European Network of
Transmission System Operators
for Electricity

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RESULTS OF CBA LER ACCORDING TO ART.156(11) SO GL

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CONTENTS

Acronyms

ACE: Area Control Error

aFRR: automatic Frequency Restoration Reserve.

BSP: Balance Service Provider.

CBA: cost-benefit analysis.

CE NRAs: all the Continental Europe National Regulatory Authorities.

CE SA: Continental Europe Synchronous Area.

CE TSOs: all the Continental Europe Transmission System Operators.

FCR: frequency containment reserves.

FRP: Frequency Restoration Process.

FRR: Frequency Restoration Reserve.

ISP: Imbalance Settlement Period.

LER: providing units or groups with limited energy reservoirs.

LFC: Load Frequency Control.

MARI: Manually Activated Reserves Initiative.

PICASSO: Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation.

SOGL: Commission Regulation (EU) 2017/1485 establishing a guideline on electricity transmission system operation.

EES: Electricity Storage Systems

References

1. “All Continental Europe and Nordic TSOs’ proposal for assumptions and a Cost Benefit Analysis methodology in accordance with Article 156(11) of the Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation”.

2. “Updated input data and assumptions for CBA LER according to art.156(11) SO GL”.

Executive Summary

According to Art.156(11) SO GL, CE TSOs shall develop a proposal concerning the minimum activation period to be ensured by FCR with Limited Energy Reservoir during alert state based on a Cost Benefit Analyses (CBA LER).

CE TSOs submitted their proposal based on the outcome of the CBA in December 2021. CE NRAs analysed the TSOs’ proposal and issued in December 2022 a Request for Amendment of the proposal, asking a set of further analyses and a new run of the CBA methodology with updated input and assumptions. Updated input and assumptions have been consulted with stakeholders.

This document presents the results of the new run of the CBA perform by CE TSOs.

The results show that TminLER = 30 min ensures the lowest system costs in all scenarios where LER exceeds a threshold in the FCR procurement roughly equal to 1500 MW. The key reason is that additional LER15 requires FCR increases that are larger than those caused by additional LER30. The additional burden of requiring more FCR outweighs the minor €/MW·h of LER15.

Such scenarios are associated with a widespread increase in LER installation that could follow by a widening of the FCR exchange between Blocks (beyond FCR cooperation) and by the introduction of market-based FCR procurement in Blocks currently procuring FCR with mandatory schemes.

The scenarios where TminLER = 15 min costs less for the system are those where LER increase is hampered by the absence of market-based FCR procurement schemes and by the presence of significative Blocks implementing mandatory schemes for FCR procurement.

According to these results, TSOs have decided to propose a minimum activation time period equal to 30 min, with no retroactive application to LER not formerly prequalified for 30min.

Framework and scope of the document

Pursuant to Article 156(10) of the SOGL, CE TSOs shall develop a proposal concerning the minimum activation period to be ensured by FCR LER during alert state (hereinafter referred to as: proposal for Tmin LER definition). The proposal shall take full account of the results of the CBA conducted pursuant to Article 156(11) of SOGL. According to Article 6(3)(d)(v) of SOGL, the CE TSOs' proposal referred to in Article 156(10) of SOGL is subject to approval by CE NRAs.

CE NRAs approved the CBA methodology in October 2021 [1].

According to the CBA methodology, CE TSOs developed a probabilistic simulation model able to calculate the minimum amount of FCR needed to maintain the steady state frequency within maximum steady state frequency deviation. The CBA methodology provides for three different sources of frequency disturbance to be used as input by the probabilistic simulation model (Art.4.2 of [1]):

- Deterministic frequency deviation.
- Long-lasting frequency deviation.
- Outages of relevant grid elements.

Both deterministic and long-lasting frequency deviations must be derived from an analyses of frequency historical trend over several years.

Furthermore, the CBA methodology requires an assessment of cost of FCR (Art.5 of [1]). CE TSOs must define FCR cost curves which includes both LER and non-LER FCR providers.

This document is aimed at presenting updated assumptions regarding all the previous input.

The need for an update of all CBA input derives from an explicit request of CE NRAs. CE TSOs submitted indeed their proposal for the Tmin LER definition based on the outcome of the CBA in December 2021.

CE NRAs analysed the TSOs' proposal and issued in December 2022 a Request for Amendment of the proposal. In such Request for Amendment, CE NRAs request TSOs to run a new instance of the CBA methodology after having updated some of the key input regarding frequency and FCR costs.

TSOs consulted updated input and assumptions in the period April-May 2024 and a public workshop with stakeholders was held on 8th May 2024.

Considering the updated input and assumptions, TSOs performed a new run of the CBA according to the approved methodology.

This document presents the results of the new run of the CBA and the consequent TSOs proposal for a minimum activation time period for LER.

Input data – FCR quantities for FCR costs curves

Input data and assumptions used to perform the CBA are indicated in 2. The only further pieces of information needed to run the CBA are related to the FCR quantities to be associated to existing LER and to non-LER.

These quantities have been collected by means of a survey amongst TSOs. Each TSO has been requested to indicate the currently pre-qualified FCR provided by LER and the currently prequalified FCR provided by non-LER (divided into different technologies).

These information has been combined with the assumptions on FCR costs of LER and non-LER in order to create a FCR cost curve for each CE LFC Block.

Models to assess costs

An optimization model has been developed to calculate the system cost for FCR, given a certain FCR demand at synchronous area level (e.g., 3000 MW).

Such optimization model calculates the combination of FCR supply which minimizes the system cost, considering the cost of supplying FCR associated with the FCR cost curves of each LFC Block.

