

**PUBLIC CONSULTATION**

# Methodology for the dimensioning of the aFRR needs

June 2, 2020



## Content

<b>1.</b>	<b>Introduction</b>	<b>8</b>
1.1	Different types of reserve capacity in Elia's LFC block	8
1.2	Elia's dimensioning methodology for the needs and means for reserve capacity	10
1.3	Elia's reserve capacity volumes	12
1.4	Robustness towards expected system evolutions	13
1.5	Objective, scope and structure of the study	14
<b>2.</b>	<b>aFRR dimensioning design options</b>	<b>15</b>
2.1	aFRR dimensioning objectives	15
2.1.1	Legal and regulatory framework	15
2.1.2	Ongoing and upcoming system evolutions	18
2.1.3	ACE / SI quality	21
2.2	Methodology design options	24
2.2.1	Assessment of the current methodology	24
2.2.2	Benchmark	25
2.2.3	Literature	28
2.2.4	Conclusions	30
<b>3.</b>	<b>Selection of aFRR methodologies</b>	<b>32</b>
3.1	Selection of aFRR dimensioning methods	32
3.1.1	Step 1: choosing the methodology type	32
3.1.2	Step 2: determining the sizing variable and resolution	33
3.1.3	Step 3: facilitating the contribution of Forced Outages and iGCC	34
3.1.4	Step 4: capturing dynamic potential	35
3.1.5	Step 5: selecting the reliability level	36
3.2	Feasible approach 1: an improved probabilistic method	37
3.2.1	Calibration of sizing variable and resolution	37
3.2.2	Calibration of iGCC participation	38
3.2.3	Ball-park figures	38

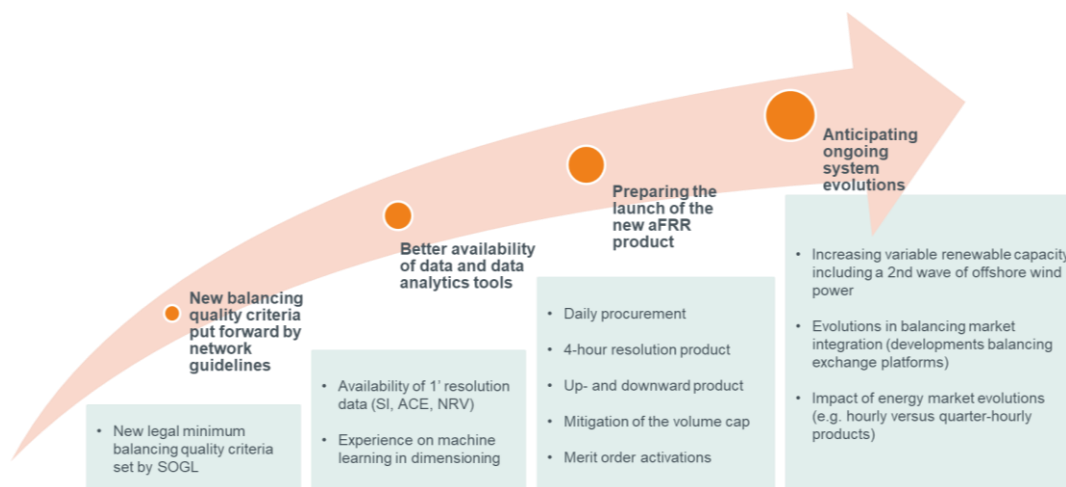
3.3	Feasible approach 2: LFC-controller simulations .....	39
3.4	Proposed approach for the Proof of Concept.....	41
<b>4.</b>	<b>Proof of Concept.....</b>	<b>42</b>
4.1	Determining the sizing variable .....	42
4.2	Determining the dynamic potential .....	43
4.3	Determining projections towards 2028 .....	43
<b>5.</b>	<b>Conclusions .....</b>	<b>45</b>

## Executive summary

This study investigates **opportunities to replace or improve the current aFRR dimensioning methodology**, in order to maintain sufficient balancing quality while taking into account future system evolutions. In the past years, some opportunities for further improvements were identified for the current method and particular attention will be put on:

- taking into account intra-15' variations of the LFC block imbalances;
- taking into account the dynamic potential, varying aFRR needs in function of the risks (if any);
- taking into account the evolutions in the FRCE quality in line with Article 157(b) of the SOGL.

As **a new methodology needs to be robust for future evolutions**, an overview is made of most important relevant evolutions in the power system. Not only does the European legislation put forward new minimum criteria concerning FRCE-quality (which is still considered acceptable for Elia's LFC block), digital technologies also brought new tools to analyze system conditions. In addition, a new aFRR product that will be launched in 2020 will be based, at least partially, on a daily procurement with a 4-hour resolution product unlocking dynamic dimensioning possibilities similar to currently implemented for FRR. Finally, the method has to be robust towards increasing renewable generation capacity, challenging balancing quality through variability and limited predictability, and future market evolutions impacting the ability of BRPs to balance their portfolio.



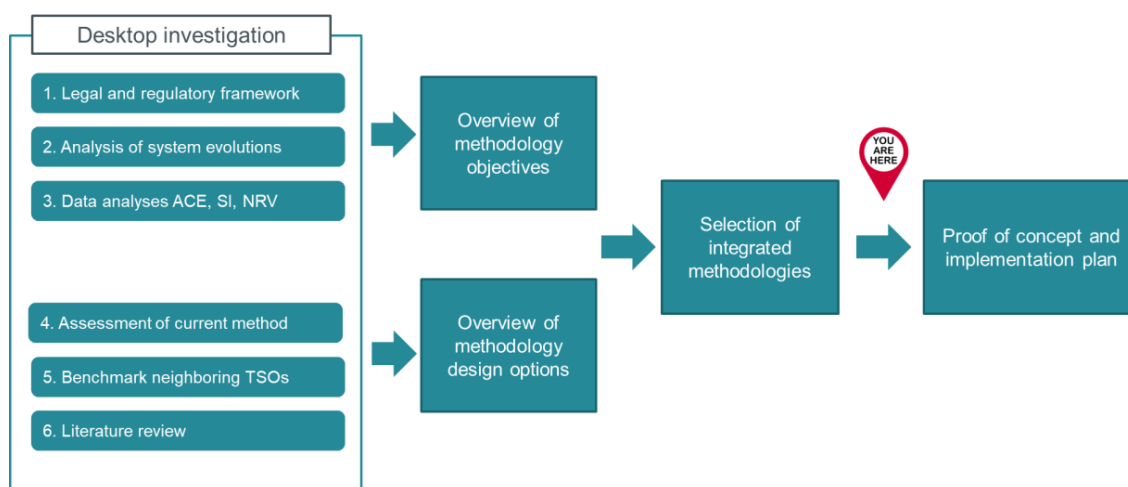
This study aims to propose methodologies to improve the current aFRR dimensioning methodology to be further investigated in the Proof of Concept. These are based on an exhaustive analysis of methodology design options which are (1) implementable from a practical point of view (in terms of transparency and complexity); (2) compliant with European legislation; (3) robust towards future power system evolutions (including installed RES capacity and HVDC interconnections), and (4) meeting minimum technical criteria maintaining reliability of the system and acceptable balancing quality.

Note that the scope of the study is on dimensioning the aFRR needs. Investigations concerning the optimal allocation of this reserve capacity to different means such as balancing capacity, non-contracted balancing energy bids or reserve sharing in line with Article 32 of the EBGL is out of scope of the study.

- **Investigating methodology objectives and methodology design options**

The study is based on an extensive desktop investigation. First, the **legal and regulatory framework** is investigated which is found to provide, in contrast to FRR dimensioning, little guidance on aFRR dimensioning principles. This is besides a few legal criteria on absolute warning limits concerning ACE / FRCE-quality. TSOs will therefore need to find themselves methods which provide a trade-off between meeting such minimum thresholds (and avoid over-procurement in general) and meeting their responsibility to cover their FRCE as good as possible and contribute to the European frequency stability. It is observed that currently:

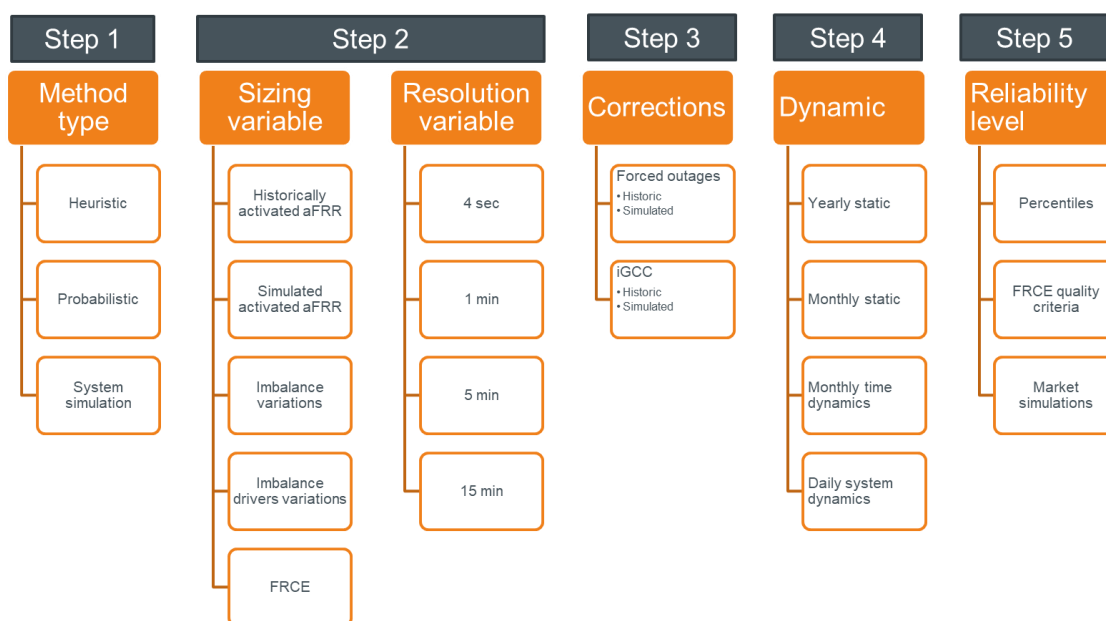
- Elia attains acceptable results concerning balancing quality compared to other TSOs, as reported in ENTSO-E's reporting. It is found to have an average performance concerning meeting Level 1 and Level 2 criteria;
- Elia currently dimensions relatively little aFRR in comparison with its neighbors compared to the peak load in the LFC block. Although this comparison does not give a full view on specific system complexities, it might give an indication that Elia already attains an acceptable FRCE-quality with minimal procurement.



The **literature analyses and benchmark** of Elia's current method with neighboring TSOs reveals some methodology design options. A trend is observed towards probabilistic approaches where the most advanced approach seems to be found in the German LFC block where a dynamic probabilistic methodology is implemented based on simulated aFRR activations. Also some interesting design options are found in the Dutch system (taking into account activated iGCC in the aFRR dimensioning).

Based on these analyses, an exhaustive list is made of all possible different **methodology design options**. These options are categorized in five categories which are walked through in order to make a selection of feasible integrated methods. In **step 1** the method type is selected being deterministic, probabilistic or simulation-based as discussed in

the literature. In **step 2**, the sizing variable and its resolution is determined which is the main variable on which the reserves are determined. Different options are found in the benchmark with other TSOs and complemented with Elia's insights analyzing the objectives and the legal framework. In the current method, this would be covering a certain percentage of all LFC block imbalance variations (sizing variable) with a resolution of 15' (resolution).

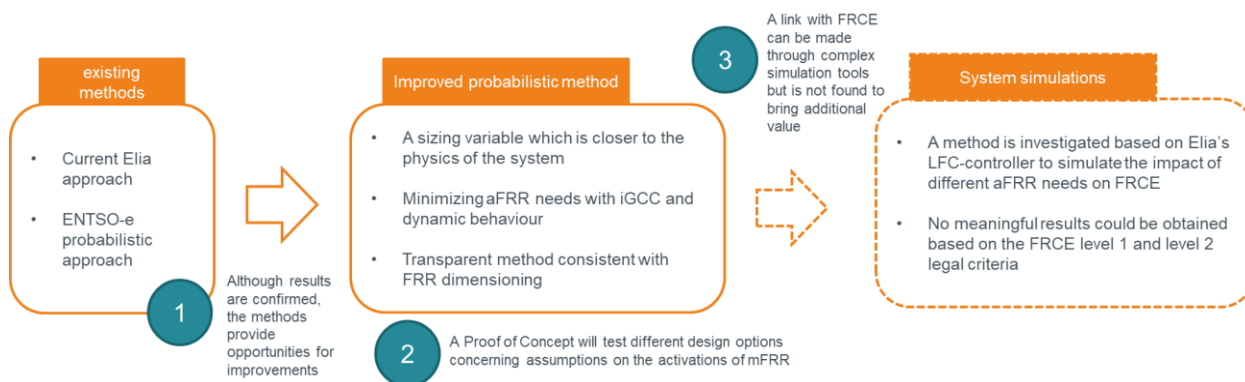


**Step 3** considers possible corrections of this variable to explicitly include or exclude the impact of forced outages of large generation units and to take into account iGCC or not reducing the aFRR needs. **Step 4** will then determine if a yearly, monthly or daily dynamic dimensioning will be considered based on the determined potential. Finally, in **Step 5**, the method to determine the reliability level is specified, i.e. the percentage of LFC block imbalance variations to be covered in the current method.

The analysis of the information shows that **existing methods** such as the current Elia approach, or even the recommended methods by ENTSO-E are found to have drawbacks or at least provide opportunities for improvement. Mainly, the robustness towards new aFRR product design and increasing renewable capacity installed is challenging the current methodology.

- The study puts forward that **improving the probabilistic method** seems the best way forward. The probabilistic method is a good trade-off between complexity and transparency, while being consistent with the FRR dimensioning method. Such method has also been recently implemented in Germany. The proposed improvement for Elia's aFRR dimensioning is to better align the sizing variable with the system physics (simulate aFRR activations, take into account iGCC) while implementing a dynamic methodology to reduced average aFRR needs.

- An in depth investigation towards **simulation-based models** shows that simulations with Elia's LFC controller allow to investigate the effect of different minimum aFRR means on the ACE / FRCE. This allows to assess the performance concerning ACE / FRCE-quality objectives. No meaningful results were obtained when assessing the impact on the minimum warning limits, i.e. the Level 1 and Level 2 criteria. It is concluded that the method substantially increases complexity without finding accurate aFRR needs, at least as long no specific reliability targets are specified which can be used for dimensioning.



**Elia proposes to continue investigating the improved probabilistic method in a Proof of Concept.** The Proof of Concept will further investigate the implementation of the aFRR simulations, i.e. determining the assumptions on the activations of mFRR, and the participation of iGCC. Also the algorithms for the dynamic method and sizing variable resolution, i.e. 5 minutes or 1 minute will be investigated. Projections towards 2028 will be made, and benchmarked with the actual method. This allows to analyze the robustness of the method towards the increasing renewable penetration, including the 2<sup>nd</sup> wave of offshore expected to be fully commissioned in 2028.

**Stakeholders are welcomed to provide their suggestions and feedback on this study in a public consultation from June 2, 2020 to July 2, 2020. Following this consultation, the Proof of concept for the chosen methodology will be executed. The results of this Proof of Concept will be published by Elia in Q4 2020.**

# 1. Introduction

## 1.1 Different types of reserve capacity in Elia's LFC block

The diagram in Figure 1 illustrates the main mechanisms of the operation of the current electricity market. **Market players are responsible for balancing injections and off-take in their portfolio.** They must therefore nominate an energy portfolio one day in advance (day-ahead) that guarantees an equilibrium and by moving further closer to real-time resolve any detected imbalance in their portfolio<sup>1</sup>. It is therefore necessary for the market to have sufficient flexibility, both intra-day and in real-time, to compensate for forecast errors on generation and demand, in particular in regards to renewable energy sources and off-take. In addition, the flexibility available in the system must always allow for the loss of power plants and relevant HVDC interconnectors (an unavailability known to occur on day-ahead as well as an unforeseen unavailability after day-ahead).

