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REPORT FOR PUBLIC CONSULTATION

Analysis and implementation of the FCR evolutions in accordance to article 154(2) of SOGL

April 29, 2022

Content

1. Introduction

On 30th of June 2021, all NRAs of the Continental Europe Synchronous Area have approved the Additional properties of FCR (hereafter, referred to as "Additional Properties") in accordance with Article 154(2) of the Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation ("SO Regulation"). This methodology introduces common additional properties of the FCR required to ensure operational security in the Continental Europe Synchronous Area (SACE).

The Additional Properties clarify and specify the SO Regulation on few aspects of the FCR activation, e.g. frequency range within which the service shall be provided and the expected behaviour in this frequency range. Additionally, the methodology covers specifically new operational challenges which come with storage and decentralized assets. It foresees that at national level a deviation from the European rule is possible on 3 aspects, the first 2 are linked to storage and the last is linked to control of decentralized assets:

- Parameters linked to the application of the Reserve Mode[1] (Additional Properties Art. 3.5)
- Retroactive application of Reserve Mode on existing BSP (Additional Properties Art. 4.4)
- Equivalent condition for a fallback solution regarding the provision of the FCR service via a centralized controller (Additional Properties Art. 3.7-3.9)

The methodology foresees a start of the implementation after the approval of all NRAs and within a timeframe of 2 years. The last NRA approved the Additional Properties on the 30th of June 2021. This report contains an introduction and a preliminary analysis of the new obligations from a design point of view. This report will serve as a basis for the design note preparing the amendment of the Terms and Conditions BSP FCR ("T&C BSP FCR"), which will formalize contractually the changes to the FCR service.

2. Objectives and Scope of the study

Pursuant to CREG's decision (PRD)658E/73 of December 9th 2021, Elia is carrying out a study to analyse and propose adequate FCR design evolutions, in the framework of the European regulation pursuant to the article 154(2) of the SO Regulation. More specifically, Elia studies the possibility to deviate nationally from the default rules defined at European level and proposes several alternative solutions after a consultation with the CREG and the stakeholders. The analysis takes into account the needs of Elia and possibilities of BSPs, as well as the impact of the obligations on national level on the development of a competitive FCR market and on the participation to this market of units or final customers connected at low voltage level, of demand side management and, of storage. The proposal of Elia is done in consultation with the market participants.

3. Structure of the report and link with the incentive

The report is structured into the following sections, in line with the points to be concretely studied as foreseen in the decision of CREG:

- Chapter 4: Prequalification of non-compliant units, covering the assessment of the technical reasons which may justify a derogation to the obligations from the Additional Properties Art 3.2.

[1] Reserve Mode will be discussed at length during this report but represents a degraded FCR activation in Alert State.

- Chapter 5: Derogation to the rated to pre-qualified power ratio, covering an alternative solution pursuant to the third bullet point of the Additional Properties Art 3.5, if relevant.
- Chapter 6: Obligation and conditions on the provision of Reserve Mode, covering the assessment of the application of the Reserve mode as defined in Annex I and Art. 4.4 of the Additional Properties and if necessary, the proposal of relevant other criteria for the application.
- Chapter 7: Obligation and conditions on the use of Centralized Controller, covering on one hand, the application of the obligation under the Additional Properties Art 3.8. On the other hand, an alternative solution as foreseen in the Additional Properties Art 3.7(c) and Art 3.9 is also assessed and developed.

4. Prequalification of non-compliant units

The Additional Properties complete the SO Regulation with regards to the expected FCR activation for a given frequency deviation. They additionally provide a possibility to derogate to the expected FCR activation for assets which can demonstrate a technical limitation, and if approved by the TSO.

This chapter starts by reminding the relevant articles from the SO Regulation and the Additional Properties which are relevant to construct the expected FCR activation. The second section covers the derogation to the two additions from the Additional Properties. Each derogation is studied separately and the impact on the expected FCR activation is explained.

4.1 Normal FCR activation

SO Regulation Art. 154.7 defines the FCR technical minimum requirements, which determine the acceptable range of the normal FCR activation: *"Each TSO of the CE synchronous area shall ensure that the combined reaction of FCR of a LFC area comply with the following requirements:*

- *a) the activation of FCR shall not be artificially delayed and begin as soon as possible after a frequency deviation;*
- *b) in case of a frequency deviation equal to or larger than 200 mHz, at least 50 % of the full FCR capacity shall be delivered at the latest after 15 seconds;*
- *c) in case of a frequency deviation equal to or larger than 200 mHz, 100 % of the full FCR capacity shall be delivered at the latest after 30 seconds;*
- *d) in case of a frequency deviation equal to or larger than 200 mHz, the activation of the full FCR capacity shall rise at least linearly from 15 to 30 seconds; and*
- *e) in case of a frequency deviation smaller than 200 mHz the related activated FCR capacity shall be at least proportional with the same time behaviour referred to in points (a) to (d)."*

In addition to the SO Regulation, the Additional Properties Art. 3.2 completes the requirements. Footnotes have been added for further information and clarification:

"Each TSO shall ensure that the activation of FCR providing units and FCR providing groups:

- *a) is not artificially delayed and begins as soon as possible but no later than 2 seconds after a frequency deviation[2]; and*
- *b) rises at least linearly.*

When one of the requirements a) or b) cannot be met[3], the FCR providing group or FCR providing unit shall provide technical evidence to the reserve connecting TSO. The reserve connecting TSO assesses these justifications and decides whether or not the unit or group can be qualified to provide FCR. A refusal to be qualified shall be duly motivated by the reserve connecting TSO. The motivated decision shall be communicated to the FCR provider and relevant regulatory authority."

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[2] Already foreseen in T&C FCR BSP (II.10.2/II.10.3)

[3] Possibility of derogation if at least one of the conditions is met. The derogation can however be on both obligations.

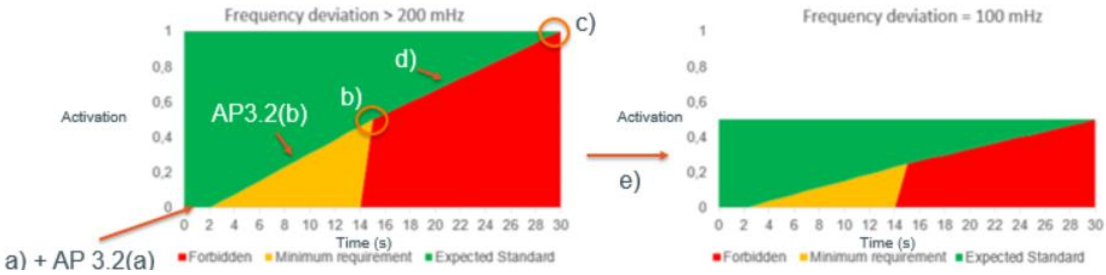

Figure 1: Visual representation of expected FCR activation for a frequency deviation of at least 200 mHz and of 100 mHz

The Figure 1 (on the left) shows the possible FCR activation for an instantaneous frequency deviation of at least 200 mHz:

- The green zone defines the standard FCR activation according to SO Regulation Art 154.7 (a-d) and Additional Properties Art 3.2 (a-b).
- The yellow zone defines the FCR activation which is permitted in case a derogation based on a demonstration of technical limitation has been granted by the TSO (which will be covered in the next section). The surface area of the yellow zone depends on the technical limitation.
- The red zone defines the FCR activation which is not allowed in any circumstances (i.e. not compliant with the FCR requirements).

For a frequency deviation of at least 200 mHz, at least all the contracted FCR is expected to be activated (i.e. over-delivery of FCR is not forbidden). The reaction may be instantaneous or may take as long as 30 seconds to be fully delivered, provided that the FCR activation respects the green zone and the yellow zone, as relevant.

The Figure 1 (on the right) shows the translation of the expected FCR activation, for a frequency deviation lower than 200 mHz. The FCR activation shall be proportional to the frequency deviation (pursuant to SO Regulation Art. 154.7(e)). In this example, the frequency deviation is 100 mHz, meaning that the FCR activation shall be at least half of the full activation (or contracted FCR).

4.2 Derogation to normal FCR activation

A derogation to Additional Properties Art 3.2 (a) and/or (b) is possible if technical evidence can be provided by the BSP to Elia. A derogation represents a decrease in the quality of the service.

The following sections analyze the effect of derogating from one of the obligation at the time on the FCR activation.

