment of marginal price and shadow costs (*referring* to the value created of the marginal MW procured, based on the change for the security of supply).

1. Background

The Nordic TSOs have developed an updated methodology for dimensioning of FRR (balancing reserves) as activation of balancing reserves is increasingly due to imbalances, which are deviations from scheduled consumption and production from energy markets, i.e. because of forecast errors and less due to forced outages. Besides, imbalances are expected to further increase correlated to the installed capacity of renewables, but also because of decentral flexible consumption.

Denmark and other coastal countries plan to exploit the vast amount of energy in the North Sea and the Baltic Sea with offshore wind. Likewise, Denmark has ambitious plans to quadruple the onshore renewable energy production by 2030. New consumption is expected to be introduced with sector coupling to absorb the immense amount of renewable production, i.e. electric vehicles, heat pumps, and electrolysers. Additionally, Denmark expects to become a net exporter of electricity and hydrogen, the latter entailing electrolysers in Denmark to convert electricity to hydrogen.

Energinet is adapting requirements and incentives in multiple places to support the unprecedented pace of the energy transition. The adaptations are based on the principles of fairness and cost reflection, i.e. that production and consumption units are responsible to not *pollute* (equal to all other units), or, alternatively, financially responsible for the *pollution*. The principle applies, among others, to grid connection requirements, tariffs, and imbalances, etc.

Dimensioning of balancing reserves is to ensure sufficient access to balancing energy, to avoid disconnection of production or consumption if an incident and/or large imbalance occur. The updated methodology is dimensioning balancing reserves for the sum of imbalances and the reference incident (largest loss due to a single failure), due to increased probability of simultaneity.

It therefore introduces an additional demand for balancing capacity derived directly from the imbalances, opposite of today, where dimensioning only considers the reference incident. Hence, a system imbalance is converted to an increased procurement need for balancing capacity, which comes with a cost in the capacity market for the balancing reserves. Today the cost hereof will be socialized through the system tariff per consumed kWh. Energinet expects the procurement of balancing capacity by 2030 to increase by ~50 and ~33 % in DK1 and DK2, respectively.

Full Cost Balancing is a concept where the true cost of resolving an imbalance is directed towards the polluter (the originator of the imbalance). The Nordic imbalance pricing design ensures exactly this, however only for the cost of energy activation to resolve the imbalance. It does not consider additional costs arising from the increased need for balancing capacity because of said imbalance. Hence, the aim of *Full Cost Balancing* is to direct the costs for additional balancing capacity arising from imbalances to the ones introducing the demand. *Full Cost Balancing* is intended as a polluter-pays zero-sum-game for balancing capacity, as the Nordic imbalance pricing design already is for balancing energy.

Energinet supports a cost reflective fee for imbalances, which includes the cost for additional FRR capacity arising from the imbalances. This is not to penalize imbalances unnecessarily. However, it will introduce additional incentive to stay balanced per BRP compared to today. The balancing philosophy of Energinet is still to allow imbalances from BRP portfolios, which will be resolved by Energinet on a system level with activation of mFRR and aFRR.

Though, the current socialization of cost of reserves cannot continue with Denmark expected to become a net exporter of electricity and hydrogen. In parallel, tariffs are updated to among others provide cost-reflective incentives to co-locate new units in hybrid plants, as energy produced and consumed *behind-the-meter* are not exposed to tariffs (as the collective infrastructure is unused). It is true for both the grid and the system tariff. Additionally, a new methodology for the system tariff, approved June 2023, reduces the system tariff paid per unit by 90 %, for consumption above 100 GWh per year, relevant for large consumers, i.e. electrolyzers. A grid-capacity tariff is introduced as well, in addition to the volume-tariff per consumed/produced unit.

In short, the classical consumption (residential households and industry) will pay an unfair share of the cost of reserves, if Energinet were to keep the current method to *finance* the procurement of balancing capacity, while the need for reserves increases and new large units are expected to mostly consume *behind-the-meter*.

2. New Nordic FRR Dimensioning methodology

The Nordic LFC block consists of four control areas (Sweden, Norway, Denmark, and Finland) and eleven LFC areas: SE1-SE4, NO1-NO5, FI, and DK2. LFC areas are equal to bidding zones in the Nordics. The Nordics are shifting from frequency-based balancing to Area Control Error (ACE)-based balancing (expected in December 2024 with go-live of mFRR EAM), hence an updated dimensioning methodology for balancing reserves (FRR) has been agreed between the TSOs and approved by the NRAs May 2023.