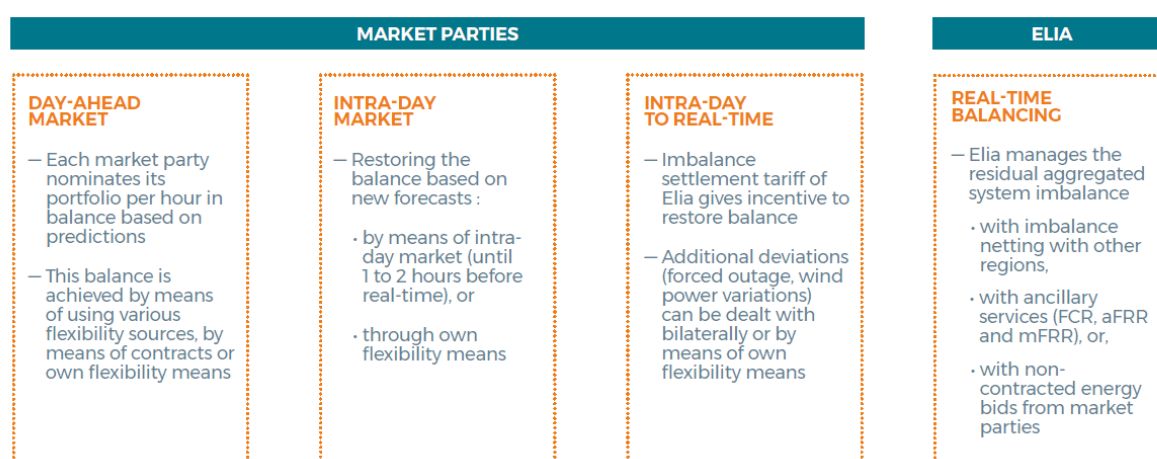


Figure 1: time horizons for flexibility (Elia's adequacy and flexibility study 2019)

The role of the system operator in managing flexibility is complementary to the market because it neutralizes the residual imbalance between injection and offtake that is not covered by market players. By means of the imbalance settlement tariff, it incentivizes the market to cover their balancing responsibility as much as possible. This imbalance tariff is driven by the cost of activating balancing energy to resolve the residual system imbalance, in both an upward (to deal with energy shortage) and downward (to deal with energy surplus) direction. Due to this 'reactive' balancing mechanism, a large part of the required flexibility is delivered by intra-day markets and real-time actions and not by Elia.

<sup>1</sup> In parallel to this study, Elia conducts a study on the advantages and disadvantages of eliminating or relaxing the obligation for BRPs to nominate a balanced portfolio in Day Ahead as provided for in article 23 of the Terms and Conditions BRP. This study is foreseen to be consulted on October 15, 2020.



The TSO uses reserve capacity to cover the residual system imbalance as represented in Figure 2. If an imbalance in the system occurs, this results in an increase or decrease in the system frequency. Because the control zones of the ENTSO-E network - also called the Load Frequency Control (LFC) blocks of which the ELIA LFC block represents the Belgian geographical area - are connected, a frequency disturbance impacts the entire synchronous zone. The Frequency Containment Reserve (FCR) must restore the balance between the power provided and the power supplied. It is used to stabilize the frequency at a level greater or smaller than the initial frequency, rather than balancing the ELIA LFC block. Section 1.2 explains how the required FCR volume is dimensioned by ENTSO-E at European level and allocated to the relevant LFC blocks.

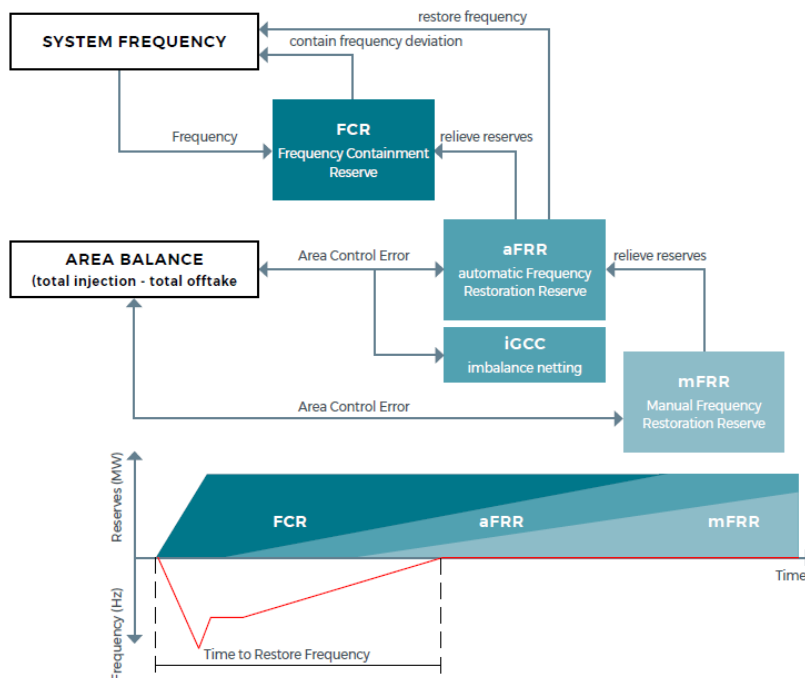


Figure 2: Schematic overview of the activation of operating reserves

The Frequency Restoration Reserve (FRR) must free up the FCR of the synchronous zone and ultimately bring the frequency to its nominal value in order to prevent network instability, or even a failure of the entire electricity system, in the event of additional system imbalances. Each control area is therefore obliged to maintain its balance which is monitored by means of quality criteria assessing the Frequency Restoration Control Error (FRCE) or Area Control Error (ACE), i.e. the real-time deviation between measured and scheduled cross-border exchanges on a quarter-hourly (and even by minute) basis.

Unlike the FCR, the FRR ensures that the frequency in the synchronous zone is restored, and that the control zone is re-balanced. The automatic FRR (aFRR) is mainly used to compensate for short and random imbalances. The manual FRR (mFRR) serves as compensation for long, persistent and/or very extensive imbalances. Once requested by Elia:

- aFRR must be activated automatically by the BSP within 30 seconds and must be fully available within 7.5 minutes;
- mFRR is manually activated by the BSP and must be fully available within 15 minutes.

## 1.2 Elia's dimensioning methodology for the needs and means for reserve capacity

The required FCR volume is dimensioned by ENTSO-E for the synchronous area of continental Europe. It is currently calculated on the largest contingency, currently the loss of 3000 MW. This volume is allocated to the corresponding LFC blocks according to their weight (in terms of consumption and generation) in the synchronous zone. The methodology is specified in the Synchronous Area Framework Agreement of Continental Europe, hereafter referred to as 'SAFA'<sup>2</sup>. The current FCR capacity in Belgium for 2020 is 78 MW.

**The required FRR reserve capacity is dimensioned by Elia for its LFC block. First the needs are determined with a methodology presented in Elia's LFC block operational agreement<sup>3</sup>. As from February 3, 2020, Elia implemented a daily dynamic dimensioning for up- and downward FRR needs. The volumes are thereafter allocated towards the different products for balancing capacity with a methodology presented in the LFC Means<sup>3</sup>.**

- Dynamic dimensioning methodology for the FRR needs

As required by Article 157(2)b of the Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation (hereafter referred to as "SOGL"), ELIA determines the positive and negative FRR needs based on a combination of a probabilistic and deterministic methodology (Figure 3). The **probabilistic methodology** is based on estimating the imbalance risks for each quarter-hour of the next day and determining the required reserve capacity on FRR to cover 99.0% of the imbalance risks, i.e. the 99.0% percentile of the probability distribution curve of the positive and negative LFC block imbalances. The probabilistic method is based on machine learning algorithms relating the imbalance risk to day-ahead predicted system features such as renewable generation, demand, weather conditions, as well taking into account the imbalance risks due to forced outages of available power plants and the Nemo Link interconnector.

In parallel, Elia considers the dimensioning incident by means of a **deterministic methodology**. This method has to ensure that the positive and negative FRR needs shall not be less than the positive and negative dimensioning incident of the LFC block, as required by Articles 157(2)e and 157(2)f of the SOGL. The dimensioning incident is defined by Article 3 of the SOGL as the highest expected instantaneously occurring active power imbalance within a LFC block in both positive and negative direction. Finally, Elia applies an additional **minimum threshold** to ensure that the required positive and negative reserve capacity is sufficient to cover at least the positive and negative historic LFC block imbalances for 99.0% of the time in order to be in line with Articles 157(2)h and 157(2)i of the SOGL.

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<sup>2</sup> Annex 1 of the SAFA which is the Policy on Load-Frequency Control and Reserves, determines amongst others the dimensioning rules for FCR, published on : <https://transparency.entsoe.eu/system-operations-domain/operational-agreements-of-synchronous-areas/show>

<sup>3</sup> Published on <https://www.elia.be/en/electricity-market-and-system/system-services/keeping-the-balance>

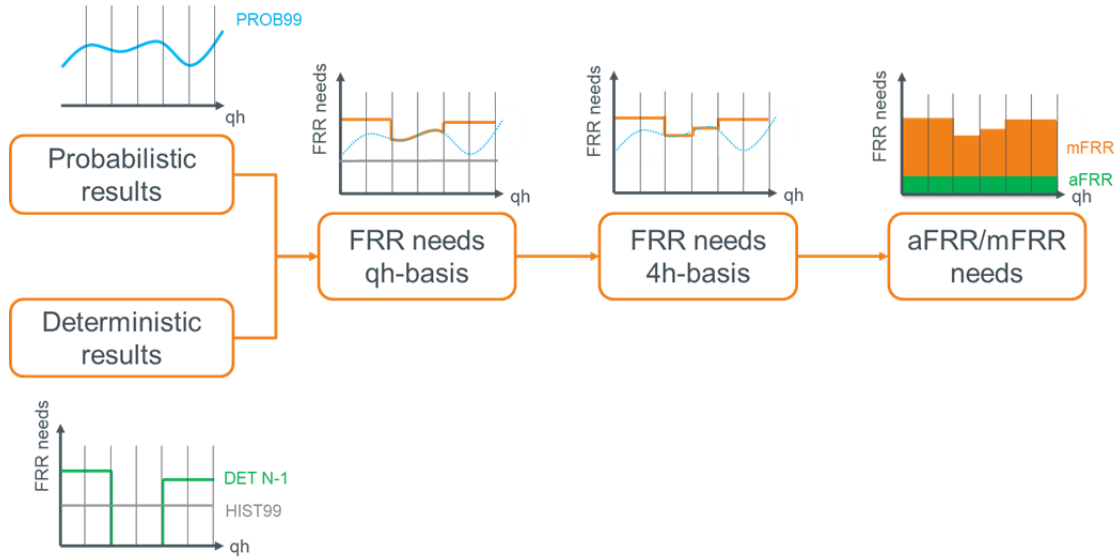


Figure 3: Calculation process of the FRR/aFRR/mFRR needs

Both methodologies are used in parallel to calculate the positive and negative FRR reserve capacity required for every quarter-hour of the next day. The required reserve capacity for each quarter-hour is determined based on the maximum value of the deterministic and probabilistic methodologies. The result is expressed in periods of 4 hours by means of the maximum over all quarter-hours in this period. The calculation is conducted before 7 AM.

Note that the mFRR need is determined by subtracting the FRR needs with the results of a 'static' aFRR dimensioning methodology for which the methodology and results are determined as well in the LFC block operational agreement. This is based on covering a fixed percentile of the expected absolute 15' imbalance variations. As improving this methodology is the scope of this study, it is discussed in more detail in Section 2.2.1.

- Methodology to determine the FRR means to be contracted

In compliance with Article 32 of Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing, hereafter referred to as "EBGL", ELIA conducts an analysis on optimal provision of reserve capacity. This analysis shall take into account the following options for the provision of reserve capacity:

- procurement of balancing capacity within control area and exchange of balancing capacity with neighboring TSOs, when applicable;
- sharing of reserves, when applicable;
- the volume of non-contracted balancing energy bids which are expected to be available both within their control area and within the European platforms taking into account the available cross-zonal capacity.

ELIA currently determines the balancing capacity for aFRR equal to the aFRR needs (taking into account the absence of aFRR sharing and the limited potential of non-contracted energy balancing bids). The aFRR capacity is determined symmetrically meaning that the downward reserve capacity is equal to the upward reserve capacity.

The upward mFRR needs are assumed to be partially covered with the sharing of mFRR but not by non-contracted balancing energy bids after showing the limited potential. In contrast, the downward mFRR needs are assumed to be

fully covered with sharing of mFRR and non-contracted balancing energy bids. More information can be found in ELIA's LFC Means.

### 1.3 Elia's reserve capacity volumes

Table 1 shows the historical global FRR/aFRR needs between 2013 and 2020. Although a decreasing trend in FRR needs is observed between 2013 and 2016, this is mainly due to market design improvements. After a small increase in 2018, the reliability target in the calculations was reduced from 99.9% to 99.0% following SOGL minimum requirements. As from 2020, Elia implemented a dynamic FRR dimensioning process where the FRR needs are dimensioned for the next day.

Table 1: Evolution of the FRR needs

[MW]	Upward FRR Needs*	Symmetric aFRR Needs*
2013	1260	140
2014	1241	140
2015	1240	140
2016	1203	140
2017	1183	144
2018	1190	139
2019	1039	145
2020	Dynamic	145(151)

Based on Elia's volume assessments (Final Decisions CREG)

Table 1 shows that aFRR needs remained fixed at 140 MW until 2017 when the reliability target was fixed at 79% which was observed to provide sufficient ACE / FRCE-quality. **However, as from 2019, aFRR needs started increasing following the increased variability in the LFC block imbalances induced by the integration of variable renewable energy (wind and solar).** This was found to further increase to 151 MW in 2020 but it was decided to freeze the volume to 145 MW while awaiting the assessment of the current methodology towards potential improvements in this study.

Note that the latest long-term projections for aFRR were conducted in 2016 in the framework of the first adequacy and flexibility study (Table 2)<sup>4</sup>. These non-binding indicative volumes are based on the 2016 applicable volume determination methodology, excluding any additional measures and volumes that would be required dealing with exceptional situation (e.g. loss of the offshore wind power generation due to storm events). While the aFRR needs were expected

<sup>4</sup> Published at <https://www.elia.be/en/electricity-market-and-system/adequacy/adequacy-studies>. Note that these volumes have as sole purpose to give an idea of the future trend with respect to volume needs and do by no means substitute for the legally or regulatory determined volume assessment process in place between Elia and the CREG.

to increase to 175 MW (and even 190 MW in the 'High RES scenario) following the integration of renewable energy (including offshore wind power).

Table 2: Estimated evolution of the FRR needs in the Base Case and High RES scenario, as published in the adequacy study and assessment of the need for flexibility of 2016

Horizon	aFRR 'Base Case'	aFRR 'High RES'
2021	175	175
2023	175	175
2027	175	190

However, in Elia's later projections, these figures were already revised downwards towards 160 MW between 2021 and 2023, based on return of experience on aFRR dimensioning with increasing shares of renewable generation. Indeed, it is found that the long-term aFRR projections might have been too conservative in terms of the impact of renewable generation prediction errors on the LFC block imbalance variations. Note that accuracy of extrapolations is improved when more data became available on wind and solar generation and forecasts.

#### 1.4 Robustness towards expected system evolutions

Figure 4 provides the main reasons to investigate a new methodology for aFRR dimensioning. First of all, **new balancing quality criteria** are put forward by the SOGL providing new legal minimum balancing quality criteria which are complemented by a set of proposed indicators. Note that since 2018, results are published by ENTSO-e in its balancing reporting, as well as reported by Elia to CREG in its balancing and reserve reporting in line with requirements defined in the LFC BOA.