4.2.1 Derogation to Additional Properties art 3.2(a)

The derogation to the Additional Properties Art. 3.2(a) allows the BSP to have a reaction time to a frequency deviation of above the 2s stipulated, as shown in yellow and which is bound by SO Regulation Art. 154.7(a-e), where 50% of the FCR activation for a given frequency deviation shall be delivered within 15 seconds. For the sake of clarity, the FCR activation shall still not be artificially delayed.

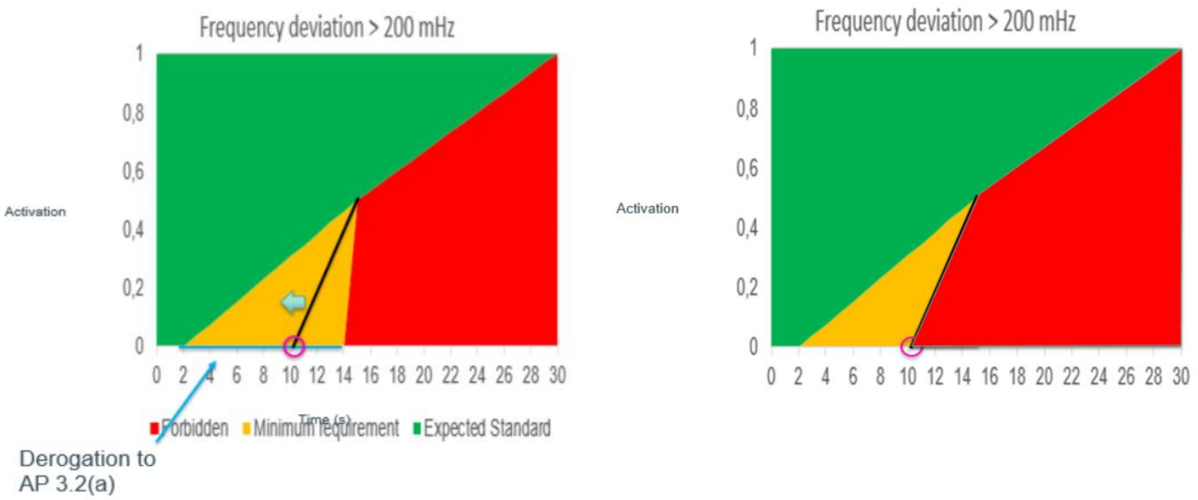

Figure 2: Visual representation of derogation to Additional Properties Art. 3.2(a) on the expected FCR activation

The blue line represents all the possibilities of derogation to Art. 3.2(a). For a given point on the blue line (pink circle), a black line can be drawn to the 50% activation after 15 second. The FCR activation shall be left to the corresponding black line if the requirement of at least a linear FCR activation (pursuant Additional Properties Art. 3.2(b)) remains applicable (new yellow zone, in the right figure).

4.2.2 Derogation to Additional Properties art 3.2(b)

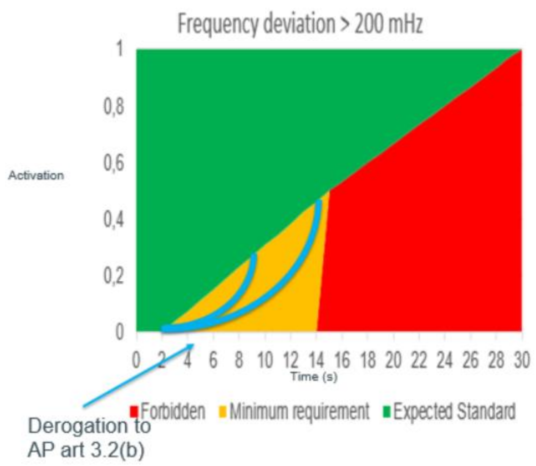

Figure 3: Visual representation of derogation to Additional Properties Art. 3.2(b) on the expected FCR activation

The derogation to Additional Properties Art. 3.2(b) allows the BSP to have sublinear reaction. The blue lines are examples of derogation to art 3.2(b). For the sake of clarity, even when derogating, the FCR activation is still in function of frequency and reacts to frequency deviation of at least 10 mHz (as foreseen by SO Regulation Annex V). Additionally, the FCR activation shall be monotonic pursuant the SO Regulation Art. 142.2.

5. Derogation to the rated to pre-qualified power ratio for LER DPs

The Additional Properties introduce new guidelines regarding the default FCR capacity which can be pre-qualified for LER assets. Nevertheless, it also foresees the possibility to deviate from this default value.

The chapter will first cover the definition of LER asset, which is different from the current definition in the T&C BSP FCR. The next section will go through the rationale behind the default FCR capacity, determined by the rated to pre-qualified power ratio. The last section of the chapter proposes an alternative solution to the default value.

5.1 Change in definition of Limited Energy Reservoir

The SO Regulation uses the concept of Limited Energy Reservoir without defining it. Elia proposed a definition in its last review of the T&C BSP FCR, which needs to be adapted with the Additional Properties. The Additional Properties pursuant to the definition in Art. 3.5 state: "*FCR providing units or FCR providing groups are deemed as LER FCR Providing Units or LER FCR Providing Groups in case a full continuous activation for a period of 2 hours in either positive or negative direction might, without consideration of the effect of an Active Energy Reservoir management[4], lead to a limitation of its capability to provide the full FCR activation […], due to the depletion of its energy reservoir(s) taking into account the Effective Energy Reservoir effectively available*".

This new definition is different from the one of Delivery Point with Limited Energy Reservoir[5] (DP LER). Firstly, the time constraint is changed from the time frame contracted by Elia to 2 hours. Secondly, the definition of the T&C BSP FCR foresees that even with the use of the Energy Management Strategy[6] (EMS), the DP LER is not able to provide the full FCR activation. Finally, the introduction of the definition of the Effective Energy Reservoir pursuant to the Additional Properties Art. 2.2(d) brings clarity on what can be considered as "effective". The energy reservoir to be considered shall be the one "which can effectively be used for energy feed/absorption". If part of a reservoir is reserved for other purposes (e.g. self-consumption of home batteries, provision of other services …) and cannot be used for FCR activation, then this part shall not be taken into account.

5.2 Rationale for the pre-qualified power ratio

The Additional Properties Art. 3.5 states: "[…]

For prequalification, the TSOs shall require that:

To enable an Active Energy Reservoir Management, LER FCR Providing Units or LER FCR Providing Groups may prequalify a power for FCR limited to 0.8 of the rated power (i.e. a ratio of rated power to prequalified power of at least 1.25:1); a deviation from this requirement is possible in case an alternative solution with an equivalent effect as in

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[4] Active Energy Reservoir Management as defined in Art 2(2)(a): *"active charging/discharging of the reservoir depending on the state of charge which results from FCR activation to avoid a status of a completely full/empty reservoir"*.

[5] As defined in T&C BSP FCR of 01/07/2020 Art. II.1 (23): A Delivery Point for which the full activation of FCR for the time frame contracted by ELIA might, even in case of an active energy reservoir management, lead to a limitation of its capability to provide the full FCR activation due to the depletion of its energy reservoir(s) taking into account the effective energy reservoir(s) available at the beginning of that time frame.

[6] Energy Management Strategy as defined in T&C BSP FCR of 01/07/2020 Art. II.1 (33): *"The strategy declared by the BSP with which proof is provided on the ability of the Pool to deliver the FCR Obligation, in accordance with Article 156 of the SOGL"*

guaranteeing a continuous FCR provision while applying an Energy Reservoir Management. Any lead time for the charging process needs to be considered for Active Energy Reservoir management. […]"

The rationale behind the ratio takes its root in the requirement of SO Regulation Art. 156.9:
"*For the CE and Nordic synchronous areas, each FCR provider shall ensure that the FCR from its FCR providing units or groups with limited energy reservoirs are continuously available during normal state. […]*"

The system remains in Normal State as long as the frequency deviation:

- remains below 50 mHz or
- does not meet the condition to switch to
    - Alert State (|Δf[7]| ≥ 50 mHz for 15 min or |Δf| ≥ 100 mHz for 5 min) or
    - Emergency State (|Δf| ≥ 200 mHz instantaneously)

The 1.25 ratio allows a standalone battery (most simple configuration of a LER asset) to be able to fulfill such obligations. As example, a battery with a rated power of 1.25 MW can at maximum pre-qualify 1 MW for the provision of FCR according to the ratio. Thus 0.25 MW of the battery may be used in the Energy Management Strategy (EMS) to charge the battery when necessary. If the frequency deviation remains at 50 mHz indefinitely, the battery shall produce 25% of the contracted FCR service. With 0.25 MW of charging capacity, the battery is capable at all time to fulfill its obligation.