Previously, the dimensioning has solely been based on the reference incident (RI) per country, as imbalances have been less significant and there generally have been enough voluntary bids to cover normal imbalances (NI). The System Operation Guideline (SOGL) requires dimensioning per RI in each LFC block, however as the Nordics is one single LFC block with regular congestions between LFC areas (cross zonal capacity, CZC, is fully used by the energy markets, meaning day-ahead and intra-day, DA and ID), the dimensioning has historically been performed per country (= per control area).

The updated dimensioning methodology allows for a dynamic implementation (targeting Q4 2024), where the Nordic TSOs will assess the need of FRR per direction per LFC area for the coming day of operation based on forecasts. The forecasts are based on the most important drivers of normal imbalance, voluntary FRR energy bids, reference incident and scheduled flow on interconnection between Nordic LFC areas (to allow for sharing of reserves and netting of imbalances).

The updated dimensioning methodology is a bottom-up approach, assessing simultaneity between historical demands for NI and RI per LFC area and voluntary bids, sharing and netting possibilities (found from historically available CZC, that is not used by the energy markets). Hence, the procurement need is the part of the balancing demand which cannot be covered by sharing of reserves, netting of imbalances, and voluntary bids.

The updated dimensioning methodology for FRR targets capability to handle the sum of the reference incident (RI) and normal imbalances (NI) per LFC area, hence addressing increased demands because of growing normal imbalances, equal to deviations from schedules from the energy markets. The sum of RI and NI is targeted, as larger and more regular imbalances increase the probability of incidents simultaneously with the imbalances.

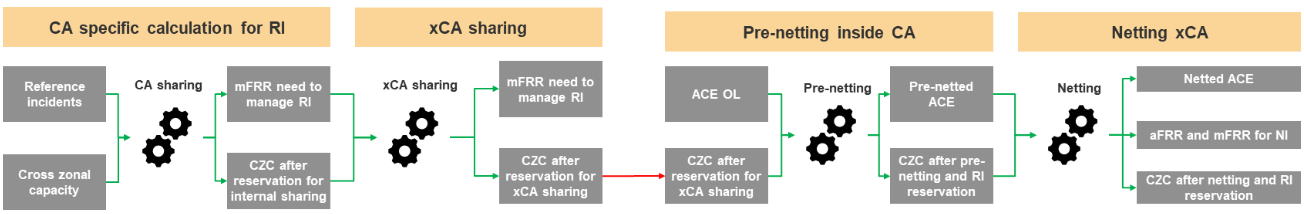

Figure 1: An illustration of the calculation and the sequential steps. xCA refers to actions cross control areas.

The dimensioning calculation is based on historical data in hourly or higher time resolution. Simultaneity between needs and optimization potentials are considered to ensure that the resulting risk level from the calculations are reflecting reality. Each hour in the historical data becomes input to the distribution of calculated balancing needs, where the resulting procurement need of balancing capacity is found from the chosen risk level, equal to the number of hours where the Nordic TSOs aim to cover both NI and RI. The data input and the calculation are updated frequently, with rolling data from the two recent years to reflect new trends and changed patterns. Voluntary energy bids are included as well, which can reduce the FRR capacity procurement need. To find the actual risk level the outage probability that triggers an activation need for RI must be considered as well.

Hence, a risk level equal to the 99th percentile chosen based on the Nordic dimensioning methodology is not to be compared with the 99th percentile from SOGL §157, as this only reflects the historical distribution of imbalances.

3. Concept for implementation of *Full Cost Balancing*

The concept for *Full Cost Balancing* shall reflect the actual costs of the additional procurement need arising from imbalances, as per the updated Nordic dimensioning methodology. However, covering the actual costs precisely is most likely difficult to achieve. The target is therefore a stable mechanism creating an incentive to balance responsible parties (BRPs) to reduce imbalances, reflecting actual introduced costs with acceptable precision.

The idea is to adopt the methodology used for tariffs, by introducing a lag, meaning that the imbalance fee of a given period aims at recovering the costs of the previous period, and by introducing an over and under recovery mechanism.

The penalty introduced to imbalances shall only apply to BRP imbalances in the dominating direction of the system imbalance. Hence the penalty shall only apply to BRP imbalances 'worsening' the system imbalance and incurring increased procurement need for FRR capacity. The penalty shall not apply directly to individual BRP imbalances, as the imbalances of BRPs will cancel out to some extent (netting within the LFC area), when summing up to find the system imbalance, exemplified in **Figure 3**.