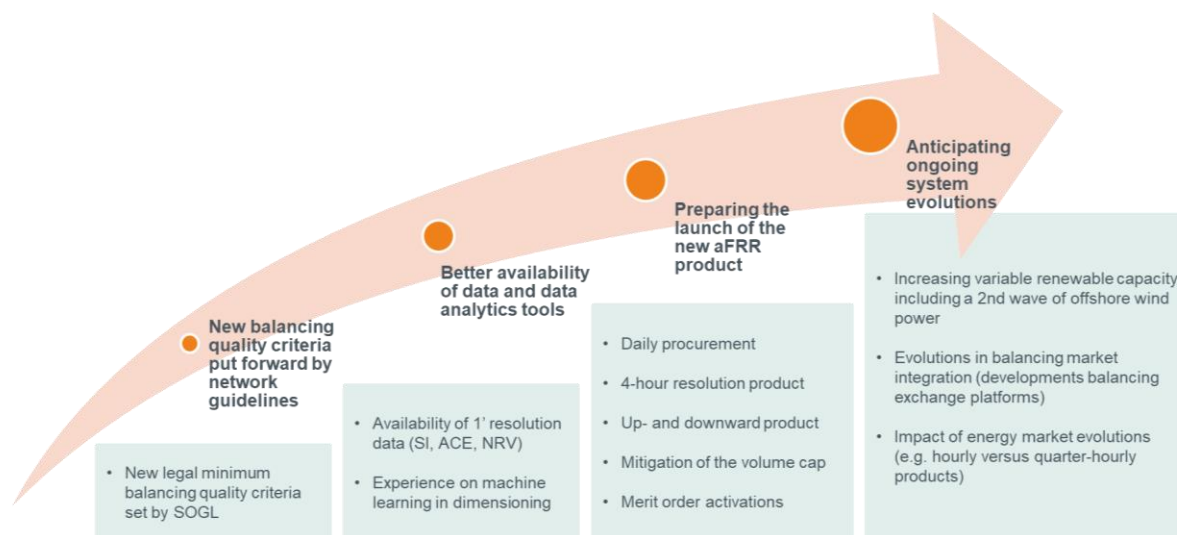


Figure 4: Overview of expected system evolutions

Secondly, **digitalization of the sector** brought new tools for data analytics which can be combined with elaborated data available and published by Elia (e.g. 1' LFC block imbalance data). In addition, in recent years, Elia gained more

experience on data analytics for several applications of which one was the dynamic dimensioning of FRR based on machine learning algorithms.

Thirdly, Elia is currently preparing the implementation of a **new aFRR product design**. This product design might hold some opportunities to conduct the dimensioning closer to real time through daily procurement and 4 hour product resolution as well as the implementation of separate up and downward products. In addition, the impact of allowing the participation of non-contracted balancing energy bids and merit order activations has to be investigated.

Finally, and not at least, there are a few **system evolutions** ahead which may impact aFRR dimensioning. Firstly, there is an increasing variable renewable capacity including a 2<sup>nd</sup> wave offshore wind power, foreseen. The variability and limited predictability of these resources are a well-known challenge for power system balancing. But also evolutions in the European balancing market integration and the impact of other market evolutions such as quarter-hourly products have to be investigated.

## 1.5 Objective, scope and structure of the study

This study investigates opportunities to improve or replace the current aFRR dimensioning methodology, in order to maintain balancing quality while taking into account future system evolution. Particular attention will be put on:

- taking into account intra-15' variations of the LFC block imbalances;
- taking into account the dynamic potential, varying aFRR needs in function of the risks (if any);
- taking into account the evolutions in the FRCE quality in line with Article 157(b) of the SOGL.

This study proposes options to improve the current aFRR dimensioning methodology to be further investigated in a Proof of Concept. These are based on an exhaustive analysis of methodology design options which are (1) implementable from a practical point of view (in terms of transparency and complexity); (2) compliant with European legislation); (3) robust towards future power system evolutions (including installed RES capacity and HVDC interconnections), and (4) meeting minimum technical criteria maintaining reliability of the system and acceptable balancing quality.

In a first step, Section 2 investigates different design options found in the literature, benchmark with neighboring TSOs and Elia's expert view and experience with dimensioning of reserve capacity. Thereafter, Section 3 proposes a selection of an integrated method which will be further investigated in a Proof of Concept in the second part of the study. Following the consultation on this document, the Proof of Concept for the chosen methodology will be executed. The results of this proof of concept will be published by Elia in Q4 2020.

## 2. aFRR dimensioning design options

Figure 5 shows an overview of the investigation method followed to find an improved or new aFRR dimensioning method. The starting point is an extensive desktop investigation. Firstly, an overview is made of the **methodology objectives**. This is based on an analysis of the legal and regulatory framework, listing ongoing system evolutions and an analysis of the current balancing quality. This allows to identify the requirements of an aFRR dimensioning methodology. Secondly, an overview is made of possible **methodology design options** which is based on an assessment of the current methodology, a benchmark of methods applied by other European TSOs and a literature review.

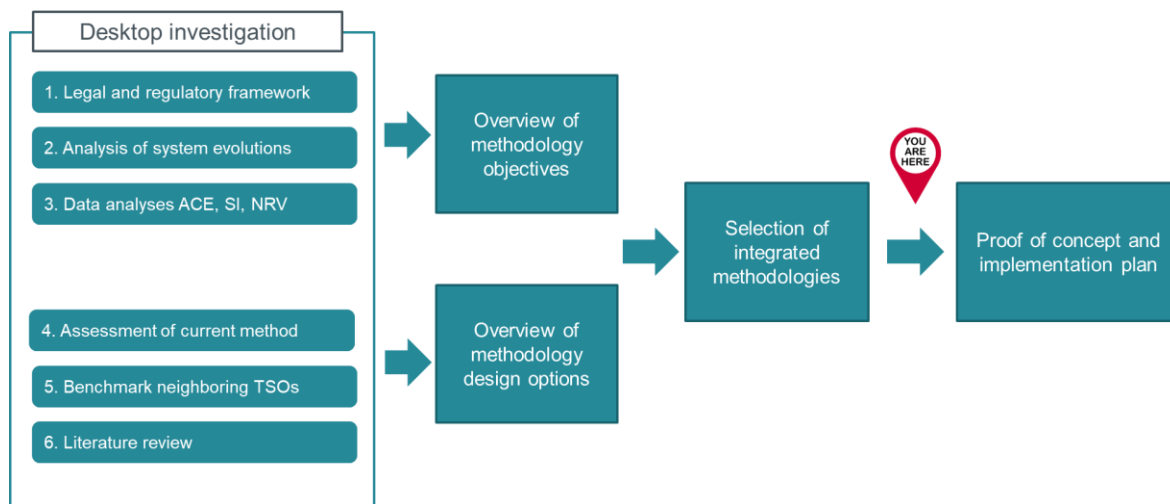


Figure 5: Overview of the approach to find a new or improved aFRR dimensioning method

These analyses allow to make a selection of integrated methodologies. After an assessment of these methods, the most promising method(s) are proposed for further investigation in a Proof of Concept with projections towards 2020 to 2028. Based on the results of the Proof of Concept, an implementation plan will be proposed. Note that the results of this Proof of Concept and the corresponding implementation plan will be dealt with in the Proof of Concept.

### 2.1 aFRR dimensioning objectives

#### 2.1.1 Legal and regulatory framework

The legal framework provides only little guidance for aFRR dimensioning. The **Clean Energy Package** or **Federal Grid Code** neither provide specific requirements for aFRR dimensioning within the LFC block. However, the 'SOGL' specifies some dimensioning rules on FRR which are given in Article 157. Despite that little attention is given to determining the ratio between aFRR and mFRR, three paragraphs in Article 157(2) of the SOGL are relevant:

*c. all TSOs of a LFC block shall determine the ratio of automatic FRR, manual FRR, the automatic FRR full activation time and manual FRR full activation time in order to comply with the requirement of paragraph (b). For that purpose, the automatic FRR full activation time of a LFC block and the manual FRR full activation time of the LFC block shall not be more than the time to restore frequency;*

*b. all TSOs of a LFC block in the CE and Nordic synchronous areas shall determine the reserve capacity on FRR of the LFC block sufficient to respect the current FRCE target parameters in Article 128 for the time period referred to in point (a) based at least on a probabilistic methodology. In using that probabilistic methodology, the TSOs shall take into account the restrictions defined in the agreements for the sharing or exchange of reserves due to possible violations of operational security and the FRR availability requirements. All TSOs of a LFC block shall take into account any expected significant changes to the distribution of LFC block imbalances or take into account other relevant influencing factors relative to the time period considered*

*a. all TSOs of a LFC block in the CE and Nordic synchronous areas shall determine the required reserve capacity of FRR of the LFC block based on consecutive historical records comprising at least the historical LFC block imbalance values. The sampling of those historical records shall cover at least the time to restore frequency. The time period considered for those records shall be representative and include at least one full year period ending not earlier than 6 months before the calculation date.*

It concluded that article (a) and (b) deal again with the dimensioning of FRR in general and are therefore also applicable on aFRR needs being part of the FRR needs. Section B-6-2-2-1-5 of the SAFA,<sup>5</sup> although this part is not approved by NRAs, provides some additional guidance by specifying two approaches to provide a recommendation for a minimum amount of aFRR:

1. *The amount of the aFRR that is needed typically depends on the size of load variations, schedule changes and generating units. In this respect, the recommended minimum amount of aFRR has to ensure:*

- that the positive aFRR is larger than the 1st percentile of the difference<sup>2</sup> of the 1-minute average ACEo<sup>β</sup> and the 15 minute average ACEo<sup>l</sup> of the LFC Block of the corresponding quarter of hour<sup>4</sup>, and*
- that the negative aFRR is larger than the 99th percentile of the difference of the 1-minute average ACEo<sup>l</sup> and the 15 minute average ACEo<sup>l</sup> of the LFC Block of the corresponding quarter of hour.*

*This recommended statistical approach is based on historical data with:*

<sup>2</sup> *Difference to be calculated on 1-minute resolution*

<sup>3</sup> *ACEo<sup>l</sup> means remaining ACE open loop without contribution of mFRR and RR activations.*

<sup>4</sup> *To be calculated between minutes 0:00-14:59, 15:00-29:59, 30:00-44:59, 45:00-59:59 of each hour of the day*

2. *An alternative approach based on empiric noise management (recommended in the former UCTE) may also be taken into account leading to recommended minimum amount of aFRR given in the following graph [Figure 6] with L<sub>max</sub> being the maximum anticipated consumer load for an LFC Area over the period considered.*

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<sup>5</sup> Annex 1 of the SAFA which is the Policy on Load-Frequency Control and Reserves, specifies amongst others the aFRR minimum amount recommendations (B-6-2-2-1-5), published on : <https://transparency.entsoe.eu/system-operations-domain/operational-agreements-of-synchronous-areas/show>



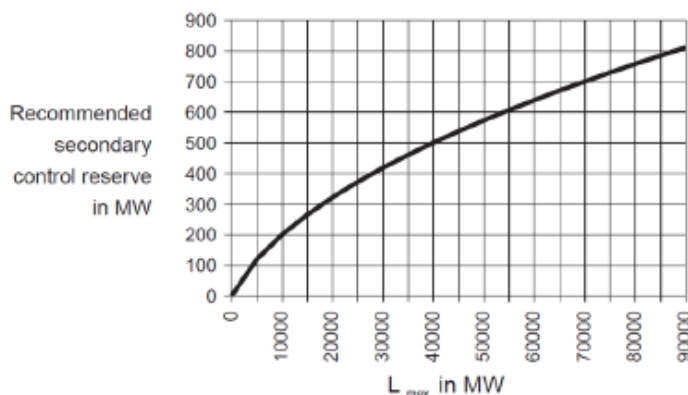


Figure 6: Recommended minimum aFRR reserve in the former UCTE

However, it is specified that that the first method is considered more future proof as it also takes into account other features as only the peak load.

Some additional guidelines can be derived from legal objectives on FRCE-quality. First of all, some indicators are specified in Article 131(1) of the SOGL:

b. for each LFC block of the CE or Nordic synchronous areas during operation in normal state or alert state in accordance with Article 18(1) and (2), on a monthly basis:

- (i) for a data-set containing the average values of the FRCE of the LFC block over time intervals equal to the time to restore frequency:
  - the mean value,
  - the standard deviation,
  - the 1-,5-,10-, 90-,95- and 99-percentile;
  - the number of time intervals in which the average value of the FRCE was outside the Level 1 FRCE range, distinguishing between negative and positive FRCE, and
  - the number of time intervals in which the average value of the FRCE was outside the Level 2 FRCE range, distinguishing between negative and positive FRCE;
- (ii) for a data-set containing the average values of the FRCE of the LFC block over time intervals with a length of one minute: the number of events on a monthly basis for which the FRCE exceeded 60 % of the reserve capacity on FRR and was not returned to 15 % of the reserve capacity on FRR within the time to restore frequency, distinguishing between negative and positive FRCE;

Note the article 128 of the SOGL also attach legal target parameters to the Level 1 and Level 2 indicators:

3. All TSOs of the CE and Nordic synchronous areas shall endeavour to comply with the following FRCE target parameters for each LFC block of the synchronous area:

- (a) the number of time intervals per year outside the Level 1 FRCE range within a time interval equal to the time to restore frequency shall be less than 30 % of the time intervals of the year; and
- (b) the number of time intervals per year outside the Level 2 FRCE range within a time interval equal to the time to restore frequency shall be less than 5 % of the time intervals of the year.

It is to be noted that these criteria are never intended to be used as the basis for dimensioning, but rather as an ex post verification if absolute warning limits are not exceeded, as specified in B-1 of the SAFA:

*The objective behind the level 1 and level 2 parameters is to provide quality targets for the individual ACE quality of each LFC block. Since it is the responsibility of each TSO in its LFC block to keep ACE as low as possible, the level 1 and level 2 parameters must not be exploited in order to reduce reserves or reserves activation. These parameters should rather be interpreted as an absolute warning limit that shows that quality of ACE is below the required standard and that respective countermeasures have been reported and will be implemented urgently.*

In addition, Article 152 of the SOGL also identifies some 'soft' targets which should be endeavored by TSOs, or may act as a trigger for additional measures.

*9. The TSOs of a LFC block shall endeavour to avoid FRCEs which last longer than the time to restore frequency.*

*12. If the 1-minute average of the FRCE of a LFC block is above the Level 2 FRCE range at least during the time necessary to restore frequency and where the TSOs of a LFC block do not expect that FRCE will be sufficiently reduced by undertaking the actions in paragraph 15, TSOs shall have the right to require changes in the active power production or consumption of power generating modules and demand units within their respective areas to reduce the FRCE as specified in paragraph 16.*

*13. For the CE and Nordic synchronous areas, where the FRCE of a LFC block exceeds 25 % of the reference incident of the synchronous area for more than 30 consecutive minutes and if the TSOs of that LFC block do not expect to reduce sufficiently the FRCE with the actions taken pursuant to paragraph 15, the TSOs shall require changes in the active power production or consumption of power generating modules and demand units within their respective areas to reduce the FRCE as specified in paragraph 16.*

It is concluded that the legal framework does not provide specific aFRR dimensioning rules as it does with FRR. Also the legal criteria on balancing criteria can only give some ex post indications on reserve capacity shortages but cannot be used as sole objective of aFRR dimensioning. The only objective is that of the aFRR product which is activated to restore the FRCE where temporary deviations are netted or resolved by FCR. It has to be taken into account that a perfect FRCE is not possible due to the activation lead time of aFRR (7.5 minutes and expected to evolve towards 5 minutes) and mFRR (15 minutes). **Due to the absence of clear legal requirements on aFRR dimensioning, the proposed dimensioning methodology and proposed reliability level shall need to find trade-off between meeting such minimum thresholds (and avoid over-procurement in general) and meeting their responsibility to cover their FRCE as good as possible and contribute to the European frequency stability.**

### 2.1.2 Ongoing and upcoming system evolutions

The objective of improvements in aFRR dimensioning is to have a method which can correctly take into account ongoing and future system evolutions. An overview is listed for which attention is given in the development of a new method, and testing in the Proof of Concept.

- **Modifications related to the new aFRR product design** : some modifications to the aFRR product design are currently under implementation by Elia and can have an impact on the dimensioning:

- the evolution towards a 4-hour product with a daily procurement, at least for a part of the balancing capacity<sup>6</sup>, facilitates a daily dynamic dimensioning processes such as with mFRR. A dimensioning closer to real time allows to reduce uncertainty and have a more accurate dimensioning reducing aFRR needs in lower risk periods, while increasing in higher risk periods;
  - having separate up- and downward products for the 4-hour product facilitates to separately assess reserve capacity needs and should allow to reduce reserve capacity for one if asymmetry in the needs is identified;
  - the merit order activation should have no impact on the ACE / FRCE-quality or aFRR dimensioning as aFRR reserve capacity has a full activation time is 7.5 minutes, independently of the volume requested by Elia to be activated by the BSP;
  - the mitigation of the limit on activated capacity, through the activation of additional available non-contracted balancing energy bids, can positively impact the ACE / FRCE-quality by activating more aFRR reserve capacity with a faster activation time as mFRR..
- **Balancing energy platforms:** Elia already participates for several years in an imbalance netting platform (iGCC), netting imbalances between LFC blocks before activating aFRR when netting potential and ATC are available. In addition, as from 2022, Elia will participate in the EU balancing energy exchange platforms (MARI for mFRR and PICASSO for aFRR) that will facilitate the activation of balancing energy outside the LFC block upon availability.
    - the iGCC cooperation has proven to have a significant impact on the aFRR activations and balancing quality and evolutions may therefore impact aFRR dimensioning. Releasing the current profile limits for iGCC (maximum allowed import and export) will further increase FRCE-quality and might therefore have a downward effect on required aFRR needs if this is taken into account in the dimensioning (note that until now, iGCC has never been directly accounted in the dimensioning due to the non-guaranteed capacity). Furthermore, the netting opportunities will increase following the interconnection capacity with Germany through ALEGrO.
    - PICASSO will allow to activate more volumes than locally available, but this will however never be guaranteed.