The CE FCR demand is distributed on each Block according to k-factors (α˙FCR), but Blocks can exchange FCR with other Blocks according to SO GL rules:

- Core FCR: minimum 30% of Block α˙FCR shall be supplied locally.
- The FCR export shall be limited to the minimum between 130% α˙FCR and α˙FCR +100 MW

The model implements a single busbar model: no topology of the grid is considered. Figure 1 shows the key features of the optimization model.

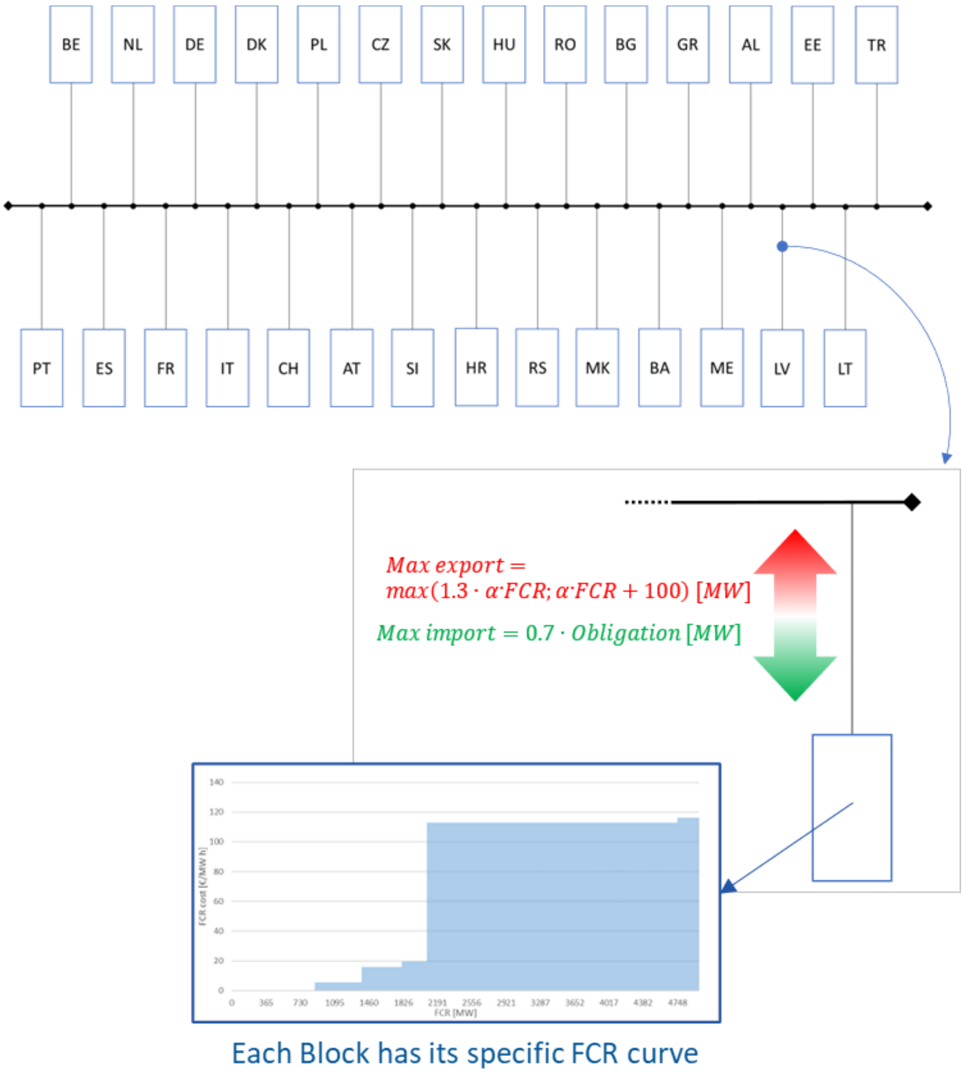

Figure 1: Optimization model to calculate the FCR cost at SA level

The optimization is based on yearly figures. The FCR costs for non-LER are derived from yearly average DAM prices for each Block. Furthermore, non-LER quantities are fixed: there is no variations in FCR quantities/availability due to dispatch.

The optimization model is an improvement to the previous run of the CBA (2020), where a single pool model was used (without constraints on FCR exchange).

In the model, new LER are considered as potentially unlimited. The hypothesis is that new LER will be installed as long as they are cost-efficient for the system (i.e., they cost less than non-LER).

The model could be used to simulate either FCR exchange at SA level (model A) or FCR exchange limited to a set of Blocks (with other countries procuring FCR internally, model B). A schematic representation of the two variations Is shown in Figure 2.

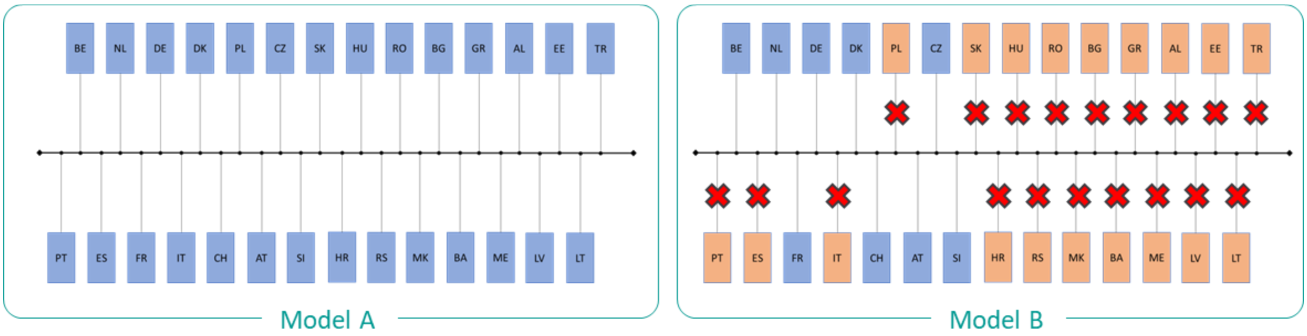

Figure 2: Variations of the optimization model depending on the possibility for FCR to be exchanged

Furthermore, the actual possibility of having new LER installed in each Block has been addressed considering two different options:

a. New LER can be installed in each Block no matter of the FCR procurement scheme.

b. New LER are not possible in Blocks where the FCR is currently procured via mandatory schemes.

