
Elia LFC block operational agreement

October 4, 2019

Revision History

V1.1	10.07.2018	ELIA's proposal for public consultation
V1.2	14.09.2018	ELIA's proposal submitted to CREG
V1.3	27.05.2019	Version approved by CREG
V2.1	04.10.2019	ELIA's consolidated proposal integrating the changes of the public consultation

Disclaimer

This document, provided by ELIA, is the draft for stakeholder consultation of the ELIA proposal for the ELIA LFC Block Operational Agreements in accordance with Article 119 of Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation.

CONTENTS

Whereas.....	3
Introduction	3
TITLE 1 General Provisions.....	4
Article 1. Objective	4
Article 2. Timing for implementation.....	4
Article 3. Definitions and interpretations	4
Article 4. Subject	5
TITLE 2 Methodologies referred to under Article 6(3)e of the SOGL.....	7
Article 5. Ramping restrictions for active power output in accordance with Article 137(3) and (4) of the SOGL.....	7
Article 6. Coordinated actions aiming to reduce the FRCE as defined in Article 152(14) of the SOGL	8
Article 7. Measures to reduce the FRCE by requiring changes in the active power production or consumption of power generating modules and demand units in accordance with Article 152(16) of the SOGL.....	8
TITLE 3 FRR dimensioning rules in accordance with Article 157 and Article 6(3)e of the SOGL	9
Article 8. Dimensioning rules for reserve capacity on FRR	9
Article 9. Determination of the ratio of automatic FRR and manual FRR	15
Article 10. Determination of the reduction of reserve capacity on FRR following the sharing of FRR.....	17
TITLE 4 Methodologies in accordance with Article 119, but not referred in Article 6 of the SOGL	18
Article 11. LFC block monitor in accordance with Article 134(1) of the SOGL	18
Article 12. FRR availability requirements and on the control quality, defined in accordance with Article 158(2) of the SOGL.....	18
Article 13. Roles and responsibilities for sharing of FRR in accordance with Article 166(7) and Article 175(2) of the SOGL	19
TITLE 5 Final Provisions.....	19
Article 14. Language.....	19

THE BELGIAN TRANSMISSION SYSTEM OPERATOR, TAKING INTO ACCOUNT THE FOLLOWING.

Whereas

1. This document is a proposal developed by Elia System Operator (hereafter referred to as “Elia”) regarding the methodologies and conditions included in the LFCBOA for the Elia LFC block.
2. The Elia LFC block is determined in a common proposal developed by all Transmission System Operators (hereafter referred to as “TSOs”) of synchronous area Continental Europe (hereafter referred to as “CE”), regarding the development of a proposal for the determination of LFC blocks in accordance with Article 141(2) of the SOGL.
3. The subject matter of the SOGL is to safeguard operational security, frequency quality and the efficient use of the interconnected system and resources as specified in Article 1 of the SOGL, including the rules aiming at the establishment of a Union framework for load-frequency control and reserves.
4. Article 119(1) of the SOGL lists the requirements of the LFCBOA for which all TSOs of each LFC block shall jointly develop common proposals by 12 months after entry into force of the SOGL. Elia is the only TSO operating in its LFC block and Elia’s proposal constitutes therefore a LFC block operational methodology proposed unilaterally by Elia.
5. At least those methodologies and conditions referred to under Article 119 of the SOGL, and detailed by Article 6(3-~~e~~) of the SOGL and by the relevant national legislation by application of Article 6(5) of the SOGL have to be submitted for approval to the relevant regulatory authorities. Since Elia is the only TSO operating in its LFC block, Elia submits those proposals for methodologies and conditions for approval to the relevant national regulatory authority, i.e. CREG.
6. Elia has consulted the stakeholders on the draft proposal in accordance with Article 11 of the SOGL. This consultation has taken place from July 10, 2018 until August 21, 2018.
7. The LFCBOA is compliant with the common proposals provided for under the Synchronous Area Operational Agreement developed by all TSOs of each synchronous area according to Article 118 of the SOGL, hereafter referred to as SAOA.

SUBMITS THE FOLLOWING PROPOSAL FOR APPROVAL TO THE CREG:

Introduction

This LFC block operational agreement (hereafter referred to as “LFCBOA”), applies to the ELIA LFC block and contains the methodologies listed in Article 119 of Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation (hereafter referred to as “SOGL”).

TITLE 1 General Provisions

Article 1. ~~Objective and timing for implementation~~

1. By dimensioning the frequency restoration reserve (hereafter referred to as FRR) and defining the processes to fulfil the frequency quality target parameters, the methodologies and conditions specified in this LFCBOA proposal contribute to the general objectives as defined in Article 4 of the SOGL to the benefit of all TSOs, the Agency, regulatory authorities, market participants and the end consumers. In particular, by determining the dimensioning rules for FRR and specifying the operational processes to fulfil the load-frequency obligations, the LFCBOA serves the objectives of:
 1. determining common operational security requirements and principles;
 2. determining common interconnected system operational planning principles;
 3. determining common load-frequency control processes and control structures;
 4. ensuring the conditions for maintaining operational security throughout the Union;
 5. ensuring the conditions for maintaining a frequency quality level of all synchronous areas throughout the Union;
 6. promoting the coordination of system operation and operational planning;
 7. ensuring and enhancing the transparency and reliability of information on transmission system operation;
 8. contributing to the efficient operation and development of the electricity transmission system and electricity sector in the Union.

Article 2. Timing for implementation

1. The LFCBOA will enter into force ~~3 months~~ after its approval by the National Regulatory Authority, CREG, ~~in line with SOGL Article 119(2) at the same day as the Terms and Conditions for balancing service providers for manual Frequency Restoration Reserve (hereafter referred to as T&C BSP mFRR). Until that date, the methodologies and results of the previous version remain valid.~~

Article 2. Article 3. Definitions and interpretations

1. For the purposes of this proposal, the terms used have the meaning of the definitions included in Article 3 of the SOGL.
2. All references to other legislation is explicitly defined. All articles without explicit reference to other legislation concern articles in this LFCBOA.
3. Balancing Service Provider or BSP is defined according to Article 2(6) of the commission regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing.