Exchange of aFRR balancing capacity and sharing are at this moment too premature to contribute in the analyses.

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<sup>6</sup> Note that part of the aFRR balancing capacity will still be procured with a 24-hour symmetric product on D-2. In D-1 six blocks of 4-hour product are procured, separately for up- and downward capacity.

- **Energy market design** : energy markets determine the ability of BRPs to deal with variations of demand and generation through day-ahead, intra-day markets and might therefore reduce residual LFC block imbalances to be covered by the TSO with aFRR and mFRR;
  - Shorter market resolutions such as 15' minutes in day-ahead and intra-day may increase the ability of BRPs with limited flexibility in their portfolio to balance their portfolio. It will also result in less hour to hour imbalances due to high ramps of the residual load. As the imbalance settlement period is fixed at 15', the effect is mainly expected for FRR but reduced variability of the LFC block imbalances could also affect the aFRR needs.
  - Imbalance settlement impacts the incentive for BRPs to balance their portfolio. Specific measures are implemented to further fortify this incentive (e.g. alpha reinforcing the LFC block imbalance prices in case of large deviations) or tools allowing BRPs to have better estimations of positions and optimize their portfolio (e.g. a tool to estimate the DSO-infeed of individual BRPs). Elia will continue to investigate ways to incentivize and facilitate BRPs to balance their portfolio. As the imbalance settlement period is fixed at 15', the effect is mainly expected for FRR but reduced or increased variability of the LFC block imbalances should impact the aFRR needs as well.
  - Deterministic Frequency Deviations are a phenomenon which results in frequency deviations during particular change of hours in the day with high physical demand variations. Among the identified causes is the fact that the market rules between generation and consumption are based on the exchange of energy blocks of fixed time periods. A dedicated study is conducted in parallel with this study<sup>7</sup>. However the solutions to mitigate the DFD issue is unlikely to have an impact on aFRR needs (although there might be an indirect impact when the aFRR needs are dynamically dimensioned taking into account the time of the day). In fact, additional aFRR volumes will have limited impact to solve DfDs with high rate of change of frequency (RoCoF), therefore can be considered as less effective comparing to other solutions.
  
- **Energy transition**
  - Increasing RES, including the second wave of offshore wind energy investigated in parallel in a specific study, challenges the BRP portfolio balance through its inherent variability and limited predictability resulting in more residual imbalances. Variations within 15' can therefore impact the aFRR needs which might be expected if BRPs focus on balancing their portfolio on a 15' basis. Offshore is characterized by a higher variability than onshore and photovoltaics. This is due to the highly concentrated location. In a separate study, DTU is investigating the effect of variability and limited predictability of offshore wind power generation. These inputs will be used to investigate the effect of offshore on the new method.

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<sup>7</sup> The results of this study are foreseen to be consulted on July 1, 2020

- More and more new flexibility providers enter the system. The adequacy and flexibility study of 2019 shows that sufficient flexibility is expected to be installed in the system to deal with fast variations but that it will not be available when needed. Specific reservation mechanisms for BRPs or TSOs remain necessary. While these will contribute to the BRPs' flexibility to balance their portfolio, these are expected to mainly mitigate the impact on FRR but effect can spill-over through aFRR needs when facing less LFC block imbalance variations.

In conclusion, we can say that the new methodology should be robust to some evolutions, in particular the new aFRR product design provides interesting opportunities for close-to-real-time and asymmetric dimensioning to keep aFRR needs as low as possible. On the other hand, increasing renewables, in particular offshore challenge the balancing quality and the impact will be specifically studied in the Proof of Concept. Finally, it should be investigated how iGCC, for which the availability cannot be guaranteed, can be taken into account to reduce aFRR needs. The methodology should also be robust for other market evolutions such as shorter resolution products or increased system flexibility. Preferably, a self-learning method based on historical LFC block imbalance or FRCE quality can take into account the effects of measures on balancing quality of BRPs.

### 2.1.3 ACE / SI quality

Figure 7 visualizes the evolution of monthly absolute average and standard deviation of the 15' LFC block imbalances, the 15' FRCE / ACE and the 15' Net Regulation Volume (NRV). Table 3 shows yearly statistics, i.e. average, absolute average, standard deviation, and the 1% / 99% percentile for the 15' LFC block imbalances and variations, and the 15' FRCE and variations.

Despite the growth in variable RES, the absolute average levels of the LFC block imbalances has remained relatively stable since 2016, despite a small increase in 2019. However, the standard deviation, an indicator for the variability, already started increasing slightly since 2017. While the first is mainly relevant for the FRR dimensioning, the second is relevant for the aFRR needs and clarifies the increasing aFRR needs since 2017.

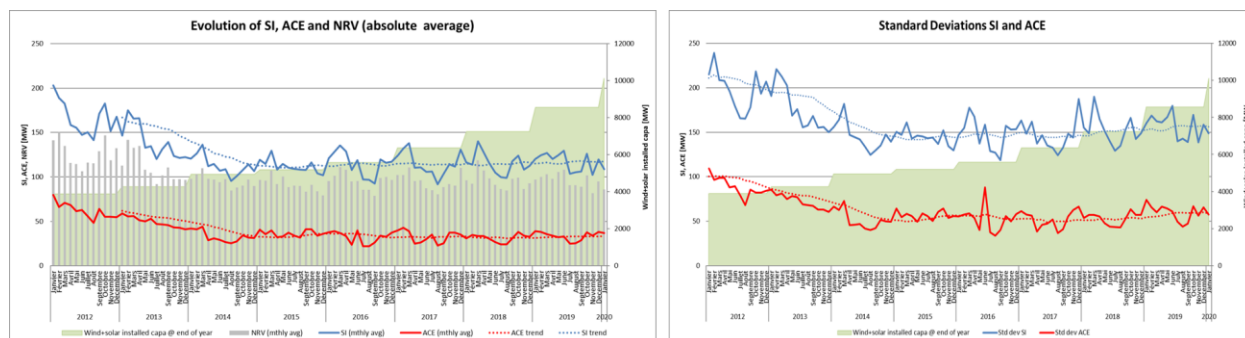


Figure 7: Evolution of the monthly average (left) and standard deviation (right) SI, ACE/FRCE and NRV

Table 3 : Key statistics of the LFC block imbalances and FRCE between 2015 and 2019

[MW]	LFC block imbalances					LFC block imbalance variations				
	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019
AVG	4.0	16.7	23.0	1.5	4.8	0.0	0.0	0.0	0.0	0.0
MAE	112.0	114.8	114.8	115.0	117.4	93.7	91.4	95.2	99.6	100.0
ST.DEV	146.6	151.1	151.4	153.5	158.3	124.7	122.9	127.9	134.6	136.4
P1	-356.2	-384.0	-375.8	-401.6	-404.2	-342.8	-340.9	-347.1	-364.4	-374.2
P99	376.1	391.3	400.1	409.4	414.2	307.8	315.1	327.2	362.8	358.4
[MW]	FRCE					FRCE variations				
	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019
AVG	-2.4	-0.6	0.8	-1.9	0.3	0.0	0.0	0.0	0.0	0.0
MAE	94.9	10.1	211.9	1.0	10.0	41.9	8.0	194.9	1.0	34.0
ST.DEV	53.9	45.0	46.4	47.9	49.8	71.5	56.2	59.5	63.3	63.1
P1	-179.4	-157.8	-152.4	-166.6	-165.7	-203.6	-178.2	-190.5	-195.7	-201.2
P99	150.7	142.5	151.3	150.1	159.1	206.2	174.3	182.5	197.5	194.2

In 2018, Elia started monitoring the FRCE-quality with new indicators specified in Article 131 of the SOGL. As explained in Section 4.1, this monitoring is conducted in dedicated documents. Table 4 shows with FRCE-indicators that the Level 1 and Level 2 target are fulfilled in 2018 and 2019 (note that the target for level 1 and level 2 is to be compared with the sum of the number of times where the FRCE exceeds the positive and negative level 1 and level 2). In terms of the absolute legal limit, Elia is at 24% for level 1 and 35% for level 2 limit. Nevertheless, when comparing this performance with other countries in Continental Europe (Figure), we can see that Elia shows an average performance compared to other TSOs.

Table 4 : FRCE-indicators compliant with article 131 of the SOGL for 2018 and 2019

FRCE-indicators	2018	2019	FRCE-indicators	2018	2019	Target
The mean value	-1.9	0.3	Number of time intervals: average FRCE > Level 1 positive	1059	1211	10512
The standard deviation	47.9	49.8	Number of time intervals: average FRCE < Level 1 negative	1417	1250	
1-percentile	-166.6	-165.7	Number of time intervals: average FRCE > Level 2 positive	262	300	1752
5-percentile	-75.6	-69.9	Number of time intervals: average FRCE < Level 2 negative	352	345	
10-percentile	-40.0	-35.2				
90-percentile	32.9	36.4				
95-percentile	63.0	67.9				
99-percentile	150.1	159.1				

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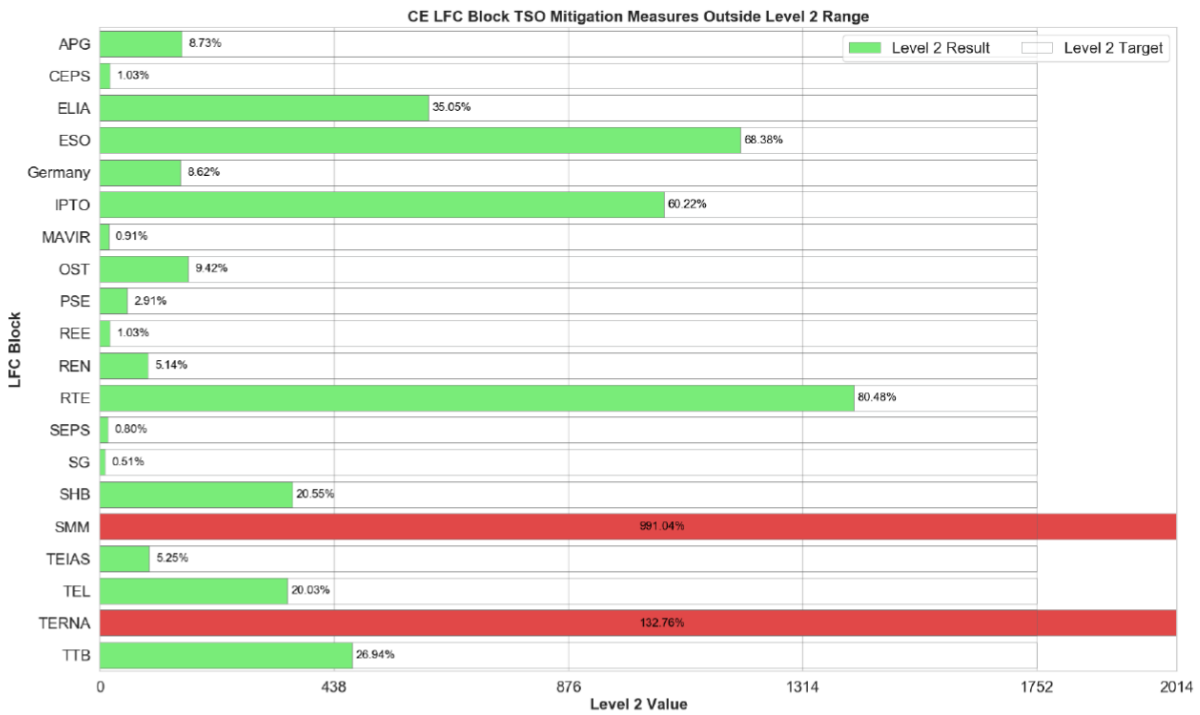
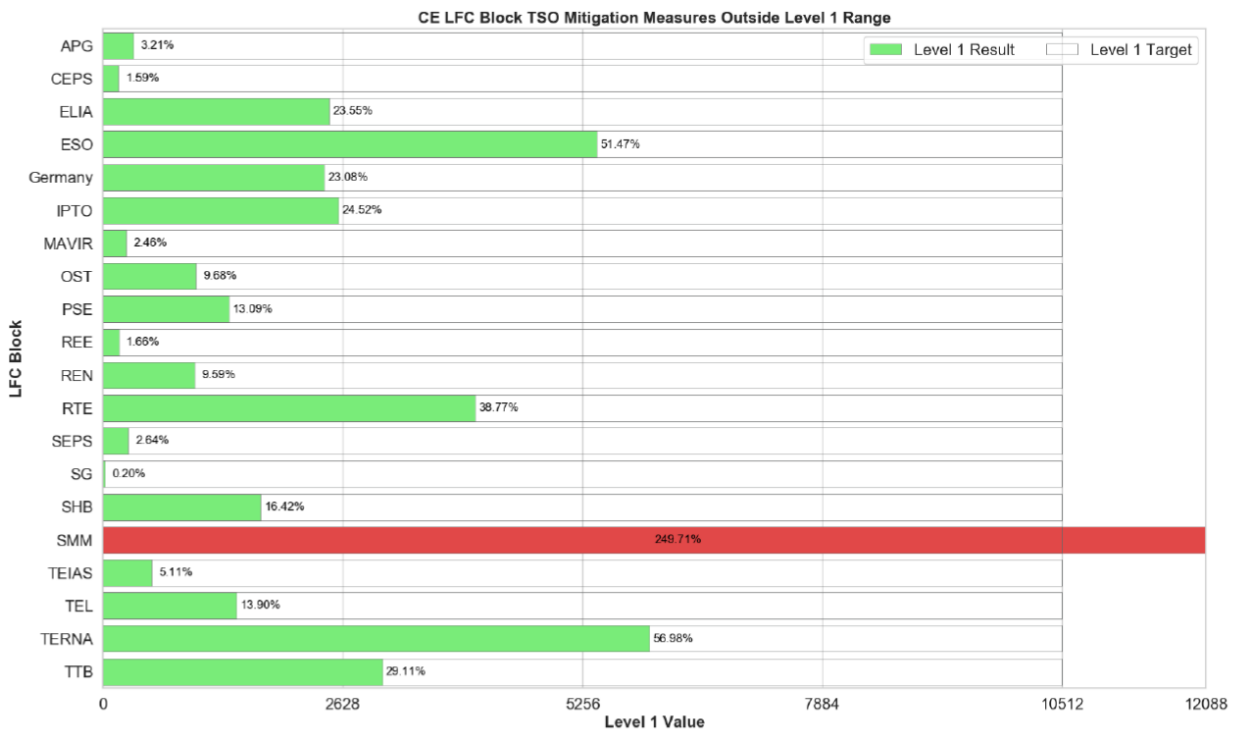


Figure 8: Level 1 and Level 2 performance in 2018 (ENTSO-E LFC block monitor 2018)

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Figure 9 shows the aFRR procured in neighboring countries as registered in the ENTSO-E transparency platform for December 2019. Of course, absolute figures are difficult to compare due to the size of the LFC block but the empirical noise method of ENTSOe (Section 2.1) is useful to make such comparison: in this method, the aFRR needs are solely based on the peak load of a LFC block. It can be seen that Elia already procures little aFRR in comparison with its neighbors.