The information about the FCR procurement scheme is derived from “ENTSO-e Survey on Ancillary services procurement Balancing market design 2021”.

With option b, new LER installations are considered in all Blocks except those marked as “Mandatory only” in Figure 3 (Turkey is assumed as a “Mandatory only” Block).

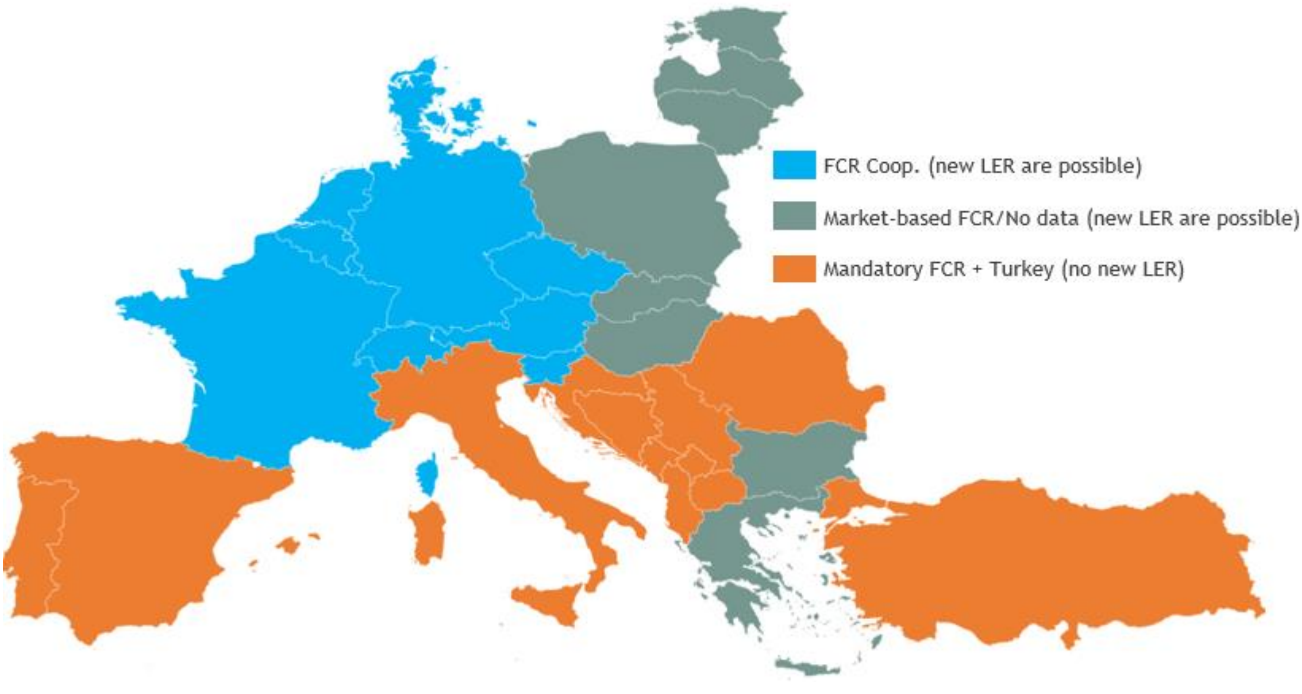

Figure 3: Possibility of new LER installations with option b model

Process to calculate the equilibrium point with different TminLER

The purpose of the CBA is to calculate the final cost of providing FCR at synchronous area level, given a specific TminLER and under all the assumptions on input that have been described in 2.

A key aspect to consider is that the LER share in the FCR procurement (the LER penetration) impacts on the amount of FCR required at SA level. A significative presence of LER in the FCR procurement requires an increased amount of FCR to be procured at SA level (i.e., above the quantity needed without LER). Furthermore, the impact of LER15 (with TminLER of 15 minutes) is higher than the impact of LER30 (with TminLER of 30 minutes).

The model to calculate the FCR required at SA level, given a specific quantity of LER in the FCR procurement, is the probabilistic model developed according to the CBA methodology (1). The model is based on a probabilistic approach and simulates 200 years of operation of the system, combining the effects of three potential sources of power imbalance in the system:

- Deterministic Frequency Deviations (DFDs)
- Long-lasting Frequency Deviations (LLFDs)
- Outages on power plants

The CBA probabilistic model also include a module that calculates the LER SOC resulting from the frequency deviation deriving from the combined sources of imbalance and the consequent FRR activation. It’s therefore able to consider the events of LER exhaustion and their effect on frequency deviation. The CBA probabilistic model output is then the FCR amount required at SA level in order to ensure that the steady-state frequency deviation exceeding of the ±200 mHz range (FCR exhaustion) occurs not more than once every 20 years.

In costs-based assessment of the FCR procurement, the LER penetration depends on the competitivity of LER as compared to non-LER. The model to assess costs described in the previous section has indeed the capability to determine the LER penetration in the FCR procurement, given the cost curves in each LFC Block and the constrained on how much FCR can be exchanged between Blocks.

