European Network of
Transmission System Operators
for Electricity

Supporting Document for the Network Code on Load-Frequency Control and Reserves

28.06.2013

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1 Introduction to the Supporting Document

This document has been developed by the European Network of Transmission System Operators for Electricity (ENTSO-E) to accompany the consultation of the Network Code on Load-Frequency Control and Reserves (NC LFCR) and should be read in conjunction with that document.

The document has been developed in recognition of the fact that the NC LFCR, which will become a legally binding document after comitology, inevitably cannot provide the level of explanation which some parties may desire. Therefore, this document aims to provide interested parties with the background information and explanation for the requirements specified in the NC LFCR, as well as the document outlines the following steps of the work.

1.1 Document Structure

The supporting paper is structured within the framework for all System Operation Network Codes supporting papers as follows:

Background:

- Chapter 2 introduces the legal framework within which the System Operation Network Codes have been developed and complies with the requirements of the Framework Guidelines on System Operation (FG SO [1]) regarding the NC LFCR developed by the Agency for the Cooperation of Energy Regulators (ACER).
- Chapter 3 explains the approach which ENTSO-E has taken to develop the NC LFCR and outlines some of the challenges and opportunities lying ahead of System Operation. Furthermore, concepts used in the NC LFCR are also clarified in this section.

Explanatory notes:

- Chapter 4 to 9 focus on the objectives of the NC LFCR topic by topic identifying the enhancement of technical requirements with an assessment of their associated benefits. Choices appearing in the code will be justified in this section.
- Chapter 10 describes the benefits of implementing the technical and operational principles set by the NC LFCR and gives an overview with regards to the base line
- Appendix A describes the current practices of electrical time control
- Appendix B provides a mapping of FCR, FRR and RR to products
- Appendix C to F describe different approaches in the Synchronous Areas Great Britain, Ireland, Northern Europe and Continental Europe
- Appendix G provides a list of articles in the NC LFCR in which Reserve Providers, Reserve Providing Units or Reserve Providing Groups are mentioned.
- Appendix H provides a Glossary of Terms
- Appendix I is explaining how stakeholders' comments during public consultation were managed

1.2 Legal Status of the Document

This document accompanies the NC LFCR but is provided for information only and therefore it has no binding legal status.

2 PROCEDURAL ASPECTS

This section provides an overview of the procedural aspects of the Network Code development. It explains the legal framework within which Network Codes are developed and focuses on ENTSO-E's legally defined roles and responsibilities. It also explains the next steps in the process of developing the NC LFCR.

2.1 THE LEGAL FRAMEWORK FOR DEVELOPING THE NETWORK CODES

The NC LFCR has been developed in accordance with the process established within the Third Energy Package, in particular in Regulation (EC) 714/2009. The Third Package legislation establishes ENTSO-E and ACER and gives them clear obligations in developing of the Network Codes (cf. figure 1).

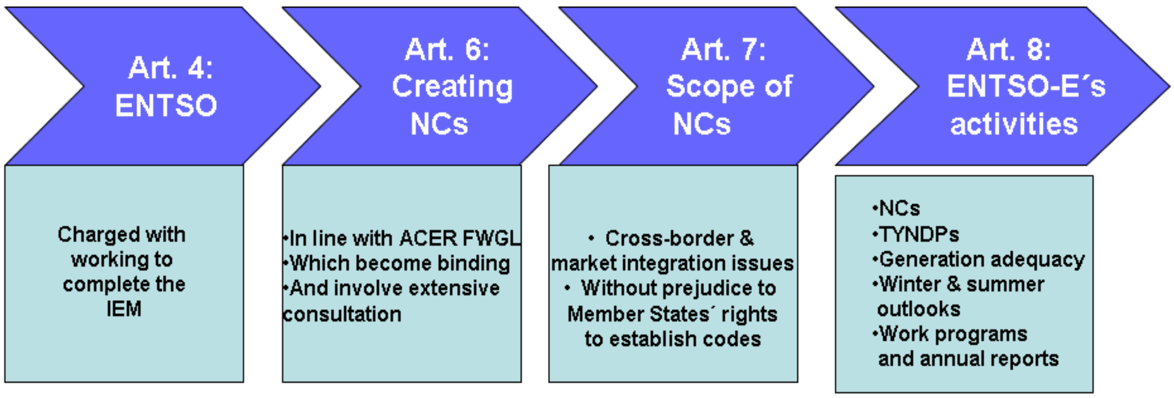


Figure 1: ENTSO-E's legal role in Network Code development according to Regulation (EC) 714/2009

Moreover, this framework creates a process for developing Network Codes involving ACER, ENTSO-E and the European Commission as shown in figure 2 below.

The NC LFCR has been developed by ENTSO-E to meet the requirements of the System Operation Framework Guidelines (FG SO) [1] published by ACER in December 2011. ACER has also conducted an Initial Impact Assessment associated with its consultation on its draft FG SO in June 2011 [2]. ENTSO-E was formally requested by the European Commission to begin the development of the NC LFCR on 1st July 2012. The deadline for the delivery of the code to ACER is the 1st July 2013.

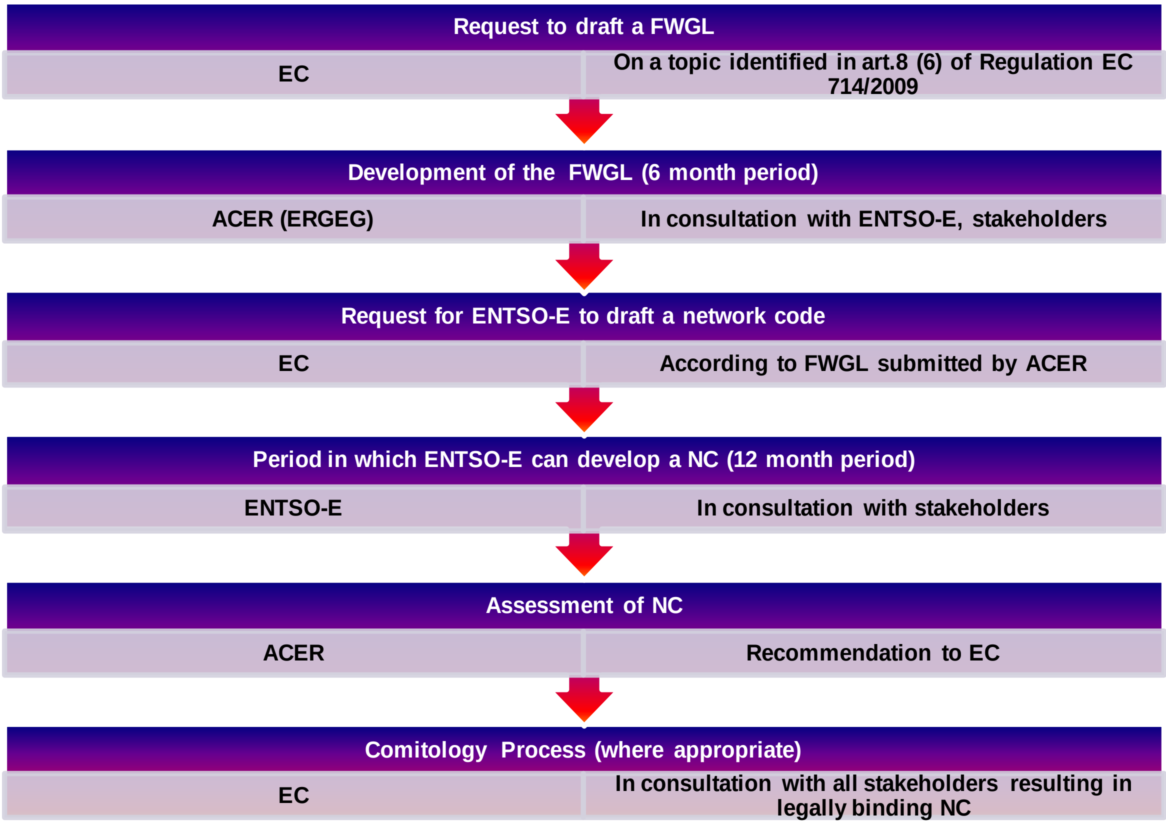


Figure 2: Network codes' development process [source: ENTSO-E]

2.2 RELATIONSHIP BETWEEN NC LFCR AND THE FRAMEWORK GUIDELINES

2.2.1 THE FRAMEWORK GUIDELINES

As figure 3 shows, the FG SO focuses on three key challenges, which shall be addressed by four objectives [1].

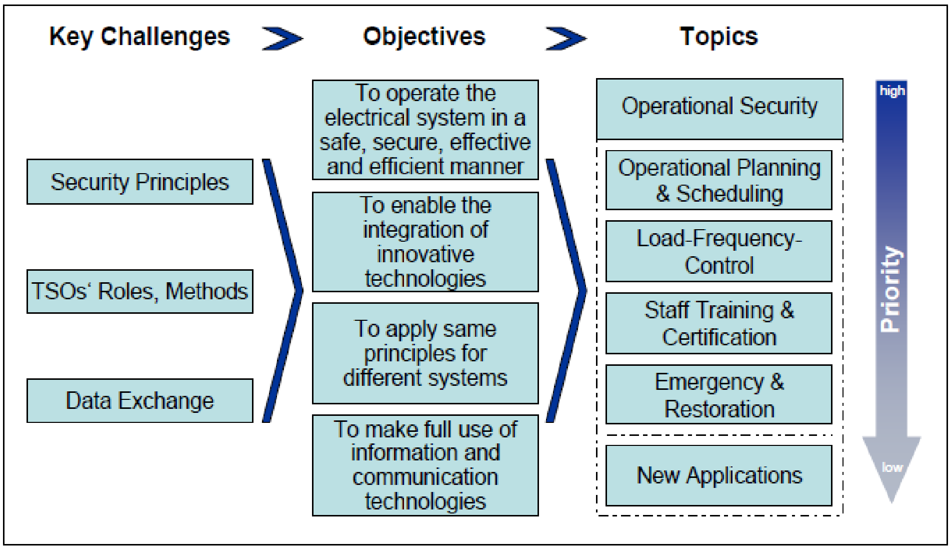


Figure 3: Structure and development flow of the FG SO

The overall scope and objectives of the FG SO is "*Achieving and maintaining normal functioning of the power system with a satisfactory level of security and quality of supply, as well as efficient utilisation of infrastructure and resources*". The FG SO focuses on defining common principles, requirements, standards and procedures within Synchronous Areas throughout EU, especially regarding the roles of and the coordination/information exchange between the TSOs, DSOs and significant grid users [1].

2.2.2 Framework Guidelines for NC LFCR

According to the FG SO the NC LFCR shall define

- various terms used in relation to Load-Frequency Control within the different Synchronous Areas;
- technical features of different levels of Load-Frequency Control in terms of time frames, reserve power used and the reaction time in different Synchronous Areas
- frequency quality criteria;
- appropriate minimum standards and requirements applicable to TSOs and reserve providing units; and
- requirements for TSOs with regards to the implementation of controllable generation, load characterisation and demand side management.

Furthermore, the NC LFCR shall

- foresee that TSOs co-ordinate their Load-Frequency Control activities at regional, Synchronous Area and EU level – as technically necessary and within the most appropriate entities – in order to ensure meeting the objectives and applying the most appropriate measures to prevent and / or remedy system disturbances; and
- describe principles for exchange of all necessary information between TSOs to handle the different Load-Frequency Control activities in a co-ordinated and co-operative manner.

The requirements of the NC LFCR are formulated in line with the FG SO and the new developments on System Operation, with the aim to ensure a satisfactory level of operational security and an efficient utilisation of the power system and resources by providing coherent and coordinated preparation of real-time operation.

2.3 Working with Stakeholders & Involved Parties

The legally binding nature of the Network Codes, which is achieved through the comitology process means that they can have a fundamental bearing on stakeholders businesses. As such, the ENTSO-E recognises the importance of engaging with stakeholders at an early stage, involving all interested parties in the development of the code, in an open and transparent manner.

ENTSO-E's stakeholder involvement comprised of workshops with the DSO Technical Expert Group and public stakeholder workshops as well as ad-hoc meetings and exchange of views with all interested parties as necessary.

Due to the many questions concerning the function of the transmission system from an operational point of view that arose during the public consultation of the NC RfG [4], the first ENTSO-E stakeholder workshop on system operation was held on 19 March 2012 in Brussels. The aim of the workshop was to present information focusing on the operation of an interconnected transmission system, and the physical basis for scoping and drafting the system operation Network Codes. Stakeholders also had the opportunity to express feedback and expectations. Material is available on ENTSO-E webpage (https://www.entsoe.eu/events/system-operation/).

In line with suggestions by stakeholder organisations and following requests by the EC and ACER, ENTSO-E has organized four workshops for NC LFCR with the DSOs Technical Expert Group and with all stakeholders prior to, during and after the public consultation.

ENTSO-E held four workshops with stakeholders and launched a public consultation for two months from February 2013 until beginning of April 2013. Stakeholders and involved parties submitted comments and provided proposals for addressing the concerns they had with the draft of the code at that time. ENTSO-E carefully considered all comments which were provided and updated the Network Code in light of the proposed changes and comments. Results of this consultation are exposed in Appendix H and were presented and discussed in the last Workshop held on the 7th of May 2013.

Following agreement and approval within ENTSO-E, the Network Code will be submitted to ACER in line with the defined deadline of 1. July 2013. ACER is then expected to assess the NC LFCR to ensure it complies with the FG ESO and will make a recommendation to the European Commission. When the European Commission agrees with the ACER recommendation, the European Commission can conduct the Comitology process which should transform the NC LFCR into a legally binding integral component of Regulation (EC) N°714/2009.

3 SCOPE AND GUIDING PRINCIPLES OF THE NC LFCR

Based on the FG SO and on the Initial Impact Assessment (IIA) provided by ACER, the NC LFCR states the principles for Load-Frequency Control and Active Power Reserves in terms of technical needs while considering market solutions compatible and supporting to maintain the security of supply.

The present section summarizes the scope and the principles which have guided the drafting approach of the NC LFCR.

3.1 TECHNICAL BACKGROUND AND SCOPE OF THE NC LFCR

The system frequency is a common physical parameter of a Synchronous Area and, therefore, has an impact on all installations connected to the transmission system. At the same time, all generation and demand facilities connected to the transmission system have an impact on frequency quality. For this reason, even though each TSO has its own Responsibility Area, the maintenance of frequency quality by secure and efficient Load-Frequency Control is a common task for all TSOs of the Synchronous Area and a necessary precondition for security of energy supply. Therefore

- Secure Load-Frequency Control requires close coordination and cooperation.
- Efficient system operation requires close collaboration between all stakeholders - the main purpose of the liberalisation and harmonisation of the electricity sector was efficiency, and efficient utilisation of the available resources for balancing requires close collaboration and coordination on EU level.