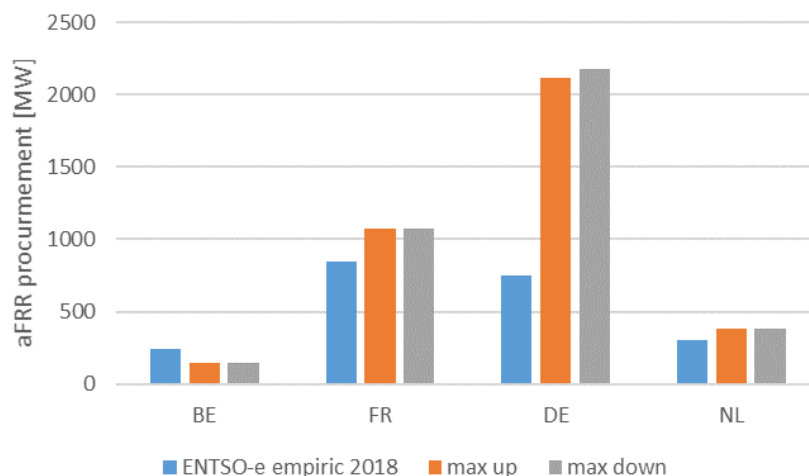


Figure 9 – aFRR procured compared to the aFRR needs in the empirical noise method

In conclusion, Elia has a good FRCE-quality which is shown by its average performance in terms of the legal minimum criteria. This is not only achieved by its available aFRR means, but also the availability of iGCC (although the availability is not guaranteed) and the dispatch procedures. It must however be noted that a small increasing trend is observed since 2017 in the 15' variations which was already translated in increasing aFRR needs under the current method. In addition, Elia procures little aFRR in comparison with its neighboring countries.

Of course, Belgium as a small well-interconnected country, benefits from the availability of iGCC to manage its FRCE. Nevertheless, it has little margin for average aFRR means reductions as the available aFRR means procured are already relatively low compared to other countries and FRCE-management of individual LFC blocks is important to maintain stable frequency in the European synchronous zone.

## 2.2 Methodology design options

### 2.2.1 Assessment of the current methodology

Considering the evolutions described in previous chapters, the current dimensioning methodology deserves a review and provides some opportunities for further improvement. In particular:

- **Dimensioning process**

The expected LFC block imbalance variations result from an upscaling of historic imbalances to the expected values in the future. This upscaling is based on the forecast errors of the incremental capacity installed of wind and photovoltaics while forecast tool and LFC block imbalance improvements are taken into account by means of extrapolation



factors (which are uncertain). Currently, the dimensioning is conducted on a yearly basis, based on a LFC block imbalance time series of 2-years.

The new aFRR product design allows to consider a closer to real time calculation and might even allow to take into account system features for the next day. This should allow to reduce uncertainty and therefore avoid the use of extrapolation factors.

- **Dimensioning variable**

The system imbalance variations are determined as the absolute power variation between two periods of 15 minutes. The 15' values are covered by FRR, while the 15' variations are assumed to be covered by aFRR. In addition the dimensioning variable does not take into account asymmetry for up- and downward dimensioning.

Foreign examples and literature point out the importance of intra-15' variations, and with the availability of 1' data, it might be useful to investigate if an increased resolution can bring the results closer to the system physics. A separate up- and downward sizing also makes sense when facilitating up- and downward products.

- **Dimensioning accuracy**

The aFRR needs are determined to cover 79% of absolute variations of imbalance. The percentile is determined based on acceptable historic FRCE-quality (based on Elia's experience and ex post analyses). However, with the integration of new balancing criteria in SOGL, this reliability level and approach may be subject for revision.

## 2.2.2 Benchmark

An analysis is conducted of available information concerning the dimensioning methodology for aFRR of Elia's neighboring TSOs, i.e. The Netherlands, France, Denmark and Great-Britain. Also Ireland and Nordics are added following their particular interests concerning the renewable developments in the country, and the development of a regional dimensioning approach. Figure 10 provides a summary overview.

- **The Netherlands**

The volume of FRR is based on historical imbalance values and on the size of a reference incident, or in other words the largest imbalance that can result from an instantaneous change of active power of a single power generation module, single demand facility or single HVDC interconnector, or from a tripping of an AC line within the LFC block.

Until 2019, the subdivision of the dimensioning of FRR into aFRR and mFRR is conducted according to the 'empirical noise method' in ENTSOE SAFA. The policy describes the deterministic method to determine the minimum required volume of aFRR based on the historical peak load of the Netherlands for the same semester of the year. However, TenneT may raise this minimum with an additional volume if required due to low FRCE-quality.

Since 2019 (2<sup>nd</sup> semester), a new method is implemented based on the probabilistic method described in SAFA where the aFRR is dimensioned on the 1% percentile of the 1-minute average and the 10-minute average of the LFC block imbalances which are increased with the activated FRR and imbalance netting.

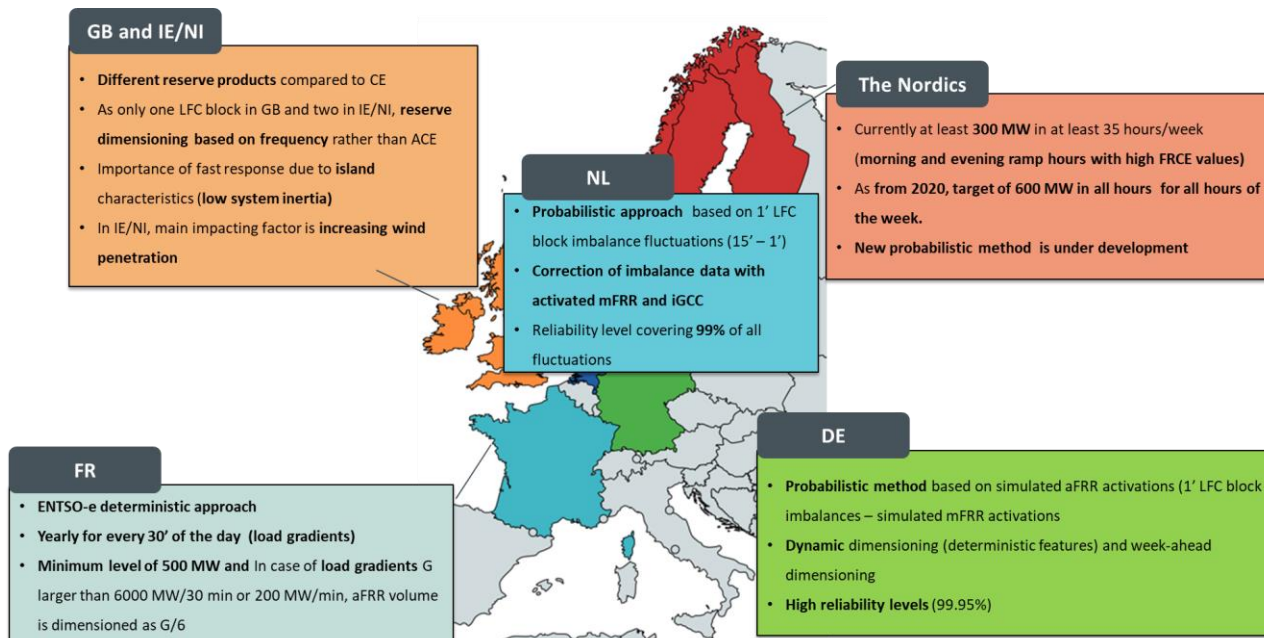


Figure 10- Overview of aFRR dimensioning with other TSOs

- **Germany**

Germany has a common methodology for the four LFC area's for which the general principles are described in the LFC block agreement approved by the NRA. Until 2019, FRR dimensioning was based on a 'static' quarter-yearly dimensioning using 15' LFC block imbalances for representative quarter-hours covering 99.95% of all imbalances. In contrast, the aFRR needs were calculated based on a statistical 'noise', i.e. fluctuations within the 15' and the ramps of planned exchanges with other LFC blocks.

The new methodology is based on a week-ahead dynamic dimensioning taking into account the dimensioning incident and a probabilistic method based on historic 1' LFC block imbalances up to 3 year (filtered from forced outages). Note that in Germany, the probabilistic outcome is always larger as the dimensioning incident. The probabilistic methodology is a dynamic method where reserves are determined week-ahead with projections up to a year. In the current implementation, only deterministic parameters such as time of day and day of week, month and season are therefore taken into account. A machine learning clustering method is used to determine periods with similar LFC block imbalances. The probability distribution curve of these LFC block imbalances are convoluted with the forced outages.

The split between aFRR and mFRR is conducted by developing a new time series of simulated mFRR activation based on the historical 1' LFC block imbalances. With the technical characteristics of the mFRR product with minimum action duration and activation lead times, the remaining demand for aFRR activations can be derived. A probability distribution of these simulated aFRR activations is made for the same cluster (after convolution with the forced outages) and a reliability level is set to cover 99.9% of all simulated aFRR activations.

- **France**

France determines the FRR needs based on a specific model comparing the expected LFC block imbalances with the available capacity in the system. The FRR needs are calculated with a dynamic dimensioning methodology covering 99% of the expected LFC block imbalances. Note that this is a continuous process.

For aFRR, there is a deterministic aFRR calculation where on yearly basis, the aFRR is determined for each period of 30' in a day in function of the demand and the demand gradients. The method is based on the deterministic method specified in Continental Europe Operation Handbook Policy 1. However, during high demand gradients, another formula is used to have more aFRR during these periods and a minimum level of 500 MW is set. Note that there are discussion ongoing on modifications of this methodology.

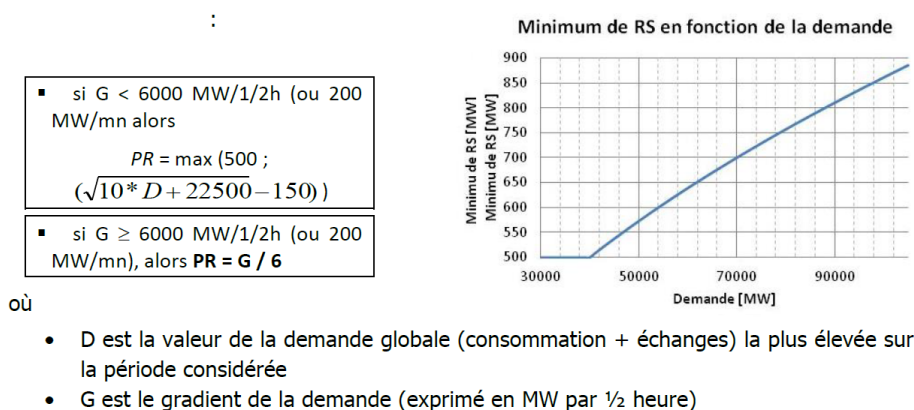


Figure 11: aFRR dimensioning methodology (RTE 2020)

- **Nordic**

In the Nordics, a new FRR dimensioning methodology is currently under development and it might therefore be a case for inspiration. This will be based on a common methodology for the four LFC area's (new methodology is currently under development as the existing methodology is not compliant with SOGL).

Until now, each TSO is dimensioning mFRR needs based on dimensioning incident in its area (but allowing reserve capacity sharing). In addition, 300 MW of aFRR needs are contracted during hours in morning and evening hours where the frequency variations are most challenging (i.e. max 35 hours a week). Note that the TSOs expect that future challenges will require more automated balancing. The Nordic TSOs will increase the number of aFRR contracting hours to all hours. After that, the aFRR volume will gradually be increased from today's level of 300 MW to a tentative target volume of 600MW for all hours of the week.

A new methodology for FRR dimensioning is being developed and specific details are not available yet. However, the basis is to have one common dimensioning where normal imbalances are determined based on the needs for each area, while taking into account cross-zonal capacity to optimize reserve requirements over the different LFC areas. aFRR needs are then determined as part of the total FRR needs. In addition each TSO is responsible to determine the reserve capacity requirements to handle their dimensioning incident.

- **Ireland and Great Britain**

Despite the high penetration of RES in more stringent island conditions, it is difficult to draw lessons from Great-Britain and Ireland as product structure is fundamentally different and focusing on frequency management rather than FRCE-management. EirGrid and SONI for instance do not operate an aFRR process, all FRR in the load frequency control block is mFRR. The dimensioning is conducted based on the largest positive and negative dimensioning incident.

Also NGESO does not operate an aFRR process. In Great Britain, frequency response is referred to in terms of Primary, Secondary and some specific products. Primary and secondary response are automatically provided and dimensioned according to the calculation based on a probabilistic and deterministic approach.

The (fast) reserves are manually applied and needs to cover the largest loss. The overall requirement are calculated using a statistical analysis of historic non-wind plant losses and demand forecasting errors and is set with the objective that there is no more than a 1 in 365 chance (or alternatively a 99.7% confidence).

### 2.2.3 Literature

In general, it is recognized that **deterministic methodologies** became too simplistic to correctly represent the increasing complexity of power systems with increasing variable renewable generation. Most scientific articles propose approaches that are based on **probabilistic methodologies**, where the main differentiating factors are the reliability level (going from 99.0% to 99.9% until 99.995%), the considered historical input data and the quantity (aFRR or mFRR) derived by difference from total FRR. Probabilistic methods are undoubtedly going to be broadly adopted with the entry into force of European Network Codes (SOGL Article 157).

It is generally acknowledged that aFRR is sized based on the distribution of variations inside the settlement period and the imbalance ramps between consecutive settlement periods, whereas mFRR is based on the distribution of the average prediction error over the settlement period. This reasoning is for instance followed in (De Vos, 2012)<sup>8</sup> where a probabilistic approach with a 99% reliability level is developed based on wind power time series.

(Mauer, 2009)<sup>9</sup> presents the Graf-Haubrich approach, which was used until recently in Germany. This method calculates the necessary control reserve considering all important drivers for power imbalances like power plant outages, load variations and forecast error. Each of the selected drivers of the imbalances is modelled separately to estimate the probabilistic behavior of the consequent power imbalance. The probability density function of the total imbalance is then calculated using a convolution of the algorithm on these separate probabilistic imbalance contributions, as illustrated in Figure 12. An important assumption of this approach is that the combined imbalance drivers (load oscillations,

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<sup>8</sup> De Vos, K., Morbee, J., Driesen J. and Belmans, R. (2013) "Impact of wind power on sizing and allocation of reserve requirements", IET Renewable Power Generation (7)1

<sup>9</sup> Maurer, C., Krahl, S., Weber, H. (2009) "Dimensioning of secondary and tertiary control reserve by probabilistic methods", European Transactions of Electrical Power, 2009 (19)

load forecast error, plant outage, intermittent generation error) are independent. This is required to make the convolution step sound from a mathematical point of view. Note that 0.1% deficit and overrun probabilities are considered.

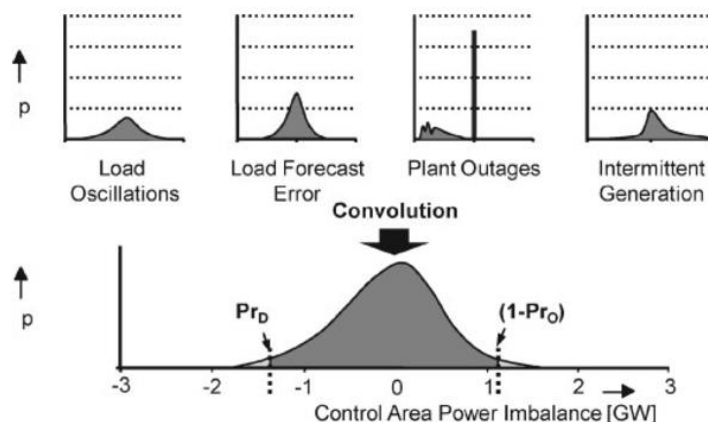


Figure 12: Illustration of the Graf-Haubrich method

The German case is often brought forward to highlight a clear need for dynamic sizing due to the increasing generation of renewable generation. (Jost, 2015a)<sup>10</sup> introduced a dynamic sizing approach based on the method developed by (Mauer, 2009). This dynamic approach allows to size reserves on day-ahead for a product length of 1 hour. Each component of the imbalance is modelled separately using kernel density estimators. An important difference with the Graf-Haubrich method is that the RES forecast error is separated into wind and photovoltaic errors. The total reserve need is estimated by convolving error distributions. The secondary reserve need is computed by convolving these same error distributions scaled by a factor 0.33.