Given the cost curves of each Block and the FCR to be procured at SA level, the model to assess cost can derive the LER penetration. It’s therefore clear that there is two-way interaction between the model that calculate FCR costs (and thus LER penetration) and the model that calculates the FCR required with a given level of LER penetration:

- The FCR required at SA level (to ensure the once in 20 years criterion on FCR exhaustion) depends on the LER penetration.
- The LER penetration depends on the FCR required at SA level

Because of this mutual dependency, the process to calculate the FCR cost associated with a specific minimum activation time period is based on an iterative cycle involving both the model to assess costs and the CBA probabilistic model. The cycle is shown in the Figure 4.

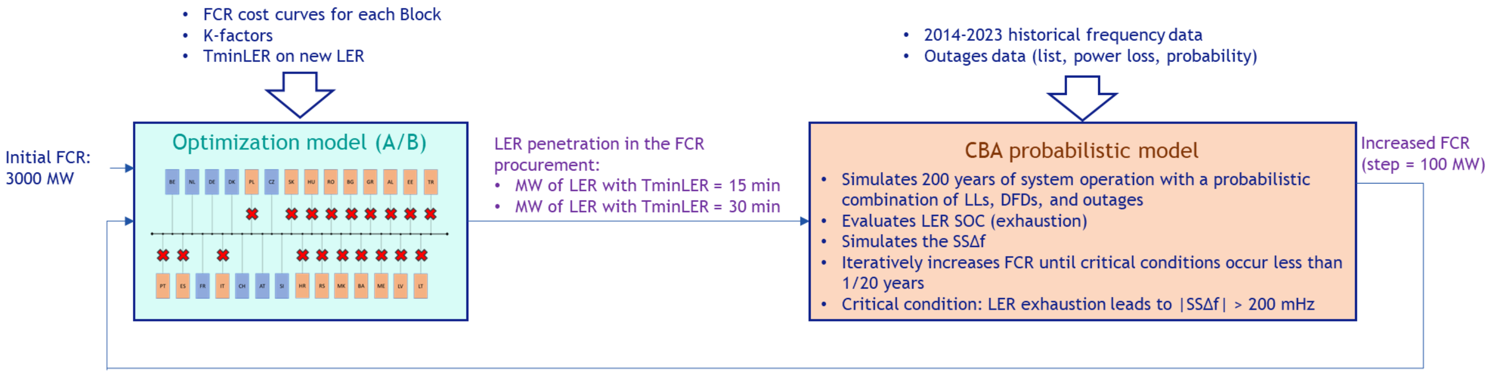

Figure 4: Iterative loop between model to assess costs and CBA probabilistic model

The process starts with an initial FCR amount (i.e., the deterministic FCR; e.g., 3000 MW). This value is then fed into the costs assessment model which calculates the LER penetration, considering the FCR cost curves of each LFC Block.

The resulting LER penetration (i.e., MW of LER15 and/or MW of LER30) is then fed into the CBA probabilistic model to calculate the required amount of FCR needed to cope with such LER penetration.

The updated FCR amount is fed back into the cost assessment model for a new iteration of the process.

The process end (i.e., the equilibrium is reached) when two consecutive iterations have the same results. In other words, the equilibrium is reached when the increased LER penetration doesn't require anymore an increased amount of FCR.

A key feature of this process is that the increased FCR required at SA level (e.g., from 3000 MW to 3100 MW) usually entails an increase in the LER penetration in the FCR procurement. This result is related to the fact that the increased FCR demands enables more space for existing and new LER to enter in the procurement. The increased demands in each LFC Block intersect the supply curve at a higher price point.

It's fundamental to stress that the LER that can enter in the procurement fall into two different categories:

- Existing LER: these installations are already present in the system. Their quantity in each LFC Block have been communicated by their connecting TSO in terms of pre-qualified MW. According to the cost assumptions (2), their costs are very low, corresponding only to their variable costs.

- New LER: these installations are not present yet, but they could be installed if the market conditions provide appropriate signals to investors. Such appropriate signals are the fact that a LER offering at its long-run marginal cost can enter the procurement.
  In this sense, in each LFC Block a potentially unlimited quantity of new LER are considered[1].
  This assumption is aimed at modelling the fact that investors can install new LER as long as LER are profitable (i.e., as long as offering at long-run marginal costs allows to enter in the procurement).

The potentially unlimited availability of new LER in a Block doesn't mean that such LER are actually feasible from the economic point of view. On the contrary, their presence is aimed at considering the *possibility* of their presence.
In a specific Block, the costs assessment model could either procure new LER or not.
If new LER are not procured, it means that there is not a real incentive for investors to install new LER because the FCR cost is kept low by other, more competitive, FCR providers (e.g., existing LER or very cheap non-LER).
If new LER are procured up to a specific quantity, it means that the market is signalling to investors that these installations are potentially profitable (up to that specific amount), because the FCR prices could be higher than the LER long-run marginal costs.

In this sense, a run of the model to assess costs is modelling long-term results, arising once the investors have responded to market signals with new LER installations.
This consideration is useful for interpreting the cycle adopted for the calculation of final equilibrium.
As shown in Figure 5, the iterative process can be interpreted as the cycle between increased LER installation due to their competitiveness and the increased FCR required as a consequence of LER presence. Each step could however take several years:

- The increase in FCR demand is a signal to investors for new LER installation.
- As these new LER are pre-qualified, FCR shall be increased to consider their presence.

[1] With option B, this is true only for LFC Block currently implementing a market-based FCR procurement. Blocks implementing mandatory schemes do not provide any incentive for LER installations.