5.3 Alternative solution to the ratio rated power/pre-qualified power of 1.25

As explained previously, the ratio rated power/pre-qualified power has been set to ensure that in the simplest configuration involving a DP LER, FCR can always be delivered. With this principle in mind, Elia considers that any Delivery Point(s) LER may be pre-qualified with a ratio of rated power/pre-qualified power between [1; 1.25] as long as in the EMS, an indefinite FCR activation in Normal State can be demonstrated.

The EMS shall be designed so that the FCR service is actually provided (i.e. results in a variation of power in function of frequency) as opposed to being artificial (i.e. resulting from the charging/discharging correction (CH/DCH Correction[8]), as foreseen by SO Regulation Art. 142. Similarly to what Elia intends to propose for the aFRR EMS, the FCR EMS can use a combination of strategies. The demonstration of the effectiveness of the EMS can either be based on:

- a deterministic analysis
- a statistical analysis, performed on a period of 2 historical years. Elia has the right to request an update of the statistical analysis, should the historical data used for the demonstration appear not be representative anymore.

[7] Δf or 'frequency deviation' means the difference between the actual and the nominal frequency of the synchronous area which can be negative or positive, according to SOGL Art. 3.40
[8] As defined in the T&C BSP FCR ART. II.1 (27): "*The power used for charging/discharging (in MW) of a Delivery Point with Energy Limited Reservoir. This value is positive (respectively negative) for charging (respectively discharging) and sent for each Time Step*';

6. Obligation and conditions on the provision of Reserve Mode

The Additional Properties Art. 3 introduces a new operating mode, the Reserve Mode for which: "*[…], LER FCR providing units (either single or belonging to a LER FCR providing group) that are prequalified for the first time after the entry into force of the Additional Properties and are technically capable (especially inverter-connected assets) shall ensure that close to the upper or lower bounds of the energy reservoir the remaining capacity is sufficient for keeping a proper response on short-term frequency deviations*".

Therefore, all newly prequalified (and technically capable) DP LER after the entry into force of the amended T&C BSP FCR shall provide the Reserve Mode.

The first section of this chapter goes shortly over the rationale behind the Reserve Mode before diving into the details in a second section. This second section goes through the variables and functions which define the Reserve Mode and assesses whether improvements could be achieved to lower entry barriers while keeping the system safe. The applicability of Reserve Mode on existing units will be further detailed in section 6.3.

6.1 Reserve Mode

Before the Additional Properties, the "operating mode" of a DP LER in Alert State (and Emergency State) was determined solely by SO Regulation Art. 156.9: "*For the CE and Nordic synchronous areas, as of triggering the alert state and during the alert state, each FCR provider shall ensure that its FCR providing units or groups with limited energy reservoirs are able to fully activate FCR continuously for a time period […]*", which is referred to as " "Normal Mode". The period of time in Alert State for a continuous and full FCR activation (T-min LER) is currently set in the T&C BSP FCR at 25 min.

For DP LER, the Additional Properties foresees an additional operating mode in Alert State (and Emergency State), the Reserve Mode. The rationale behind the Reserve Mode is to avoid the depletion (resp. saturation) of the energy reservoirs of the DPs LER during extended period of positive (resp. negative) frequency deviation events and the loss of the FCR activation from those DPs LER. The Reserve Mode aims therefore that a DP LER provides a (limited) FCR activation based on short-term frequency deviation instead of no FCR activation at all during such events. A comprehensive explanation of the Reserve Mode is available in Annex 1.

6.2 Parameters linked to the use of Reserve Mode (Art. 3.5)

As further detailed in Annex 1, the Reserve Mode contains a number of variables and functions which may be subject to evaluation and changes:

- The triggers to initiate the transition from Normal Mode to Reserve Mode: the minimum and maximum state of charge (SoC_{min} & SoC_{max})
- The reaction function, the frequency signal to which the BSP should react to, in Normal Mode and Reserve Mode
- The weighting function, T, defining the transition from Normal Mode to Reserve Mode and vice versa
- The zero-mean frequency, representing the short-term frequency deviation

Those variables and functions are analysed from a system point of view, and assessed with a view to lower entry barriers for the BSPs and harmonize practices with other TSOs of the FCR Cooperation to create a level playing field, if relevant.

6.2.1 SoC_{min}, SoC_{max} and FAT Value

The triggers to initiate the transition from Normal Mode to Reserve Mode and vice-versa, SoC_{min} and SoC_{max}, are in function of 3 parameters as shown the following formula:

$$SoC_{min} = \frac{P * t_{FAT}}{C}$$

$$SoC_{max} = 1 - SoC_{min}$$

- C is the storage capacity in MWh;
- P is the power offered for FCR provision in MW;
- t_{FAT} is the aFRR full activation time in h.

Out of the 3 parameters, only the t_{FAT} is worth discussing as the other 2 are fixed during prequalification. The rationale behind the thresholds in function of the t_{FAT} is to compensate the decrease of the FCR activation resulting from the Reserve Mode by an aFRR activation. The activation of the Reserve Mode reduces the expected contribution of Belgium to the system frequency (via the k-factor[9]). As such, the underdelivery of the FCR activation creates Area Control Error (ACE) which is compensated by an aFRR activation. The aFRR activation would substitute the FCR activation to an amount equivalent to the average frequency deviation. The goal of the Reserve Mode is then that all frequency deviations from this average can still be tackled by the (reduced) FCR activation.

The value of the t_{FAT} to be considered in the present context is analysed under the view of the entry barriers for BSP, a benchmark of other TSOs of the FCR Cooperation and system security.

Entry Barrier linked to the value of the t_{FAT}

The State of Charge that triggers the Reserve Mode has a direct consequence on the energy reservoir to be allocated for FCR activation and therefore the ability of the BSP to use its assets optimally. Intuitively, some energy needs to be kept for the transition from Normal Mode to Reserp Mode and the FCR in Reserve Mode. This becomes therefore a new requirement, as indicated by the Additional Properties Art. 3.5: "*LER FCR providing units […] shall ensure that close to the upper or lower bounds of the energy reservoir the remaining capacity is sufficient for keeping a proper response on short-term frequency deviation*".

In conclusion, SoC_{min} and SoC_{max} are additional dimensioning factors for the allocation of energy reservoir. The lower the SoC_{min} value is (and as a consequence the higher the SoC_{max} is), the more flexibility a BSP has to optimize its assets and the more FCR it can sell to the TSO.

Benchmark in the FCR Cooperation

The Full Activation Time (FAT) of aFRR is used in the determination of the SoC_{min} and SoC_{max}. The aFRR FAT is currently set a 7.5 min in Belgium. By 18 December 2024, pursuant to the Art. 3.8(g) of the aFRR Implementation Framework, the aFRR FAT shall be 5 min.

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[9] With k [MW/Hz], which represents the assumed FCR activation to a frequency deviation for a given LFC area. Practically, the Reserve Mode reduces the actual FCR activation compared to the assumed FCR activation. This discrepancy between the actual and assumed FCR activation creates Area Control Error (ACE).

All other TSOs of the FCR Cooperation intend to use 5 min as the value for the t_{FAT}, regardless of the actual aFRR Full Activation Time.

Given the deadline for harmonization the aFRR FAT and the foreseen timing for the modification of the T&C BSP FCR for the Additional Properties, Elia proposes to also use 5 min as the value for the t_{FAT} ensuring therefore stability of the requirement as well as a level playing field on this matter with the other TSOs of the FCR Cooperation.

System needs

While the idea is to substitute FCR activation by aFRR activation, the practice shows that the power substitution cannot be matched one to one, at least instantaneously due to the following reasons:

- **Local LFC controller:** due to the filters in the controller, a latency between the measured reduction of FCR activation (impacting the $k\Delta f$) and the actual request of aFRR activation occurs. The aFRR FAT starts counting at the moment of the request. This inherently creates Area Control Error (ACE), as previously explained.
- **aFRR activation approach:** Elia has a control request model[10] for aFRR, which limits the aFRR activation to the ramped requested value. Additionally, the aFRR activation itself is directly impacted by the size of the bid, i.e. 1 MW requested from a 50 MW bids is delivered faster than from a 10 MW bid. Elia envisages to change activation method of aFRR to a control target model[11] that should result in a faster activation.
- **European platforms:** netting from cross-border exchanges reduces the ACE created by the power substitution.