Secure and efficient Load-Frequency Control can be made possible, if there is in place

- a well-organised structure of Load-Frequency Control and an application of EU-wide harmonised processes based on commonly shared quality targets;
- the TSOs use of all means necessary to control the system in real-time, when it is either subject to normal changes of operational conditions or facing incidents affecting generation, demand or transmission equipment; and
- an obligation for the TSOs and the Reserve Providers to cooperate and to meet the relevant minimum technical requirements for the implementation and operation of Load-Frequency Control for all interconnected systems of a Synchronous Area.

While the NC OS provides the global Operational Security framework, the NC LFCR ensures Operational Security with respect to System Frequency stability by providing

- harmonised System Frequency quality targets;
- harmonised control processes and operational procedures;
- harmonised minimum technical requirements for organisation of Reserve provision by TSOs;
- harmonised minimum technical requirements for Reserve Providing Units and Groups; as well as
- harmonised procedures related to cross-border exchange, sharing and activation of Active Power Reserves within one and between different Synchronous Areas improving the overall efficiency of operation.

In relationship to the NC EB, the NC LFCR sets the boundary conditions for products and cross-border coordination where it is related to market design (figure 4).

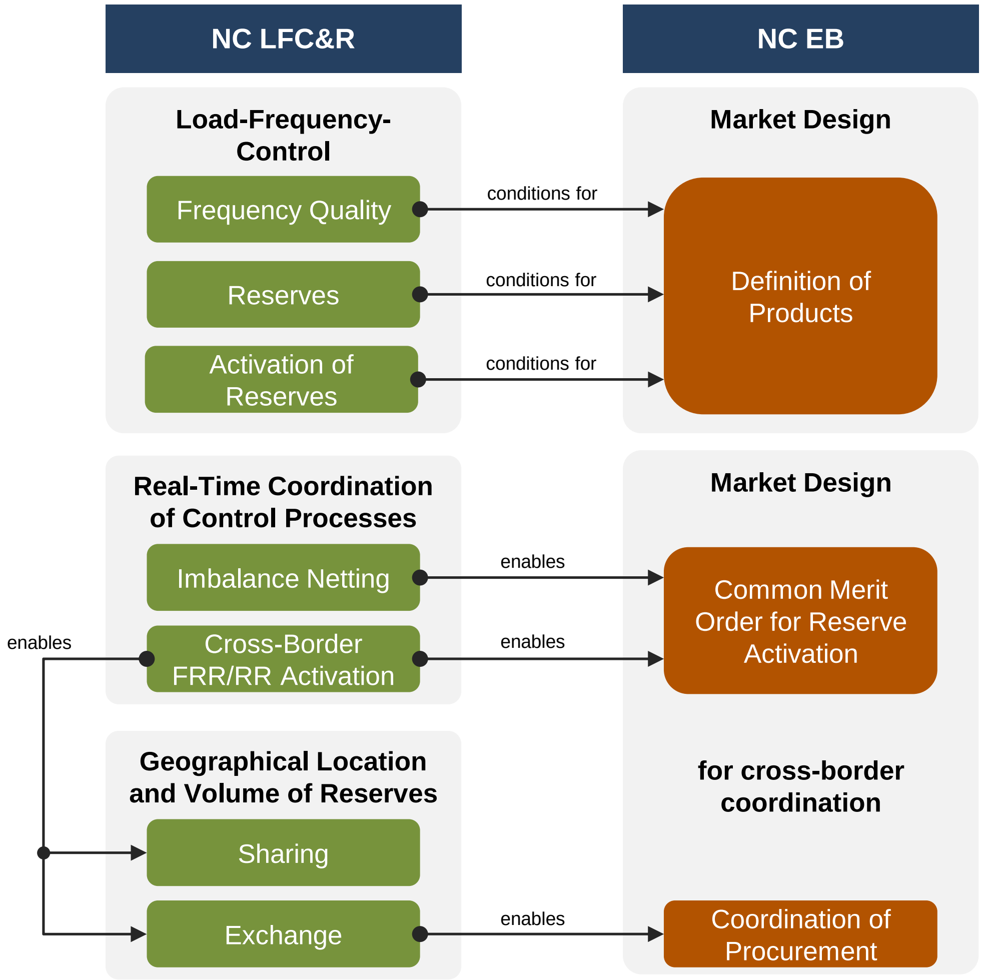


Figure 4: Relationship with NC EB

All stakeholders, including TSOs, should respect the common requirements for control processes and Active Power Reserves set forth in the NC LFCR to maintain the frequency quality and stability in the Synchronous Areas and to support the efficient functioning of the European IEM.

3.2 Applicability of the NC LFCR

3.2.1 Applicability to Member States

Whereas the requirements of the NC LFCR are directly applicable in all Member States, it should be noticed that the provisions set in the NC LFCR should not apply in the following cases:

- In the isolated systems in accordance with the Article 8(7) of Regulation (EC) N° 714/2009. (see also below, sub-section 3.2.2)
-
- In power systems operating under synchronous mode in a Synchronous Area in which not all the systems are bound by the EU legislation, the provisions of this Network Code shall apply only to the extent they could be duly applied and implemented within the entire Synchronous Area as long as these power systems are

operating therein, taking into account the physical and technical nature of frequency regulation implemented in the whole Synchronous Area. This applies to the TSOs of Estonia, Latvia and Lithuania operated in the IPS / UPS system.

3.2.2 Isolated Systems

According to Article 8(7) of Regulation EC N° 714/2009 the Network Code is developed for cross-border network issues and market integration issues. The right of the Member States to establish national network codes which do not affect cross-border network issues and market integration issues is not limited.

First is to mention, that this Network Code only applies within EU, Energy Community and third countries being Member of ENTSO-E as these third countries will also apply this NC. For this reason neither cross-border network issues to third countries outside ENTSO-E nor market integration with such third countries are in the scope of this NC.

In light of the above, this network code shall not apply to those systems which do not present any cross-border network issues or market integration issues.

Articles 2(26) and 2(27) of Directive EC N° 72/2009 define Small and Micro isolated systems referring to consumption in 1996 and level of interconnection of those systems. These terms have been defined in the Directive with the sole purpose of applying article 44 which allows the systems that comply with those criteria to request and obtain derogation from the application of certain provisions of the Directive. The provisions of the Directive from which those systems could get derogation are not of technical nature but rather linked to the unbundling obligations and third party access to the system (chapters IV, VI, VII and VIII).

In many cases, it is obvious that such Small or Micro isolated systems (like Canary Islands, Cyprus and Malta) as well as other Systems not being classified as Micro or Small isolated systems that have no link to a Transmission System would not possibly have cross border or market integration impact and therefore, would be out of the scope of the Network Code.

In several cases a transmission system or a part of a transmission system (such as the transmission system of an Island) belonging to the Responsibility Area of a TSO (like Balearic Islands) or having its own TSO Responsibility Area (like Aland) not fulfilling the criteria of a system as mentioned in the previous paragraph has no impact or only a very small and negligible impact on cross-border network issues or market integration issues. This might be due to the fact of not being operated synchronously (e.g.: connected to the mainland only through a DC link) with the rest of the Synchronous Area.

Therefore, in addition to the explanations provided in the recital 18 and in order to bring further clarity as regards the geographical scope of application of this network code, a specific exemption was inserted in Article 1 of the Network Code. This exemption concerns all those isolated systems (whether or not they qualify as small isolated system or micro isolated system) by a) referring to those transmission systems which are not synchronously operated with the rest of the Synchronous Area (main element of the exemption) and b) specifically exempting Aland islands which are synchronously operated but nevertheless need to be exempted due to the limited size of its TSO (9 employees) and the small demand consumption of the islands.

3.3 Guiding Principles

The guiding principles of the NC LFCR are:

- to determine common Load-Frequency Control processes and control structures,
- to ensure the conditions for maintaining a frequency quality level of all Synchronous Areas throughout the EU as well as
- to determine common requirements to Reserve Providing Units and Groups for the provision of Active Power Reserves to the Reserve Connecting TSO (or another TSO appointed by the Reserve Connecting TSO in case of Exchange of Reserves).

These principles are essential for the TSOs' professional business to manage their responsibilities regarding a sufficient level of Frequency quality efficiently.

The main goal of the System Operation Network Codes is to achieve a harmonised and solid technical framework including the implementation of all necessary processes and taking into account the rapid growth of the generation from Renewable Energy Sources (RES) and their impact on System Operation due to their inherent characteristics. Consequently, the requirements have been designed in order to ensure the proper functioning of Load-Frequency Control taking into account the integration of the RES and the effective development of the European IEM.

The requirements set out in System Operation Network Codes on TSOs, DSOs, HVDC owners and operators and grid users are building upon a long history of existing common and best practices, lessons learned and operational needs throughout the European transmission systems. This, together with the fact that the European experience of interconnected transmission systems operation dates back to the 1950s (ENTSO-E Regional Group Central Europe (CE), former Union for Coordination of (Production) and Transmission of Electricity (UC(P)TE)), 1960s (ENTSO-E North, former Nordel), and 1970s (TSO Associations of Great Britain and Republic of Ireland, UKTSOA and ITSOA), distinguishes the NC LFCR and all other System Operation NCs from other Network Codes in following terms:

- The work on the System Operation Network Codes does not start from "scratch" but builds upon a wide and deep range of requirements, policies and standards of the previous European transmission system interconnections (Synchronous Areas), adapting and developing further these requirements in order to satisfy the requirements from the FG SO, to meet the challenges of the "Energy Turnaround" including RES and increasing volatility and dynamics of market operations as well as to support effective and efficient completion of the IEM.
- System Operation of the interconnected transmission systems of Europe, is vital, not just for the continuous and secure supply of European citizens with electricity but also for the electricity market to function at all. Therefore, any changes, adjustments and developments based on the new (legally binding after comitology) System Operation Network Codes must acknowledge and respect the fact that system operation cannot be interrupted and "restarted" – the work is being done on a "living grid".
- By their nature and because of the level of technical detail involving all aspects of transmission system operations, the System Operation Network Codes are mainly addressing the TSOs and ENTSO-E; nevertheless, firm links and cross-references, as well as practical dependencies and explanations are established in relation to

other Network Codes, most notably those addressing grid connection, market and regulating power / balancing.

3.4 LEVEL OF DETAIL

The System Operation NCs provide minimum standards and requirements related to System Operation. The level of detail matches the purpose of the codes such as

- harmonisation of security principles and methods;
- definition of roles and responsibilities of operators and grid users; as well as
- to enable and to ensure adequate data exchange;

in order to future proof the system for

- integrating innovative technologies and sustainable energy sources;
- ensuring a safe, secure, effective and efficient System Operation; and
- applying the same principles and procedures for different systems to establish a wider level playing field for market participants.

In order to achieve the necessary level of European harmonisation, allowing at the same more detailed provisions at the regional / national level where necessary, and with the view of drafting Network Codes for System Operation which is open for future developments and new applications, an approach focusing on pan-European view and most widely applicable requirements has been pursued throughout all the development phases.

The FG SO provided further clarification concerning the issue of European-wide applicability while pointing out that "[…] *ENTSO-E shall, where possible, ensure that the rules are sufficiently generic to facilitate incremental innovation in technologies and approaches to system operation being covered without requiring code amendments*" [1].

Thus, the requirements have been drafted considering a period of approximately 5 years as a reasonable cycle within which changes to the NC LFCR will have to be implemented, building up a coherent legal mechanism with the appropriate balance between level of detail and flexibility, which focuses on what-to-do, not so much how-to-do.

Regarding NC LFCR, harmonisation principles are handled through a global framework consisting of the three following levels addressed coherently:

- **European level:** Definition of the common control processes for Frequency Containment, Frequency Restoration and Reserve Replacement as well as the according Active Power Reserves and rules for cross-border cooperation;
- **Synchronous Area level:** Establishment of the control structure, definition of a common frequency quality target and application of the Frequency Containment Process;
- **LFC Block level:** Definition of a frequency restoration target and application of the FRR and RR Dimensioning Rules; as well as
- **LFC Area level:** Application of the Frequency Restoration and Reserve Replacement Processes.

Regarding methodologies, the approach adopted is to tune the provisions through a global framework giving high level principles while requirements for detailed specifications shall be defined outside of the code in a transparent process including NRA and stakeholder involvement and leaving place to further evolutions and improvements.

Whereas the first NC LFCR picks up as much input from involved parties as possible in order to enable a high level of system security, regional requirements concerning the different Synchronous Areas, regions or even single TSOs may lead to further and more detailed provisions.

3.5 Operational Agreements and NRA Approval

The crucial parameters and methodologies of Load-Frequency Control are explicitly defined in the NC LFCR. These parameters include:

- Main parameters defining the System Frequency quality and targets for TSOs;
- Load-Frequency Control processes and their implementation;
- cross-border Load-Frequency Control processes;
- Dimensioning Rules;
- Minimum Technical Requirements for Reserve Providing Units and Reserve Providing Groups;
- limits for Exchange and Sharing of Reserves; and
- transparency requirements.

Some of the values and operational procedures need to be defined within Operational Agreements (Article 10 – Article 18) mainly on the level of the Synchronous Area and LFC Blocks for several reasons.

The first reason is that the definition of requirements and task assignment necessary in practice, such as,

- organisational procedures (which are currently implemented and have to remain implemented);
- appointment of roles to specific TSOs; and
- detailed technical implementation;

may

- go far beyond the level of detail which can be covered by the NC LFCR;
- do not have an impact on stakeholders or facilitation of the IEM; and/or
- require flexible adaptation.

Typical examples are:

- appointment of the Synchronous Area Monitor and LFC Block Monitor;
- appointment of roles related to coordination of operational procedures;
- agreements of organisational roles for cross-border Load-Frequency Control processes, Exchange and Sharing such as assignment of responsibilities for notifications, monitoring, detailed technical implementation in the digital control systems;
- detailed processes for information exchange between TSOs etc.

The second reason of Operational Agreements is that there are some values and procedures which have impact on stakeholders cannot be defined within the scope of the NC LFCR due to the following reasons:

- The definition of values requires flexibility in presence of a living grid and significant challenges to Operational Security in general and System Frequency stability in particular;
- While the technical description of the Load-Frequency Control processes which affect the stakeholders is provided by the code, the implementation of cooperation between TSOs has to be based on more detailed agreements (and case by case approval by NRAs).
- A value cannot be fully harmonised at the European or Synchronous Area level due to fundamentally different physical boundary conditions and/or national regulation;

Typical examples are:

- Additional requirements for FCR Providing Units or FCR Providing Groups which have to be defined by the Reserve Connecting TSO in order to ensure monitoring and Operational Security (or by a TSO appointed by the Reserve Connecting TSO in case of the Exchange of Reserves);
- Implementation of a cross-border Load-Frequency Control process between different LFC Blocks;
- Implementation of Exchange or Sharing of Reserves between different LFC Blocks;
- Change in responsibility structure.