Information for the system imbalance direction and size shall be available for all in real-time, in high resolution (i.e. per minute) to ensure transparency. Hence, giving BRPs the opportunity to react if their imbalance position is worsening the system imbalance. This does not exist in the Nordics, other than in a pilot in Finland. Energinet expects to publish real-time information in late Q2 2024, in a similar pilot as the one by Fingrid.

As the updated dimensioning methodology aims at ensuring a certain risk level, the dimensioning will be impacted by the larger imbalances in the historical distribution of system imbalances. The specific percentile is not settled yet; however, it is expected to be in the range of P90-P99. P90 equals the 90th percentile/quantile of the distribution. System imbalances in the magnitude below a certain threshold are therefore not expected to impact the dimensioning. This shall be reflected with a deadband for the system imbalance where no penalty is applied. As the procurement need is a result of more than imbalances, the deadband for the system imbalance might be smaller than what is found from the P9X of the historical distribution of the system imbalance. Additionally, it is important to note, that the deadband will be asymmetric as the distribution for positive and negative system imbalances are different.

The updated dimensioning methodology creates the possibility to calculate 'backwards' to find the relationship between a MW of system imbalance synthetically added or subtracted to the historical distribution, and the resulting additional procurement need for FRR capacity. As this is expected to be non-linear, the relationship can be found for multiple steps added to the system imbalance to form a linearization (or perhaps to increase the fee with the size of the imbalance).

Historical procurement costs allow a TSO to convert the relationship between synthetical imbalances and additional procurement need to cost, if the additional FRR capacity was to be procured. An alternative could be to consider the impact on the costs for the TSOs, as the capacity markets are marginally priced. If the marginal price increases, the cost for the TSO increases for the existing procurement as well.

Nonetheless, BRP imbalances worsening the state of the system, when the system imbalance is outside the deadband, can be translated to a cost reflective penalty. The yearly income for the TSO of the fee shall be equal to or smaller than the cost it must recover. This shall be analysed on historical data and continuously monitored, creating a feedback loop allowing for needed adjustments if necessary.

Alternatively, the deadband and the penalty could be adjusted to recover, as precisely as possible, the introduced costs of a larger balancing capacity procurement need. If the deadband is to reflect the size of the system imbalance that impacts the dimensioning of balancing reserves, then the penalty becomes the only parameter to adjust.

The penalty is proposed to be introduced as an addition to the imbalance fee, or simply replacing the current fee. The imbalance fee can be nationally independent, which will be needed as cost of additional balancing capacity will be different in each LFC area, and also direction (up and down). Today, the imbalance fee is also nationally independent, where the imbalance fee in Denmark today is 0.13 EUR/MWh, the imbalance fee in Norway, Sweden and Finland is 1.15 EUR/MWh.

An imbalance fee is settled in the existing imbalance settlement framework, which will become per 15 minutes when introducing 15 minutes imbalance settlement periods (15 min ISP). The size of the system imbalances will be an average during the 15 minutes of the ISP, where the individual BRP contributions will be found as per the same principles.

The imbalance fee is proposed to be adjusted per quarter year/per year. There are no strong seasonal patterns of FRR capacity cost in Denmark. The imbalance fee will be published prior to the relevant period. Additionally, a fixed price for longer periods will create stability and higher financial security for BRPs. If FRR capacity prices changes, locking the fee for a longer period will of course create a lag, however deemed of lesser importance than stability for the fee. The nature of the system imbalances are not expected to change per quarter year, hence stability is weighed higher than frequent updates based on a feedback loop.

Imbalances for a specific day does not impact the dimensioning of that day. The historical data will be included in the distribution which acts as input to the dimensioning calculation, but first when the input data is updated and the specific hour/day is included in the historical distribution. Updating input data is expected to be done with a monthly frequency or higher.

A saturation limit could also be introduced, where the imbalance price acts as a sufficient incentive to reduce imbalance for BRPs. However, this would require real time information on imbalance prices (which does not exist in the Nordics yet, and is not straightforward to implement). This opposes the principles of reflecting cost, as the primary driver for the fee is not to incentivize less severe imbalances but reflecting actual costs. Therefore, this is not proposed.