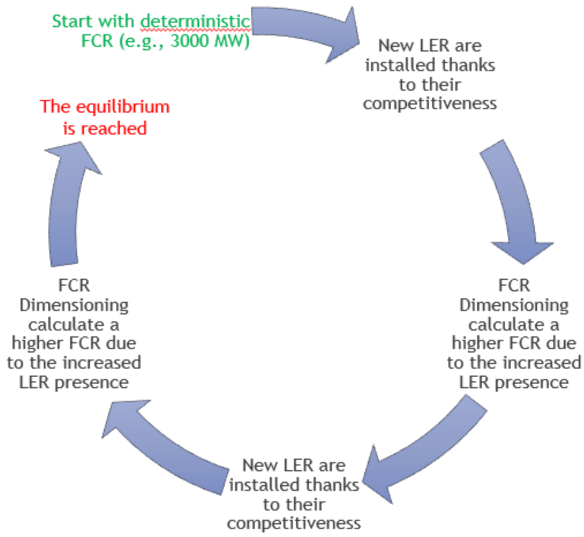

Figure 5: Interpretation of the iterative process

Iterative process results

The iterative process described in the previous section has been applied on a set of different scenarios:

- Scenario A
  FCR Exchange is possible only within FCR Cooperation (Model B). Each Block with unlimited availability of new LER (Option A).

- Scenario B
  FCR Exchange is possible between all Blocks (Model A). Each Block with unlimited availability of new LER (Option A).

- Scenario C
  FCR Exchange is possible only within FCR Cooperation (Model B). Unlimited availability of new LER only in Blocks with market-based FCR procurement (Option B).

- Scenario D
  FCR Exchange is possible only within FCR Cooperation (Model B). Unlimited availability of new LER only in Blocks with market-based FCR procurement (Option B). The starting deterministic FCR is 3200 MW instead of 3000 MW as for other scenarios.

The results of the iterative process for each scenario are presented in Figure 6.

Scenario A

- FCR Exchange only within FCR Cooperation (Model B)
- Each Block with unlimited availability of new LER

Scenario A-15:

FCR = 3000 MW
LER15 = 2405 MW
Cost = 7676 € /h

⇩

FCR = 3800 MW
LER15 = 3178 MW
Cost = 10297 € /h

⇩

FCR = 4500 MW
LER15 = 3845 MW
Cost = 12831 € /h

Scenario A-30:

FCR = 3000 MW
LER15 = 1160 MW
LER30 = 1137 MW
Cost = 9209 € /h

⇩

FCR = 3600 MW
LER15 = 1441 MW
LER30 = 1418 MW
Cost = 11542 € /h

Scenario B

- FCR Exchange between all Blocks (Model A)
- Each Block with unlimited availability of new LER

Scenario B-15:

FCR = 3000 MW
LER15 = 2283 MW
Cost = 5681 € /h

⇩

FCR = 3800 MW
LER15 = 3076 MW
Cost = 8781 € /h

⇩

FCR = 4400 MW
LER15 = 3671 MW
Cost = 11527 € /h

⇩

FCR = 4500 MW
LER15 = 3770 MW
Cost = 11985 € /h

Scenario B-30:

FCR = 3000 MW
LER15 = 1505 MW
LER30 = 483 MW
Cost = 6745 € /h

⇩

FCR = 3400 MW
LER15 = 1685 MW
LER30 = 698 MW
Cost = 8384 € /h

⇩

FCR = 3600 MW
LER15 = 1776 MW
LER30 = 807 MW
Cost = 9203 € /h

Scenario C

- FCR Exchange only between within FCR Cooperation (Model B)
- No new LER in “Mandatory only” Blocks

Scenario C-15:

FCR = 3000 MW
LER15 = 1498 MW
Cost = 22621 € /h

Scenario C-30:

FCR = 3000 MW
LER15 = 1164 MW
LER30 = 243 MW
Cost = 23011 € /h

Scenario D

- FCR Exchange only between within FCR Cooperation (Model B)
- No new LER in “Mandatory only” Blocks
- Deterministic FCR = 3200 MW

Scenario D-15:

FCR = 3200 MW
LER15 = 1615 MW
Cost = 24929 € /h

Scenario D-30:

FCR = 3200 MW
LER15 = 1258 MW
LER30 = 260 MW
Cost = 25346 € /h

Figure 6: Results of iterative process for each scenario

The presented results show all the iteration performed in each scenario (except for the last one: the final iteration is the one where the equilibrium is reached). In each scenario both the results with TminLER = 15 min and with TminLER = 30 min are presented.

For each iteration the following data are shown:

- FCR: is the FCR amount required at SA level. At the first iteration is the deterministic value, for the following iteration is the value calculated by the CBA probabilistic model in the previous iteration.

- LER15 / LER30: are the quantities of LER (with either TminLER of 15 min or 30 min). LER15 and LER30 are both present in scenarios with TminLER = 30 min. This is because TminLER = 30 min requirement is not considered retroactively. All existing LER remain subject to the current TminLER = 15 min. Only new LER are considered as subject to TminLER = 30 min.

- Cost: it's the FCR cost as calculated by the costs assessment model. This cost is referred to one hour. The annual cost is 8760 times that value.
  The resulting figures can't be directly compared to real costs currently borne by TSOs for providing FCR. It should be considered real markets are based on marginal prices, while the estimated figures are instead "costs" (the area below the part of costs curves that enter the procurement). Wherever no market is currently in place, the explicit cost to provide FCR is zero while the cost considered in the model is still the area below the part of costs curves that enter the procurement.
  Overall, the presented costs are not meant to represent the real costs to be borne by TSOs but rather an indication of the system cost to provide FCR under all the assumptions made. While their absolute value is subject to all the approximations and assumptions of the study, the comparison between different scenarios is still considered a reliable driver in the definition of the minimum activation time period.