Conclusions

A larger range between SoC_{min} and SoC_{max} offers more flexibility to BSPs to operate their assets and lowers entry barriers for new entrants. Given the expected exceptionality of situations when the Reserve Mode would be triggered, especially in the period during which an aFRR FAT of 7.5 min will apply in Belgium, Elia proposes considering in the context of the implementation of Additional Properties a t_{FAT} of 5 min. The slight resulting increase of the operational risk seems acceptable, and justified considering the benefits for the BSPs concerned by the Reserve Mode. The proposed value is also in line with the other TSOs of the FCR Cooperation, which levels the playing field for BSPs.

Elia also proposes to keep the definition of SoC_{min} and SoC_{max} symmetrical as no increase in operational security has been identified for the time being by making the Reserve Mode triggers based on SoC asymmetrical. The analysis above equally applies to SoC_{min} and SoC_{max} and the symmetry of the trigger limits the complexity of the mechanism.

6.2.2 Reaction function, weighting function and Zero-mean frequency

The reaction function, the weighting function and the zero-mean frequency determine all together the behaviour of the Reserve Mode and the transitions between the 2 modes. The following sections briefly explain their construction and potential alternatives.

Reaction function and weighting function

The reaction function ($f_{reaction}$) provides the frequency deviation to which a BSP needs to react. In Normal Mode, the $f_{reaction}$ is simply equal to the frequency deviation (Δf). The weighting function T is equal to 0. When the Reserve Mode

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[10] Elia activates aFRR automatically by sending a set-point every four seconds. The requested energy is ramped, taking into account a FAT of 7.5 minutes. The BSP is expected to strictly follow the set-point (within a tolerance band)

[11] Pursuant to CREG's decision (PRD)658E/73 of December 9th 2021, CREG has approved an incentive to study the impact of control target model for the aFRR activation.

is triggered and the transition starts, T is non-zero and therefore the first term of the equation composed is not negligible anymore.

The reaction function is calculated based on an average weighted by the function T, between the actual frequency deviation (Δf) and the short term frequency deviation ($\Delta f_{zero\text{-}mean}$). The weighting function foresees the transition from Normal Mode to Reserve Mode (and vice-versa) to be linear.

$$f_{reaction}(t) = \Delta f_{zero-mean}(t) * T + (1 - T) * \Delta f(t)$$

No added value for the system has been identified in changing the weighting function. A faster transition may remove the support from the LER DP faster than the activation of aFRR, which would deteriorate further the frequency of the whole synchronous area. A slower transition (without adjusting the State of Charge) risks also to deteriorate the state of the system as the very objective of the Reserve Mode is to avoid the depletion of the reservoir and total loss of FCR activation.

By using the standard values, the reaction of the LER FCR is simpler and more understandable. This in turns avoids complex implementation for the BSP and hence decreases entry barriers for BSPs. Additionally, a level playing field would be ensured with the other TSOs of the FCR Cooperation, that will also apply a linear transition between the two modes.

Zero-mean frequency

The zero-mean frequency[12] is a part of the reaction function for Reserve Mode and is the short-term frequency deviation. After the transition into Reserve Mode, the $\Delta f_{zero\text{-}mean} * T$ is the only non-zero term of the reaction function ($f_{reaction}$) given that T will be equal to 1. The $\Delta f_{zero\text{-}mean}$ is calculated by subtracting from the actual frequency deviation a simple moving average of the frequency deviation, calculated for a time period corresponding to the t_{FAT}.

$$\Delta \mathbf{f}_{\mathbf{zero-mean}}(\mathbf{t}) = \Delta \mathbf{f}(\mathbf{t}) - \frac{\mathbf{1}}{\mathbf{t}_{\mathbf{FAT}}} \sum_{\mathbf{i=0}}^{\mathbf{t}_{\mathbf{FAT}}-\mathbf{1}} \Delta \boldsymbol{f}(\mathbf{t} - \mathbf{i})$$

An alternative to the simple moving average could be a weighted moving average, to put more weight to newer frequency deviation data. However, the system security would be degraded as even less FCR activation would take place in Reserve Mode. Intuitively, the quicker the moving average adapts, the smaller the zero-mean frequency is because the newer frequency deviation plays a bigger role on determining the steady-state frequency deviation.

Similarly to the weighting function, keeping the standard definition of the zero-mean frequency is the most appropriate for the system frequency. Additionally, Elia proposes to keep the time period corresponding to the FAT used for the SoC threshold in order to keep the consistency; considering a different time period would add complexity without any clear added value.

[12] It has to be noted that the formula of the zero-mean frequency in Annex I of the Additional Properties is incorrect. The second term does not express a simple moving average. The formula will be corrected in the next version of the Additional Properties.

6.3 Application of the reserve mode requirements towards existing BSPs (Art. 4.4).

Additional Properties Art. 4 further indicates that "*Each TSO may recommend to extend the provisions of the Reserve Mode to existing LER FCR providing units which are connected to the grid by means of inverters*". In this case the rules for the application of requirements to existing units reported in Art 4.1(b) of Requirement for Generation apply and the deadline for the implementation is set accordingly:

"1. Existing power-generating modules are not subject to the requirements of this Regulation, except where:

a) (…)

b) a regulatory authority or, where applicable, a Member State decides to make an existing power-generating module subject to all or some of the requirements of this Regulation, following a proposal from the relevant TSO in accordance with paragraphs 3, 4 and 5 (of RfG Article 4)

2. (...)

3. Following a public consultation […] and in order to address significant factual changes in circumstances, such as the evolution of system requirements including penetration of renewable energy sources, smart grids, distributed generation or demand response, the relevant TSO may propose to the regulatory authority concerned, or where applicable, to the Member State to extend the application of this Regulation to existing power-generating modules.

For that purpose a sound and transparent quantitative cost-benefit analysis shall be carried out […]. The analysis shall indicate:

(a) the costs, in regard to existing power-generating modules, of requiring compliance with this Regulation;

(b) the socioeconomic benefit resulting from applying the requirements set out in this Regulation; and

(c) the potential of alternative measures to achieve the required performance.

4. <u>Before</u> carrying out the quantitative cost-benefit analysis referred to in paragraph 3, the relevant TSO shall:

a) carry out a preliminary qualitative comparison of costs and benefits;

b) obtain approval from the relevant regulatory authority or, where applicable, the Member State.

5. The relevant regulatory authority or, where applicable, the Member State shall decide on the extension of the applicability of this Regulation to existing power-generating modules within six months of receipt of the report and the recommendation of the relevant TSO in accordance with Article 38(4). The decision of the regulatory authority or, where applicable, the Member State shall be published. (…)"

First of all, the TSO has the initiative to study the retro-active application of obligation on existing assets. The application needs to address significant evolutions of the system and thus evolutions of the system requirements. In the current situation, batteries are already a significant part of the FCR market in Belgium and their integration is expected to further accelerate. This would qualify Elia to launch the procedure as foreseen by the Requirement for Generation.

However, the process to apply obligations retro-actively on existing assets imposes a number of stringent steps. A first qualitative cost-benefits analysis is needed, which is subject to regulatory approval. An approval leads to a second quantitative cost-benefits analysis. In the case of the application of the Reserve Mode, a sound analysis would require sufficient real data of Alert State situations. As Alert State situations are per definition infrequent, a cost-benefits analysis would most likely be inconclusive.

For the above reasons, Elia does not intend for the time being to propose the application of the Reserve Mode on the existing LER DP.