Still in the family of probabilistic methods (Jost 2015b)<sup>11</sup> apply quantile regression techniques with artificial neural networks to forecast the needed reserve capacity required to reach a given reliability level. In this approach, the sizing variable (or target variable) is the 15 minutes LFC block imbalance. In the German context, they identify the following features as relevant for neural network: load (and its gradient), solar and wind generation (and their gradient), residual load (and its gradient), temperature, time of day, day of the week. (Jost 2016)<sup>12</sup> improves on this by (i) correcting the bias of the trained neural network, (ii) tackling the allocation of the total FRR between aFRR and mFRR, and (iii) analyzing the impact of product length, see Figure 13. Such allocation is done by applying the method separately on

<sup>10</sup> Jost, D., Speckmann, M., Sandau, F., Swinn, R. (2015a) „A new method for day-ahead sizing of control reserve in Germany under a 100% renewable energy source scenario“ Electric Power System Research (119)

<sup>11</sup> Jost, D., Braun, A., Fritz, R. (2015b) Dynamic dimensioning of frequency restoration reserve capacity based on quantile regression, International conference on the European Energy Market, Lisbon

<sup>12</sup> Jost, D., Braun, A., Fritz, R., Otterson, S. (2016) Dynamic sizing of automatic and manual Frequency Restoration Reserves for different product lengths, International conference on the European Energy Market, Porto

historical aFRR needs (estimated as aFRR activation corrected with iGCC exchanges) for aFRR dimensioning and on LFC block imbalances for FRR dimensioning

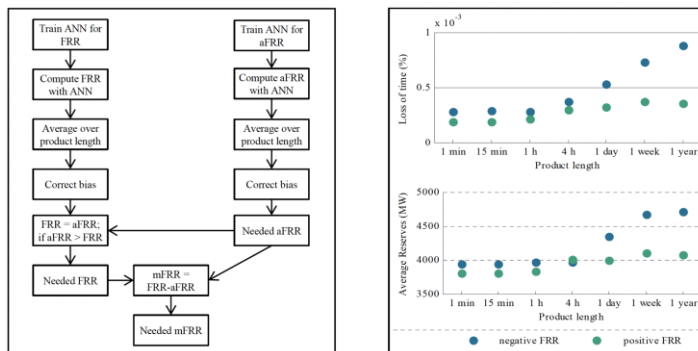


Figure 13- Jost et al. use quantile regression to compute needed aFRR and mFRR volumes.

(Morin, 2019)<sup>13</sup> presents a dimensioning method called OPIUM, based on manual clustering and on specific modelling of each of the imbalance components (i.e. kernel density estimator for wind error, gaussian estimation for other components). Two important conclusions are put forward. First, the risk level (reliability target) chosen by the TSO plays a major role in the aFRR requirement. Secondly, the massive development of RES will lead to a significant rise of aFRR needs.

In (Kippelt, 2013)<sup>14</sup> and (Breuer, 2013)<sup>15</sup>, the probabilistic approach is combined with a market simulator tool (i.e. unit commitment) to determine a prognosis of the hourly unit dispatch in order to refine the necessary distributions of the imbalance drivers. Indeed, scientific literature often uses **simulation models** that co-optimizes energy and reserves together. Although this makes sense to represent central dispatch systems, or to investigate the impact of renewables or other aspects on the energy and reserve needs, it is less relevant for developing European dimensioning methods.

## 2.2.4 Conclusions

Based on the analyses of this section, an exhaustive list is put forward in Figure 14 representing all possible different methodology design options found in the literature, benchmark and the regulatory framework complemented with options put forward by Elia. These options are classified in five categories which are walked through in the next section in order to make a selection of feasible integrated methods.

13 Morin, J., Prime, G., Wang, Y. (2019) “Probabilistic estimation of the aFRR requirement in the future European power system with high RES penetration” Wind Integration Workshop 2019

14 Kippelt, S., Schlüter, T., Rehtanz C. (2013) Flexible Dimensioning of Control Reserve for Future Energy Scenarios, IEEE Grenoble Conference

15 Breuer, C. Engelhardt, C., Moser, A. (2013) “Expectation-based Reserve Capacity Dimensioning in Power Systems with an Increasing Intermittent Feed-in”, International Conference on the European Energy Market, Stockholm

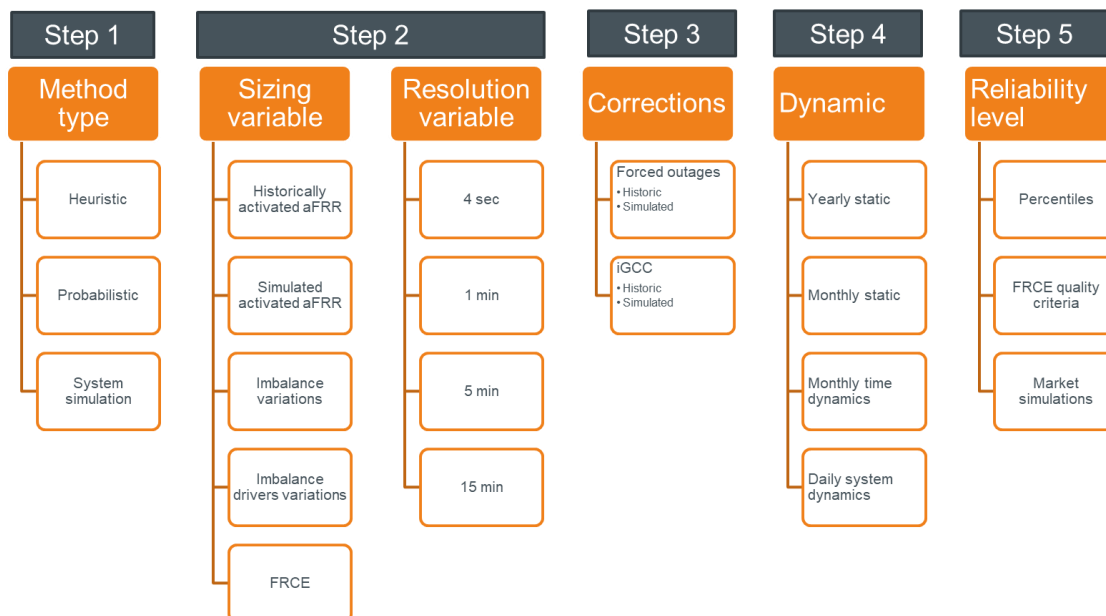


Figure 14: overview of methodology design options

In **step 1** the method type is selected being deterministic, probabilistic or simulation-based as discussed in the literature (Section 2.2.3). In **step 2**, the sizing variable and its resolution are determined which is the main variable on which the reserves are determined as found in the benchmark with other TSOs (Section 2.2.2) and complemented with Elia's insights analyzing the objectives and the legal framework. In the current method, this would be covering a certain percentage of all LFC block imbalance variations (sizing variable) with a resolution of 15' (resolution).

**Step 3** considers possible corrections of this variable to explicitly include or exclude the impact of forced outages of large generation units and to take into account iGCC or not reducing the aFRR needs. **Step 4** will then determine if a yearly or monthly to daily dynamic dimensioning will be considered based on the determined potential. Finally, in **Step 5**, the method to determine the reliability level is specified, i.e. the percentage of LFC block imbalance variations to be covered in the current method.

### 3. Selection of aFRR methodologies

The previous section showed an exhaustive list of all design options found in the literature, best practices of other TSOs and Elia's own analyses. These are categorized in five steps which are walked through to find two feasible integrated methods.

#### 3.1 Selection of aFRR dimensioning methods

##### 3.1.1 Step 1: choosing the methodology type

Three types of methods are put forward in Figure 15. **Heuristic methods** are typically on an iteration based on past performance, or dimensioning aFRR needs as a function of a single system feature (e.g. the peak load of a LFC block). Such methods are still put forward in SAFA as an alternative to the probabilistic method, i.e. the empirical noise method, and is still the basis of aFRR dimensioning in some countries (e.g. France). It is concluded in the literature that these methods cannot grasp the complexity of power system with increasing renewable energy and would for Elia's LFC block even be a step back from the current approaches in use. Also in France and the Netherlands, the methods are currently under revision. For these reasons, heuristic methods are not further investigated in this study.

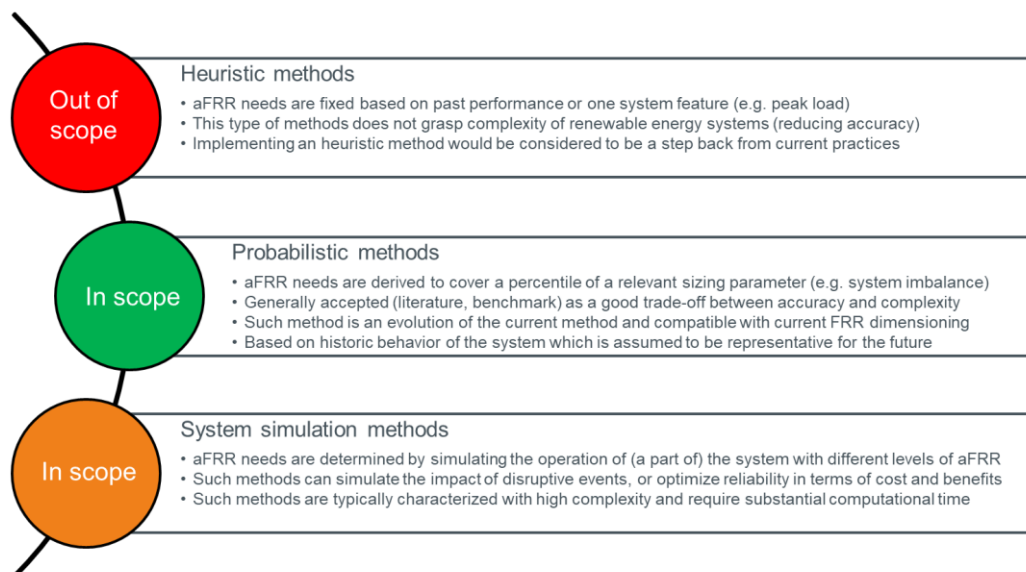


Figure 15: overview of methodology types

**Probabilistic methods** are considered as a good compromise between accuracy and complexity. In this type of methods, aFRR needs are typically dimensioned to cover a certain percentile of a relevant sizing parameter. Elia's current aFRR dimensioning method is an example of a probabilistic method sizing aFRR needs to cover 79% of historic 15' LFC block imbalance variations. Elia's current FRR dimensioning method is another example. Furthermore, it is also the basis of the recommended approach in SAFA where aFRR is dimensioned based on 1' LFC block imbalance fluctuations. Also in Germany, a probabilistic method is implemented for a while and The Netherlands and Nordics are currently implementing probabilistic methods. These methods will therefore be the main focus of this study. However



these methods are based on the assumption that historic data is representative for the future and are therefore less suitable to take into account disruptive events.

Finally **system simulation methods** are considered. In academic literature, some methods are proposed where dimensioning of aFRR needs are integrated in system simulations determining energy and reserve capacity needs together. However, these methods are not suitable with the current European framework where energy and reserve capacity are procured separately. Instead, Elia investigated a particular approach based on its LFC-controller where aFRR needs are determined by simulating the historic activation of aFRR with different aFRR means and assessing the impact on FRCE-quality. Such methods may be useful to simulate the impact of disruptive events or optimize reliability in terms of cost and benefits but are however characterized by high complexity in terms of data requirements and computational efforts and go at the cost of transparency. Although this method exhibits some serious disadvantages, and no examples could be found with other TSOs, such a method is investigated in Section 3.2.

### 3.1.2 Step 2: determining the sizing variable and resolution

Choosing the sizing variable is the core of a probabilistic method. As shown in Figure 16, this determines the aFRR needs to cover a certain percentage of occurrences, e.g. to cover 79% of historic absolute LFC block imbalance variations in Elia’s current methodology.

- **Sizing variable**

First possible approach would be to dimension on the **FRCE**, i.e. to cover for instance a certain percentage of all historic or expected FRCE. In any case, the starting point would be to use historic 15' to 4" data, which might be scaled based to take into account system evolutions. This sizing variable is found to be difficult to use in a probabilistic method as sizing on the result of the aFRR activations will lead to circular calculations where higher FRCE would result in higher aFRR needs that would in its turn result in lower FRCE. These oscillations may not result in a stable aFRR need.

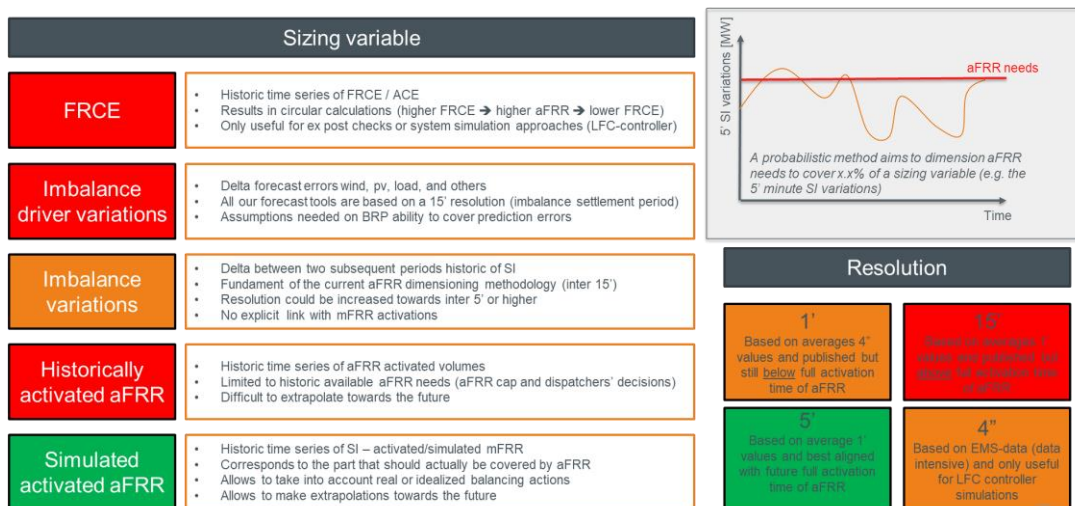


Figure 16: Overview of sizing variables and resolution options

A possibility could be found in simulation methods which can immediately take into account the activation of the dimensioned aFRR. A new method based on emulating Elia’s LFC-controller is investigated in Section 3.3 that determines

iteratively the effect of different levels of aFRR on FRCE-criteria. Note that no examples could be found where aFRR needs are dimensioned on the FRCE.

Another possibility is considered based on **individual imbalance drivers**, i.e. the variations of wind power, photovoltaic and demand forecast errors. However, it can never be certain that all imbalance drivers are captured. Furthermore, Elia's forecast tools are currently only based on 15' forecasts resolution (in line with BRP forecasts that are based on the imbalance settlement period of 15') which is a serious constraint for the implementation of this method. Finally, additional assumptions would be needed concerning the ability of BRPs to deal with these prediction error variations as Elia should only cover residual LFC block imbalances. Therefore, it is more suitable to dimension directly on these **residual LFC block imbalance variations**. This is the basis of the current methodology (i.e. the absolute difference in power between two periods of 15') and FRR dimensioning. A possible improvement could be to refine the resolution to 5' or 1'. This type of probabilistic method is also proposed by the ENSTOE SAFA, and implemented by The Netherlands, although variations are determined as the difference between the 1' and 15' LFC block imbalances. The main disadvantage is that it makes no explicit relation with the activation characteristics of aFRR and mFRR and assumes that all fast variations can be covered by aFRR.

An improvement could therefore be to take into account these characteristics. An approach on **historically activated aFRR** is abandoned as very dependent on historic conditions, i.e. dispatch behavior and product design, but also on the historically dimensioned aFRR reserve capacity. Another approach implemented in Germany is to use **simulated activated aFRR** where mFRR activations are subtracted from the LFC block imbalances. By means of simulating mFRR activations (considering full activation time and even possibly other product or dispatch characteristics) abstraction can be made from historic product design or dispatch behavior. It allows to estimate aFRR needs based on a perfect mFRR activation strategy.

- **Sizing variable resolution**

Next step consists in choosing the resolution of the sizing variable. The current resolution of **15 minutes** does not match well with the full activation time of aFRR which is currently specified at 7.5 minutes and foreseen to further evolve to 5 minutes. Therefore, a **5 minute** or even a **1 minute** approach would be more adequate to take into account intra-15 minute variations. However, a problem with using 1 minute data is that these fluctuations will never be covered by the aFRR product which can only fully react in 7.5 to 5 minutes.

The highest possible resolution is the 4 second power measurement data which is the output of Elia's EMS. Note that all other data result from averages of this EMS data. This resolution is however discarded for probabilistic approaches as this would be too data intensive without providing additional value considering the full activation time of aFRR. However, this resolution is useful when investigating the simulations of aFRR activations based on Elia's LFC controller in Section 3.3.