The impact on the marginal price of FRR capacity, and hence increasing cost the for TSO for '*existing'* procurement need (arising from the reference incident), could also be reflected. With an increasing demand for balancing capacity introduced by imbalances, the TSO would have to climb the merit order list for balancing capacity, hence not only introducing additional costs equal to the additional need multiplied by the *new* marginal price. As the target of the fee is a polluter-pays zero-sum-game, then the socialization of costs via the system tariff, introduced by the polluter should be avoided. To avoid this, the fee should revocer costs reflecting the difference in total FRR capacity procurement costs with and without including the need arising from imbalances.

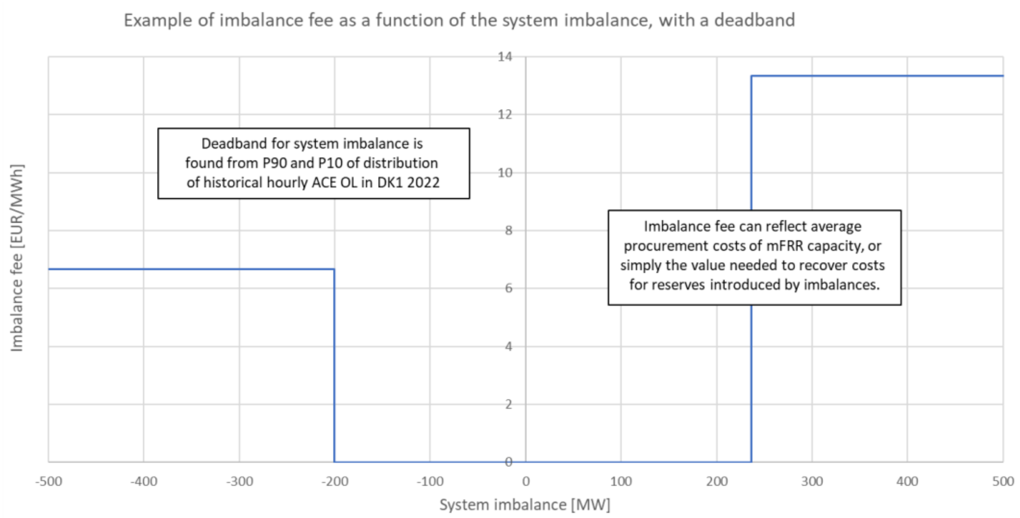

Figure 2: Illustration of an imbalance fee as a function of the system imbalance, implemented with a deadband found from the P10 and P90 from the historical hourly ACE OL distribution of DK1 from 2022.

The imbalance fee is proposed to penalize the imbalances proportional to the system imbalance, illustrated in **Figure 3**. Assume that three BRPs have imbalances as illustrated in the figure. The system imbalance is the sum of the three portfolios. The grey bars are the proportional imbalance of the individual BRPs so the system imbalance. Hence, the BRP, A, with an opposite imbalance is not penalized. The two BRPs, B and C, worsening the system state, are penalized corresponding to half of their individual imbalances in this specific example.

Alternatively, the full individual imbalances of BRP B and C could be penalized. This will give the BRPs a more direct conversion of individual imbalances of their portfolios to a given penalty. However, it will introduce an uncertainty for the TSO as the volume of MWh of imbalance that will be penalized will see larger variation, compared to the size of system imbalance following the netting of opposite BRP imbalances.