All methodologies or values which

- are not defined in the NC LFCR but must be defined in an Operational Agreement; and
- have impact on stakeholders, especially in case of System Frequency quality or conditions for the amount, provision and activation of FCR, FRR and RR

shall be approved by the responsible NRAs.

3.6 TRANSPARENCY REQUIREMENTS

The NC LFCR defines wide-ranging requirements for transparency. In particular, all technical requirements for

- Reserve Providing Units and Reserve Providing Groups
- Dimensioning Rules; and
- actual Reserve Capacities

for all TSOs will be published on a central transparency platform for the first time. The location for this publication is chosen to be the transparency platform developed by ENTSO-E in order to comply with the upcoming Transparency Regulation. Having a centralised location for all publications is in the interest of transparency, as information will be easy to find and to access by different parties throughout Europe. It is also in the interest of harmonisation, as it will ensure that parties have the same information independent of their location.

With a few exceptions for practical operational reasons the information mentioned above will be published at least 3 months before they will be used in practice.

The Synchronous Area Operational Agreement will also be made publically available on the ENTSO-E transparency platform. Since relevant material contained within this operational agreement is already published separately, the publication of the Synchronous Area Operational Agreement shall be done after its entry into force one an agreement has been reached. The relevant NRAs will of course be informed in advance.

For reasons of confidentiality, and because the relevant information is already published separately, it has been decided not to make the LFC Block Operational Agreements publically available, although they will of course be shared with the relevant NRAs and will include

Moreover, the transparency requirements include

- a monthly publication of the detailed Frequency Quality Evaluation Criteria for the Synchronous Area; and
- a detailed Annual Report on Load-Frequency Control.

The transparency requirements defined by the NC LFCR provide a significant added value by facilitating the understanding and evaluation of Load-Frequency Control in Europe.

4 FREQUENCY QUALITY REQUIREMENTS

All modern electricity transmission systems are operated with alternating current. The frequency of the current in the transmission system, the System Frequency, is a direct indicator for the total Active Power balance in the whole Synchronous Area:

- If the Active Power generation exceeds the Active Power consumption, the System Frequency will rise, and, vice versa,
- if the Active Power consumption exceeds the Active Power generation, the System Frequency will fall

and will result in a deviation from the Nominal Frequency. The gradient (the speed) of the Frequency Deviation is determined by the amount of kinetic energy stored and released by the synchronously connected rotating masses (Inertia) after a disturbance of the Active Power balance (there are also first attempts to obtain the same effect from non-synchronously connected generators via power electronics).

Imbalances and therefore Frequency Deviations cannot be physically avoided for two fundamental reasons:

- The electricity demand is only predictable up to a certain extent and its controllability is limited. Therefore the dispatch of power plants must rely on forecasts which are subject to errors which cause deviations between generation and consumption.
- At the same time, the controllability of power plants is also physically limited, especially in the case of plants which rely on fluctuating RES to generate electricity. Furthermore, the operational equipment itself is subject to disturbances.

Since for technical reasons the operational range of generators is limited to a certain System Frequency range, Frequency Deviations outside of this range would trigger the according automatic protection mechanisms leading to a disconnection of the generators in the whole Synchronous Area, immediately followed by a complete blackout.

Therefore, the System Frequency quality, which can be measured based on the size and duration of Frequency Deviations with respect to the Nominal Frequency. This is an important measure of security of supply and being a “common good” for all users of the Synchronous Area, the System Frequency quality must be monitored and maintained properly.

Based on best practices, the operational experience of the last decades and future challenges, the NC LFCR defines harmonised requirements for System Frequency quality design, evaluation methodology and monitoring processes while considering the different physical properties of the European Synchronous Areas (cf. Article 19 – Article 24).

4.1 FREQUENCY QUALITY DEFINING PARAMETERS

The Frequency Quality Defining Parameters represent the values which are used for the design of control processes and reserve dimensioning. Furthermore, they are aligned with emergency procedures and operation ranges for generators.

The operation of Synchronous Area has been designed in such a way to guarantee that after a disturbance of the Active Power balance Frequency Deviations are kept within a certain range. For large Synchronous Areas this implies that large imbalances do not lead to Frequency Deviations that would trigger under-frequency load-shedding. The largest imbalance which by design shall not cause a violation of admissible System Frequency ranges is named the Reference Incident (it also serves as input to the dimensioning of FCR).

The Frequency Quality Defining Parameters define these acceptable ranges for System Frequency after an occurrence of the Reference Incident (figure 5). It is important to notice that the parameters do not only include ranges but also the time durations (Time To Recover and Time To Restore Frequency) in which the respective ranges should be reached.

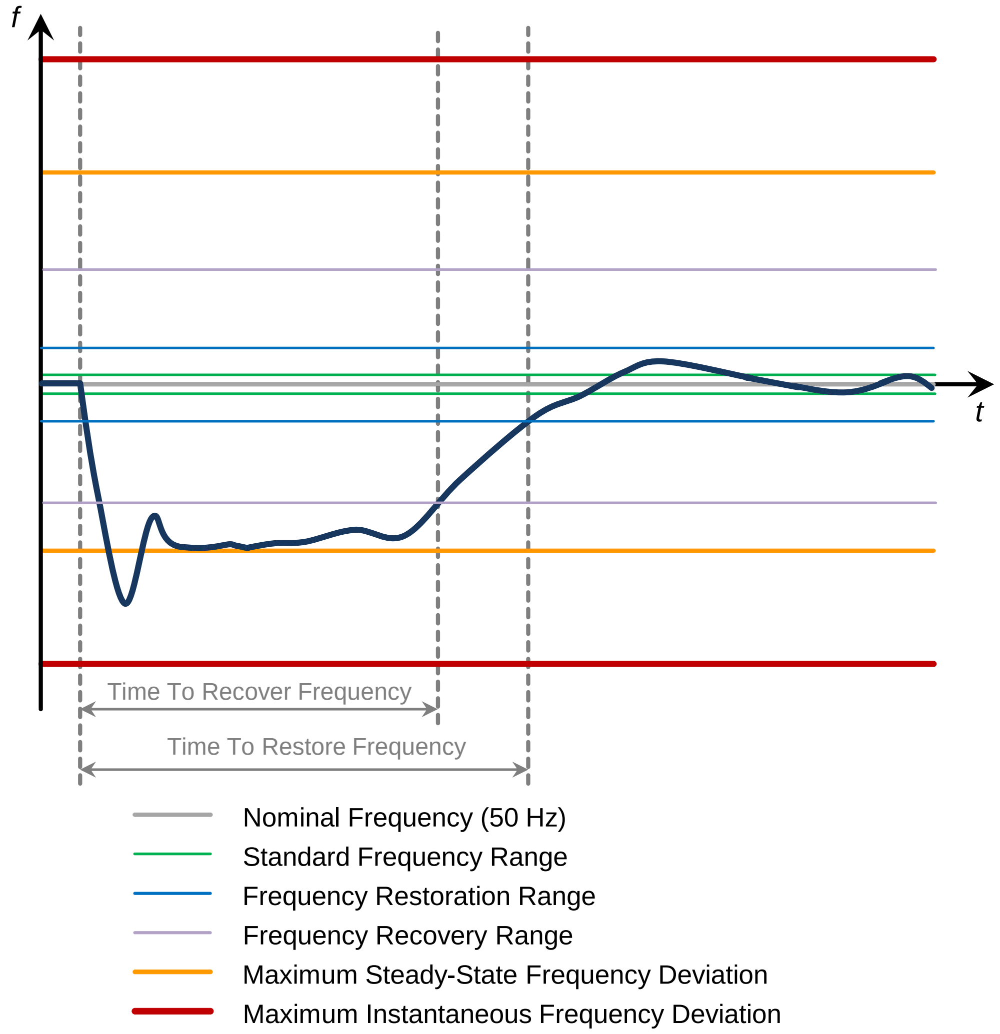


Figure 5: Frequency Quality Defining Parameters

The Frequency Quality Defining Parameters are the following:

- **Nominal Frequency:** The rated value of the System Frequency for which all equipment connected to the electrical network is designed.
- **Standard Frequency Range:** Frequency range within which the system should be operated for defined time intervals. It is used as a basis for System Frequency quality analysis.

- **Maximum Instantaneous Frequency deviation:** Maximum expected instantaneous system frequency deviation after the occurrence of a Reference Incident assuming predefined system conditions.
- **Maximum Steady-State Frequency Deviation:** Maximum expected system frequency deviation at which the System Frequency oscillation after the occurrence of a Reference Incident stabilizes assuming predefined system conditions. This stabilization occurs after the deployment of FCR. At the Maximum Steady-State Frequency Deviation FCR must be fully activated.
- **Time To Recover Frequency**: Maximum expected time after the occurrence of an imbalance smaller than or equal to the Reference Incident in which the System Frequency returns to the Maximum Steady State Frequency Deviation. This parameter is used in GB and IRE only (in larger SAs it is not necessary to require Power Generating Modules to operate continuously within higher System Frequency ranges).
- **Frequency Recovery Range**: The System Frequency range to which the System Frequency is expected to return after the occurrence of an imbalance equal to or less than the Reference Incident within the Time To Recover Frequency.
- **Time to Restore Frequency:** Maximum expected time after the occurrence of a Reference Incident in which the System Frequency is restored inside a tolerance range which is named Frequency Restoration Range. The specified duration of the full deployment of FCR must be at least the time to restore System Frequency in order to maintain system balance and frequency stability until the FRR are deployed. Once sufficient FRR are deployed to return the System Frequency to the band defined by the tolerance range for FCR activation, the FCR will be restored and therefore no longer needed until the next imbalance.
- **Frequency Restoration Range**: Range to which the System Frequency should be restored after the Time to Restore Frequency has elapsed since a Reference Incident occurs.

These Frequency Quality Defining Parameters shall be coordinated between all TSOs of a Synchronous Area in order to ensure proper Synchronous Area behaviour. They shall fulfil the requirements that are set to generators and loads, which are included in the NC RfG and in the NC DCC [4, 5].

The choice of values for Frequency Quality Defining Parameters depends heavily on the following Synchronous Area characteristics:

- Size of consumption and generation of the Synchronous Area and the inertia, both natural and synthetic; synthetic inertia may be a service achieved through power electronics which dynamically and rapidly alter the Active Power contribution of a connected reserve provider according to system frequency.
- Grid structure and/or network topology.
- The behaviour of Power Generating Modules and Demand Units and Facilities, in particular their reaction to Frequency Deviations.
- For all Synchronous Areas except GB and Ireland, the currently observed System Frequency quality in order to perform the probabilistic analysis. The analysis may lead to a risk evaluation of having a total imbalance larger than that the Synchronous Area is able to withstand while maintaining the System Frequency within the Frequency Quality Defining Parameters. Otherwise it is not guaranteed that the

Synchronous area could run into a situation with a large scale incident as a consequence of imbalances. For GB and Ireland a deterministic method is used with continuous re-evaluation of system conditions to ensure appropriate reserve holdings at all times.

Since each Synchronous Area has its own physical properties related to dynamic System Frequency behaviour, it is not possible to define the same values for the Frequency Quality Defining Parameters in all of them. Furthermore, these parameters are some of the main parameters to which the Synchronous Area is designed and its values have a very high impact on the amount of FCR, FRR and RR that the Synchronous Area shall require. Therefore, it is important that they remain stable with time but should be reviewed regularly and revised as and when the system characteristics significantly change. The current values are shown in Article 19(3) and 19(4).

4.2 FREQUENCY QUALITY TARGET PARAMETERS

The size and duration of the total System Frequency deviations determines frequency quality. The Synchronous Areas are designed to be able to withstand a Reference Incident within the design parameters under assumption that System Frequency is at its Nominal Frequency when the disturbance occurs. Therefore, the larger and the more persistent the Frequency Deviations, the more likely the Synchronous Area could experience a large disturbance at the time where there with an already existing Frequency Deviation leading to an event outside of the design parameters.

A common frequency quality model must be defined per Synchronous Area as a goal to assure with reasonable certainty that the risk of an incident is very low. A simple and effective way to quantify frequency quality is by assuming that

- the type of the probability distribution of Frequency Deviations remains constant; and
- this probability distribution can be defined univocally by setting the value of the probability for the Frequency Deviations to be outside a certain range.

With these assumptions, the System Frequency quality of a Synchronous Area is determined by the

- probability for the Frequency Deviations; or
- by the number of minutes per year in which the System Frequency is outside the Standard Frequency Range.

It is important to notice that the Frequency Quality Defining Parameter Standard Frequency Range does not mean that this value should be or is directly related to the standard deviation of the distribution of the Frequency Deviations.

The larger the number of minutes outside the Standard Frequency Range the worse the frequency quality and the higher risk that an event outside the design criteria occurs. To target a desired frequency quality the Frequency Quality Target Parameter, defined in Article 19(4) as the maximum number of minutes outside the Standard Frequency Range, is used. This parameter shall be common for all Synchronous Areas but due to the different characteristics of each of them a different number of minutes per year may apply to each:

For CE, the value is defined is as 15000 minutes per year. The number is derived from a probabilistic risk calculation for exhaustion of FCR (cf. section 7.1) based on the current risk level (once every 20 years) due to a combination of a persisting Frequency Deviation and a sudden disturbance due to generator or HVDC tripping.

As Table 1 shows the value defined by the NC LFCR does not introduce a change from the current values.

Table 1: Comparison of current and NC LFCR target values for minutes outside the Standard Frequency Range for CE

Year	Minutes outside the Standard Frequency Range	Deviation from the value defined by NC LFCR	
		in minutes	in % of the year
2010	14189	811	0.15
2011	13400	1600	0.30
2012	15521	521	0.1

For NE, the value is defined as 15000 minutes per year. The number is derived from historical data and an evaluation of increased deterministic and stochastic imbalances resulting from further energy market developments. Automatic FRR was implemented in 2013. As table 2 shows, the value defined by the NC LFCR does not introduce a change from the current values.

Table 2: Comparison of current and NC LFCR target values for minutes outside the Standard Frequency Range for NE

Year	Minutes outside the Standard Frequency Range	Deviation from the value defined by NC LFCR	
		in minutes	in % of the year
2010	11236	3764	0.72
2011	12834	2166	0.41
2012	11683	3317	0.63

The same value (15000 minutes per year) is also used for GB where the parameter has been set in order to meet the statutory requirements of the National Electricity Transmission System Security and Quality of Supply Standards which are agreed with the GB NRA. This is based on the number of occasions the frequency may deviate outside the standard frequency range per annum and that the frequency should return to this range within 10 minutes.

In IRE the Irish incentive regulation currently includes a system performance incentive related to System Frequency quality. EirGrid is incentivised to maintain the System Frequency within the range of 49.9 Hz – 50.1 Hz for a defined percentage of time. There are three target time percentage values: The “central” target is equal to 96 % of the time, the lower bound is 94 % and the upper bound is 98 % (these are the 2012 targets).