7. Frequency measurement and controller

While Reserve Mode was targeting the technologies with a limited energy reservoir, the new obligations which is covered in this chapter target mainly decentralized assets with a centralized control model that relies on a central frequency measurement. The following articles of the Additional Properties are especially relevant to the BSP with decentralized assets, with some useful definitions in the footnotes:

"7. FCR providing groups shall implement alternatively one of the following approaches:

- *a) Decentralised Frequency Measurements[13] at least per connection point in analogy to what is foreseen for FCR providing units in paragraph 6;*
- *b) a Centralised FCR Controller[14] with Decentralised Frequency Measurements per connection point (based on local frequency measurement) to be used as a fallback solution to ensure an autonomous function and a proper activation in case of errors in the Centralised FCR Controller itself (e.g. outage of SCADA, faults of communication lines) or in case of a system split affecting the perimeter of the group; if the group includes FCR providing units, local frequency measurements available for these units pursuant to paragraph 6 shall be part of the fallback solution;*
- *c) an alternative solution with equivalent effect to the fallback solution pursuant to b), as in guaranteeing a proper activation in case of errors in the Centralised FCR Controller or in case of a system split.*

8. In case the Decentralised Frequency Measurements are used as a fallback solution pursuant to paragraph 7(b):

- *a) an observation function shall detect any kind of errors of the central control or frequency discrepancies among the technical entities within the perimeter of the group;*
- *b) the FCR provider shall immediately initiate appropriate counter-measures to ensure that the FCR provision is not significantly negatively impacted by switching to the Decentralised Frequency Measurements; and*
- *c) the minimum accuracy of the local frequency measurement used as a fallback solution can be reduced according to the national terms and conditions applicable to the reserve connecting TSO.*

9. In case the alternative solution with equivalent effect pursuant to paragraph 7(c) is implemented:

- *a) if the FCR providing group includes FCR providing units, the local frequency measurements available for these units pursuant to paragraph 6 may be integrated in the alternative solution;*
- *b) the FCR provider shall demonstrate the effectiveness of the alternative solution with respect to the decentralised frequency measurements; and*
- *c) the solution may be implemented only if allowed by the national terms and conditions, applicable to the reserve connecting TSO."*

While the integration of decentralized assets represents an opportunity to the grid to leverage the flexibility at lower voltage level and thus create more liquidity on the market, the usual centralized control model of those assets based

[13] As defined in Additional Properties Art. 2.2 (b): *Decentralised Frequency Measurement: principle of using independent on-site frequency measurements at the connection points or below at site of generating units of the technical entities forming FCR providing units or FCR providing groups and activation of FCR based on this on-site measurement;*

[14] As defined in Additional Properties Art. 2.2 (c): *Centralised Frequency Measurement or Centralised FCR Controller: principle of using a single frequency measurement for activation of a number of decentrally located technical entities forming a FCR providing unit or providing group. The application of this principle requires the respective transmission of the frequency signal to the individual FCR providing unit or FCR providing group;*

on a centralized frequency measurement also creates risks in terms of the reliability of the FCR service. It has however to be noted that decentralized assets with a local control and measurements does not carry those risks. Two main risks come inherently with such decentralization:

- Outage of controller (SCADA) and/or failure of communication (between the assets and the controller)
- Inappropriate FCR activation of all assets, in case of system split.

Outage of controller and/or failure of communication

Except on the real-time communication[15] between Elia and the BSP, Elia does not impose explicit requirements in terms of IT redundancy. It is being understood that the BSP bears the responsibility of ensuring the quality and reliability of its IT system that the FCR service demands. In general, Elia does not intent to start imposing specific requirements on IT redundancy on communication means as this creates further entry barriers. The penalties associated with the non-provision of FCR activation and the opportunity costs stemming from the non-participation to the FCR service due to IT issues are expected to be sufficient incentives for the BSP to ensure the quality of the service. Therefore, the following sections will focus on the case of system split, where a proper FCR activation needs to be ensured as it is the most needed at that moment.

Appropriate FCR activation in case of system split

A system split in a synchronous area is a separation of the synchronous area in two or more areas of different frequencies due to the generation and load repartition. This usually happens due to the outage of multiples transmission network elements (in cascade), linking the areas.

In case of system split, the main risk linked to a Centralized FCR Controller with a unique frequency measurement is that the assets are not reacting correctly the local frequency but rather to a frequency measurement made in another area. For example, if the frequency measurement is in an under-frequency area, all assets located in an over-frequency area will further deteriorate the frequency of their area. If there are several under-frequency areas in the system split, the FCR activation may still not be proportionate to the right local frequency deviation.

The obligations which are detailed in the following sections look into mitigating the described issues that could be faced with a Centralized FCR Controller with a unique frequency measurement. It is assumed that all IT systems and communications are not experiencing any failure at the same time, or that redundancy has been foreseen.

7.1 Obligation and conditions on the use of Centralized Controller with Decentralized Frequency Measurement

To address the risk of system split, the Additional Properties foresee per default to install a local frequency measurement at least at each connection point. The rationale is that a local frequency measurement can then be used in an observation function to detect the system split and trigger appropriate counter-measures. The Additional Properties also foresee some margin regarding the precision of the local frequency measurements that can be allowed by the TSO.

[15] As specified in the FCR RT Data exchange document and for the data foreseen in Annex 10.C Real-time Communication of the T&C BSP FCR.

7.1.1 Observation function

The observation function is intended to detect frequency discrepancies among the assets within the perimeter of the BSP. An observation function is necessary for all BSPs having a Centralised FCR Controller. The design of the observation function highly depends on the BSP and the distribution of its assets. A BSP is expected to explain to Elia its strategy to detect a system split.

Example of an observation function

The following figure shows the Belgian grid divided into several zones, with a different color identifying each of the zones (cf. 7.2.1). Each of the colored bubbles represents a local frequency measurement. For the sake of simplicity, the frequency measurement is located on the connection point behind which asset(s) react to this frequency measurement. The number in the bubbles are used for identification purposes only as explained below. The yellow line and the magenta line represents 2 different system split scenarios.

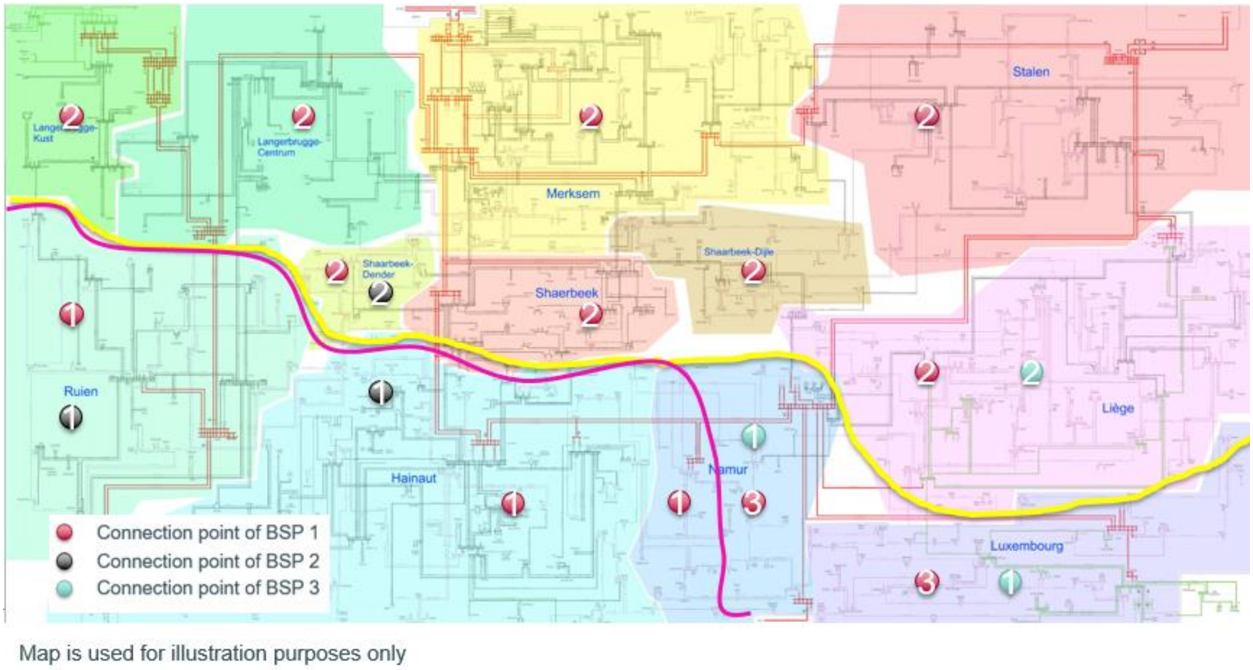

Figure 4: Illustration of the Belgian grid divided in several zones

The observation function shall compare the frequency between each of the connection points and identify the “fault line” (in yellow), if such fault line is between connections points. The fault line in this “yellow” case considers a system split between zones only.