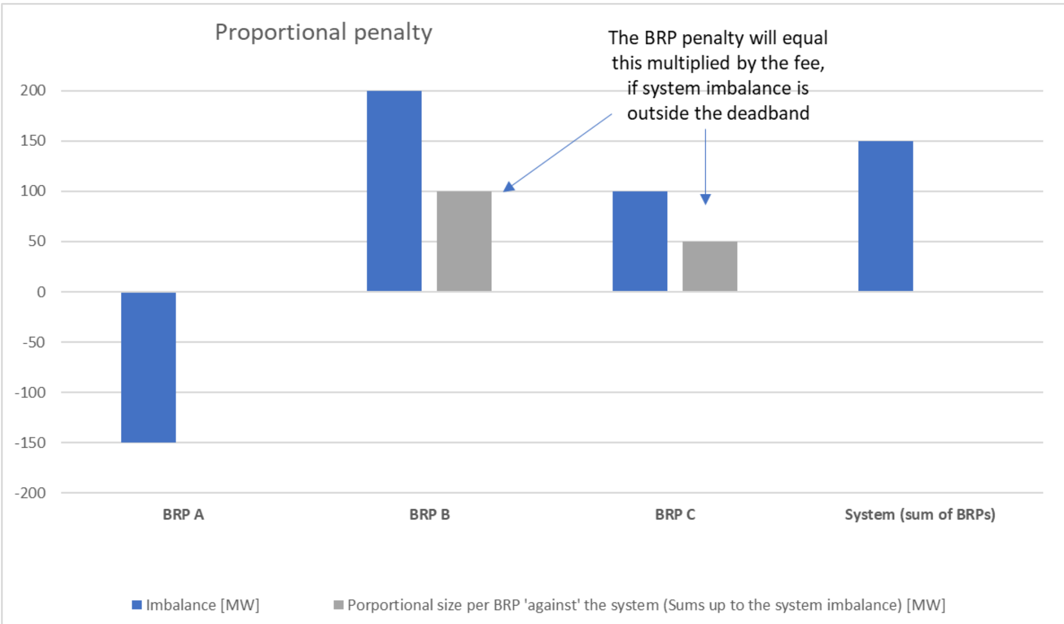

Figure 3: Example of proportional distribution of system imbalance onto individual BRP imbalances.

If following the above illustrated principles in **Figure 3**, the revenue for the TSO from the fee can be found as the sum of MWh of system imbalance when outside the deadband, multiplied by the imbalance fee. If the P10 and P90 are chosen, the imbalance is expected to be outside 20 % of the time, 10 % in each direction. The average imbalance when outside the deadband in the example case of DK1 in 2022 is respectively 618 MWh/hr and -513 MWh/hr for positive and negative imbalances. As an example an arbitratily chosen fee of ~8.5 EUR/MWh for negative imbalances, will result in a revenue from the fee to Energinet of 3.8 mio. EUR/year, which equals the cost for upwards regulation mFRR capacity procurement in 2022. In average 297 MW/hr, at 1.5 EUR/MW/hr.

Similarly, to recover to full cost of upwards regulation mFRR capacity procurement in DK2 in 2022, the fee would be substantially higher. If taking the same imbalance distribution as in DK1, the fee would have to be ~186 EUR/MWh, as the costs are much larger. In average 603 MW/hr, at 15.8 EUR/MW/hr.

It is important to stress that these are not the expected costs to be recovered by the *Full Cost Balancing* mechanism, as the procurement needs today does not reflect the expected needs based on the updated Nordic dimensioning methodology. Additionally, *Full Cost Balancing* is targeting the needs arising from imbalances, and not the full procurement need, see *section 4* for examples reflecting this.

If the yearly revenue does not recover the additional cost from imbalances, either the deadband or the fee could be adjusted. This could be part of the quarterly/yearly feedback process.

4. The imbalance fee based on historical data

Figure 4 illustrates the distribution of the isolated system imbalance for DK1 and DK2 in the past two years. There are noteworthy differences between DK1 and DK2, however not between the individual years for each zone. For DK2 the average system imbalance is also noticably positive (=surpluss of energy, demanding downwards regulation). For DK1 the average is evenly distributed around zero.