Article 3- Article 4. Subject

1. According to Article 119(1) of the SOGL, the LFC block operational agreement will contain proposals for the following methodologies :
 - a. where the LFC block consists of more than one LFC area, FRCE target parameters for each LFC area defined in accordance with Article 128(4) of the SOGL;
 - b. LFC block monitor in accordance with Article 134(1) of the SOGL;
 - c. ramping restrictions for active power output in accordance with Article 137(3) and (4) of the SOGL;
 - d. where the LFC block is operated by more than one TSO, the specific allocation of responsibilities between TSOs within the LFC block in accordance with Article 141(9) of the SOGL;
 - e. if applicable, appointment of the TSO responsible for the tasks in Article 145(6) of the SOGL;
 - f. additional requirements for the availability, reliability and redundancy of technical infrastructure defined in accordance with Article 151(3) of the SOGL;
 - g. operational procedures in case of exhausted FRR or RR in accordance with Article 152(8) of the SOGL;
 - h. the FRR dimensioning rules defined in accordance with Article 157(1) of the SOGL;
 - i. the RR dimensioning rules defined in accordance with Article 160(2) of the SOGL;
 - j. where the LFC block is operated by more than one TSO, the specific allocation of responsibilities defined in accordance with Article 157(3) of the SOGL, and, if applicable, the specific allocation of responsibilities defined in accordance Article 160(6) of the SOGL;
 - k. the escalation procedure defined in accordance with Article 157(4) of the SOGL and, if applicable, the escalation procedure defined in accordance with Article 160(7) of the SOGL;
 - l. the FRR availability requirements, the requirements on the control quality defined in accordance with Article 158(2) of the SOGL, and if applicable, the RR availability requirements and the requirements on the control quality defined in accordance with Article 161(2) of the SOGL;
 - m. if applicable, any limits on the exchange of FCR between the LFC areas of the different LFC blocks within the CE synchronous area and the exchange of FRR or RR between the LFC areas of an LFC block of a synchronous area consisting of more than one LFC block defined in accordance with Article 163(2), Article 167 and Article 169(2) of the SOGL;
 - n. the roles and the responsibilities of the reserve connecting TSO, the reserve receiving TSO and of the affected TSO for the exchange of FRR and/or RR with TSOs of other LFC blocks defined in accordance with Article 165(6) of the SOGL;

- o. the roles and the responsibilities of the control capability providing TSO, the control capability receiving TSO and of the affected TSO for the sharing of FRR and RR defined in accordance with Article 166(7) of the SOGL;
 - p. roles and the responsibilities of the control capability providing TSO, the control capability receiving TSO and of the affected TSO for the sharing of FRR and RR between synchronous areas in accordance with Article 175(2) of the SOGL;
 - q. coordination actions aiming to reduce the FRCE as defined in Article 152(14) of the SOGL;
 - r. measures to reduce the FRCE by requiring changes in the active power production or consumption of power generating modules and demand units in accordance with Article 152(16) of the SOGL.
2. According to Article 119(1) of the SOGL, the methodologies and conditions in a., d., e., f., g., i., j., k., m. and n. are without application for the Elia LFC block :
 - a. Elements under a., d., e. and j. are not applicable as Elia is the only TSO in the Elia LFC block, or due to the fact that the LFC block consists in only one LFC area.
 - b. The element under f. is not applicable as Elia does not apply additional requirements on technical infrastructure other as defined in the SAOA following Article 151(2) of the SOGL.
 - c. The element under m. is not applicable as Elia does not apply additional limits on the exchange on FCR with other LFC blocks other as the limit specified in Article 163(2) of the SOGL.
 - d. The element under i. is not applicable as RR is currently not applied in the Elia LFC block.
 - e. The element under n. is not applicable as reserve exchange for FRR or RR is currently not applied in the Elia LFC block.
 - f. The elements under g., k. are not applicable as no procedure in case of exhausted FRR or RR or an escalation procedure are currently implemented in the Elia LFC block.
3. According to Article 6(3-~~e~~) of the SOGL, the methodologies and conditions determined in c., h., q. and r. of Article 119 of the SOGL shall be submitted to the CREG for approval. The methodologies and conditions in c., q. and r. are specified in Title 2, while the methodology in h. is specified in Title 3.
4. The methodologies and conditions in b., l., o. and p. of Article 119 of the SOGL are specified in Title 4.

TITLE 2 Methodologies referred to under Article 6(3-e) of the SOGL

Article 4. Article 5. Ramping restrictions for active power output in accordance with Article 137(3) and (4) of the SOGL