For every BSP, the following results should be achieved if the observation function has been properly implemented:

- BSP 1 (red bubbles): the BSP has assets in every zone.
  - Bubbles 1&3: assets located in Ruien, Hainaut, Namur, Luxembourg react to the frequency “south” of the system split
  - Bubbles 2: assets located in the rest of the zones react to the frequency “north” of the system split
- BSP 2 (black bubbles); the BSP only has assets in the “western” zones

    - Bubbles 1: assets located in Ruien, Hainaut react to the frequency “south” of the system split
    - Bubble 2: assets located in Schaerbeek-Dender react to the frequency “north” of the system split
- BSP 3 (turquoise bubbles): the BSP only has assets in the “eastern” zones
    - Bubbles 1: assets located in Namur, Luxembourg react to the frequency “south” of the system split
    - Bubble 2: assets located in Liège react to the frequency “north” of the system split

In case the fault line is the one in magenta, the system split is within a zone. Given that BSP 1 has 2 assets in the zone Namur, the BSP shall be able to detect the “intra-zonal” system split. The assets behind bubbles 1 & 3 should react correctly

7.1.2 Appropriate counter-measures & minimum accuracy of local frequency measurement

Regarding the appropriate counter-measures, Elia proposes that counter-measures to inappropriate FCR activation (after system split) are in place within a reasonable time and no longer than 2s considering the initial event trigger. Elia expects that the counter-measures are to be activated automatically. For all BSPs having a Centralised FCR Controller, Elia expects that the counter-measures are explained altogether with the observation function.

In essence, the countermeasures should be a new control strategy considering the distribution of assets and technologies in frequency areas resulting from the system split, if relevant. The FCR service shall be provided in accordance to SO Regulation Art. 154.7(a-e) and Additional Properties Art 3.2 (a-b) after the time to put in place the countermeasures.

Regarding the minimum accuracy of the local frequency measurement, Elia proposes to have the accuracy of frequency measurement to 10 mHz, which corresponds to the upper boundary of the requirement of SO Regulation Annex V.

7.2 Alternative to the use of Centralized Controller with Decentralized Frequency Measurement

As explained, having a Centralized Controller with a unique frequency measurement may lead to inappropriate FCR activation in case of system split. The default solution foreseen by the Additional Properties to mitigate the risk is quite stringent. The Additional Properties allow however that alternative solutions could be developed under the condition that they have an equivalent effect to the default solution (i.e. FCR activation is not significantly negatively impacted) and that it can be demonstrated by the BSP. Such alternative solutions may mitigate the creation of entry barriers.

Elia proposes one alternative solution which balances its needs for operational security and the entry barriers that the solution creates. All BSPs are welcomed to provide during prequalification their own alternative solution based on their assets, technologies and capabilities, pursuant to the Additional Properties Art. 3.7(c).

7.2.1 Elia’s proposal of alternative solution: defined zones for system split

The aim of the alternative solution of Elia is to provide a standard “off-the-shelf” solution that a BSP can readily use without having to perform an additional design and therefore to further lower entry barriers stemming from the obligation. Nevertheless, the BSP shall demonstrate its capability to apply this solution during prequalification. This alternative solution can be used for decentralized assets which are not equipped with a local frequency meter which is used for FCR activation (Decentralized Frequency Measurement), in other words assets pooled in a Virtual Delivery Point[16].

The proposed solution follows the rationale that there are zones within which a system split cannot or is unlikely to occur. These zones are the congestion zones (CRI zone) defined in iCAROS. A unique frequency meter per zone could be accepted to control all the assets in that zone. The determination of the zones is the critical aspect. If the zone is Belgium, one frequency meter would be sufficient. In the other extreme, if one zone needs to be defined for each single connection point, the default obligation as stated in Additional Properties Art. 3.7(b) would apply. After system analysis, Elia's proposal is a middle ground between the two extremes. Belgium is divided into electrical zones, for which it is assumed that, for a split which will affect the network of Elia, the split within the zones is unlikely (and if it occurs the consequences on FCR activation are acceptable).

In accordance with the T&C BSP FCR, a BSP can rely today on the same frequency measurement for the activation of several Technical Units (aggregated in a Virtual Delivery Points) provided the total contribution of the assets reacting to this measurement does not exceed 1.5 MW. Elia intends to apply the same logic in the future, while mitigating the risk of inadequate FCR activation in case of a system split by allowing a BSP to rely on the same frequency measurement for several Virtual Delivery Points provided the total contribution of the assets reacting to this measurement in the corresponding zone does not exceed 1.5 MW. The BSP may decide on where in the zone to install the frequency meter of the Virtual Delivery Point(s), which would ideally be distributed geographically to minimize the overall risk.

In case of split, the BSP shall detect subsequent frequency measurement divergence with the observation function and apply relevant counter-measures to ensure that the assets are reacting correctly to the frequency measurement at zone levels. Frequency checks may be performed between Delivery Points to identify divergence with central measurement.

[16] T&C BSP FCR Annex 3 under 3.C. Measurement requirements stipulates that: *"The frequency measurements must be local, meaning that a frequency meter must be installed at the site of each Delivery Point. This rule is not applicable in case of Virtual Delivery Points and Technical Units used as part of the Energy Management Strategy which are not performing the FCR Service."*

8. Conclusions and implementation plan

In the present report, Elia looked into the new obligations that the Additional Properties impose on BSPs, especially for those operating decentralized assets as well as assets with a limited energy reservoir. These new obligations can be regrouped into five topics:

- Prequalification of non-compliant units
- Derogation to the rated to pre-qualified ratio for DP LER
- Obligations and conditions on the provision of Reserve Mode
- Frequency measurement and controller.

For each of the topics, an introduction and the rationale behind the new obligations have been detailed. Where relevant and allowed by the Additional Properties, Elia has made a proposal of alternative solutions to the proposed default solution. Each of the proposals made by Elia aims to lower entry barriers and foster the participation of assets (demand side management or storage) connected at low voltage level while ensuring that operational security of the grid is not put at risk.

The proposals made by Elia in the framework of this report shall be further detailed in a design note and formalized in the Terms and Conditions BSP FCR, according to the Implementation Plan.

8.1 Implementation plan

The Additional Properties foresee a start of the implementation after the approval by all NRAs and within a timeframe of 2 years. The last NRA approved the proposal on the 30th of June 2021. Therefore, the legal deadline for the entry into force of the new T&C BSP FCR which includes the new obligations is the 30th of June 2023.

A proposal of the implementation plan shall be discussed with the CREG and the stakeholders in the Working Group Balancing before the final submission of this report.

Annex 1: Reserve Mode

Before the Additional Properties, the "operating mode" of DP LER in Alert State (and Emergency State) was determined solely by SO Regulation Art. 156.9: "*For the CE and Nordic synchronous areas, as of triggering the alert state and during the alert state, each FCR provider shall ensure that its FCR providing units or groups with limited energy reservoirs are able to fully activate FCR continuously for a time period […]*", which is referred to as " "Normal Mode". The period of time in Alert State for a continuous and full FCR activation (T-min LER) is currently set in the T&C BSP FCR at 25 min.

For Delivery Point with Limited Energy Reservoir (DP LER), the Additional Properties foresees an additional operating mode in Alert State (and Emergency State), the Reserve Mode. The rationale behind the Reserve Mode is avoid the depletion of the energy reservoirs of the DP LER during extended period of frequency deviations events and the loss of the FCR activation from those DPs LER. The Reserve Mode aims therefore that DP LER provides a (limited) FCR activation based on short-term frequency deviation instead of no FCR activation at all during such events.