For a better understanding of the meaning of the figures presented, the detailed results of the iteration for scenario A (with TminLER = 15 min) is shown in the following Figure 7.

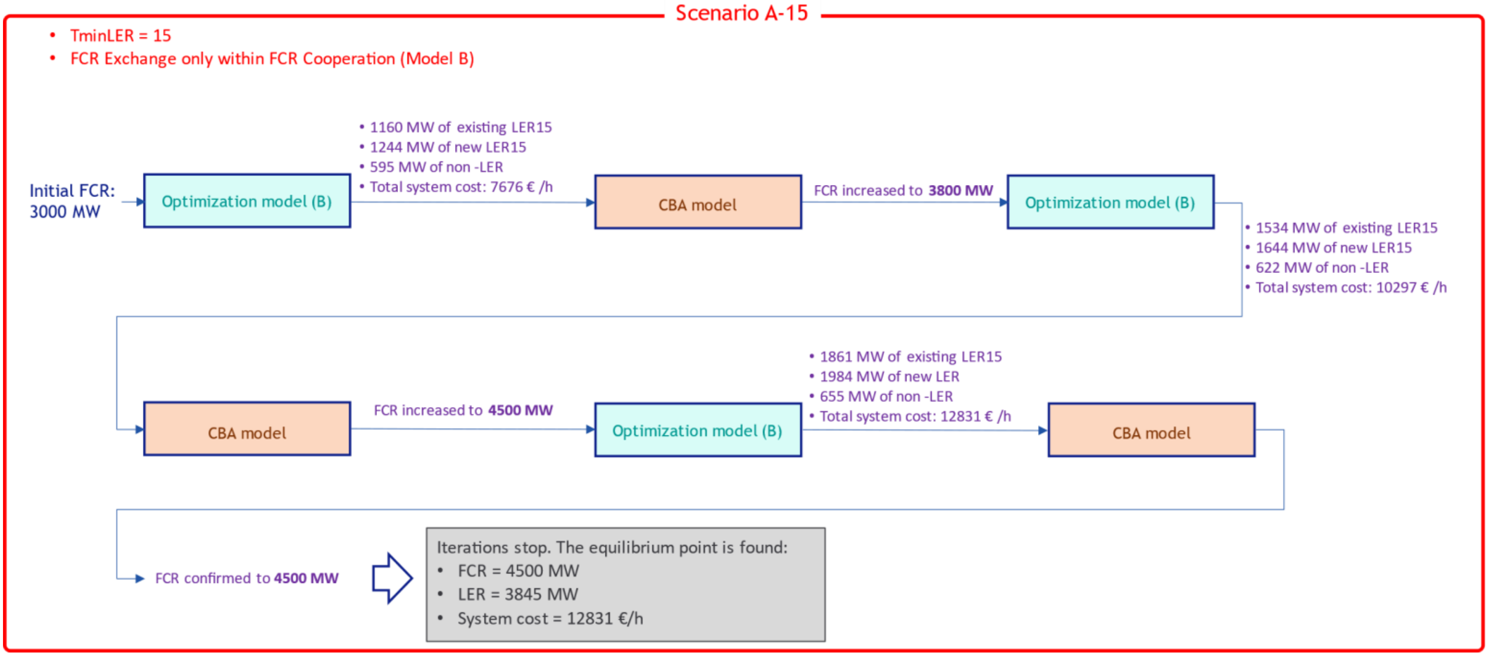

Figure 7: Detailed results for Scenario A-15

An explanation of the iterations between economic and probabilistic models

To better investigate the dependency between the LER penetration and the FCR required to cope with penetration, an in-depth study has been performed under the assumption of TminLER = 15 min. The FCR required for increased level of LER penetration in the FCR procurement has been calculated with the CBA probabilistic model.

The following Figure 8[2] shows the resulting relationship between the LER penetration (in MW) and the FCR required to ensure safety conditions (FCR exhaustion as a consequence of LER depletion not more often than once in 20 years).

[2] *The chart is calculated with increase steps of the CBA probabilistic model equal to 10 MW. The results presented in Figure 6 and Figure 7 are calculated with increase step of 100 MW.*