Since the Standard Frequency Range defined in the NC LFCR is ±200 mHz the upper bound currently used in IRE (98 % of the time) is chosen. For the NC LFCR, this results in 2 % of the time outside the Standard Frequency Range or approximately 10500 minutes.

4.3 Adaption of Frequency Quality Parameters

The values given within Article 19(3) and Article 19(4) of NC LFCR for the Frequency Quality Defining and Target Parameters have been carefully selected after consideration of the behaviour of the different Synchronous Areas within Europe. However, Article 19(5) and Article 19(6) allow for the use of modified values instead of the default values contained within the Network Code. These modified values would be defined by all TSOs of the Synchronous Area after careful investigation of the consequences of these changes, and would be approved by each of the NRAs of the Synchronous Area. Because the default values have been so carefully selected, and because many options are open to the TSOs to care for System Frequency quality, the expectation is that TSOs will not make use of this possibility to use modified values.

It is, however, important to keep the possibility of using modified values open within NC LFCR. The main reason for this is that Europe as a whole is transitioning towards a more sustainable energy market, and the integration of a large amount of RES within the system can cause the System Frequency to behave differently than in the current situation. This can for instance be related to the amount of inertia within the system. Most of the RES introduced within the system takes the place of conventional generation, which leads to a reduction of the inertia within the system, and can cause more rapid fluctuations in System Frequency. It can also be related to the inherent difficulties connected to forecasting RES generation, which inevitably lead to imbalances between demand and generation. If the changes are large enough the situation could occur in which the same considerations that have led to the default values within the Network Code could give different values for the Frequency Quality Defining or Target Parameters.

Another reason why the option to use modified values should be kept open, lies for instance in the fact that for the smaller Synchronous Areas the entering into operation of a large new Power Generating Module, HVDC or a Demand Facility could lead to a significant change within the Synchronous Area. If such a technical installation were to trip, this could cause Instantaneous Frequency Deviations outside of the Maximum Instantaneous Frequency Deviation. Such a situation would be outside of the control of the TSO, unless the amount of production or consumption of such a facility could somehow be kept within certain limits.

It is good to remember that the quality of the System Frequency is not only a function of the grid and the operation of the grid, but also of all the demand and generation connected to the grid. It is the interplay between both TSOs and grid users, both through markets and operations, that eventually leads to a specific System Frequency quality.

4.4 Frequency Restoration Control Error Target Parameters

While Frequency Quality Target Parameters define objectives for System Frequency from the perspective of Frequency Containment, the Frequency Restoration Control Error Target

Parameters are directed at the quality of the Frequency Restoration Process and is therefore related to Time To Recover Frequency and Time To Restore Frequency.

Especially in the case of Synchronous Areas with several LFC Blocks (as it is the case for CE) System Frequency quality will depend on the combined behaviour of all LFC Blocks and the sum of the respective Frequency Restoration Control Errors (in CE, historically known as Area Control Error, ACE).

Therefore, in order to comply with the Frequency Quality Target Parameters of the Synchronous Area each LFC Block has to maintain the Frequency Restoration Control Error (historically known as ACE in CE) as close as possible to zero. Obviously, the same requirement also holds for a LFC Block which is equivalent to the Synchronous Area and, consequently, the Frequency Restoration Control Error is equivalent to the Frequency Deviation (as it is the case for GB, IRE and NE). For this reason, the NC LFCR defines Frequency Restoration Control Error Target Parameters which provide a harmonised consideration of the Frequency Restoration Process as part of the quality framework while taking the physical differences between the Synchronous Areas into account.

4.4.1 Frequency Restoration Control Error Range

There are two Frequency Restoration Control Error Ranges, Level 1 and Level 2, which represents different ranges.

Under assumption that the Frequency Restoration Control Errors can be represented as stochastically independent normal distributions, there is a fixed relationship between the standard deviation of the Frequency Restoration Control Error of each LFC Block and the standard deviation of the convolution of the control errors of all LFC Blocks of the Synchronous Area which can be calculated as

$$\sigma_{ACE_i} = \sigma_{\Delta f} * \sqrt{K_T * K_i}$$

with

- K_T as the total network power-frequency characteristic of the whole Synchronous Area and
- K_i as the network power-frequency characteristic or K-factor of the LFC Block *i* calculated with its Initial FCR Obligation.

For CE the methodology for definition of the Frequency Restoration Control Error Target Range requires that these values should be proportional to the square root of the Initial FCR Obligation of a LFC Block which is based on the size of its generation and load. This assures a fair share of the quality targets between the LFC Blocks.

Just for illustration purposes table 3 shows FRCE Level 1 Ranges with the range of the largest LFC Block (arbitrarily) set to 100 MW:

Table 3: Fictional example for Level 1 FRCE Ranges with respect to the K-Factor

	K_i (MW/Hz)	Level 1 FRCE (MW)
LFC Block A	300	100.00

LFC Block B	150	70.71
LFC Block C	100	57.74
LFC Block D	75	50.00
LFC Block E	30	31.62
TOTAL	655	

Since the Level 1 and Level 2 Frequency Restoration Control Error Range of the LFC Blocks depend on the total K-Factor of the Synchronous Area and the contribution coefficients of each LFC Block, the respective values shall be revised yearly in order to take into account the possible changes in the LFC Blocks or in the Synchronous Area.

For NE the Synchronous Area corresponds to one LFC Block and LFC Areas and, therefore, the Frequency Restoration Control Error is based on System Frequency. However, due to internal congestions, NE consists of several Monitoring Areas and the respective Active Power balance is taken into account for activation of FRR and RR. Therefore, in spite of NE being one LFC Block and LFC Area, the quality model for the Frequency Restoration Process is conceptually related to the quality model of CE. For this reason the NC LFCR defines a fully harmonised methodology for CE and NE.

In contrary to CE and NE, GB and IRE are the Synchronous Areas which are operated as one LFC Block and LFC Area by only one TSO. For this reason, the Frequency Restoration Control Error is not only based on, but fully equivalent to the Frequency Deviation. This fact is reflected in Frequency Quality Defining Parameters which correspond to the Frequency Restoration Process. Therefore, the Level 1 and Level 2 Frequency Restoration Control Error Ranges can be directly linked to the Frequency Ranges within Time to Restore Frequency and the Frequency Recovery Range:

- Level 1 Frequency Restoration Control Error Range: ±200 mHz;
- Level 2 Frequency Restoration Control Error Range: ±500 mHz.

4.4.2 Time outside the Target Ranges

The time outside the Frequency Restoration Control Error Ranges is defined by setting a maximum number to the Time To Restore Frequency intervals in which the respective average Frequency Restoration Control Error is outside of the Level 1 and Level 2 ranges.

For CE and NE the time outside the Level 1 Frequency Restoration Control Error Range shall be equal to 30 % or 10512 intervals in a year. Under assumption that the 15 minutes average of the Frequency Restoration Control Error can be represented as a normal distribution the Level 1 value is equivalent to its standard deviation (the value 30 % is an approximation for the exact value of 31.73 %). The respective value for the time outside of Level 2 is set to 5 % or 1752 intervals in a year (the value 5 % is an approximation for the exact value of 4.55 %). The Level 2 range can be considered as twice the standard deviation of the average Frequency Restoration Control Error.

For GB and IRE, due to

- the relatively low inertia (especially in comparison to CE) leading to higher Frequency Deviations;
- higher rate of change of the System Frequency; and
- Time To Recover Frequency and Time To Restore Frequency parameters

the maximum number of time intervals outside of the Level 1 and Level 2 Frequency Restoration Control Error Ranges must be set to significantly lower values in comparison to CE and NE. The values for time outside the Level 1 range are set to 3 % for GB and 2 % for IRE. For the time outside the Level 2 range 1 % is used for both GB and IRE.

4.5 EVALUATION OF FREQUENCY QUALITY

The process of evaluation of the Frequency Quality Evaluation Criteria is named Criteria Application Process and consists of the gathering of the data needed for the evaluation (specified in Article 22) and the calculation of the different values for each Frequency Quality Evaluation Criteria.

The Frequency Quality Evaluation Criteria includes a series of global reliability indicators regarding both

- the System Frequency quality in order to monitor the overall behaviour of Load-Frequency Control; and
- the Frequency Restoration Control Error quality in order to monitor the Load-Frequency Control of LFC Blocks and constituent LFC Areas.

Some of the Frequency Quality Evaluation Criteria will be used to compare with the values of the Frequency Quality Target Parameters and Frequency Restoration Control Error Target Parameters. However, in order to have a closer supervision of the Frequency Quality Evaluation Criteria the evaluation period is defined to be of one month whereas the Frequency Quality Target Parameters and Frequency Restoration Control Error Target Parameters are evaluated on a yearly basis.

This section gives an overview on the Frequency Quality Evaluation Criteria which are defined by the NC LFCR and briefly explains the calculation of the criteria from available measurement data.

4.5.1 COLLECTION AND CALCULATION OF THE INPUT DATA

In order to perform the evaluation the necessary data must be collected and prepared. The collection of the necessary data and calculation of these Frequency Quality Evaluation Criteria is coordinated by the Synchronous Area Monitor and the LFC Block Monitor.

Three main data sets need to be gathered:

- Instantaneous Frequency Data per Synchronous Area;
- Instantaneous Frequency Deviation Data per Synchronous Area; and
- Instantaneous FRCE Data for each LFC Block.

The measurement period for the instantaneous data shall be smaller or equal to 1 second in the case of Instantaneous Frequency Data, which is a value small enough to capture all of the large-scale dynamic behaviour of the System Frequency of the Synchronous Area, but large enough so that the yearly sum of samples is still manageable with widely available analysis tools.

The measurement period of the Instantaneous FRCE Data shall be shorter than or equal to 10 seconds as the dynamics of the Frequency Restoration Process are significantly slower (15 to 20 minutes) compared to the dynamics of the Frequency Containment Process and high measurement resolution does not provide additional information.

It is important to ensure that the collected data is accurate and thus the minimum accuracy is set to 1 mHz in accordance with Article 22(3).

The resampling for 1 minute and Time To Restore Frequency Data shall be calculated using the arithmetic mean:

$$m_j = \frac{1}{n} * \sum_{1}^{n} a_i$$

with

- m_j as arithmetic mean for a sample interval j;
- n as the number of instantaneous data measurements in a sample interval;
- a_i as the instantaneous data measurement for a sample interval i;

In order to allow the TSOs of a Synchronous Area to exchange and use the collected data a Synchronous Area Agreement shall be done to set the file format of the sampling data and the means of exchange of the data between the TSOs.

4.5.2 Frequency Quality Evaluation Criteria

Table 4 gives an overview over the criteria applied to Instantaneous Frequency Deviation Data:

- The main criteria which evaluate the statistical properties of System Frequency are fully harmonised (mean value, standard deviation, percentiles and time outside of ranges).
- The criteria which assess the dynamic behaviour of the System Frequency after a bigger disturbance are harmonised with respect to the methodology (and partially harmonised with respect to the used parameters) in order to take the significant differences of the Synchronous Areas with respect to typical System Frequency gradients (inertia) into account.

Table 4: Criteria Applied to Instantaneous Frequency Deviation Data

Criteria Applied for Instantaneous Frequency Deviation	CE	GB	IRE	NE
Basic statistical analysis of System Frequency:				
mean value	yes	yes	yes	yes
standard deviation	yes	yes	yes	yes
1st, 5th, 10th, 90th, 95th, 99th percentile	yes	yes	yes	yes
Total time outside ranges:				
Standard Frequency Range	yes	yes	yes	yes
Maximum Instantaneous Frequency Deviation	yes	yes	yes	yes
Dynamic behaviour of System Frequency after bigger disturbances – number of events for which				
Number of events for which 200 % of the Standard Frequency Deviation in one direction was exceeded an the Instantaneous Frequency Deviation did not return within Time To Restore Frequency to:				
50 % of the Standard Frequency Deviation	yes	no	no	yes
Frequency Restore Range	no	yes	yes	no
Number of events for which Frequency Recover Ranger was exceeded an the Instantaneous Frequency Deviation did not return to Frequency Recover Range within Time To Recover Frequency	n.a.	yes	yes	n.a.

Accordingly, table 5 provides the respective criteria defined by the NC LFCR for the evaluation of the LFC Block behaviour. As the dynamics of the FRP is related to the Time To Restore Frequency (i.e. 15 or 20 minutes) the evaluation of Instantaneous Data does not provide additional information on the performance of Load-Frequency Control, therefore the respective data is sampled for CE and NE in order to evaluate the statistical trends of the control performance. For the evaluation of dynamic behaviour after a bigger disturbance 1 minute samples are used in order to eliminate measurement noise and to capture the control performance at the same time.

As GB and IRE are operated by one TSO and the FRCE correspond to the System Frequency and the dynamic behaviour is volatile, the statistical analysis with sampled values provides no additional information with respect to the evaluations resulting from table 4.

Therefore, it can be stated that the evaluation of the statistical values is harmonised fully while the evaluation of the dynamic behaviour (due to the different gradients of the System Frequency) are harmonised with respect to the methodology.

Table 5: Criteria Applied to sampled FRCE data

Criteria Applied for FRCE	CE	GB	IRE	NE
Basic statistical analysis of the FRCE sampled with Time To Restore Frequency:				
mean value	yes	n.a.	n.a.	yes
standard deviation	yes	n.a.	n.a.	yes
1st, 5th, 10th, 90th, 95th, 99th percentile	yes	n.a.	n.a.	yes
Total time (number of time intervals) outside ranges for the FRCE sampled with Time To Restore Frequency				
Level 1 FRCE (separate for positive and negative)	yes	no	no	yes
Level 2 FRCE (separate for positive and negative)	yes	no	no	yes
Dynamic behaviour of the FRCE after bigger disturbances based on 1min-sampled data - number of events (separate for positive and negative):				
FRCE exceeded the Maximum Steady-State Frequency Deviation and the was not returned to 10 % of the Maximum Steady-State Frequency Deviation within the Time to Restore Frequency	no	yes	yes	no
FRCE exceeded 60 % of the FRR Capacity and was not returned to 15 % of the FRR Capacity within the Time to Restore Frequency	yes	no	no	yes

Besides the criteria listed in the tables, the NC LFCR requires the TSOs of CE and NE to assess the risk of FCR exhaustion based a probabilistic dimensioning approach (the approach is described in section 7.1).

4.5.3 Mean Value

The mean value of the Instantaneous Frequency Data for the Synchronous Area is calculated by the following formula:

$$f_{Av} = \frac{1}{n} * \sum_{1}^{n} f_i$$

The mean value is widely used indicator of control performance and should be almost exactly 50 Hz if combined over three month and proportional to electrical time deviation. The mean value of Instantaneous Frequency Data can be used to detect deterministic tendencies of imbalances (short or long) but also different control qualities into upward and downward direction.

The same evaluation can be performed for the sampled data of FRCE.