### 3.1.3 Step 3: facilitating the contribution of Forced Outages and iGCC

In this section, it is investigated if corrections should be made to the sizing variable

- **Forced Outages of power plants or relevant HVDC-interconnectors**

Although aFRR will contribute to restoring the FRCE during forced outage events of large generation units and relevant HVDC interconnectors, in this case Nemo link, it is concluded that this is not an objective for aFRR dimensioning. Indeed, FCR is dimensioned to deal with regional dimensioning incident in Continental Europe, as well as the FRR dimensioning for which the mFRR will deal with the forced outage. It is observed that the German LFC block takes into account forced outages (statistically with a duration of 15') but in a small country like Belgium, this would result in very high aFRR needs. It is therefore proposed to **remove periods with forced outages from the dataset (as in the current methodology)**.

- **iGCC**

It is already explained that iGCC largely reduces the activation volumes of aFRR. On the other hand, it is very difficult to model since it relies on a complex optimization over different LFC blocks and since the interconnection capacity is not guaranteed as it can already have been used for long-term, day-ahead, intra-day and soon the regional balancing platforms and reserve sharing.

Nevertheless, given the large impact of iGCC, it is proposed to subtract (part of) iGCC activated volumes from the LFC block imbalances. In a dynamic probabilistic methodology with sufficient high reliability level, the risk of taking iGCC into account might be acceptable as results will be adapted if iGCC becomes less available. An alternative is to simulate available aFRR based on historic observations

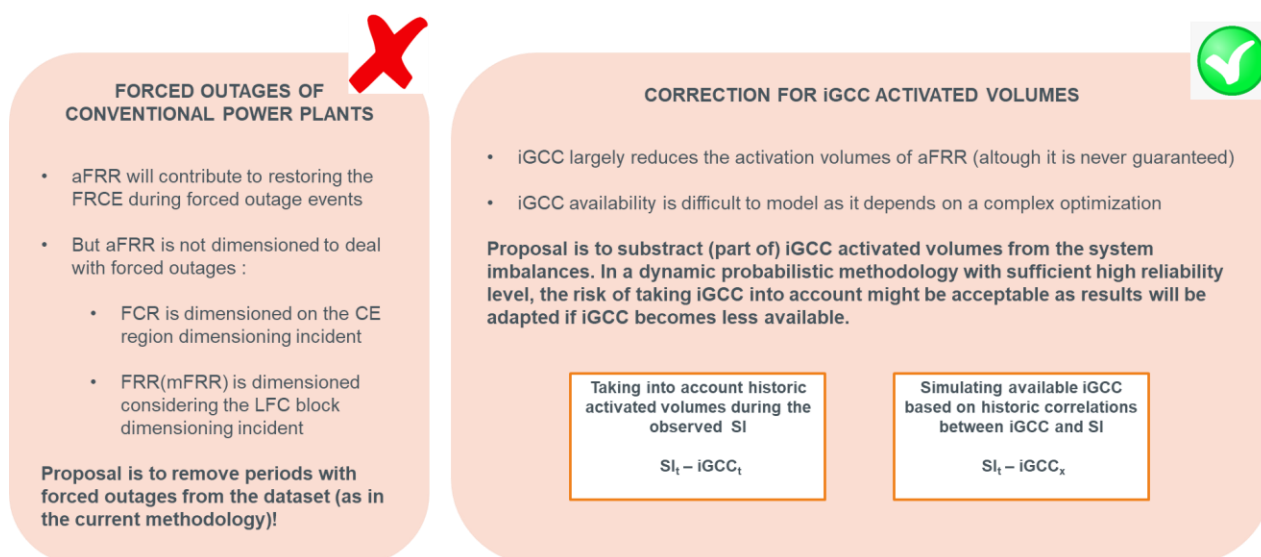


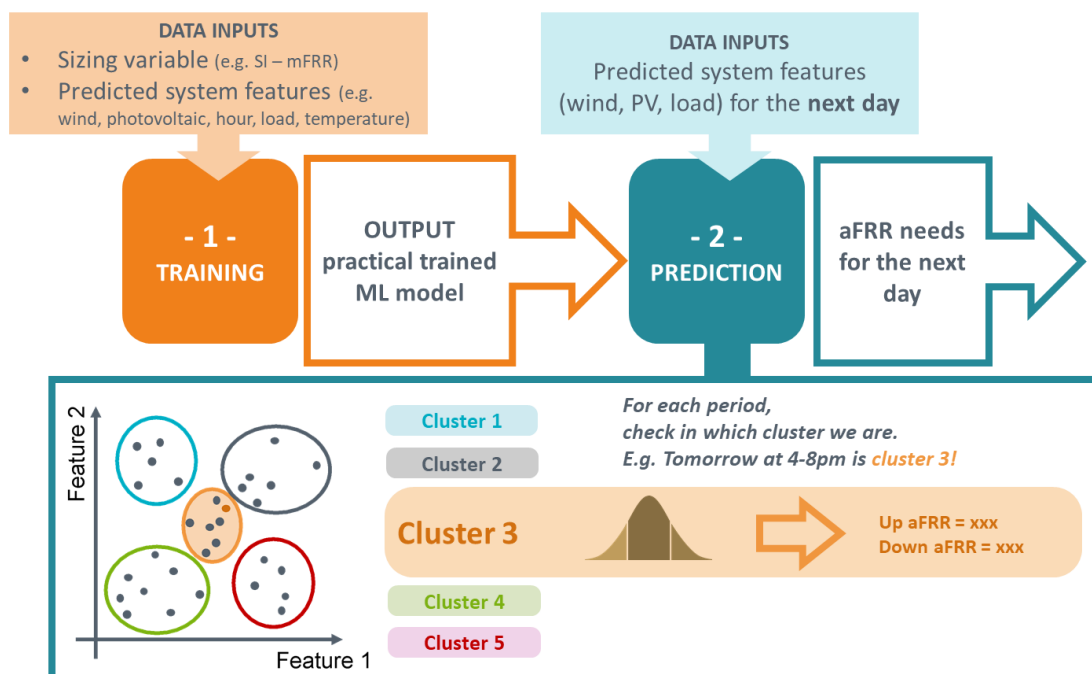
Figure 17: Overview of corrections on the sizing variable

### 3.1.4 Step 4: capturing dynamic potential

It is already explained that the new aFRR product with a (partial) daily procurement on a 4 hour resolution allows to dimension closer to real time. This would avoid upscaling the sizing variable to take into account incremental renewable capacity or other system evolutions impacting the system imbalance.

This method can be based on the FRR dimensioning methodology where machine algorithms are trained to learn correlations between system features (e.g. predicted renewable production, load and time of day) and the sizing variable, e.g; the simulated aFRR activations. Such model would be trained (e.g. monthly) based on 2 years of historic data and this could for instance rely on a clustering algorithm (as the K-MEANS method) although other methods could also be considered.

In day-ahead, expected system conditions (represented by day-ahead predicted features) could be used to determine clusters of similar historic observations. In each cluster, the distribution of the sizing variable could be derived in order to determine the corresponding aFRR needs. Note that the training step (e.g. monthly performed) could be used to determine a minimum aFRR need to still facilitate a partial procurement in D-2. The remaining (dynamic) part, would then be procured in D-1.



### 3.1.5 Step 5: selecting the reliability level

Final step is to select a proper reliability level. While it might be justified to cover all observations of the selected sizing variable, i.e. the simulated aFRR activations or the LFC block imbalance variations, this would result in a high impact of very specific events, or even data issues (e.g. outliers). This would translate into oversized aFRR needs and potentially highly volatile results. To avoid this, a reliability level of 99.0 % is proposed, i.e. covering 99.0 percentiles of simulated aFRR activations or LFC block imbalance variations. Such high reliability level aligns best with the objectives of FRR (covering the FRCE in 15 minutes) while specific events may be covered with exceptional FRCE-measures specified in the LFC BOA. Furthermore, this reliability level is consistent with the reliability level used in the FRR dimensioning method, in line with the legal provisions foreseen in the SOGL. Finally, a high percentile is justified in a methodology already taking into account iGCC (which is never guaranteed) and implementing a dynamic dimensioning method (adapting aFRR needs to the expected risk).

Further analysis with the LFC controller simulations did also not result in a solid basis to specify lower reliability levels. Main reason is that no adequate legal criteria can be used. The level 1 and level 2 targets discussed earlier can only be used as absolute warning limits and no other legal targets exist. Other potential targets have been investigated by Elia with the LFC controller simulations but results were inconclusive. Ideally, the reliability level is set as a trade-off between cost and benefits but no representative benefit of ACE quality can currently be identified due to socialization under TSOs.

### 3.2 Feasible approach 1: an improved probabilistic method

Based on the above mentioned analyses, a **first integrated method** that can be proposed is an improvement of the current probabilistic method. The proposed sizing variable is the simulated aFRR activations (compared to the LFC block imbalance variations in the current method) with an intra-15' minute resolution. The activated iGCC is taken into account to reduce aFRR needs, in contrast to the forced outages which are not supposed to impact the aFRR needs. Note that the method to determine the sizing variable and the impact of iGCC will be calibrated in the Proof of Concept.

A dynamic dimensioning approach is proposed consistent with the FRR dimensioning method. Although some dynamic potential is expected, this has to be confirmed in the proof of concept. Finally, the proposed method aims to achieve a fixed reliability level of 99.0%.

#### 3.2.1 Calibration of sizing variable and resolution

It is explained that the proposed sizing variable is based on simulating the aFRR activations by subtracting simulated mFRR activations and iGCC activations from the historic LFC block imbalances. The activation of mFRR can be simulated in different ways as shown in Figure 18, and two approaches are put forward:

- A first approach could be to simulate an **optimal mFRR activation**, assuming a perfect foresight on the LFC block imbalances for the upcoming 15'. Such approach would, for each period within a quarter-hour (e.g. 5' period) activate mFRR if there are only positive or only negative LFC block imbalances. The activated mFRR would then for instance be the average LFC block imbalances during that quarter-hour. Further calibration of the assumptions and parameters is possible but essentially, this approach is in line with a philosophy that aFRR needs are to be minimized because their faster activation speed results in a procurement cost which is higher (or at least equal) than mFRR.
- An alternative approach could be to simulate a **dispatch based mFRR activation**, assuming realistic dispatch behavior where dispatch activates mFRR without having foresight on the future LFC block imbalances. Such approach would for each period (e.g. of 5') within a quarter-hour activate mFRR if the LFC block imbalance in the two previous periods is higher than 50 MW (or lower than – 50 MW). The activated mFRR equals for instance the average LFC block imbalances during these previous periods.

Exact parameterization of these methods will be further investigated in the Proof of Concept. Results will be compared to the 1', 5' and 15' LFC block imbalance variations.

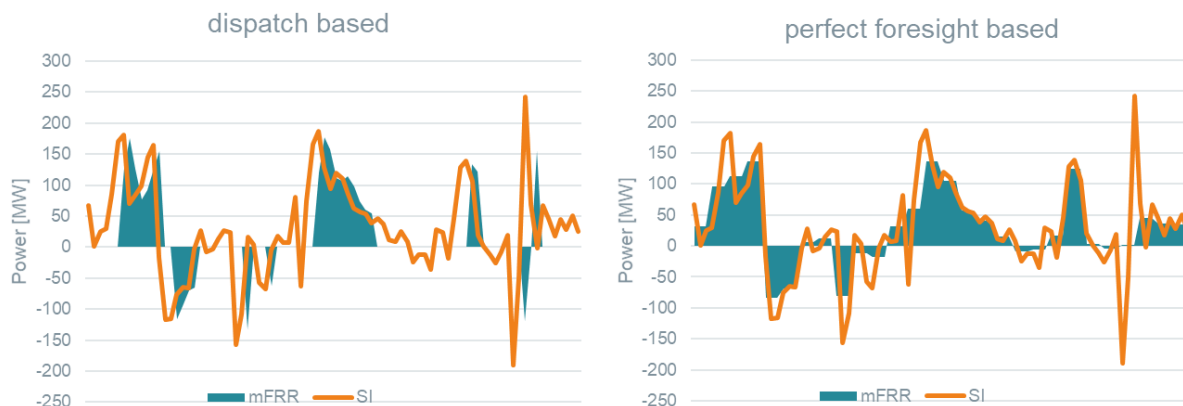
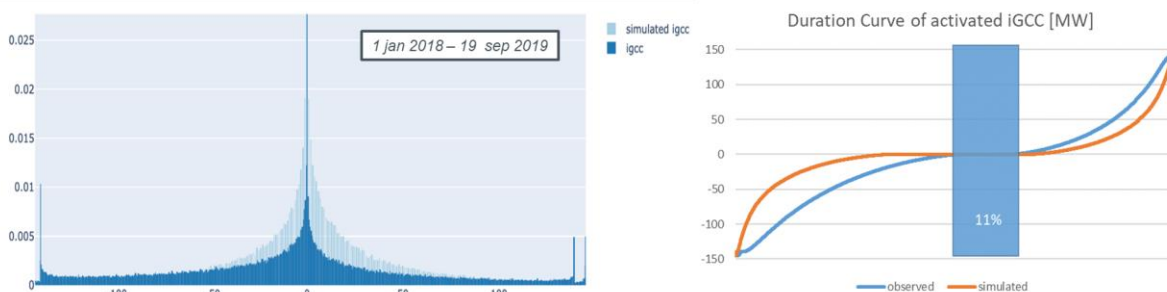


Figure 18: Illustration of simulated mFRR activations in function of the LFC block imbalance

### 3.2.2 Calibration of iGCC participation

It is explained that the proposed sizing variable can be corrected with iGCC. In a first approach, the sizing variable could be considered to subtract historic activated iGCC from the historic LFC block imbalances before compensating with the impact of mFRR activations. For large enough datasets, historical iGCC activations are sufficiently representative of the full iGCC distribution. Furthermore, this approach would allow to directly capture the correlation between the iGCC activations and the LFC block imbalances. As an alternative, to take into account the non-guaranteed availability of iGCC, or correct for future evolutions, one can consider to use a simulated-based approach.



However, as the available iGCC is difficult to predict, this would be based on a sampling. This considers a random drawing from the distribution of historic iGCC activations taking into account the probability that such volume would be available. Such approach would allow to adapt the distribution to consider limited availability or to take into account future evolutions such as for instance releasing the activated volume caps.

### 3.2.3 Ball-park figures

To get some feeling with results when selecting methodologies for further investigation, some preliminary calculations are conducted on a limited data set of **January 1, 2018 until September 19, 2019 containing 1' LFC block imbalance data and 1' iGCC activated volumes** as published on the website of Elia. This input data will be updated in the Proof of Concept, while the results will be further investigated towards dynamic potential (machine learning algorithm and calibration), as well as the calculation of the sizing variable (dispatch based or optimal) and resolution (5 minutes or

even a higher resolution). The values presented serve only to provide an order of magnitude of different implementation choices of the improved probabilistic method.

The results are shown in Table 5 where for every time series, the 1% and 99% percentile are reported. Results are set against the current method which would result in capacities of around 360 - 370 MW with those percentiles. These high values compared to the actual aFRR needs are explained by the reliability level which is set much lower in practice, i.e. at 79%. It can be seen that the increasing resolution towards 5' and including iGCC would bring the capacities closer to current aFRR needs (i.e. 145 MW).

Table 5: ballpark figures based on calculations of 1%;99%-percentiles on different sizing variables

Dataset: 1 jan 2018 – 19 sep 2019	Without iGCC		With iGCC		
[MW]	<u>up</u>	<u>down</u>	<u>up</u>	<u>down</u>	
5' Simulated activated aFRR (dispatch based)	281	275	239	229	
5' Simulated activated aFRR (optimal)	191	204	147	139	Ballpark current volumes
5' Imbalance variations	237	231	195	188	High volumes
15' Imbalance variations	370	360	314	298	Very high volumes

When analyzing the potential results of the proposed sizing variable based on aFRR simulations, it can be seen that the way the mFRR activations are modelled have a large effect on the results. **Dispatch based methods** where mFRR is activated if the LFC block imbalance exceeds a positive (negative) value of 50 MW, and up to a level of the average LFC block imbalance in that quarter-hour, seem to result in relatively high capacities, even when iGCC is taken into account.

For approaches where a **perfect foresight or optimal activation** is assumed, capacities can even be brought back to current levels. In the results of Table 5, mFRR is assumed to be activated if there are only positive (negative) LFC block imbalances in a quarter-hour and up to levels equal to the average LFC block imbalance in that quarter-hour.