1. Rules for ramping restrictions on the active power output of each HVDC interconnector between a LFC Block of another synchronous area and the Elia LFC block, in accordance with SOGL Article 137(3):
 - a. Elia and the other connecting TSOs supervising a LFC block of an HVDC interconnector shall have the right to determine common ramping restrictions in the form of ramping periods and/or maximum ramping rates and shall enter into agreement with the TSOs responsible for operating the interconnector, to determine the processes and mechanisms by which these restrictions will be put in place. These ramping restrictions shall not apply to imbalance netting, frequency coupling, cross-border activation of FRR or cross-border activation of RR. These ramping restrictions shall not apply to any service aimed at maintaining or returning one of the connected electricity systems to a normal system state. The common restriction shall also take into account the restrictions set in the SAOA for CE in accordance with SOGL Article 137(1), if applicable;
 - b. The ramping restrictions for each interconnector shall be applied in a non-discriminatory manner. Elia shall ensure alignment of ramping restrictions between all HVDC interconnectors linking the same two synchronous areas, taking into account the technical capabilities of each HVDC interconnector. A ramping rate of 100MW/min shall be applied on all interconnectors between Elia LFC block and the LFC block of Great-Britain;¹
 - c. A summary of the ramping -restrictions to be applied to HVDC interconnectors connecting to the Elia LFC Block, shall be published by ELIA on its website at least one week before the rules are enforced, in accordance with the obligations in SOGL Article 8;
 - d. Unless such action would lead Elia to be in emergency state, Elia will accept a request of the TSO of the LFC block of Great-Britain to restrict equitably the ramp rates of all interconnectors between ELIA LFC block and the LFC block of Great-Britain, in coordination with the affected interconnector operators according to the terms referred to paragraph (a) of this Article. This is typically the case if the requesting TSO is in emergency state or declares itself in emergency state as soon as practically reasonable or expects to enter into emergency state if no actions are taken. The activation of such measure is justified and analysed ex post by Elia.
 - e. Within 30 calendar days of an incident which restricted one or more of the HVDC interconnectors, under the process referred to in paragraph (d), Elia shall prepare a report containing an explanation of the rationale, implementation and impact of this action and submit it to the relevant regulatory authority in accordance with

¹ An LFC Block is defined in Article 3 of the SOGL. This terminology is also used for the control zone of Great Britain in case of a Brexit.

Article 37 of Directive 2009/72/EC and neighbouring TSOs, and also make the report available to all significantly affected system users.

2. Measures to support the fulfilment of the FRCE target parameter of the LFC block and to alleviate deterministic frequency deviations, in accordance with SOGL Article 137(4): Elia currently does not implement technological restrictions of power generating modules and demand units to support the fulfilment of the FRCE target parameters of the LFC block and to alleviate deterministic frequency deviations.

Article 5- Article 6. Coordinated actions aiming to reduce the FRCE as defined in Article 152(14) of the SOGL

1. Elia is the only TSO in the Elia LFC block. The requirement to inform other TSOs of the LFC block and implement coordinated actions to reduce the FRCE, as defined in Article 3 of the SOGL, following violations of FRCE limits defined in Article 152(12) and (13) of the SOGL, is not applicable to the Elia LFC block.

Article 6- Article 7. Measures to reduce the FRCE by requiring changes in the active power production or consumption of power generating modules and demand units in accordance with Article 152(16) of the SOGL

1. Measures related to emergency conditions are defined in the methodologies compliant with Commission Regulation (EU) 2017/2196 of 24 November 2017 establishing a network code on electricity emergency and restoration and are not in the scope of this LFCBOA. Measures related to the normal activation procedures of reserve capacity are compliant with the reserve process activation structure specified in Article 140 of the SOGL and are not in the scope of this LFCBOA.
2. On top of the procedures and measures in paragraph 1, reserve providing units or reserve providing group(s) which cannot be activated via the FRR processes may be activated by Elia via a separate measure. Under this exceptional measure, Elia mitigates the risk of facing a large FRCE (as specified in Article 152(12) and 152(13) of the SOGL) due to the exhaustion of available reserve capacity or due to an extra-ordinary event (such as an offshore storm or other exceptional events) that are not covered in the dimensioning methodology referred to in Title 3.
3. Within this operational measure, Elia may activate the capacity that cannot be called off within the full activation time of FRR as specified in Article 12~~Article 12.~~ Elia will strive towards techno-economic efficiency, i.e. at the lowest cost taking into account system constraints. Elia activates the capacity :
 - (1) in real-time in order to reduce the FRCE following the depletion of the available mFRR reserve capacity ;
 - (2) ex-ante in order to anticipate a high FRCE following the exhaustion of the available mFRR reserve capacity via the creation of additional mFRR reserve capacity.
4. Elia takes the decision to activate this capacity based on the following information:
 - a. The relevant forecasts (in MW);
 - b. The mitigation measures communicated to ELIA by the BRPs and;

- c. The volume of available FRR reserve capacity at the moment of the expected event.

The volume of flexibility activated by Elia via this procedure is limited to bring the residual risk of a large FRCE back to an acceptable level (below the conditions specified in Article 152(12) and 152(13) of the SOGL).

5. Within 30 days after the use of measures to reduce the FRCE in accordance with Article 152(16) of the SOGL, Elia shall prepare a report containing a detailed explanation of the rationale, implementation and impact of this action and submit it to the relevant regulatory authority.

TITLE 3 FRR dimensioning rules in accordance with Article 157 and Article 6(3),e) of the SOGL

~~Article 7.~~ Article 8. Dimensioning rules for **positive reserve capacity on FRR**

- ~~1. ELIA dimensions the required positive reserve capacity on FRR on a yearly basis in accordance with the minimum criteria set out in Article 157(2) of the SOGL on the basis of a probabilistic methodology.~~
- ~~2. Based on this probabilistic methodology, the required positive reserve capacity on FRR is determined for the calendar year following the calculation and is determined as a fixed value for every quarter-hour of that period.~~
- ~~3. Pursuant Article 157(2.h) of the SOGL, the probabilistic methodology ensures that the required positive reserve capacity on FRR is sufficient to cover the positive LFC block imbalances for 99.0% of the time.
 - ~~a) Pursuant to Article 157(2.a) of the SOGL, the positive LFC block imbalances are based on consecutive historical records comprising at least the historical LFC block imbalance values. The sampling of those historical records is determined at 15 minutes, and includes at least a full year period, ending not earlier than 6 months before the calculation date.~~
 - ~~b) Pursuant to Article 157(2.b) of the SOGL, ELIA takes into account in the probability distribution of the LFC block imbalances, in order to ensure to respect the current FRCE parameters in Article 128 of the SOGL for the time period referred to in Article 157(2.a) of the SOGL, the expected LFC block imbalances following the incremental renewable capacity installed of offshore wind power, onshore wind power and solar photovoltaics power between the period for which the reserve capacity is sized, and the period represented by the historical values of the LFC block imbalances. These expected imbalances, calculated based on the forecast errors of renewable generation, are added to the historical records of LFC block imbalances.~~
 - ~~c) Pursuant to Article 157(2.b) of the SOGL, ELIA takes into account in the probability distribution of the LFC block imbalances, in order to ensure to respect the current FRCE parameters in Article 128 of the SOGL for the time period referred to in Article 157(2.a) of the SOGL, the expected forced outages of power plants or relevant interconnections by removing periods with forced outages from the historic records~~~~