4.5.4 Standard Deviation and Percentiles

The standard deviation of the Instantaneous Frequency Data for the Synchronous Area is calculated by the following formula:

$$\sigma_f = \sqrt{\frac{1}{n} * \sum_{1}^{n} (f_i - f_{Av})^2}$$

The standard deviation of the control error (Frequency Deviation) is used in combination with the mean value in order to assess the volatility of the disturbances and of the control process itself.

In addition to the standard deviation, the NC LFCR requires the calculation of 1st, 5th, 10th, 90th, 95th and 99th percentile to get additional information about the extreme Frequency Deviations. The percentiles are calculated by

- ordering the Instantaneous Frequency Deviation Data (f_i-f_n) from the lowest to the highest value in the first step; and
- obtaining the Frequency Deviation that is higher than the amount of values given by the percentile of the Instantaneous Frequency.

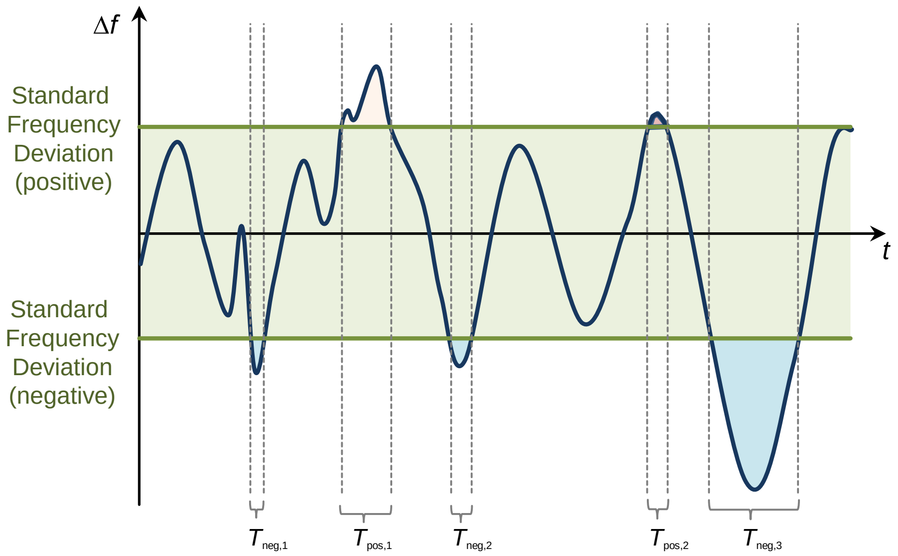
For instance, if the 5th percentile is equal to -130 mHz, it means that 5 % of the Instantaneous Frequency Deviation Data are less or equal to -130 mHz and 95 % of the data is greater than -130 mHz.

The same evaluation can be performed for the sampled data of FRCE.

4.5.5 Time outside of Ranges

The NC LFCR defines several evaluation criteria which assess the maintenance of System Frequency or FRCE within a defined range (Standard Frequency Range, Maximum Instantaneous Frequency Deviation, Level 1 FRCE Range and Level 2 FRCE Range).

The calculation of the respective criteria is demonstrated in figure 6 using the example for the time outside the Standard Frequency Range: Whenever the Instantaneous Frequency Deviation Data is below or above the Standard Frequency Deviation the respective time intervals are counted (separate for positive and negative direction) and summed up. The result provides to numbers (e.g. expressed in minutes) for an evaluation period.



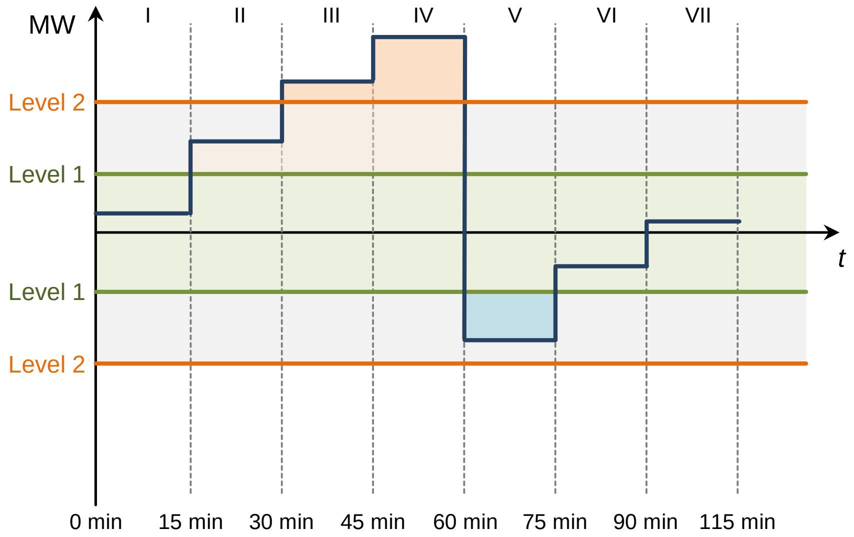
Time outside the range in positive direction $= T_{pos,1} + T_{pos,2}$

Time outside the range in negative direction $= T_{neg,1} + T_{neg,2} + T_{neg,3}$

Figure 6: Time outside the Standard Frequency Range

For the FRCE Level 1 Range and FRCE Level 2 Range evaluations which are based on the values sampled by Time To Restore Frequency, the respective criteria provide number of samples in which the FRCE exceeds Level 1 or Level 2. The calculation is illustrated by the example given in figure 7 which would lead following results

- The example considers seven discrete time intervals.
- Level 1 was exceeded three times in positive direction (in intervals II, III, and IV) and once in negative direction (interval V).
- Level 2 was exceeded twice in positive direction (in intervals III and IV) and not exceeded in negative direction.



Criteria	I	II	III	IV	V	VI	VII	**Sum**
Outside Level 1 (positive)	0	1	1	1	0	0	0	3
Outside Level 2 (negative)	0	0	1	1	0	0	0	2
Outside Level 1 (negative)	0	0	0	0	1	0	0	1
Outside Level 2 (negative)	0	0	0	0	0	0	0	0

Figure 7: Time outside FRCE Level 1 Range and Level 2 Range

4.5.6 EVALUATION OF THE DYNAMIC BEHAVIOUR

Several criteria evaluate the dynamic behaviour of the System Frequency or the FRCE when a bigger disturbance causes the respective parameter to exceed a range (e.g. Standard Frequency Range) and must be returned to the lower range. The respective criteria can be seen as different forms of “trumpet curve” evaluation.

Figure 8 illustrates the evaluation by a simple example for the FRCE. The FRCE exceeds after a bigger disturbance the 60 % of FRR Capacity. This initiates the counting of time till the FRCE is below 15 % of FRR Capacity. If the resulting time is greater than the Time To Restore Frequency the event is counted.

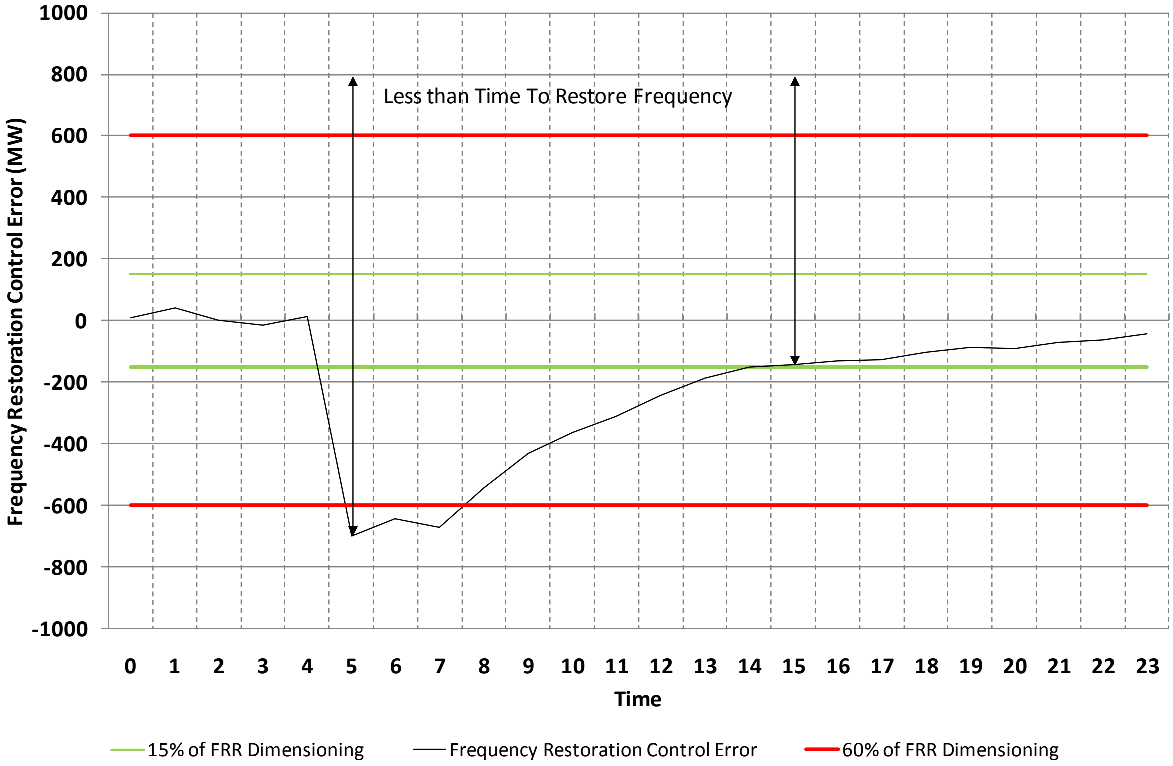


Figure 8: Evaluation of dynamic behaviour

4.6 Ramping Restrictions on Active Power Output

In the last few years practically all large Synchronous Areas of ENTSO-E have been facing an increase in number and size of frequency deviations, especially at hour changes, during the ramping periods both in the morning and in the evening periods. The origin of this frequency variations is not in the Disturbance / outage of generation or load or HVDC interconnector, as these are frequently observed mainly within a time scope of minutes centred on the change of the hour, corresponding with the standardised time interval for cross border (international) schedule changes. Since deviations around the change of the hour are much more frequent and severe, all these frequency deviations not associated with generation trips will be referred to as deterministic Frequency Deviations.*[10]*

These determinist deviations, which can even exceed 150 mHz, cause a generation-load unbalance as well and are compensated by the deployment of some FCR and lead to frequency deviations. Until the FRR replaces the deployed FCR, some FCR will be already in use and therefore not ready to counteract the effects of a generation or load trip. The larger that these frequency deviations are and the more time it takes to counteract them the more probable it is that a large generation or load incident occurs when some FCR are deployed due to deterministic deviations. This may lead to an event that will cause the frequency to surpass the established limits within the design of the system and possibly to under-frequency load-shedding.

The number and length of the frequency deviations must therefore be monitored which is the aim of the Frequency Quality Target Parameters. On the other hand, in order to limit and reduce these deviations, it is also necessary to impose some restrictions to the root causes. One of the major causes of these deterministic deviations is the ramping for active power output of generating units or HVDC links.

4.6.1 Restrictions at Synchronous Area Level

In order to reduce the impact of the market induced imbalances on Synchronous Area level and therefore fulfil the Frequency Quality Target Parameters, is could be necessary to limit the Active Power output of HVDC interconnectors between Synchronous Areas on the change of the hour. These restrictions can be imposed by agreeing a unique maximum Ramp Rate or a unique Ramping Period applicable to all HVDC Interconnectors; and or a combined Maximum Rate for all HVDC Interconnectors of the Synchronous Area.

Due to the fact each Synchronous Areas has its own grid structure, inertia and load and generation behaviour, different maximum Ramp Rates or Periods can be established for each one, as market induced unbalance effects depend on all of these factors.

Furthermore, it is required that both sides of the HVDC connectors of different Synchronous Area have the same maximum Ramp Rates, so this value will be set by the minimum maximum Ramp Rates of both sides of the HVDC connector for each Synchronous Area or LFC Block based on the slowest regulated side of the HVDC.

4.6.2 Restrictions at LFC Block Level

It is possible that ramping rates of the generation and HVDC exceed the size of the reference incident and hence must be restricted.

In order to reduce the impact of the market induced imbalances on LFC Block level and therefore fulfil the Frequency Quality Target Parameters, is necessary to limit the Active Power output of HVDC interconnectors in the same Synchronous Areas on the change of the hour. These restrictions can be imposed be agreeing a unique maximum Ramp Rate or a unique Ramping Period applicable to all HVDC Interconnectors; and or a combined Maximum Rate for all HVDC Interconnectors of the Synchronous Area.

These restrictions can also be imposed to Power Generating Modules and Demand Units, by defining and coordinating Ramping Periods, maximum Ramp Rates, and individual ramping starting times.

Due to the fact that each LFC Block has its own grid structure, inertia and load and generation behaviour, different maximum Ramp Rates or Periods can be established for each one, as market induced unbalance effects depend on all of these factors.

On the other hand, is required that both sides of the HVDC connectors of different LFC Blocks have the same maximum Ramp Rates, otherwise, this would lead to disturbances in the connector, so this value will be set by the minimum maximum Ramp Rates of both sides of the HVDC connector for each LFC Block.

4.7 Mitigation Procedures

After the evaluation of the Frequency Quality Evaluation Criteria for a certain period, it may be determined that the values obtained are worse than the Frequency Quality Target Parameters or that of the Frequency Restoration Control Error Target Parameters. If such a situation arises, the relevant TSOs shall determine and where a change is required, address the root causes that have influenced the quality of System Frequency or of Frequency Restoration Control Error and propose to their respective NRAs the proposal to solve this deficiency.

As an example, figure 9 shows the evolution of Frequency Deviations in NE. Since the TSOs are able to use control processes and tools which are available, it might not be physically possible to fulfil the targets due to the imbalances out of the responsibility of the TSOs. As a reaction to the continuous evolution, NE introduced the automatic Frequency Restoration Process in 2013.

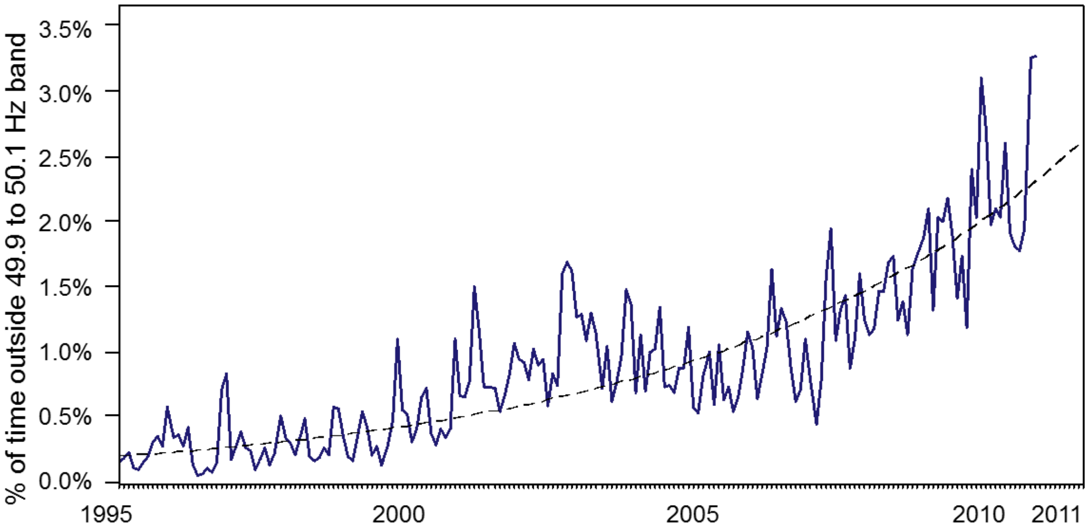


Figure 9: Evolution of Frequency Deviations in NE

Article 29 explores the possibilities that TSOs have to propose actions in order to mitigate the impact of any changes that could happen in the Synchronous Area such as deterministic Frequency Deviations or rapid changes in HVDC interconnectors.