### 3.3 Feasible approach 2: LFC-controller simulations

A potential simulation-based method that is investigated is based on Elia's LFC controller. In reality the LFC controller determines the aFRR requested volumes considering a filtered value of the ACE which is forwarded to a PI controller that determines the requested volumes to be activated for each sampling time period of 4 seconds (t). In order to reproduce the historic scenarios, under different assumptions, the previously activated reserves need to be subtracted and control activation have to be calculated again under new assumptions (e.g. lower activation lead times, different available reserve capacity,...).

The controller automatically determines the required activations based on measuring the ACE open loop (ACEol) of the previous period (t-1). The ACE open loop is the ACE after taking into account the manual mFRR activations. The activated iGCC is also taken into account when determining the required aFRR activations. Note that the objective of the controller is to bring the FRCE back to zero as soon as possible taking into account a resolution of 4". Such simulation-based method considers ramping constraints of aFRR (5min / 7.5min to reach full requested activation) and constraints on the maximum available aFRR means for activation (e.g. 145 MW or higher).

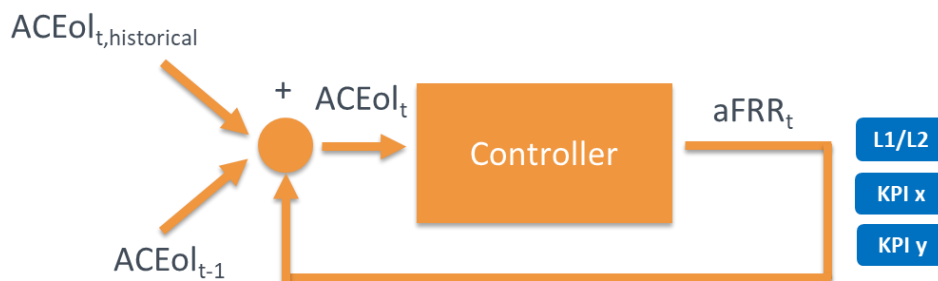


Figure 19: Visual representation of the LFC controller

By means of simulations with this controller, Elia is able to conduct simulations based on historic time series of the ACE, IGCC and the mFRR activations and simulate the resulting ACE after these activations under different scenarios and considering the assumption that market parties' reaction and available iGCC remain equivalent. This allows to assess the impact of different capacities of available aFRR on the final results. This includes the Level 1 and Level 2 FRCE parameters as specified in SOGL, but also potentially other key performance indicators such as maximum FRCE and the duration of a high FRCE.

It has already been noted that this approach is not suitable to simulate large variations of available aFRR capacity from the historic levels as this might neglect the impact of activated mFRR and other market reactions. Also, this approach results in high computational complexity due to intensive data needs and the 'iterative' approach. Though, it might be considered as an additional tool to conduct 'ad hoc' simulations of different available aFRR volumes on the FRCE quality.

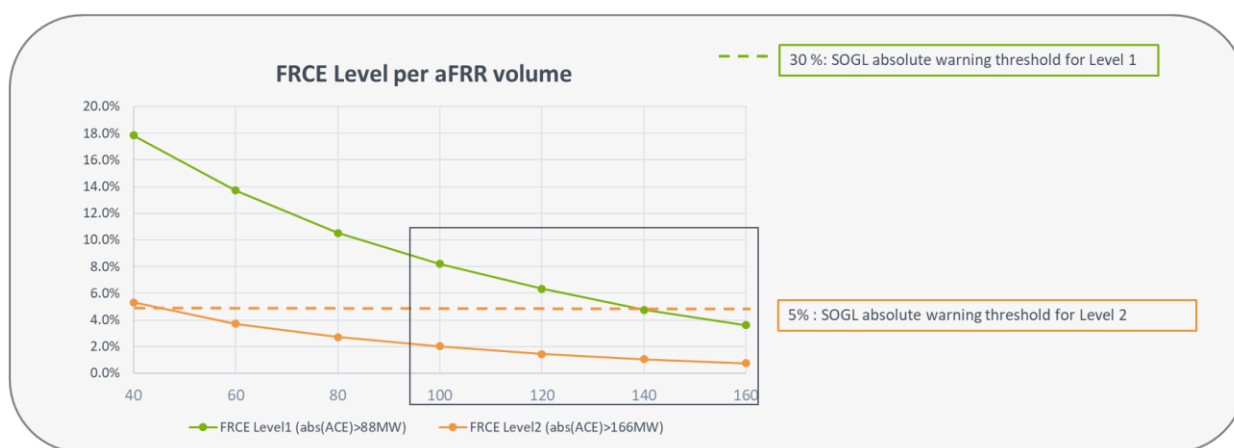


Figure 20: Impact of different aFRR availability on the Level 1 and Level 2 criteria

Unfortunately, this method did not present meaningful results. It is found that almost any level of aFRR needs can be justified when only looking at the legal criteria. Following such a recommendation would be considered as unacceptable by other European TSOs as these Level 1 and Level 2 criteria have to be considered as absolute warning limits and not as sizing targets. An investigation is conducted based on the impact on other indicators such as percentiles (% of the time ACE exceeds a certain threshold) or duration (maximum duration of an ACE above a certain threshold) but these are found to be inconclusive by lack of a legal criteria.



### 3.4 Proposed approach for the Proof of Concept

Based on the analyses presented in this section, an improved probabilistic method based on simulated aFRR activations with a 5' will be further investigated. LFC block imbalances seems to be a good trade-off between complexity and accuracy, improving the current method in an evolutive way. Furthermore, such method is consistent with the current FRR dimensioning process using similar data and applying similar algorithms.

The method starts from 1' LFC block imbalance data which will be corrected with simulated 'optimal' or 'rule based' mFRR activations. The LFC block imbalances will also exclude periods with forced outages of large generation units or unexpected outages of Nemo Link. Finally, the LFC block imbalances will be corrected to take into account (a part of) the activated iGCC. Indeed, despite that this capacity is not guaranteed, iGCC plays an important role in the FRCE-quality and the activation of aFRR.

It is proposed to maintain a 99% reliability level, aligned with other dimensioning processes. This high reliability level is justified by considering iGCC activations and optimal mFRR activations. A dynamic potential is discovered and needs to be further investigated in the Proof of Concept. The dynamic sizing process can be aligned and integrated in the FRR dimensioning process.

## 4. Proof of Concept

A Proof of Concept will further investigate the improved probabilistic method towards the dynamic behavior and robustness towards future system evolutions. Based on the analyses presented in the previous sections, this method is considered as the best candidate for replacing the current methodology:

- it dimensions aFRR reserve capacity in line with the system physics, i.e. on intra-qr simulated aFRR activations, allowing to directly relate required aFRR reserve capacity to the technical characteristics of the activation of the slower mFRR reserve capacity. In addition, one of the main advantages is to consider variations within the quarter-hour, closer to the full activation time of aFRR;
- it minimizes the aFRR needs by considering the activations of iGCC and by being suitable with a dynamic approach, while improving reliability by fixing the reliability level to cover 99.0% of the expected aFRR activations;
- it implements a 'relatively' transparent methodology which improves the current method in an 'evolutive' way and is consistent with the current FRR dimensioning approach.

Figure 21 represents a typical dynamic dimensioning process in three steps. First, the specification of the algorithms and optimal parametrization, as will be specified in the regulatory framework, i.e. LFC BOA. Secondly, a monthly training of algorithms based on historical observations of LFC block imbalances set against predicted system features such as wind and photovoltaic generation, and thirdly the day-ahead prediction of the imbalance risks and the corresponding aFRR needs. Note that this set-up does not exclude the possibility to procure a part of the balancing capacity before day-ahead.

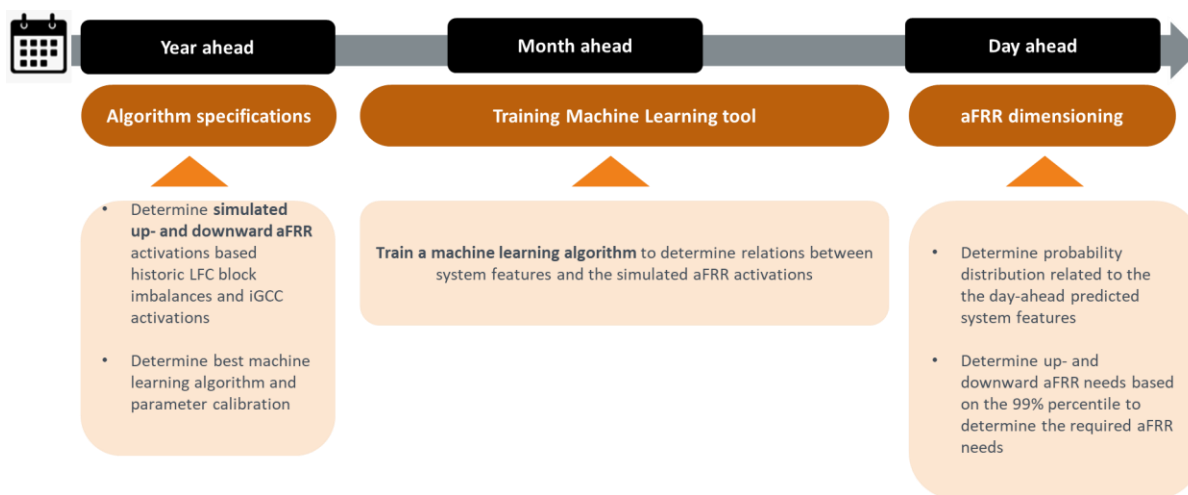


Figure 21: dynamic dimensioning process of aFRR needs

### 4.1 Determining the sizing variable

The simulated aFRR activations is based on Elia's dataset of 1' historic time series of the historic LFC block imbalances taking into account the historical activated iGCC-volumes. This data is also publicly available on Elia's website. By

means of the average, this resolution can be brought to 5'. However, several sensitivities will be conducted on the definition of the sizing variable.

- **Optimal versus dispatch-based methods;**
- **5' versus 1' resolution;**
- **Historic activated iGCC or simulation-based activated iGCC.**

Note that specific attention will be put on defining the assumptions on the optimal and dispatch-based methods (e.g. reaction lead times, activated mFRR volumes). The results will be benchmarked with the current method based on LFC block imbalance variations.

In order to allow to train the machine learning models, this first dataset is compared to a second dataset containing the day-ahead predicted features (e.g. wind, photovoltaic generation, demand, time of day, temperature or other). There will be started from the same database used in the dynamic FRR dimensioning but this does not exclude taking into account other system features if this would improve performance of the dynamic dimensioning.

## 4.2 Determining the dynamic potential

A dynamic approach allows to dimension higher aFRR needs when facing higher risk of large aFRR activations while reducing the average aFRR by means of lowering the aFRR needs during low risk periods. The effect on the average aFRR needs as well as the variations will be quantitatively determined in the Proof of Concept.

Based on the training databases as the FRR dimensioning, and the monthly training process, the dynamic potential will be assessed in a generic and efficient way using a typical clustering algorithm, i.e. similar to the KMEANS algorithm in the FRR dimensioning (cfr. LFC BOA). This allows to determine the average aFRR needs as well as the variations for the different sizing variables being investigated. **Based on the results, a subset of sizing variables (features) will be further improved and parameters settings will be fine-tuned. This approach will be compared in a quantitative way with a selection of other categories of algorithms which fit the requirements of the problem, e.g. regression, continuous neighboring, neural networks may be considered to further extract dynamic potential.**

The dynamic aFRR needs will be computed with a resolution of 4 hours aligned with the aFRR procurement granularity. A monthly training and a database going back two years in time will be considered, aligned with the FRR dimensioning method. The static current results will serve as benchmark for estimating the average aFRR volume reduction obtained by the different dynamic methods. Among others, minimum/maximum and average metrics, as well as the duration curves of the aFRR needs will be analyzed. The dynamic aFRR needs will also be compared to the historic simulated aFRR activations (i.e. sizing variable) to compare the observed reliability level with the targeted reliability.

## 4.3 Determining projections towards 2028

The improved probabilistic methodology will be used to estimate the aFRR needs evolution between 2020 and 2028, with intermediate years 2023 and 2026, for both static and dynamic approaches. Results will be compared to those of the current aFRR methodology.

This assessment will require to project LFC block imbalances and system features towards the future. Projections of LFC block imbalances will rely on projected forecast errors related to projections of incremental wind power and photovoltaics installed capacity. This approach is typically used to extrapolate historic prediction risks towards the future. Projections are taken from Elia's latest adequacy and flexibility study published in 2019. Note that forecast errors are initially projected on 15 minutes granularity. Where available, resolution of the prediction errors is refined to 5' (i.e. for offshore generation) whereas other profiles will be based on interpolations of 15' data.

To test the dynamic potential in the Proof of Concept, the two-year dataset is categorized into two parts, one part will be used to train the algorithm, while another part will be used to test the impact on the daily calculation.

## 5. Conclusions

Based on desktop research (literature, benchmark, analyses), a list of methodology objectives and possible methodology design options is composed. **Elia proposes to further investigate the improved probabilistic method in a proof of concept** (Figure 22).

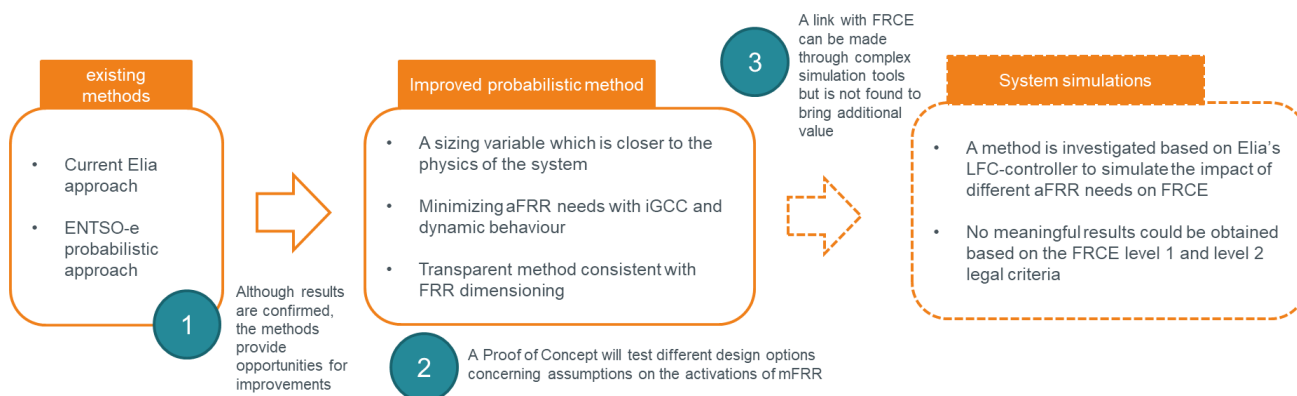


Figure 22: Overview of conclusions of the 1<sup>st</sup> part of the study

- It is found that **existing methods** such as the current Elia approach, or even the recommended methods by ENTSO-E are found to have drawbacks providing opportunities for improvement. Mainly, the robustness towards new aFRR product design and increasing renewable capacity installed is challenged.
- Analysis of possible design options puts forward that **improving the probabilistic method** seems the best way forward. The probabilistic method is a good tradeoff between complexity and transparency, and is also consistent with the FRR dimensioning method. Such method has also recently been implemented in Germany. Proposed improvements are to bring the sizing variable more in line with the system physics (simulate aFRR activations, take into account iGCC) while implementing a dynamic methodology to reduce average aFRR needs.
- An in depth investigation towards **simulation models** shows that simulations with Elia's LFC controller allows to investigate the effect of different minimum aFRR needs on the FRCE. This allows to assess the performance concerning FRCE-quality objectives. Results show that no meaningful results were obtained when assessing the impact on the minimum criteria, Level 1 and Level 2 criteria. It is concluded that the method presents an increased complexity without providing additional value to the aFRR dimensioning process.

The Proof of Concept will further investigate the implementation of the aFRR simulations, i.e. determining the assumptions on the activations of mFRR, and the participation of iGCC. Also the algorithms for the dynamic method and sizing variable resolution, i.e. 5 minutes or 1 minute will be investigated.

Projections will be made, and benchmarked with the actual method, towards 2028. This allows to analyze the robustness of the method towards the increasing renewable penetration, including the 2<sup>nd</sup> wave of offshore. **Stakeholders are welcomed to provide their suggestions and feedback for the Proof of Concept in a public consultation from June 2, 2020 to July 2, 2020. An implementation plan will be drafted following the conclusions of the Proof of Concept.**