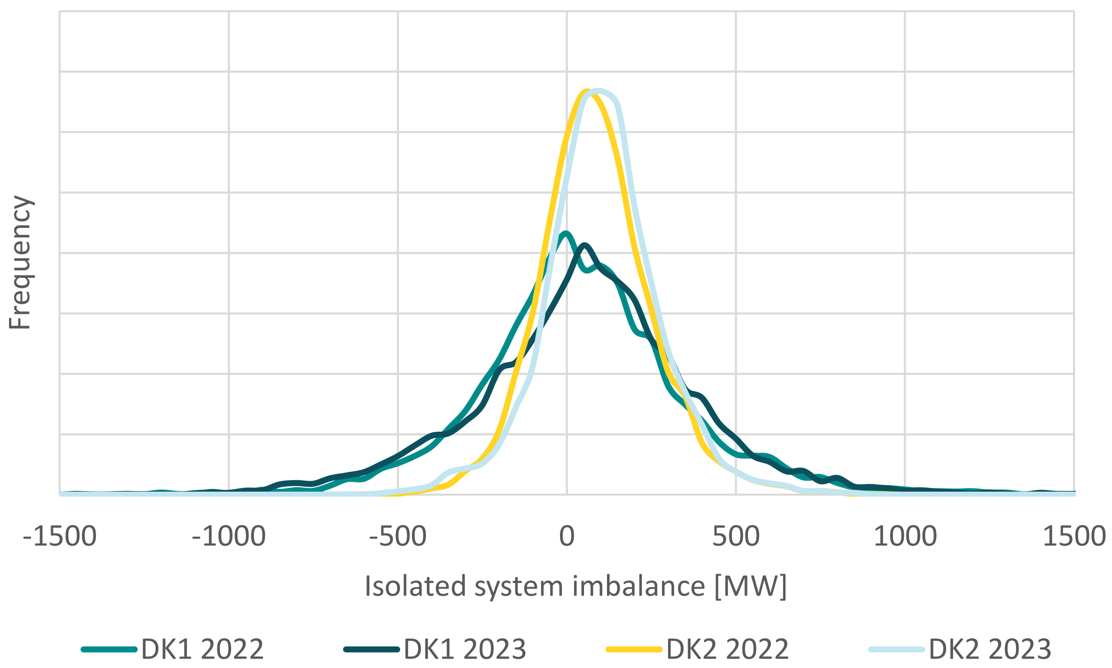

***Figure 4**: Distribution of isolated system imbalances in Denmark, respectively for DK1, DK2 in 2022, 2023.*

When performing the dimensioning calculation for 2023, the system imbalance is reduced by netting of opposite imbalances. Therefore, the arising need for additional reserves based on imbalances can be reduced to the range of 83 to 168 MW for DK1 and DK2 for upwards and downwards reserves.

It is only possible to calculate the cost for the additional reserves in 2023 for upwards reserves in DK1 and DK2, as Energinet does not procure downwards reserves for mFRR. The costs are calculated by manipulating the procurement levels in the historical mFRR CM auctions, hence using actual merit order curves on an hourly basis.

When deriving the imbalance fee, using the proportional distribution methodology, a deadband must be chosen. In the below example, the 25 % and 75 % quantiles from the historical isolated system imbalance are chosen. The reasoning behind, is that smaller imbalances are not impacting the reserve need for imbalances, while increasing the deadband would increase the resulting fee as it would be distributed to a smaller volume of imbalances. However, still arbitrarily chosen.

The resulting fee for upwards in DK1 and DK2 becomes 5.9 and 20.0 EUR/MWh respectively, proportionally distributed when the system imbalance is larger than the deadband, equal to -153 and -24 MW of deficit.

The needs, the costs and the resulting fees are to exemplify the expected range, however still based on *preliminary numbers*. The calculations will be updated continuously, and the final values will be updated accordingly before settled for a fixed period.

PRELIMINARY RESULTS	DK1 Up	DK2 Up	DK1 Down	DK2 Down
Need for additional reserves from imbalances [MW]	118	83	168	164
Cost for additional reserves if applied to 2023* [mio. EUR]	5.00	5.79	-	-
Deadband for the system imbalance (P75,P25) [MW]	-153	-24	218	179
Resulting imbalance fee, porportionally distributed [EUR/MWh]	**5.9**	**20.0**	(5.3)**	(9.0)**

***Table 1**: Resulting imbalance fee, if basing the costs for additional reserves arising from imbalances in 2023.*

* The costs are calculated by rerunning the mFRR CM auction for 2023, but with a changed procurement level according to the updated dimensioning methodology. The costs for the reserves arising from imbalances are found from the difference in cost, if including that additional need from imbalances or not.

** If assuming same costs for downwards reserves as for the additional procurement for upwards reserves.

5. Considerations for aFRR

The described concept for *Full Cost Balancing* in this report applies to mFRR in the Nordics. It is not as straightforward to introduce the concept for aFRR. Imbalances are settled per imbalance settlement period (ISP), currently per hour and soon per quarter hour in Denmark and the Nordics. However, the purpose of aFRR is to mitigate the faster imbalances, which aFRR is dimensioned for as well.

aFRR is not dimensioned for outages, but only for the fluctuating imbalances. Therefore, as per the principles for *Full Cost Balancing*, the cost for reserves for aFRR shall be recovered in a zero-sum-game (cost-reflective) polluter pays mechanism. The polluter being BRPs that worsen the fluctuations of the system imbalance that introduces an increasing need of aFRR.

Per the updated dimensioning methodology, aFRR is dimensioned based on a confidence interval for the distribution, found from the difference between the rolling averages of 5 and 15 minutes of the system imbalance (based on data with 1 minute resolution). Imbalances sustained for longer than 15 minutes are to be handled by mFRR. Where aFRR is not able to handle imbalances present in less than 5 minutes, as the Full Activation Time (FAT) of aFRR is 5 minutes.