This is especially important to minimize deterministic Frequency Deviations, which occur when changes of generating units/load do not happen simultaneously. E.g. power difference between the continuous ramp-wise physical load behaviour and discontinuous / step wise power generation behaviour (market-rule-based Schedule). These “market induced” effects depend to a large extent on the framework conditions of the respective market rules and have more or less regularly led to significant Frequency Deviations at the hour shift in CE and Northern Europe (figure 10 and figure 12).

Figure 10 shows the daily average value of System Frequency in CE for 2010 which is calculated by the arithmetical average of all System Frequency values of one year measured at the same time of day and shows the deterministic characteristic with respect to the daily patterns. It can be observed at 1:00, 5:00, 6:00, 7:00, 19:00, 20:00, 21:00 22:00, 23:00, 24:00 how there is a deterministic Frequency Deviation associated with the change of the hour. Furthermore, deterministic Frequency Deviations also arise due to large schedule steps at certain half hour shifts (12:30, 21:30 and 22:30).[10]

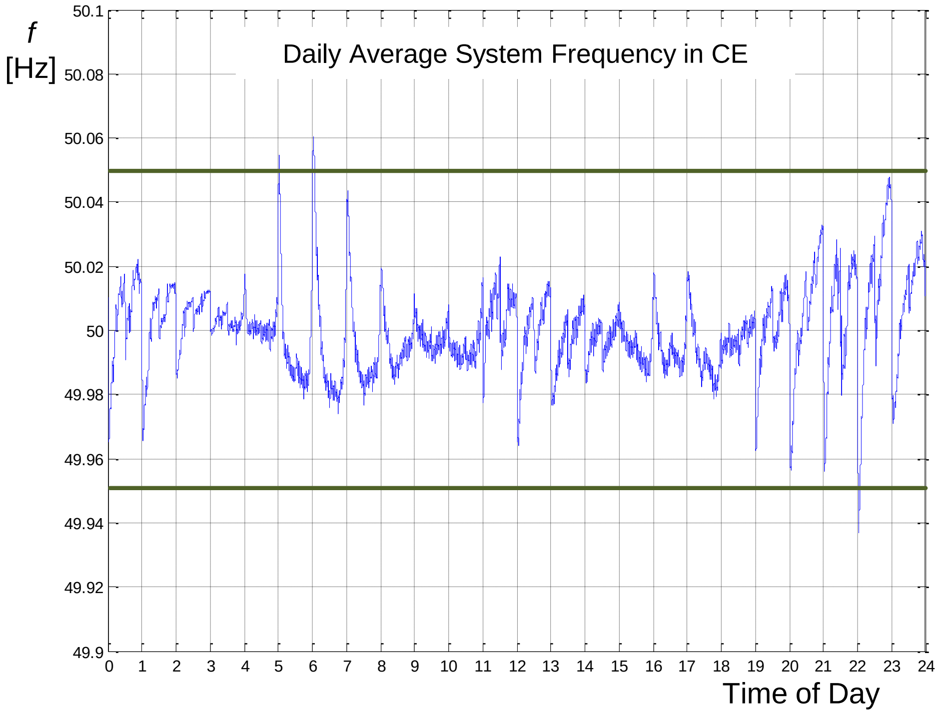


Figure 10: Daily average System Frequency in CE in 2010

Figure 11 shows the value of System Frequency Quality in NE for 2009 and 2010 in terms of minutes outside the band as a percentage of time for each hour to show the daily patterns. It can be observed at 4:00, 5:00, 6:00, 7:00, 19:00, 20:00, 21:00 22:00, how there is a deterministic Frequency Deviation associated with the change of the hour. In particular at 7:00, and 20:00 and 21:00 where the HVDC flows change significantly with CE Synchronous Area change significantly. Furthermore, deterministic Frequency Deviations also arise due to large schedule steps at certain half hour shifts (08:30, 16:30, 18:30 and 22:30).

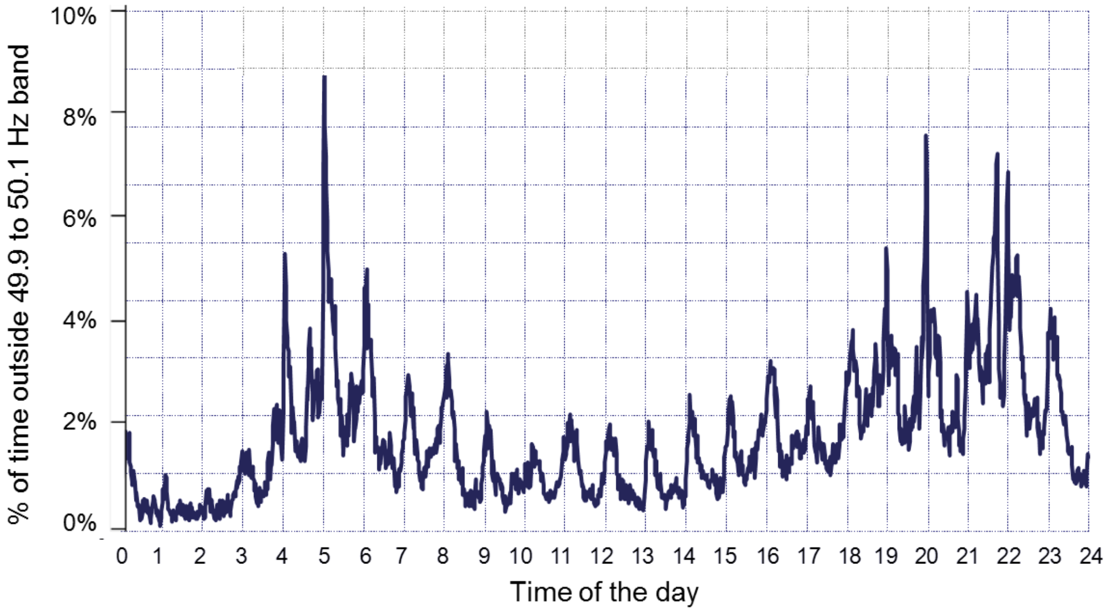


Figure 11: Daily occurrence of high average System Frequency Deviations in NE in 2009-2010

Figure 12 shows how the proportion of the extreme values of the Frequency Deviation are much more likely to happen in the hour shift, from minute 55 in the preceding hour to minute 5, than during the other minutes of the hour. This distribution of the proportion of extreme values can be compared to a SA like Baltic that does not suffer from deterministic Frequency Deviations.

Since the Load-Frequency Control is based on either actions taken after an observed disturbance or on forecasted disturbances, its capability to prevent deterministic Frequency Deviations is physically limited. Therefore, the mitigation procedures defined in the NC LFCR may be the only adequate tool to achieve the stability of System Frequency and Operational Security.

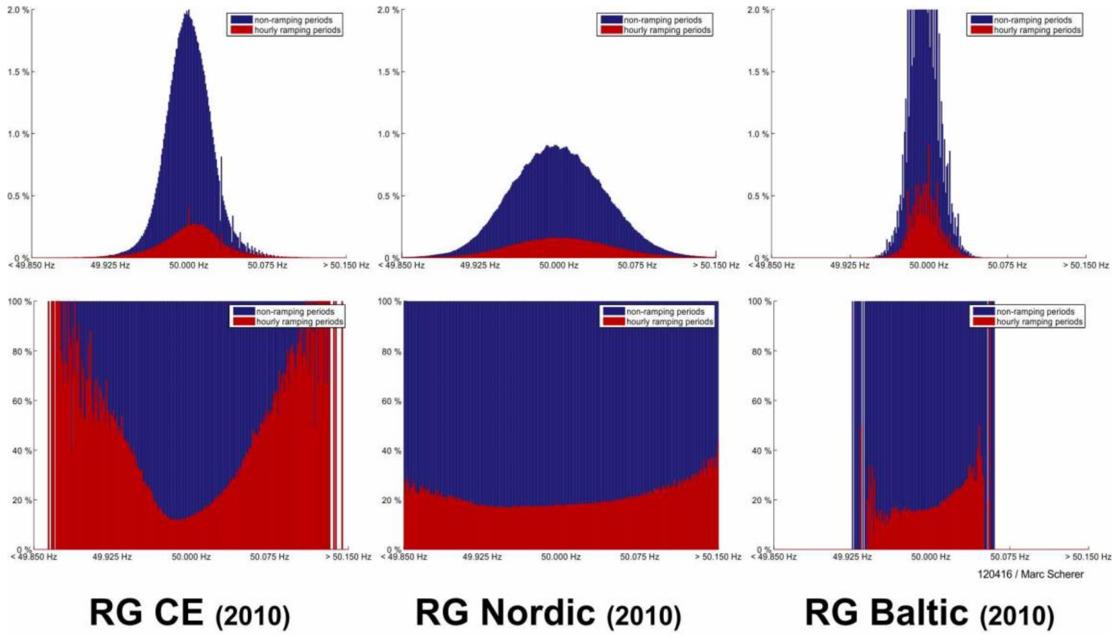


Figure 12: Distribution of Frequency Deviations in CE, Northern Europe (Nordic) and Baltic for 2010 distinguishing all minutes and the minutes around the change of the hour.

Due to the physical and technical limitations of Load-Frequency Control (and control systems in general) control targets for System Frequency or FRCE can be reached with a given amount of Active Power Reserves and activation speed only for imbalances which were considered ex-ante. This physical limitation is taken into account by stating that the TSOs shall make best endeavours to fulfil the targets.

4.8 Added Value of the NC LFCR

The NC LFCR provides added value by defining a consistent and harmonised framework for System Frequency Quality. The benefits provided by the NC LFCR include:

- full harmonisation of terminology on the European level;
- clear definitions of quality targets for a Synchronous Area and single TSOs;
- full harmonisation of quality evaluation, where applicable for Synchronous Areas with significantly different inertia;
- partial harmonisation of quality evaluation where physical boundary conditions of the Synchronous Area must be respected;
- introduction of FCR exhaustion risk assessment; and
- involvement of stakeholder and NRAs in the process of changing the quality targets.

5 LOAD-FREQUENCY CONTROL PRINCIPLES

The NC LFCR explicitly formulates an obligation for TSOs to take over responsibility for Load-Frequency Control processes and the respective quality. At the same time the NC LFCR has to consider the fact that due to the physical properties of synchronously operated transmission systems, System Frequency is a common parameter of the whole Synchronous Area on all voltage levels. For this reason all TSOs operating in a Synchronous Area are obliged to cooperate and are also depending on cooperation in order to keep the System Frequency within acceptable ranges.

In order to organise the cooperation of TSOs in an efficient way and to ensure the Operational Security, the cooperation among TSOs requires a clear definition of responsibilities for Load-Frequency Control processes, organisation of Reserve availability and assignment of individual quality targets.

The NC LFCR tackles the definition of these responsibilities in a harmonised way for all Synchronous Areas by formulation of requirements for the Load-Frequency Control Structure which has to be implemented and operated in each Synchronous Area by all TSOs according to Article 30:

> *All TSOs of a Synchronous Area shall define in the Synchronous Area Operational Agreement the Load-Frequency Control Structure for the Synchronous Area. Each TSO is responsible for implementing and operating according to the Load-Frequency Control Structure of its Synchronous Area.*

The Load-Frequency Control-Structure includes control processes (Process Activation Structure) and geographical responsibilities (Process Responsibility Structure).

The Process Activation Structure defines:

- mandatory control processes which have to be implemented and operated by one or more TSOs in each Synchronous Area; and
- optional control processes which may be implemented and operated by the TSOs in each Synchronous Area.

Accordingly, the Process Responsibility Structure defines:

- obligations for TSOs to operate and apply control processes for the respective geographical areas (Monitoring Areas, LFC Areas, LFC Blocks and Synchronous Areas); and
- the responsibilities and obligations related to the control processes applied for geographical areas.

This chapter provides a common European framework for the Load-Frequency Control processes by setting technical requirements for the technical control structure and the according responsibilities of the TSOs:

- The first part of the chapter deals with the basic structure of Load-Frequency Control providing requirements for mandatory and optional control processes as well as different operational geographical area types (area hierarchy) with attached area process obligations.

- The second part of the chapter provides detailed requirements for the design, implementation and operation of the control processes.

5.1 Responsibility for Load-Frequency Control Processes

The framework of the Load-Frequency Control processes is based on the current best practices in power system operation and in control engineering in general:

- The Frequency Containment Process stabilizes the frequency after the disturbance at a steady-state value within the permissible Maximum Steady-State Frequency Deviation by a joint action of FCR within the whole Synchronous Area.
- The Frequency Restoration Process controls the frequency towards its Setpoint value by activation of FRR and replaces the activated FCR. The Frequency Restoration Process is triggered by the disturbed LFC Area.
- The Reserve Replacement Process replaces the activated FRR and/or supports the FRR activation by activation of RR. For GB and IRE the Reserve Replacement Process replaces both, FCR and FRR. The Reserve Replacement Process is implemented by the disturbed LFC Area.