The energy content (State of Charge or SoC) of LER asset shall always be sufficient in order to continuously react to frequency deviations, by applying an Active Energy Reservoir Management[17]. Only when the Synchronous Area Continental Europe enters into Alert State or Emergency State, after the T-min LER period[18] and the LER assets reach or exceed the upper (SoC_{max}) or lower limit (SoC_{min}) of its energy reservoir, shall those LER assets be obliged to switch to the Reserve Mode. These thresholds are defined by the amount of energy necessary to provide FCR for a time interval equal to the local Full Activation Time (FAT) of aFRR. The FAT will be harmonized (by 2025) to 5 minutes for all TSOs.

$$SoC_{min} = \frac{P * t_{FAT}}{C}$$
$$SoC_{max} = 1 - SoC_{min}$$

Where:

- $\mathrm{t_{FAT}}$ is the full activation time of aFRR in h;
- P is the provided FCR power corresponding to a frequency deviation ±200 mHz in MW; and
- C is the energy capacity of the battery in MWh

The transition from Normal to Reserve Mode is therefore initiated at time $\mathrm{t_{start}} = \mathrm{t(SoC <= SoC_{min}\ or\ SoC >= SoC_{max})}$ and lasts $\mathrm{t_{FAT}}$. During the transition from Normal Mode to Reserve Mode (from $\mathrm{t_{start}}$ to $\mathrm{t_{start}} + \mathrm{t_{FAT}}$), the LER asset shall react to $f_{reaction}(t)$, the combination of normal frequency deviation, $\Delta f(t)$ and short-term frequency deviation, $\Delta f_{zero-mean}(t)$:

$$f_{reaction}(t) = \Delta f_{zero-mean}(t) * T + (1 - T) * \Delta f(t)$$

[17] According to definition in Art. 2.2(a) of the Additional Properties: active charging/discharging of the reservoir depending on the state of charge which results from FCR activation to avoid a status of a completely full/empty reservoir;

[18] It should be noted that the minimum activation time of a LER asset must be always guaranteed irrespective of the implementation of the Reserve Mode.

Where T is the weighting function defined as follows:

$$T = \begin{cases} 0 & t < t_{start} \\ \frac{t - t_{start}}{t_{FAT}} & t_{start} \leq t < t_{start} + t_{\Delta FAT} \\ 1 & t \geq t_{start} + t_{\Delta FAT} \end{cases}$$

By the time the SoC is restored ($SoC_{min} < SoC < SoC_{max}$) and the system is back to Normal State, the LER asset shall switch again to the Normal Mode. The transition to Normal Mode is similar to the transition to Reserve Mode and is initialized at $t_{restore}$ and lasts t_{FAT}. During the transition from Reserve to Normal Mode the LER asset must react to the $\Delta f_{reaction}(t)$. The weighting function in this case is defined as follows:

$$T = \begin{cases} 1 & t < t_{restore} \\ \frac{t_{restore-t}}{t_{FAT}} + 1 & t_{restore} \leq t < t_{restore} + t_{FAT} \\ 0 & t \geq t_{restore} + t_{FAT} \end{cases}$$

While in Reserve Mode, the LER asset reacts to a zero-mean frequency deviation, representing the short-term frequency deviation and is calculated by subtracting the normal frequency deviation, $\Delta f(t)$ by the steady-state frequency deviation, $\frac{1}{t_{FAT}} \sum_{i=0}^{t_{FAT}-1} \Delta f(t-i)$.

$$\Delta f_{zero-mean}(t) = \Delta f(t) - \frac{1}{t_{FAT}} \sum_{i=0}^{t_{FAT}-1} \Delta f(t-i)$$

Exemplary Cases – Reserve Mode To facilitate the understanding of the definition and implementation of Reserve Mode two reference cases are simulated.

CASE I: Reserve Mode on a single battery

This case is based on the frequency measurements of Swissgrid for the 07.06.2019 and made the following assumptions:

LER asset: One single battery;

- t_{FAT}: 5 min (300 sec);
- P: 1 MW; and
- C: 1 MWh

The minimum and maximum SoC-values, below or above which the switch from Normal to Reserve Mode are calculated as follows:

$SoC_{min} = 0.083; \; and$

$SoC_{max} = 0.917$

The SoC-values are calculated based on the relative change of the actual (normal) frequency deviation. The SoC-value at the beginning of the simulation is assumed to be 0.25.

Figure 5 illustrates the transition from the Normal to the Reserve Mode. The X-axis corresponds to the frequency deviation. The black curve represents the actual (normal) frequency deviation, Δf, whereas the red curve represents the zero-mean frequency deviation, $\Delta f_{zero-mean}$, calculated as the difference between the actual (normal) frequency deviation (black curve) and the moving average (green curve).

The Y-axis (on the right) corresponds to the transition function, which is used as a weighting factor for the calculation of the frequency deviation $\Delta f_{reaction}$ that should be followed during the transition between Normal Mode and Reserve

Mode. At the moment when the transition is initiated (at $t = t_{start}$), the $\Delta f_{\text{reaction}}$ equals the normal frequency deviation Δf (the blue curve coincides with the black curve). From the moment the battery exits the transition and enters the Reserve Mode (at $t = t_{start} + t_{FAT}$), the $\Delta f_{\text{reaction}}$ equals the zero-mean frequency deviation $\Delta f_{\text{zero-mean}}$ (the blue curve coincides with the red curve).

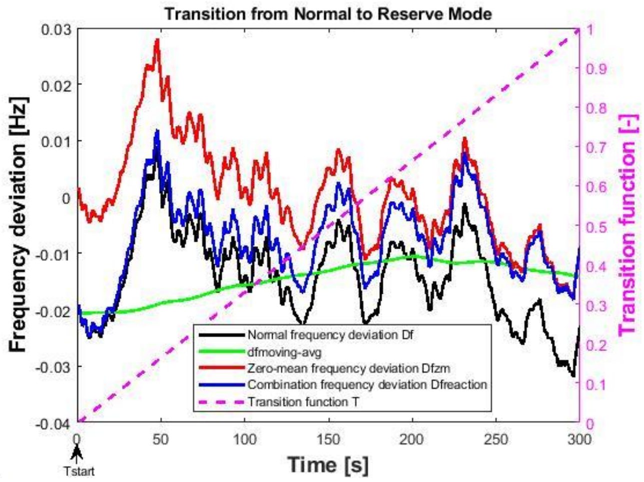

Figure 5: Transition from Normal to Reserve Mode

The impact of the Reserve Mode to the SoC is illustrated in Figure 6. The magenta curve represents the SoC that would have resulted if the battery had followed the actual (normal) frequency deviation Δf (black curve). The dotted magenta curve shows the SoC if the battery applies the Reserve Mode.

By the time the SoC falls under the SoC_{min} the battery enters the transition between the operating modes (grey area on the left) and follows the $\Delta f_{\text{reaction}}$ (blue curve). After t_{FAT} and given that the SoC continues to be lower than the SoC_{min}, the battery enters the Reserve Mode (grey area on the right) and follows the zero-mean frequency deviation $\Delta f_{\text{zero-mean}}$ (red curve). The battery exits the Reserve Mode once the SoC becomes greater than the SoC_{min} and assuming that the system is in Normal State.

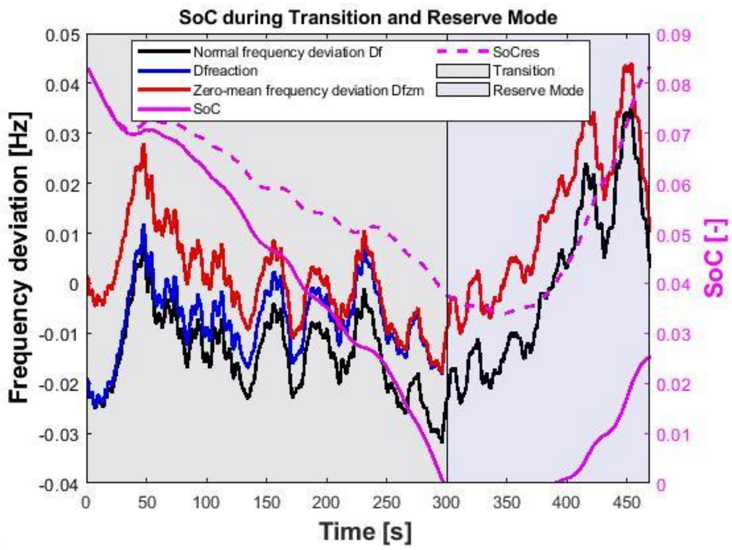

Figure 6: Impact of the Reserve Mode on the SoC

The effect of following the $\Delta f_{reaction}$ during the transition and the $\Delta F_{zero-mean}$ during the Reserve Mode, as described in Figure 6, on the provided FCR is shown in Figure 7. One can observe the difference between the FCR provided without applying the Reserve Mode (black curve) and the FCR provided if the Reserve Mode is applied (blue curve).