~~and convoluting the distribution of system imbalances, including the expected imbalances, with a distribution curve representing the forced outages (including relevant HVDC-interconnectors). This distribution follows a simulation of at least 500 years taking into account the outage probability, the outage duration and the installed capacity of the projected generation fleet, as well as relevant transmission elements, for the period for which the reserve capacity is sized.~~

- ~~4. Pursuant Article 157(2.e) of the SOGL, ELIA determines the required positive reserve capacity on FRR in order that it is not less than the positive dimensioning incident of the LFC block, as defined in Article 3 of the SOGL. The positive dimensioning incident is equal to the positive reference incident as defined in Article 3 which shall, pursuant to Article 157(2.d) of the SOGL be the largest positive imbalance that may result from an instantaneous change of active power of a single power generating module, single demand facility, or single HVDC interconnector or from a tripping of an AC line within the LFC block.~~
- ~~5. Pursuant Article 157(4) TSOs of a LFC block shall have sufficient positive reserve capacity on FRR at any time in accordance with the FRR dimensioning rules. The required positive reserve capacity shall be covered with the options for the provision of reserve capacity specified in Article 32(1) of the commission regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing.~~

Article 8. — Dimensioning rules for negative reserve capacity on FRR

~~6.1. ELIA dimensions the negative~~Elia dimensions the required reserve capacity on FRR on a daily basis in accordance with the minimum criteria set out in Article 157(2) SOGL on the basis of ~~a probabilistic methodology~~;

~~7. Based on this a dynamic probabilistic methodology further specified in paragraphs 2 to 7, the required negative reserve capacity on FRR is determined for every period of four hours of the day following the calculation.~~

~~a) Pursuant and in line with Article 157(2.i))b of the SOGL, the probabilistic methodology ensures that negative reserve capacity on FRR is sufficient to cover at least the negative LFC block imbalances for 99,0% of the time~~;

~~b) a dynamic **deterministic methodology** based on the dimensioning incident further specified in paragraph 8~~Pursuant and in line with Article 157(2-a))e and 157(2)f of the SOGL;

~~c) a **minimum threshold** based on the historic LFC block imbalances further specified in paragraph 9 and in line with Articles 157(2)h and 157(2)i of the SOGL.~~

~~2. The probabilistic methodology is based on a convolution of two distribution curves, one representing the **prediction risk** (paragraph 3) and another representing the **forced outage risk** (paragraph 5, the). This methodology has been designed to cover 99.0% of the LFC block imbalance risk. After the convolution, the new distribution is decomposed in a distribution of potential positive LFC block imbalances, and a distribution of potential negative LFC block imbalances. This calculation is conducted for each-quarter hour of the next day, and the 99.0% percentile of each probability distribution curve determines the minimum positive and negative required reserve capacity.~~

a) The probability distribution representing the **prediction risk (PE)** is based on historic LFC block imbalances. The LFC block imbalances are based on consecutive historical records comprising at least the historical LFC block imbalance values. The sampling of the historical records covers with a resolution of 15 minutes, and includes at least a full year^a period of two years, ending not before the last day of the second month before the month of the day for which the reserve capacity is calculated.

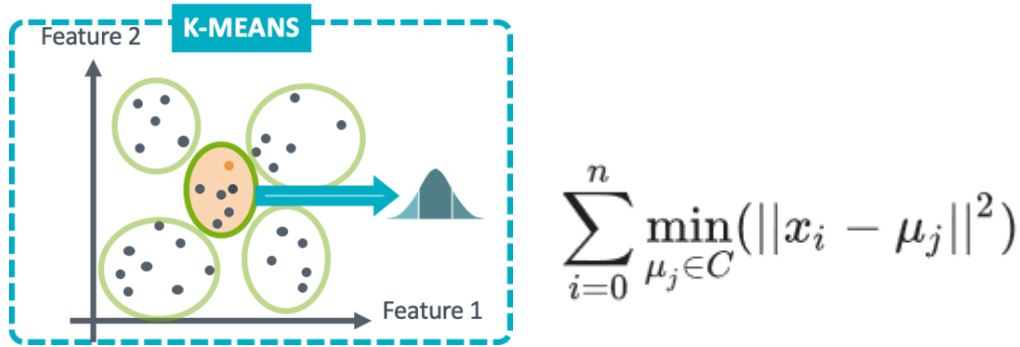
~~8.3. Pursuant to Article 157(2.b) of the SOGL, ELIA takes into account in the probability distribution of the LFC block imbalances, in order to ensure to respect the current FRCE parameters in Article 128 of the SOGL for the time period referred to in Article 157(2.a) of the SOGL, the expected forced outages of power plants or relevant interconnections by removing The time series is filtered to remove periods with forced outages from the historic records and convoluting the distribution of LFC block imbalances, including the expected imbalances, with a distribution curve representing the forced outages (including relevant HVDC interconnectors). This distribution follows a simulation of at least 500 years taking into account the outage probability, the a forced outage duration and the available capacity of the projected generation fleet, as well as relevant transmission elements, for the period for which the reserve capacity is sized. of NEMO Link or generating units with a loss of power larger than 50 MW (until the end of the forced outage but limited to 8 hours after the start of the forced outage), periods with exceptional events (e.g. market decoupling) and periods with data quality problems (e.g. missing data).~~

4. The prediction risk is modelled for each quarter-hour of the next day based on the probability distribution of the LFC block imbalances specified in paragraph 3. Four methodologies to determine this selection of LFC block imbalances are implemented:

a) **STATIC PE** in which the probability distribution of the LFC block imbalances is determined once per month (the month before the month of the day for which the reserve capacity is calculated) based on all historical records specified in paragraph 3. The distribution remains constant and valid for the next month.