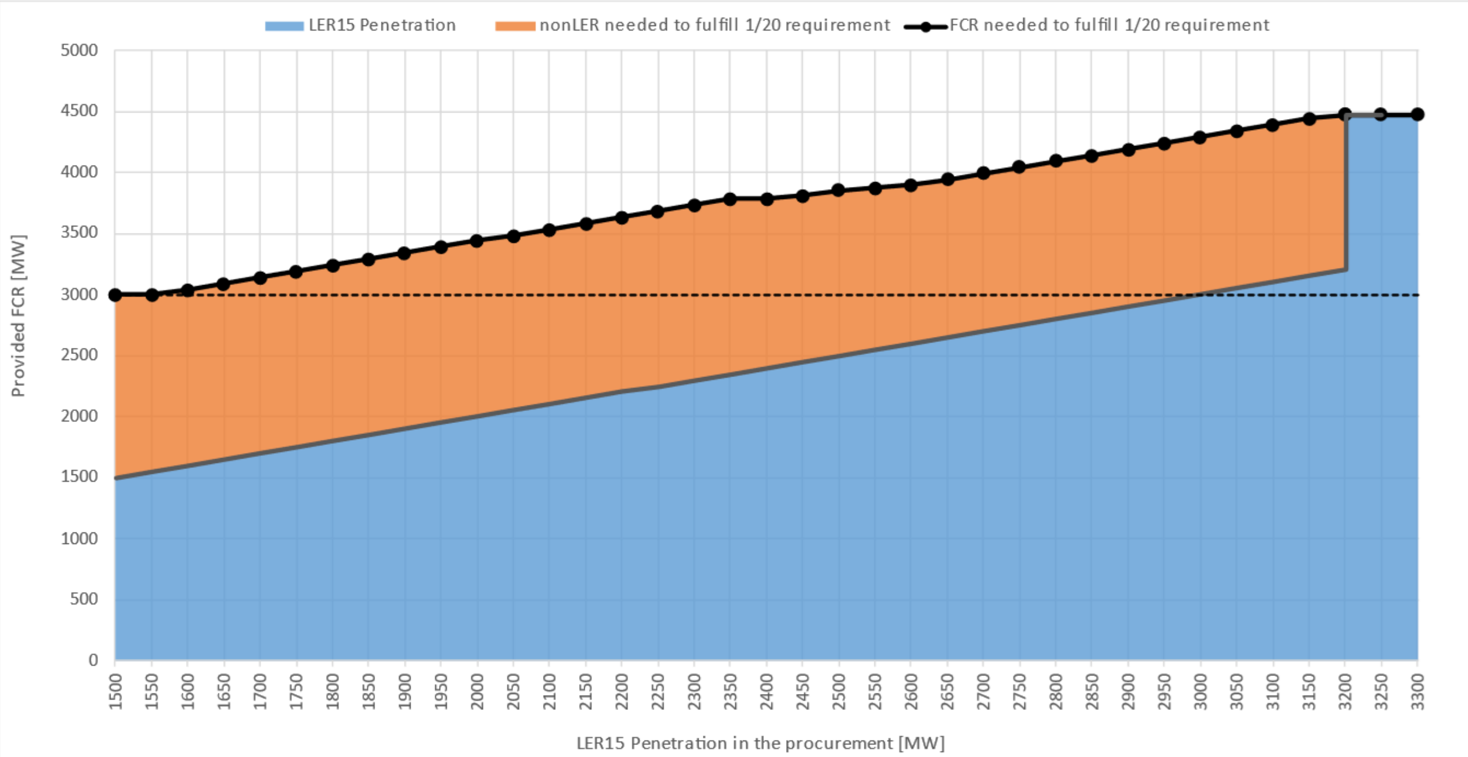

Figure 8: Relationship between LER penetration and FCR required (TminLER = 15 min)

The results of previously shown iterations with TminLER = 15 min (e.g., as in Figure 7) can be interpreted as movements along this curve:

1. At the 1st iteration, the LER15 penetration with 3000 MW of FCR (from the economic model) is used to enter the curve and derive the FCR required to cope with such LER15 quantity. Such additional FCR is assumed to be non-LER.

2. The additional FCR is occupied by a combination of LER15 and non-LER. The ratio of LER and non-LER is calculated with the economic model.

3. The new LER15 penetration is used to enter in the curve and derive the FCR required to cope with it, and the process is repeated.

The key factor in defining the result is the ration of LER15/non-LER in the additional FCR.

The example of such interpretation for Scenario B is presented in the following Figure 9.