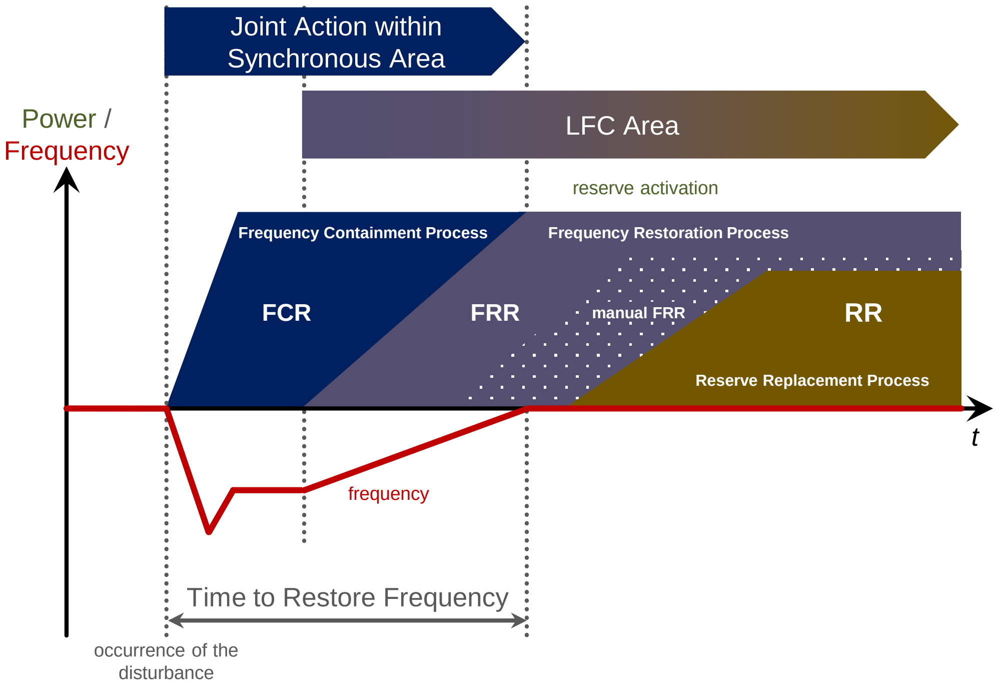


Figure 13: Dynamic hierarchy of Load-Frequency Control processes (under assumption that FCR is fully replaced by FRR)

While implementation details (e.g. activation time frames) may differ between Synchronous Areas, the structure provided in the NC is harmonized on the European level.

As stated above, the operation of Load-Frequency Control processes are attached to operational areas. The area hierarchy is illustrated in figure 14. Each Synchronous Area consists of one or more LFC Blocks, each LFC Block consists of one or more LFC Areas, each consists of one or more Monitoring Areas and each Monitoring Area consists of one or more Scheduling Areas.

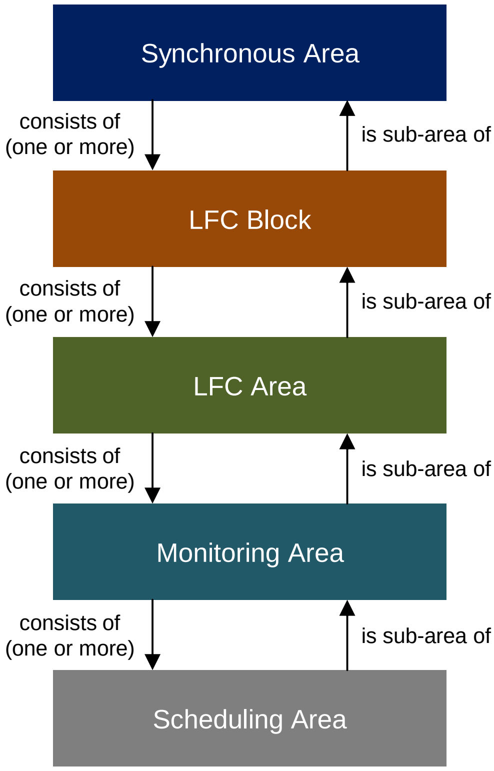


Figure 14: Types and hierarchy of geographical areas operated by TSOs

The different area types are necessary to define responsibilities of single TSOs in the common task of System Frequency quality allowing a harmonised approach for all Synchronous Areas. Table 6 summarizes the different area process obligations defined in NC LFCR.

For instance, a TSO operating an LFC Area has the obligations

- to collect and calculate the Schedules for the area;
- to measure and monitor the actual power interchange;
- to calculate (or measure) the Frequency Restoration Control Error; and
- to operate a Frequency Restoration Process

At the same time all TSOs operating LFC Areas within the same LFC Block have the obligation to cooperate with other TSOs of the LFC Block to fulfil the area process obligations, i.e. to fulfil the Frequency Restoration Quality Target Parameters. Also TSOs have to organise the availability of a sufficient amount of FRR and RR according to dimensioning criteria (where an LFC Block consists of more than one LFC Area the TSOs shall agree on individual Frequency Restoration Quality Target Parameters).

When an area, whether it is a Synchronous Area, a LFC Block, a LFC Area or a Monitoring Area, is operated by more than one TSO, the TSOs involved shall define their cooperation within a legally binding multi-party agreement (Article 32(7) – Article 32(11)). This agreement shall define responsibilities of each TSO with respect to the fulfilment of the area process obligations. For example, all TSOs of a Synchronous Area have to agree on issues related to the Frequency Containment Process, while all TSOs of the same LFC Block have to agree on issues related to the Frequency Restoration Process.

Table 6: Obligations related to areas

Obligations	Scheduling Area	Monitoring Area	LFC Area	LFC Block	Synchronous Area
Scheduling	MANDATORY	MANDATORY	MANDATORY	MANDATORY	MANDATORY
online calculation and monitoring of actual power interchange	NA	MANDATORY	MANDATORY	MANDATORY	MANDATORY
calculation and monitoring of the Frequency Restoration Error	NA	NA	MANDATORY	MANDATORY	MANDATORY
Frequency Restoration Process	NA	NA	MANDATORY	MANDATORY	MANDATORY
Frequency Restoration Quality Target Parameters	NA	NA	MANDATORY	MANDATORY	MANDATORY
FRR/RR Dimensioning	NA	NA	NA	MANDATORY	MANDATORY
Frequency Containment Process	NA	NA	NA	NA	MANDATORY
Frequency Quality Target and FCR Dimensioning	NA	NA	NA	NA	MANDATORY
Reserve Replacement Process	NA	NA	OPTIONAL	NA	NA
Imbalance Netting Process	NA	NA	OPTIONAL	NA	NA
Cross-Border FRR Activation Process	NA	NA	OPTIONAL	NA	NA
Cross-Border RR Activation Process	NA	NA	OPTIONAL	NA	NA
Time Control Process	NA	NA	NA	NA	OPTIONAL
Mandatory cooperation to fulfil obligations of	Monitoring Area	LFC Area	LFC Block	Synchronous Area	NA

It has to be noted that some processes are defined as optional but can be mandatory for some TSOs if implementing them is a precondition for the fulfilment of the respective area process obligations: for example, if a TSO receives FRR from providers located in a different LFC Area a Cross-Border FRR Activation Process is necessary and therefore mandatory for the involved TSOs. Some other conditions that cause optional processes to become mandatory are explained in section 6.4.

Furthermore, a control process which is optional from the technical perspective of NC LFCR may become mandatory according to provisions of another Network Code, such as NC EB.

The added value of different area types and area process obligations formulated in the NC LFCR can be summarized as follows:

- The different area process obligations provide clear responsibilities for TSOs operating different areas.
- The methodology of defining the area hierarchy and area process obligations is flexible and allows for a European harmonization of terms and procedures regardless of different physical characteristics of each Synchronous Area (see figure 15). At the same time the best practices for the different Synchronous Areas within Europe are respected.
- The methodology allows flexibility with respect to changing requirements while providing strict principles.

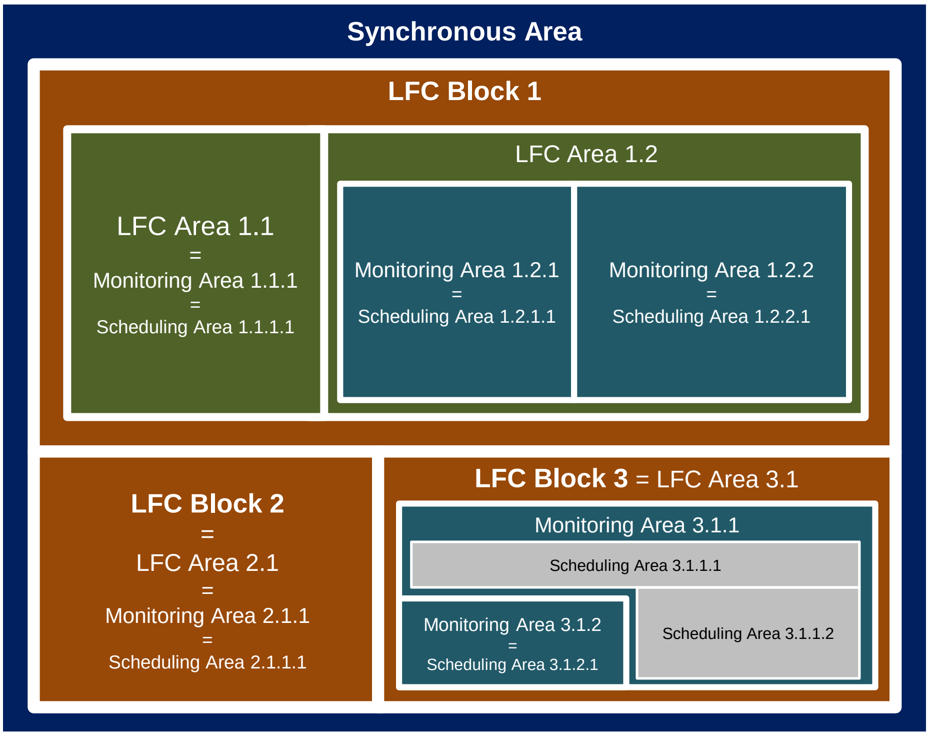


Figure 15: Fictional example for configuration of areas

Although the area hierarchies will be redefined during the implementation of NC LFCR and could differ from the current situation, differing area hierarchies are currently implemented in different Synchronous Areas (figure 16). For example:

- GB, IRE and NE currently consist of exactly one LFC Block and LFC Area.
- CE currently consists of many LFC Blocks as shown in figure 16. Most of these LFC Blocks consist of one LFC Area, such as LFC Blocks operated by RTE, ELIA, TenneT NL, and Terna but there are also several examples of LFC Blocks that consist of more than one LFC Area such as
  - the LFC Block of Spain and Portugal with LFC Areas operated by REN and REE; and
  - the German LFC Block with four LFC Areas operated by 50HzT, Amprion, TenneT Germany (including Energinet.dk) and TransnetBW.

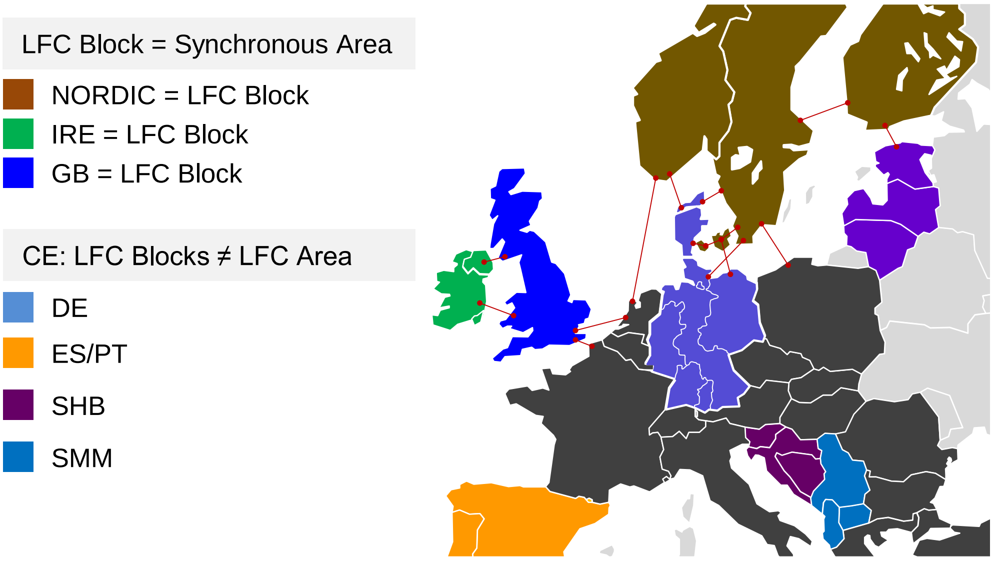


Figure 16: Synchronous Areas, LFC Blocks and LFC Areas

5.2 Frequency Containment Process

The FCR is activated by a joint action of FCR Providing Units and FCR Providing Groups within the whole Synchronous Area with respect to the Frequency Deviation.

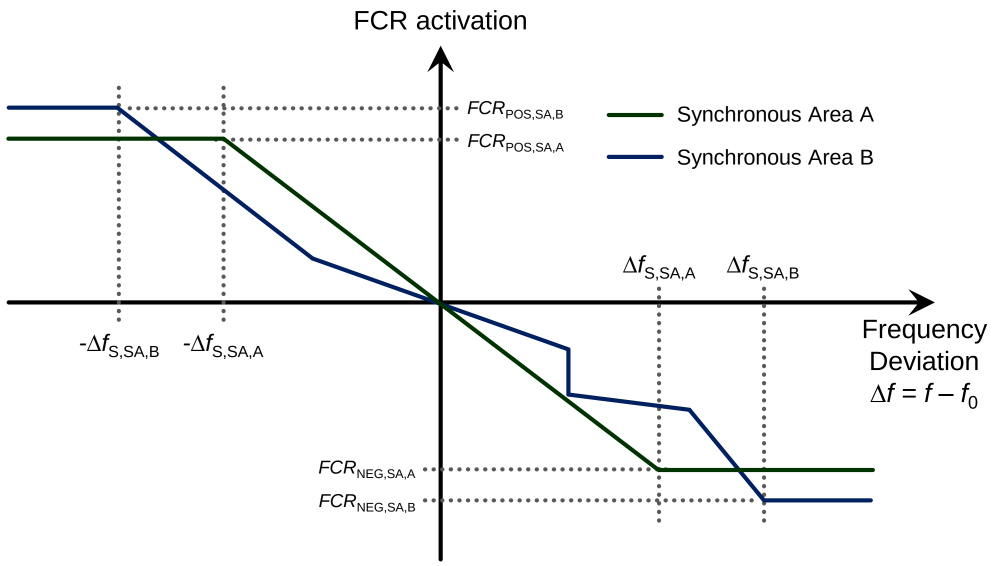
Depending on the best practices for a Synchronous Area the activation requirements for single FCR Providing Units and FCR Providing Groups may differ, nonetheless, the overall behaviour shall follow two principles which are illustrated in figure 17:

- The overall FCR activation is characterised by a monotonically decreasing function of the Frequency Deviation.
- The total FCR capacity shall be activated at the maximum steady-state frequency deviation.

It is very important to keep in mind that the respective requirement stated in Article 33(2) of the NC LFCR does not apply to a single FCR Providing Unit or FCR Providing Group but reflects the overall FCR response of the Synchronous Area.

The NC LFCR provides a European harmonisation of Frequency Containment Process design while allowing the necessary flexibility for different Synchronous Areas and types of FCR Providers. For example, NE has two FCR responses one for disturbances occurring outside the Standard Frequency Range where full FCR activation is achieved in 30s and one for imbalance inside the Standard Frequency Range were the FCR Full activation is currently defined as 120 to 180 s. In GB and IRE there are different types of FCR activation in different System Frequency ranges.