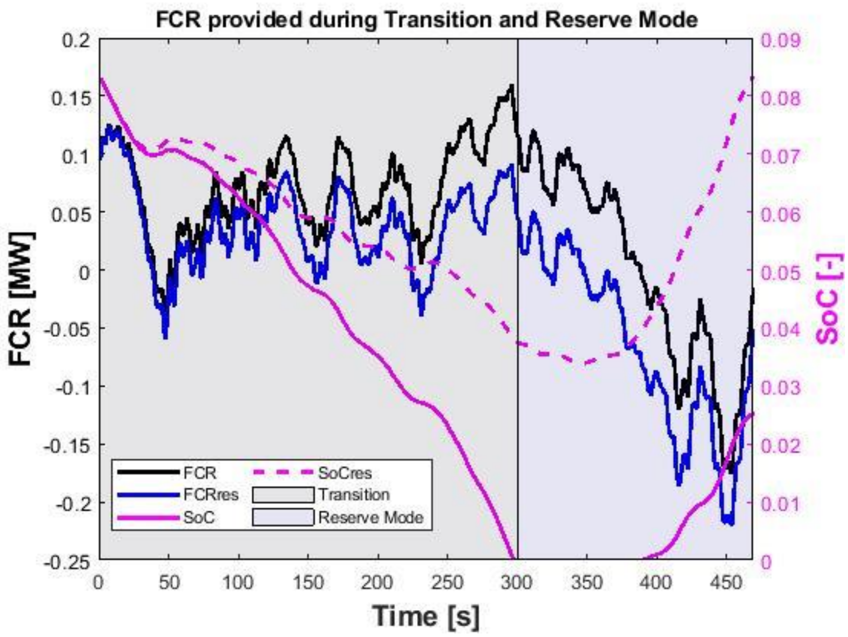

Figure 7: Impact of the Reserve Mode on the FCR provided

At last, Figure 8 shows the FCR provided (X-axis) with respect to the frequency deviation (Y-axis on the right). The black curve represents the FCR that would have been provided, if the battery had followed the Δf (black dotted curve). The blue curve represents the FCR that would have been provided, if the battery applies the Reserve Mode (following frequency deviation of the blue dotted line within the transition and of the red dotted line within the Reserve Mode).

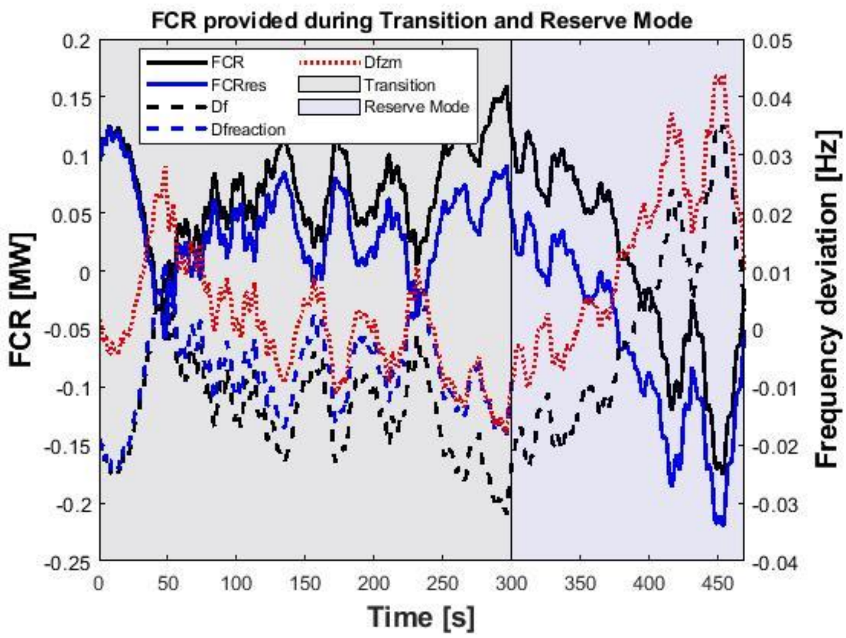

Figure 8: FCR provided In Reserve Mode vs Frequency deviation

CASE II: Short Term Over frequency

Case 2 represents the scenario of a short term over frequency. The SoC-value at the beginning of the simulation is assumed to be 0.50. The simulated frequency serie is composed of the actual frequency deviation of 18.10.2020 during 08 to 09 a.m. and to which a frequency deviation in the form of a trapezoid with a maximum frequency deviation of 200 mHz has been added.

Once the State of Charge reaches the upper limit the LER switch from Normal Mode to Reserve Mode by using the transition. Thereby the Reserve Mode prevents from reaching physical limits and FCR base on the zero-mean frequency can be provided continuously. Without the Reserve Mode, the LER would stop providing FCR when the physical limit of their reservoir are reached. The second figure shows that the FCR provision in Normal Mode skips to 0.

Figure 9 shows that without the Reserve Mode, the LER reaches its energy reservoir maximum at approximately 8:40 a.m. With the Reserve Mode however, the LER units or groups can still provide FCR.

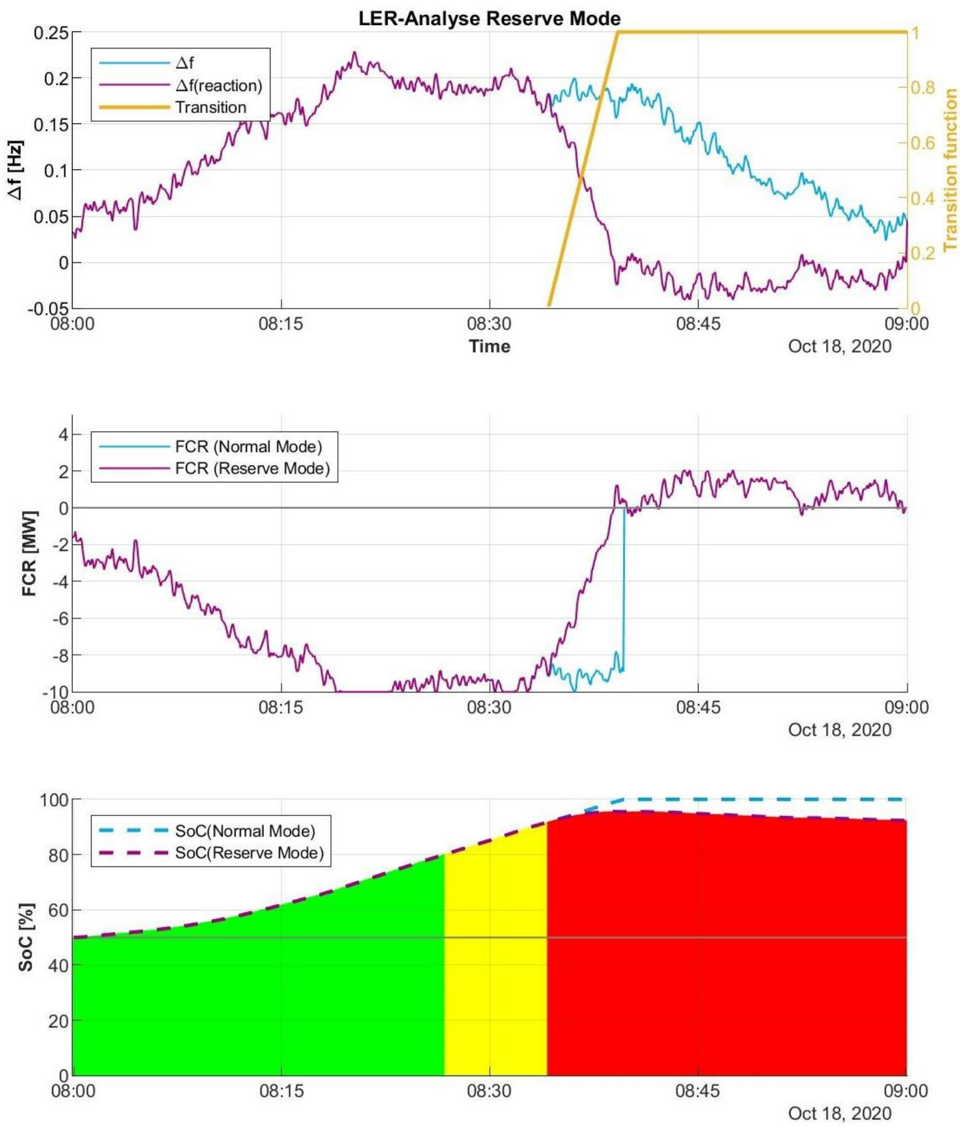

Figure 9 Case II LER Analysis Reserve Mode