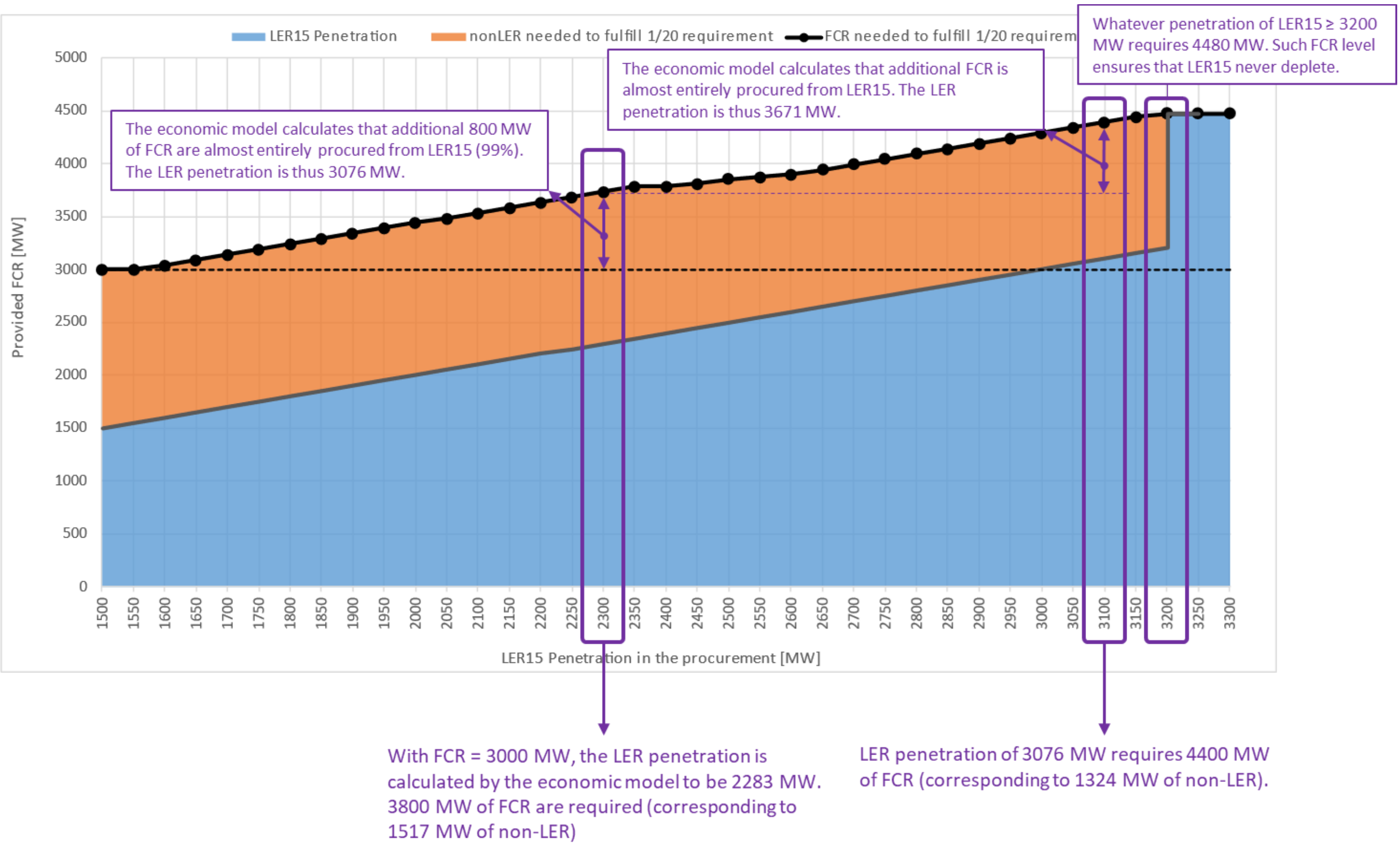

Figure 9: Iterations as movements along the curve (Scenario B-15)

If TminLER = 15 min, whenever the LER penetration exceeds a threshold (roughly 1550 MW), a "run-away" phenomenon is triggered. That is a process of recursive increase of FCR followed by increase of LER15 penetration. In these cases, the results will always end up requiring 4500 MW of FCR (i.e., the FCR level ensuring no LER15 depletion whatsoever).

As long as the additional FCR in each iteration is even partially provided by LER, the iterations continue, and the equilibrium points are gradually moved to the right. Such condition (additional FCR even partially provided by LER) is virtually always verified.

The rate at which the phenomenon occurs depends on the ratio between LER15 and non-LER in the procurement of additional FCR. The higher the ratio, the quicker the run-away phenomenon.

The only "stable equilibria" are therefore the extreme conditions:

- LER15 ≤ 1550 MW (no run-away is triggered)
- LER15 ≥ 3200 MW (no LER depletion with FCR = 4480 MW)

If TminLER = 30 min, the relationship between LER penetration in the FCR procurement, and the required FCR is more complex. If TminLER = 30 min, existing LER15 won't change (no retroactivity). There is therefore a coexistence of LER15, LER30 and non-LER.

Each combination of LER15 and LER30 requires a different quantity of non-LER (and thus FCR) to fulfill the 1/20 years SO GL requirement. The acceptable combinations (those fulfilling the requirements) can theoretically be represented by a surface on the 3D space of LER15/LER30/nonLER. At each iteration, the additional FCR is provided by a combination of LER15/LER30/nonLER (as a results of the economic model). It results in a movement on the surface. The final required FCR depends on how much LER15/LER30 penetrate in the FCR procurement.

Considerations about iterative process results

TminLER = 30 min ensures the lowest system costs in all scenarios where LER are widespread (installations possible in each Block). The key reason is that additional LER15 requires FCR increases that are larger than those caused by additional LER30. The additional burden of requiring more FCR outweighs the minor €/MW·h of LER15.

Such scenarios are associated with a widespread increase in LER installation that could follow by a widening of the FCR exchange between Blocks (beyond FCR cooperation) and by the introduction of market-based FCR procurement in Blocks currently procuring FCR with mandatory schemes.

The scenarios where TminLER = 15 min costs less for the system are those where LER increase is hampered by the absence of market-based FCR procurement schemes (Scenario C and D).

A set of sensitivity analyses have been performed (not presented in this report). They show that:

- LER costs have an impact only when the costs are increased by several times the assumptions.
- Non-LER costs have very limited impact on the results
- assumptions on non-LER quantities (for Blocks non-responding to the survey) have very little impact as well.

The key input impacting these results is the historical frequency deviation. The presence of the four most energetic LLEFDs (2018, 2023) leads to a significantly higher increase of FCR with new LER with 15 min.

The decision on TminLER could be addressed with a comprehensive approach, considering these results on the wider context of the current presence of LER.

Decision on minimum activation time period

The TSOs' proposal for TminLER assumes that in the next years a more widespread adoption of market-based FCR procurement is very likely, in Blocks currently adopting a mandatory procurement. This will provide market signals to investors that would result in further installations of LER also in Blocks where currently a very limited LER penetration has been observed.

Furthermore, the exchange of FCR is likely to become more widespread in coming years, with more Blocks progressively joining to FCR Cooperation or adopting bilateral scheme of exchange. This development will allow a more integrated FCR market at SA level, with a consequent increase in LER penetration in the FCR procurement.

These likely developments lead TSOs to consider the scenario A as the reference scenario to be considered in the CBA. In that scenario, the significative increase in LER penetration requires a constant increase in FCR requirement to ensure the system safety. In such context, the 30 min solution ensure the minimization of system costs.

At the same time, TSOs are aware that a lot of investment have already been done in LER and that a retroactive requirement is not a feasible solution.

The TSOs proposal is therefore as follows:

- The new requirement for a minimum activation time period for LER is set to 30 minutes.
- Non retroactive requirements are applied. The 30 min requirement shall apply only to LER whose prequalification takes place after the end of an interim period after the entry into force of the new requirement.
- LER prequalified before the end of the interim period are not subject to the new requirement. They're subject to the maximum between:
    - Time Period legally in force in their connecting area at the moment of the entry into force of the present regulation;
    - Time Period for which they have been prequalified, whenever it is different from Time Period legally in force in their connecting area.
- The duration of the interim period can be agreed with NRAs.