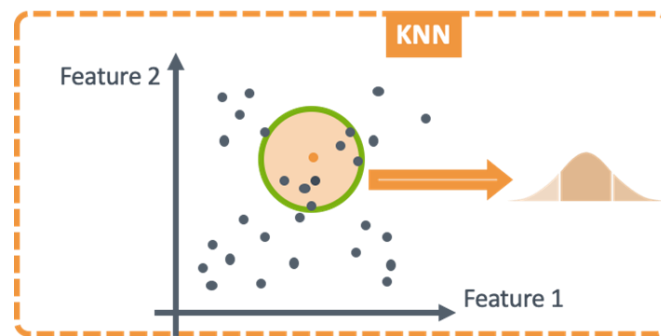
b) **KMEANS PE** in which the historical records specified in paragraph 3 are categorized in a set of clusters. These clusters are determined the month before the month of the day for which the reserve capacity is calculated based on a predefined list of 8 features (i.e. categories of observations that exhibit close system conditions: onshore, offshore, photovoltaic, total load predictions, time of day, predicted solar and load gradients and temperature). To determine the set of clusters, a “k-means clustering” machine learning algorithm is used². The k-means algorithm allocates a set of all observation in the historical records specified in paragraph 3 into disjoint clusters, each described by the mean μ_i of the observations in the cluster, such that the within-clusters sum-of-squares is minimized in the space of features. This is illustrated in the following figure for a simplified case with 5 clusters and 2 features. The implementation considers 15 clusters.

²Specified in the Scikit-learn library for Python programming. <https://scikit-learn.org/stable/modules/generated/sklearn.cluster.KMeans.html> where parameters are determined as: `sklearn.cluster.KMeans(n_clusters=15, random_state=0)`. All other parameters are set at their default value.



In each cluster, the probabilistic distribution of LFC block imbalances of the periods associated with each cluster is calculated. During the day-ahead calculation of the FRR reserve capacity needs, it is determined for each quarter-hour to which cluster the corresponding day-ahead prediction of features is associated. This determines the relevant LFC block imbalance distribution representing the prediction risk.

- c) **KNN PE** in which in which the historical records specified in paragraph 3~~This~~ are categorized based on an unsupervised nearest neighbour algorithm³. The principle behind nearest neighbor methods is to find a predefined number of training samples closest in distance to the new point, and predict the label from these. The number of samples in in this case a user-defined constant (k-nearest neighbor learning, i.e. 3500). This distance is calculated based on the same predefined list of features as with KMEANS PE This method is illustrated on the following figure with 7 neighbors and 2 features, the orange dot being one of the periods being sized.

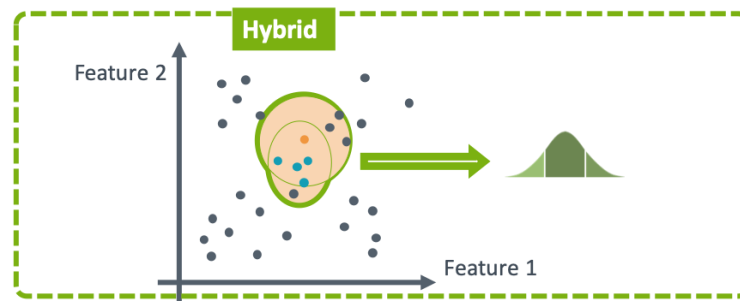


During the day-ahead calculation of the FRR reserve capacity needs, the relevant LFC block imbalance distribution representing the prediction risk is calculated based on the relevant 3500 nearest neighbours.

- d) **HYBRID PE** method combines KMEANS PE and KNN PE method where observations belonging to the relevant cluster of the KMEANS PE calculation and to the relevant neighbourhood of the KNN PE calculations are used to determine the probability distribution, as illustrated on the figure below. Some observations

³Specified in the Scikit-learn library for Python programming <https://scikit-learn.org/stable/modules/generated/sklearn.neighbors.NearestNeighbors.html#sklearn.neighbors.NearestNeighbors> where parameters are determined as: `sklearn.neighbors.NearestNeighbors(n_neighbors=3500)`. All other parameters are set at their default value.

(blue dots) are selected by both KNN and KMEANS methods, whereas other observations are selected by only one of the two methods (black dots in orange areas).



To avoid giving more weight to features with large order of magnitude, the distance between two observations in KMEANS PE and KNN PE is computed as the Euclidean distance between the corresponding vector of features: $d(obs_1, obs_2)^2 = \sum_{j=1, \dots, \#features} (f_{1,j} - f_{2,j})^2$. Therefore, each feature is scaled by means of a normal scaler and defined as $f_{i,j,scaled} = \frac{f_{i,j} - mean(f_{all,j})}{std(f_{all,j})}$ where $f_{i,j}$ is the value of unscaled feature j for the i -th observation, and $f_{all,j}$ is the set of all observations of feature j .

All probability distributions of the LFC block imbalances used in this paragraph have been modelled with a **Kernel Density Estimator**⁴ with imbalance steps of 5 MW (from -2500 MW to 2500 MW)⁵.