As the imbalance fee is applied to imbalances settled per ISP, there is not necessarily a clear connection between the settled imbalance of a BRP and the fluctuations within the ISP, which is the actual cause of the need for aFRR. Additionally, the fluctuation of an imbalance from a given BRP can both worsen or reduce the fluctuations of the system imbalance. As the fluctuations within the ISP per BRP are not 'measured' in the current setup for the imbalance settlement, it is difficult to apply the polluter pays principles, as the size of the fluctuation is not given nor closely correlated to the size of the imbalance per ISP. It is not given either if the fluctuation is polluting or not (worsening or reducing the fluctuation of the system imbalance).

At first, Energinet advances with the implementation of Full Cost Balancing aimed at sustained imbalances, that are applicable to the current setup with mFRR in mind. In parallel, Energinet continues to develop the concept for aFRR, which is expected to follow if a reasonable setup can be implemented.

6. Price elastic procurement of balancing capacity

On top of *Full Cost Balancing* Energinet considers introducing a second principle denoted as *price elastic procurement of balancing capacity*. The price of balancing capacity, both for aFRR and mFRR, has skyrocketed for shorter periods in mulitple occasions in the past years. In these situations, the principle of price elastic procurement would potentielly have decreased the procurement, if assessed that the value of a given amount of the procured reserve was lower than the additional cost. Similarly, in periods with relatively low prices, price elasticity might introduce an increased procurement of reserves.

As for *Full Cost Balancing* there are many considerations if introducing a mechanism like price elastic procurement. The intention is not to keep the price of balancing capacity below a certain threshold, nor to decrease procurement every now and then. The intention is to slightly reduce procurement in rare situations where a single or few balancing capacity bids, that does not significantly impact the security of supply, potentially increases the marginal price manyfold. If procuring such bids, the significant additional cost (with little value) would be socialized via the system tariff per consumed unit of electricity.

One could argue, that the price elastic procurement becomes a measure to manage unfair distribution effects, to avoid that consumers have to pay an unnecessary bill. It corresponds to paying an insurance premium higher than the cost of the actual incident.

If introducing price elastic procurement, the providers of balancing capacity would see reduced revenue. Again, the intention is to capture the rare situations where the prices skyrocket, where the marginal units potentially not procured because of the price elasticity, would see no revenue at all. The capacity bids still procured would see decreased revenue, as the marginal price will decrease. To hopefully avoid negative impact on the supply of balancing capacity, it is considered to introduce a range that the price elastic procurement works within, either as a range for the risk level or a range for the allowed decrease or increase of MW to be procured. Say for the risk level, that the default target is P95. Then, the allowed range could be from P90 to P99. For the consideration in absolute numbers of MW, the range could as an example be +/- 50 MW from the number derived from the targeted risk level.

Price elasticity of balancing capacity comes with a change in probability of needing remedial actions, ultimately controlled brown outs. It is natural to ask, what happens in the situation, where Energinet has reduced procurement below the default risk level, and scarcity of balancing energy dictates the need for load shedding (brown out)? Implementing a range for the price elasticity ensures that Energinet avoids theoretical situations where little to no reserve is procured, or vice versa that the procured volume becomes larger than what is assessed to be relevant by the TSO. Hence, limiting the range of the price elasticity will also decrease the probability that an actual brown out will happen, because of a reduced procurement, or of a larger brown out than what would have happened with the default procurement level.

The impact on the probability needing remedial action and ultimately controlled brown out will therefore be minimal, due to the limited range, and as the price elasticity will be relatively low (almost inelastic) because of the estimated value of lost load (VoLL). It is also important to note, that even without price elasticity, there is a risk of brown outs due to lack of balancing energy in operations, as Energinet does not procure an infinite amount of reserves. Hence, Energinet will follow ordinary operational procedures if scarcity of balancing energy occurs, regardless if the procurement of balancing capacity was more or less than the default risk level. It is a calculated risk.

Another consideration is how price elastic procurement links with *Full Cost Balancing*, which is relatively straightforward. If the cost for balancing capacity for a given period has decreased, it will reduce the imbalance fee set to recover the cost via *Full Cost Balancing*, and vice versa.