5. To calculate the probability distribution representing the **forced outages risk (FO)**, a distribution curve will be calculated on a daily basis taking into is calculated representing the probability to face a shortage or surplus capacity following forced outages (including HVDC-interconnectors with Great Britain). This is based on two approaches:

a) STATIC FO in which the probability distribution curve is determined analytically once a month taking into account the rated capacity of each generation unit larger than 50 MW and the rated capacity of the interconnectors with Great-Britain, the duration with which a forced outage is assumed to impact the LFC block imbalance is assumed to be 8 hours and the probability (expressed below as outages per year) per technology type of facing a forced outage:

Technology type	Forced outages per year
Nuclear	1.6
Classical	6.1
CCGT	5.2
GT	2.8
TJ	2.2
Waste	1.3
CHP	3.5
Pumped storage	1.9

⁴ Specified in the Scikit-learn library for Python programming <https://scikit-learn.org/stable/modules/generated/sklearn.neighbors.KernelDensity.html#sklearn.neighbors.KernelDensity> where parameters are determined as `klearn.neighbors.KernelDensity(bandwidth=rule of thumb, kernel='cosinus')`

⁵ Specified in the Scikit-learn library for Python programming <https://scikit-learn.org/stable/modules/generated/sklearn.neighbors.KernelDensity.html#sklearn.neighbors.KernelDensity> where parameters are determined as `KernelDensity(bandwidth="rule of thumb", kernel='cosinus')`. All other "Rule of thumb" is specified in https://en.wikipedia.org/wiki/Kernel_density_estimation#A_rule-of-thumb_bandwidth_estimator

b) DYNAMIC FO where the probability distribution curve is determined daily for each quarter-hour of the next day taking into account :

- the available capacity of each generation unit taking into account latest information concerning the rated capacity and unavailability of (part of) the installed capacity due to unavailability known at the moment of prediction ;
- the predicted schedule of the relevant HVDC interconnector for the next day based on a prediction of the day-ahead price difference between Great Britain and Belgium. This is derived from the algorithm specified in paragraph 6 interconnectors. Also limitations on maximum capacity, known at the time of the prediction, are taken into account;
- Pursuant Article 157(2.f) the probability of the SOGL outage and duration of impact of a forced outage on the LFC block imbalance is the same as in the STATIC FO.

6. The day-ahead price difference between Belgium and Great Britain is determined for each quarter-hour of the next day based on a machine learning method taking into account total demand, wind and photovoltaic forecasts. For each quarter-hour the next day:

- Price BE – Price GB > 7, the interconnector is considered in import ;
- Price BE – Price GB < -7, the interconnector is considered in export ;
- -7 € < Price BE – Price GB < 7, the interconnector is considered as uncertain and both import and export direction are covered,

7. Elia will determine the reserve capacity needs for every quarter-hour based on the convolution of the HYBRID PE and DYNAMIC FO method. If a technical problem occurs with the calculation of the prediction risk, Elia will fall back first to a KNN PE and thereafter to a STATIC PE. Similar, if due to technical reasons, the DYNAMIC FO is not available, the STATIC FO is taken. The STATIC FO combined with the STATIC PE prediction risk will be the monthly fall-back value.

8. For each-quarter hour of the next day Elia determines the required positive and negative reserve capacity on FRR in order that it is ~~not~~ never less than the positive and negative dimensioning incident of the LFC block, as defined in Article 3 of the SOGL. It is equal to the negative reference incident of the LFC block, as defined specified in Article 3 which shall, pursuant to and Article 157(2.d) of the SOGL be. The potential cut-out of the largest negative imbalance that may result from an instantaneous change of active offshore wind power of a single park following a storm is not considered as dimensioning incident. The dimensioning incident is determined for each quarter-hour of the next day:

- a. for the positive dimensioning incident based on the highest value of available power generating module, single demand facility, or single of a generating unit (taking into account unavailability and maximum capacity modifications known at the time of the day-ahead dimensioning) or the predicted schedule of the HVDC interconnector with Great-Britain (taking into account unavailability and capacity reductions known at the time of the day-ahead dimensioning), determined in paragraph 6 interconnector or from a tripping of an AC line within the LFC block.;

- b. for the negative dimensioning incident based on the predicted schedule of the HVDC-interconnector with Great-Britain taking into account unavailability and capacity reductions known at the time of the day-ahead dimensioning), determined in paragraph 6.
9. For each-quarter hour of the next day, ELIA determines the required positive and negative reserve capacity on FRR in order that it is sufficient to cover at least the positive and negative historic LFC block imbalances for 99.0% of the time in line with Articles 157(2)h and 157(2)i of the SOGL. These thresholds are determined based on the consecutive historical records specified in paragraph 3 and before removal of any periods as discussed in paragraph 3.
10. Pursuant to Article 157(2)b of the SOGL, Elia ensures to respect the current FRCE criteria in Article 128 of the SOGL. This analysis is conducted ex post based on the reporting on FRCE quality specified in Article 11.
11. The required positive and negative reserve capacity on FRR is calculated each day before 7 AM for every period of 4 hours of the next day by means of the maximum value of the positive and negative reserve capacity on FRR over all quarter-hours of the corresponding period.
- ~~9.12. Pursuant Article 157(4) of the SOGL, TSOs of a LFC block shall have sufficient positive and negative reserve capacity on FRR at any time in accordance with the FRR dimensioning rules. The required negative reserve capacity shall be covered with the options for the provision of reserve capacity specified in Article 32(1) of the commission regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing.~~

Article 9. Determination of the ratio of automatic FRR and manual FRR

1. Pursuant to Article 157(2-~~c~~) of the SOGL, the TSO of a LFC block shall determine the ratio of automatic FRR (hereafter referred to as aFRR), manual FRR (hereafter referred to as mFRR), the aFRR full activation time and mFRR full activation time in order to comply with the requirement of Article 157(2-~~b~~) of the SOGL.
- a) Elia determines the automatic FRR full activation time and manual FRR full in Article 12 ~~activation time as specified in (2).~~
- b) The required reserve capacity for FRR is determined by means of the probabilistic methodology described in ~~and~~ Article 8.
- ~~2. The probabilistic methodology ensures that the required reserve capacity on aFRR is sufficient to cover needs are determined based on the absolute LFC block imbalance variations for 79% of the time~~
- ~~3.2. The LFC block imbalance variations which~~ are determined as the difference in potential LFC block ~~imbalance~~ imbalances over two subsequent periods of 15 minutes. The probability distribution of the LFC block ~~imbalances~~ imbalance variations is based on at least the same historical records two years of LFC Block imbalance values ~~as specified in (3-a) (from July 1, 2017 to June 30, 2019).~~ The sampling of the historical records covers 15 minutes, and includes ~~at least~~ a full year period, ending not earlier than 6 months before

the calculation date. ~~Periods with forced outages of power plants or relevant interconnections are removed from the historic records.~~

~~3. ELIA takes into account in the probability distribution of the The potential LFC block imbalances, in order to ensure to respect the current FRCE parameters in article 128 of the SOGL used for the time period referred to in Article 157(2.a) of the SOGL, the expected aFRR needs calculation are based on :~~

~~a) an extrapolation of the historic LFC block imbalances by adding forecast errors following the incremental renewable capacity installed of offshore wind power, onshore wind power and solar photovoltaics power between the period/year for which the reserve capacity is sized, and the period represented by the historical values of the LFC block imbalances. These expected system imbalances, calculated The incremental renewable capacity will be based on latest projections as shown below :~~

Months	2017-18			2018-19			2020		
	PV	Onshore Wind	Offshore Wind	PV	Onshore Wind	Offshore Wind	PV	Onshore Wind	Offshore Wind
jul	3.426	1.808	878	3.788	2.113	1.010	4.805	2.666	1.759
aug	3.458	1.829	878	3.817	2.141	1.091	4.858	2.688	1.759
sep	3.490	1.851	878	3.846	2.169	1.179	4.911	2.710	1.759
oct	3.523	1.872	878	3.875	2.198	1.179	4.964	2.731	1.759
nov	3.555	1.894	878	3.903	2.226	1.179	5.017	2.753	1.759
dec	3.587	1.915	878	3.932	2.254	1.179	5.070	2.775	1.840
jan	3.616	1.943	878	3.974	2.276	1.179	4.486	2.535	1.920
feb	3.645	1.972	878	4.016	2.297	1.207	4.539	2.557	2.001
mar	3.673	2.000	878	4.057	2.319	1.225	4.592	2.579	2.085
apr	3.702	2.028	878	4.099	2.340	1.326	4.645	2.600	2.169
may	3.731	2.056	878	4.141	2.362	1.442	4.698	2.622	2.253
jun	3.760	2.085	937	4.183	2.384	1.529	4.752	2.644	2.253

~~b) An overall system imbalance improvement of 2% is taken into account. Furthermore, an improvement of the forecast errors of renewable generation, are added accuracy following intra-day predictions is assumed to be 35% for each technology, and the historical records of LFC block ability of the BRP to adjust its portfolio is assumed to be 100% in case of wind and PV.~~

4. The required positive and negative (symmetric for both directions) reserve capacity on aFRR is determined ~~for to cover 79% of the calendar year following the calculation and LFC block imbalance variations. It is determined as a fixed value for every hour of that period at 151 MW.~~

~~5. The required reserve capacity on Elia will present in a next version of the LFC BOA a new methodology to assess the aFRR is needs. While awaiting the implementation of this new methodology, Elia will limit the symmetric aFRR needs at the same value as in 2019, i.e. 145 MW.~~

~~6. Pursuant to Article 157(2)b of the SOGL, Elia ensures to respect the current FRCE criteria in Article 128 of the SOGL. This analysis is conducted on the reporting on FRCE quality as specified in Article 11 for the positive and negative direction. This analysis is conducted every year in the first trimester in line with Article 157(2)a of the SOGL.~~

~~5.7. Elia determines the required positive and negative reserve capacity on mFRR each day before 7 AM for every period of 4 hours of the next day as the difference between the required positive and negative reserve capacity on FRR and aFRR.~~

Article 10. Determination of the reduction of reserve capacity on FRR following the sharing of FRR

1. Pursuant to Article 157(2-~~j~~) of the SOGL, the TSOs of an LFC block may reduce the positive reserve capacity on FRR of the LFC block resulting from the FRR dimensioning process by concluding a ~~FRR~~-sharing agreement with other LFC blocks in accordance with provisions in Title 8 of the SOGL. Elia takes into account the restrictions specified in Article 157(2-~~j~~) of the SOGL for the CE synchronous area:
 - a. the reduction of the positive reserve capacity shall not exceed 30% of the size of the positive dimensioning incident (currently determined at 1039 MW), i.e. 312 MW;
 - b. the reduction of the positive reserve capacity on FRR of a LFC block shall be limited to the difference, if positive, between the size of the positive dimensioning incident and the reserve capacity on FRR required to cover the positive LFC block imbalances during 99.0% of the time based on the historical records referred to in Article 157(2)~~a~~ of the SOGL. Based on the historical records specified in Article 9-a) of the SOGL;(2), the maximum positive reserve capacity which can be shared is determined at 547 MW (1039 MW - 492 MW).
 - ~~b) the reduction of the positive reserve capacity shall not exceed 30 % of the size of the positive dimensioning incident.~~
2. Pursuant to Article 157(2-~~k~~) of the SOGL, the TSOs of a LFC block may reduce the negative reserve capacity on FRR of the LFC block, resulting from the FRR dimensioning process by concluding a FRR sharing agreement with other LFC blocks in accordance with the provisions of Title 8. ELIA takes into account the restrictions specified in Article 157(2-~~k~~) of the SOGL for the CE synchronous area:
 - ~~e.a.~~ in periods when NEMO-link is foreseen to be in export, or when the prediction is indecisive, the reduction of the negative reserve capacity on FRR of a LFC block shall be limited to the difference, if positive, between the size of the negative dimensioning incident and the reserve capacity on FRR required to cover the negative LFC block imbalances during 99.0% of the time based on the historical records referred to in Article 157(2-~~a~~) of the SOGL. Based on the historical records specified in Article 9(2), the maximum negative reserve capacity which can be shared is determined at 560 MW (1024 MW - 464 MW);
 - b. in periods when NEMO-link is foreseen to be in import, or in maintenance, the reduction of the negative reserve capacity on FRR of a LFC block shall be limited to the difference, if positive, between the size of the negative dimensioning incident and the reserve capacity on FRR required to cover the negative LFC block imbalances during 99.0% of the time based on the historical records referred to in Article 157(2)a of the SOGL. Based on the historical records specified in Article 9(2), the maximum negative reserve capacity which can be shared is determined at 0 MW;
- ~~2.3.~~ Pursuant to Article 157(2-~~g~~) of the SOGL, Elia can determine possible geographical limitations for sharing of reserves with other LFC blocks to comply with the operational security limits. (represented by the remaining ATC after intra-day). Elia also ~~take~~take into account the restrictions defined in the FRR sharing agreements due to possible violations