In contrast to *Full Cost Balancing*, as of now Energinet is not as confident about implementation of the concept of *price elastic procurement of balancing capacity*. However, it is considered very important to address the increasing cost of security of supply, and challenge if the historically achieved level of security of supply is a necessity in all hours during the year, and if the desired level is equal for all stakeholders? It is therefore expected that Energinet will pursue both questions, the first adressed with *price elastic procurement of balancing capacity*, and the second further investigated in a innovation project focused on differentiated security of supply. But the intention is not to implement the concept of price elastic procurement or differentiated security of supply at the same time as *Full Cost Balancing*.

Detailed considerations for *Price Elastic Procurement of Balancing Capacity*, and an example

The updated dimensioning methdology will produce a procurement need from the historical distribution, hence it is possible to translate a risk level, i.e. a quantile from P90-P99, to a procurement need. This allows to see the difference in procurement need from two risk levels, i.e. P94 to P95, etc. At the time of the auction, the merit order list for balancing capacity is known by the TSO, and therefore it can be further converted to a cost. The delta in cost for a delta in risk level, can therefore be compared to the shadow cost, equal to the expected value of the balancing capacity.

The shadow cost for upwards regulation balancing capacity is considered to be the value of lost load (VoLL), considered to be 174 DKK/kWh[1], times the probability that load shedding will occur. Similarly, a value of lost production can be found, i.e. derived from balancing energy prices. The probability that load shedding will occur, must be the increase or decrease in probability for the increased or decreased amount of load that potentially will be shed, based on a change in balancing capacity procurement. Again, similar for production.

To exemplify. Assume that the P95 equals a procurement need of 500 MW, while the P94 equals 480 MW. According to the updated dimensioning methodology, the P95 means that there is sufficient balancing energy

[1] https://ens.dk/presse/energistyrelsen-udgiver-ny-analyse-om-danske-elforbrugeres-omkostninger-ved-stroemafbrud

to cover the balancing demand arising from the sum (simultaneity) of imbalances and the reference incident in 95 % of the time based on the historical distribution. The difference to P94, the 20 MW in this example, means that procuring 20 MW less of balancing capacity, will decrease the sufficiency of balancing energy to 94 % of the time.

The insufficiency will occur if the reference incident happens, therefore the probability is assessed to be equal to the probability of a reference incident to occur. In this example, the shadow cost becomes 20 MW times the outage probability, say of 5 %, times the value of lost load (=174 DKK/kWh). This is equal to 174,000 DKK/hr (23,200 EUR/hr). If the total cost of reserves, based on the merit order list of balancing capacity increases more than this, when procuring 500 MW instead of 480 MW, then the price elasticity would reduce the procurement to 480 MW instead of the default value of 500 MW.

To exemplify, say that the marginal price for 480 MW is 100 DKK/MW/hr (~13 EUR/MW/hr). The total cost per hour becomes 48,000 DKK/hr (6,400 EUR/hr). In this example, if the marginal cost stays below ~350 DKK/MW/hr (~47 EUR/MW/hr), then 500 MW would be procured. If the marginal cost increases to more, then 480 MW would be procured. If the outage probability is defined to be 1 %, then the price elasticity trigger for the marginal price would be ~165.5 DKK/MW/hr (~22 EUR/MW/hr) instead. Hence, the defined outage probability has a large impact, which dictates the need for extensive analysis of outage statistics before set.

7. Key conclusions

The rapid introduction of variable renewables and price sensitive consumption leads to larger imbalances and in general larger system variations, hence leading to larger reserve demands, captured in the new Nordic dimensioning methodology for FRR. Imbalances are expected to continue to increase many years to come, due to the correlation with introduction of additional renewable capacity and price sensitive consumption.

The overall idea is to transfer increasing reserve procurement cost due to increased normal imbalances to those causing the increased demand. This is to be done reflecting real cost, to create incentives for market participants to be synchronized with the system balancing need.

The concept of *price elastic procurement of balancing capacity* is to avoid unfair distribution effects because of few or single balancing capacity bids that increase the marginal price manyfold, and hence introduce a large additional cost to consumers via the tariff, which in return has provided little value as an insignificant reduced probability of brown outs.

This document is an early conceptualization of *Full Cost Balancing* and *Price elastic procurement of balancing capacity* as envisioned by Energinet, which is shared to ignite discussion and inputs for potential implementation. Energinet will invite interested stakeholders to discuss the concepts in a workshop open for all, and welcomes written comments or bilateral discussions.

Multiple new questions are expected to be raised when discussing the topic and further exploring the potential design of the concept of *Full Cost Balancing* and *Price elastic procurement of balancing capacity*.