of operational security (network congestions within Elia's LFC block) and the FRR availability requirements (availability of the sharing service) as specified in Article 157(2-b).

3.4. In accordance with Article 166(3) of the SOGL, the reserve capacity available for FRR sharing shall be determined in an agreement with each TSO. Elia also defines the tasks and responsibilities of the control capability providing TSO, the control capability receiving TSO and the affected TSO for sharing FRR as specified in Article 166(7) of the SOGL (parts of FRR within the synchronous zone) and Article 175(2) SOGL (parts of FRR between synchronous zones) in Article 13.

TITLE 4 Methodologies in accordance with Article 119, but not referred in Article 6 of the SOGL

Article 11. ~~LFCBOA~~LFC block monitor in accordance with Article 134(1) of the SOGL

1. Following article 134(1) of the SOGL, Elia, as only TSO of the Belgian LFC block, is appointed as LFC Block Monitor. In its role as LFC Block Monitor, Elia collects the frequency quality evaluation data for the LFC block in accordance with the criteria application process referred to in Article 129 of the SOGL.
2. Besides relevant ENTSO-E publications, Elia will provide the relevant national regulatory authority with a yearly report on FRCE quality in the framework of its reserve reporting, as well as a monthly reporting on FRCE quality as part of its reporting on the balancing mechanism.

Article 12. FRR availability requirements and on the control quality, defined in accordance with Article 158(2) of the SOGL

1. FRR providing units and FRR providing groups are required to be available at any time. Availability is monitored by Elia and subject to penalties as described in the terms and conditions for BSPs. A secondary market allows the transfer of FRR obligations in order to facilitate BSPs meeting their obligations.
2. The maximal aFRR full activation time of the Elia LFC block and the mFRR full activation time of the Elia LFC block are defined at respectively 7.5 and 15 minutes. Therefore, the aFRR full activation time of a LFC block and the mFRR full activation time of the LFC block shall not be more than the time to restore frequency.
3. The control quality criteria are specified in the terms and conditions for BSPs as availability (as described in paragraph 1), exclusivity (no activations are allowed for own use) and start-up requirements to ensure the full-activation time (as described in paragraph 2). FRR providing units and FRR providing groups shall demonstrate their compliance with control quality criteria by means of a prequalification process as described in the terms and conditions for BSPs.

Article 13. Roles and responsibilities for sharing of FRR in accordance with Article 166(7) and Article 175(2) of the SOGL

1. The roles and responsibilities for the control capability providing TSO, the control capability receiving TSO and the affected TSO are defined conform respectively Article 3(103), (104) and (94) of the SOGL.
2. The control capability receiving TSO is the TSO benefiting from the activation of the reserve capacity of the control capability providing TSO. He may request the activation of balancing energy from the control capability providing TSO by stating the requested volume of balancing energy, and timing of delivery. The control capability receiving TSO shall calculate the available cross zonal capacity before making such a request in order to ensure that the activation of balancing energy will not lead to power flows that violate the operational security limits. The control capability receiving TSO shall adapt the input of its LFC controller in order to take into account the activation of balancing energy by the control capability providing TSO.
3. The control capability receiving TSO takes into account reserve capacity which is accessible through a control capability providing TSO in its dimensioning of reserve capacity for FRR in accordance with the principles of Article 10~~Article 10.~~
4. Elia shall notify all TSOs of the same synchronous area about its intention to exercise the right to implement sharing of reserves according to Article 150(1) of SOGL. Any TSO identified as affected TSO according to Art 150(2) of SOGL has the responsibility to declare this to Elia within 1 month after receipt of the aforementioned notification. Upon this declaration, the affected TSO shall have the rights specified in Article 150(3) of SOGL.
5. The control capability providing TSO shall trigger the activation of its reserve capacity for a control capability receiving TSO. Prior to the activation of balancing energy, the control capability providing TSO shall confirm to the control capability receiving TSO the availability or unavailability of its reserves and the necessary cross zonal capacity after an activation request. The control capability providing TSO is responsible for the proper delivery of balancing energy by its connected BSPs. He shall adapt the input to its LFC controller in order to take into account the activation of balancing energy activated for the control capability receiving TSO.
6. As from 14/5/2020 the latest, the remaining cross zonal capacity shall be adapted by Elia after each activation where Elia acts as control capability providing TSO or control capability receiving TSO pursuant paragraph 22 and 55 of this article.

TITLE 5 Final Provisions

Article 14. Language

The LFCBOA is published in English, Dutch and French. In case of discussion on interpretation of the methodologies presented in the LFCBOA, the French and Dutch version prevail over the English version.