In particular, the NC LFCR allows FCR provision by Demand Units through triggering of frequency relays with different activation ranges.



$\Delta f_{S,SA1}$	–	maximum steady-state frequency deviation in Synchronous Area A
$\Delta f_{S,SA2}$	–	maximum steady-state frequency deviation in Synchronous Area B
$FCR_{POS,SA,A}$, $FCR_{NEG,SA,A}$	–	total positive/negative FCR capacity in Synchronous Area A
$FCR_{POS,SA,B}$, $FCR_{NEG,SA,B}$	–	total positive/negative FCR capacity in Synchronous Area B

Figure 17: Example for the design of total FCR response in a two Synchronous Areas

5.3 FREQUENCY RESTORATION AND RESERVE REPLACEMENT PROCESSES

The Frequency Restoration Process is designed to control the Frequency Restoration Control Error towards zero by activation of manual and automated FRR within Time to Restore Frequency. In this way, the frequency is controlled to its Setpoint value and the activated FCR are replaced. The Reserve Replacement Process replaces or supports the Frequency Restoration Process. In contrary to the Frequency Containment Process the respective Setpoints for FRR and RR activation are calculated by the TSOs operating the LFC Area.

Figure 18 shows the implementation of the Frequency Restoration and Reserve Replacement Process from perspective of a LFC Area as a general control scheme.

Where a Synchronous Area contains more than one LFC Area the Frequency Restoration Control Error (P_{err}) or Area Control Error (ACE) is calculated from the deviation between the scheduled and actual power interchange of a LFC Area (including Virtual Tie-Lines if any) corrected by the frequency bias (K-Factor of the LFC Area multiplied by the Frequency Deviation).

Otherwise the Frequency Restoration Control Error is based solely on Frequency Deviation, the control schemes for GB, IRE and NE can be represented by choosing

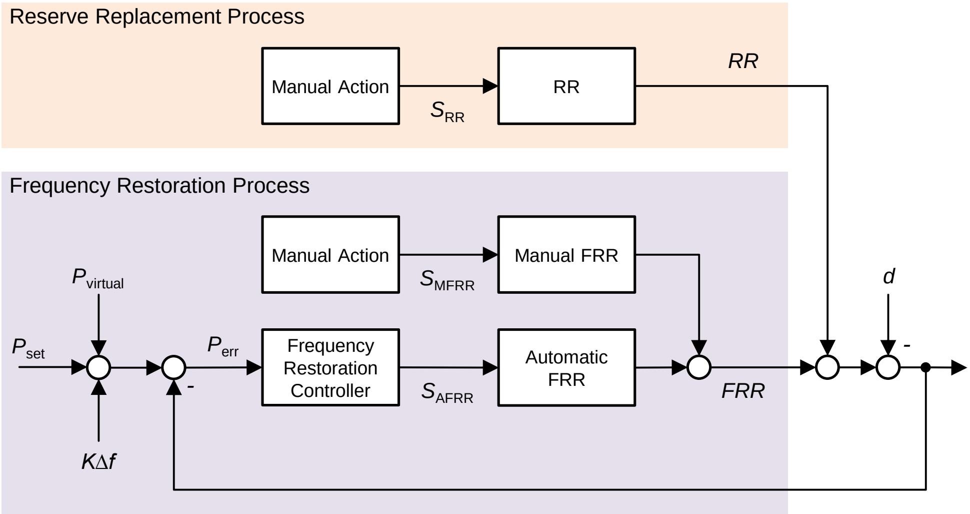
- $P_{set}= P_{virtual}$=0; and
- K=1 (as there is only one LFC Area)

The Setpoint value for FRR activation can be determined manually by the operator (feed-forward control) and / or in an automated way (feed-back control). The latter requires a Frequency Restoration Controller with proportional-integral behaviour implemented in the control system of the TSO.

The Replacement Reserve Process is implemented by manual action. The sum of activated FRR and RR adjust the power balance to its Setpoint value.

It is worth noticing that despite the similarity from control point of view, manual FRR activation and RR activation lead to different control performances due to different activation time frames.

Although the Frequency Restoration Process is mandatory, it is up to the TSO to decide upon the necessity of having only automatic or manual FRR or a combination of both. Furthermore the Reserve Replacement Process is not mandatory



P_{set}	–	scheduled power balance (positive for export and zero if the LFC Area corresponds to the Synchronous Area)
d	–	deviation from scheduled power balance (positive for deficit)
$K\Delta f$	–	frequency bias
$P_{virtual}$	–	power exchange over Virtual Tie-Lines (positive for export, not applicable if the LFC Area corresponds to the Synchronous Area)
P_{err}	–	Frequency Restoration Control Error
S_{AFRR}	–	Setpoint value for automated FRR activation
S_{MFRR}	–	Setpoint value for manual FRR activation
S_{RR}	–	Setpoint value for RR activation

Figure 18: Frequency Restoration Process and Reserve Replacement Process

The added value provided by the NC LFCR is the harmonization of terms and methodology for the design and implementation of the Frequency Restoration and Reserve Replacement Processes on the European level while allowing the necessary flexibility for different Synchronous Areas. Furthermore, by explicitly considering Virtual Tie-Lines as part of the Frequency Restoration Control Error cross-border processes are also included in Frequency Restoration.

5.4 Time Control Process

At the Synchronous Area level, the electrical system operation is based on Active Power control with the aim of maintaining continuously the equilibrium between consumption and generation. In this process, the global parameter controlled is the system frequency meaning the number of times that the repeated event (voltage wave cycle) occurs per unit time (1 second). Whichever is the adopted control process structure for the repeated phenomena (frequency or time of voltage wave cycle) the performance for a long term period is the deviation of the electrical time from a time reference. In this sense, the final evaluation and control refers at the same values: time as integration of period of voltage wave and time etalon as Universal Time Control (UTC). The integration of frequency / voltage time period is considered the electrical time or the synchronous time (the electrical time of the Synchronous Area). If the nominal frequency is 50 Hz, the voltage time period represents 1/50 Hz^{-1} or 20 ms.

A long term integration of nominal frequency is absolute interval of astronomical time, while that same time integration of real voltage time period (frequency) has a different value. This difference serves in the majorities of Synchronous Area as a performance indicator for the real time operating of the structure of control and maintaining the system power equilibrium.

During the normal operation, the average system frequency usually deviates from its nominal value. These deviations can be the consequences of different events which occur in system operation and typically controlled by the Frequency Restoration Process. Even in normal operation due to the fact that the Frequency Deviation cannot be controlled exactly to zero, especially in presence of imbalances pointing in one direction. Thus, electrical time deviations cannot be avoided and have to be controlled.

The electrical time control is both a final frequency control process as long-term frequency stability and a service given by the TSOs of a Synchronous Area to its users which have internal processes based on electrical time.

In this last category are devices which dependent on electrical time:

- meters of electrical energy which calculate different tariff periods in a precise time measurement based on frequency as input value,
- power plants control energy;
- power quality devices;
- old industry's processes;
- customers in textile industries and
- synchronous motors.

Moreover, significant electrical time deviations are proportional to the energy amount delivered due to FCR activation.

For CE, due to these facts that

- the Time Control Process is implemented in CE and NE for decades;
- contributes to the overall System Frequency quality; and
- currently unforeseeable consequences of non-implementation

the NC LFCR explicitly requires its implementation. Other Synchronous Areas with different operational backgrounds, faster dynamics of the System Frequency and higher Standard Frequency Ranges shall have the right to implement the Time Control Process.

5.5 Operational Procedures

The requirements defined in Article 42 reflect the fact that the real-time operation of Load-Frequency Control may face additional challenges as unexpected high imbalances resulting in persistent Frequency Deviations. In order to provide an ability to react on unforeseen challenges the NC LFCR provides rules and gives the TSOs additional tools if certain predefined limits are reached. The rules are formalised as common rules for the operation of the Load-Frequency Control at Synchronous Area level and LFC Block level.

The NC LFCR defines

- two states, the Normal State and the Alert State, for the whole Synchronous Area based on Frequency Deviation;
- thresholds for a LFC Block based on the FRCE and FRR or RR exhaustion.

Whereas the Normal State is to be seen as a situation with usual Frequency Deviations, the Alert State constitutes situations in which the operation of the Synchronous Area faces extraordinary challenges. Thus the NC LFCR obliges the TSOs of a Synchronous Area to cooperate with other TSOs to take appropriate measures. A similar approach is defined for the LFC Block operation.

Depending on the thresholds the NC LFCR gives the TSOs opportunities or obliges the TSOs to take additional measures including instructions for Power Generating Modules to change the Active Power Output if necessary for Operational Security.

5.6 Technical Infrastructure

The technical infrastructure which is needed to perform Load-Frequency Control is critical for Operational Security. The detailed requirements shall be defined at the Synchronous Area level.

5.7 Added Value of the NC LFCR

The NC LFCR provides an added value by defining a consistent and harmonised framework for System Frequency Quality. The benefits provided by the NC LFCR include:

- full harmonisation of terminology on the European level;
- clear definitions of responsibilities based on obligations related to operational areas;
- introduction of cross-border Load-Frequency Control Processes which allow cross-border activation of Reserve Capacity and therefore a cost-optimisation of balancing energy;
- involvement of NRAs.

6 Cross-Border Load-Frequency Control Processes

While section 5.3 describes the FRP and RRP under assumption that the Active Power Reserves are instructed by the same TSO that operates the LFC Area which the reserves are connected to, the NC LFCR also enables cross-border reserve activation and Imbalance Netting.

The present chapter describes the respective requirements and concepts of

- Imbalance Netting;
- the Reserve Connecting TSO and the Reserve Instructing TSO;
- cross-border activation of reserves.

6.1 Imbalance Netting Process

The Imbalance Netting Process is designed to reduce the amount of simultaneous and counteracting FRR activation of different participating and adjacent LFC Areas by Imbalance Netting Power exchange. The Imbalance Netting Process is applicable between LFC Areas which are part of one or more LFC Blocks within one Synchronous Area or between LFC Areas of different Synchronous Areas. Where there is only one Frequency Restoration Process in a Synchronous Area and the Frequency Restoration Control Error is based on Frequency Deviation (e.g. IRE, GB or NE), the Imbalance Netting Process is implemented implicitly in the control error calculation.

Figure 19 shows the basic principle of the Imbalance Netting Process: The participating TSOs calculate in real time the demand for FRR activation based on the power balance of the LFC Area. This value represents the total amount of FRR needed to reduce the Frequency Restoration Control Error to zero (as required in Article 36(5), the Imbalance Netting Power Interchange shall not exceed this value). In the second step these values are transmitted to an algorithm which nets the single FRR demands and calculates the Imbalance Netting Power Interchange for each participating LFC Area. Where the participating LFC Areas are located in the same Synchronous Area the Imbalance Netting Power Interchange is implemented by a Virtual Tie-Line. The term Virtual Tie-Line is used for a real-time control signal which is exchanged between two LFC Areas for adjustment of ACE.

The Imbalance Netting Power Interchange can also be implemented by adjusting the Active Power flow over one or more HVDC interconnectors.

Figure 20 shows the integration of the Imbalance Netting Process into the Frequency Restoration Process from the perspective of one LFC Area based on the general structure illustrated in figure 19 (for easier understanding the Reserve Replacement Process is neglected in this figure).

The FRR demand is calculated from the sum of the actual Frequency Restoration Control Error minus the Imbalance Netting Power Interchange and the already activated automated FRR. In other words, the FRR demand corresponds to the automated part of the ACE Open Loop (manual FRR and Replacement Reserves are not considered in this calculation).

The Imbalance Netting Power Interchange is considered as part of the Frequency Restoration Control Error (Virtual Tie-Line or by adjustment of physical Active Power flow over HVDC Interconnectors).

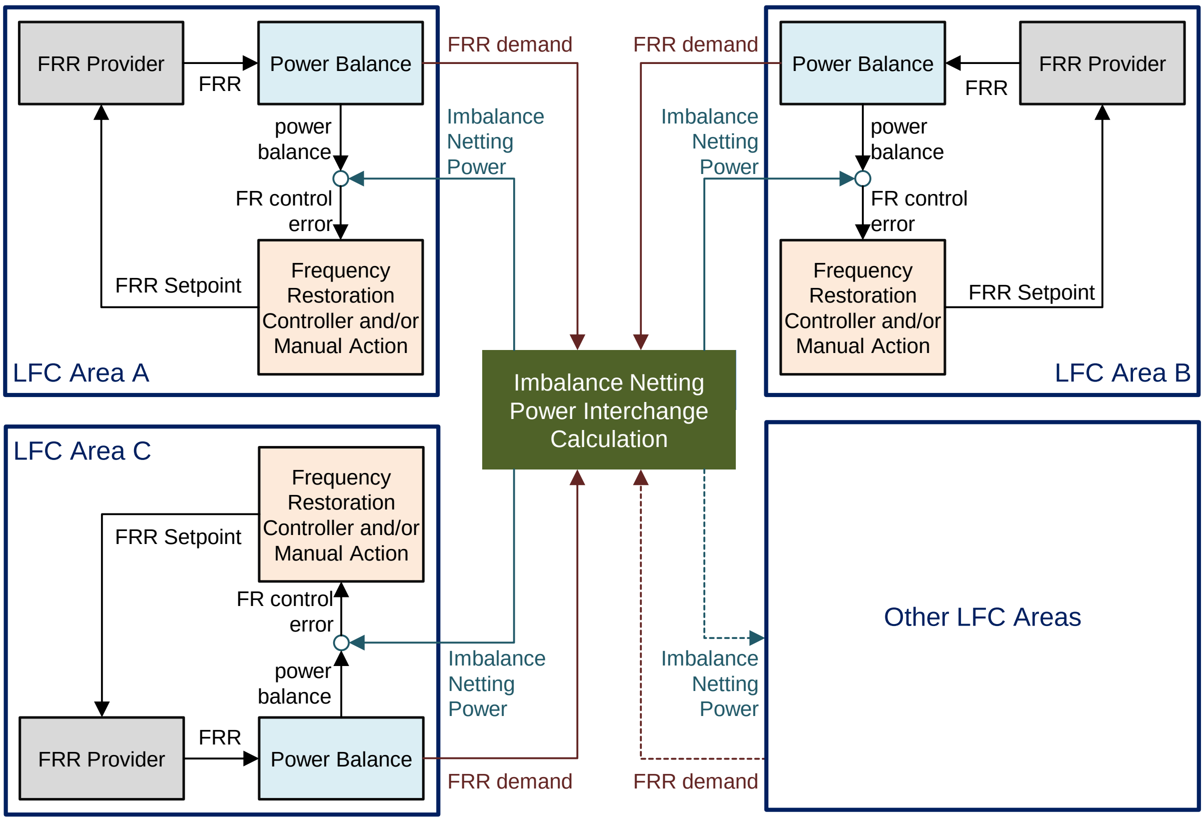


Figure 19: Imbalance Netting Process – basic principle

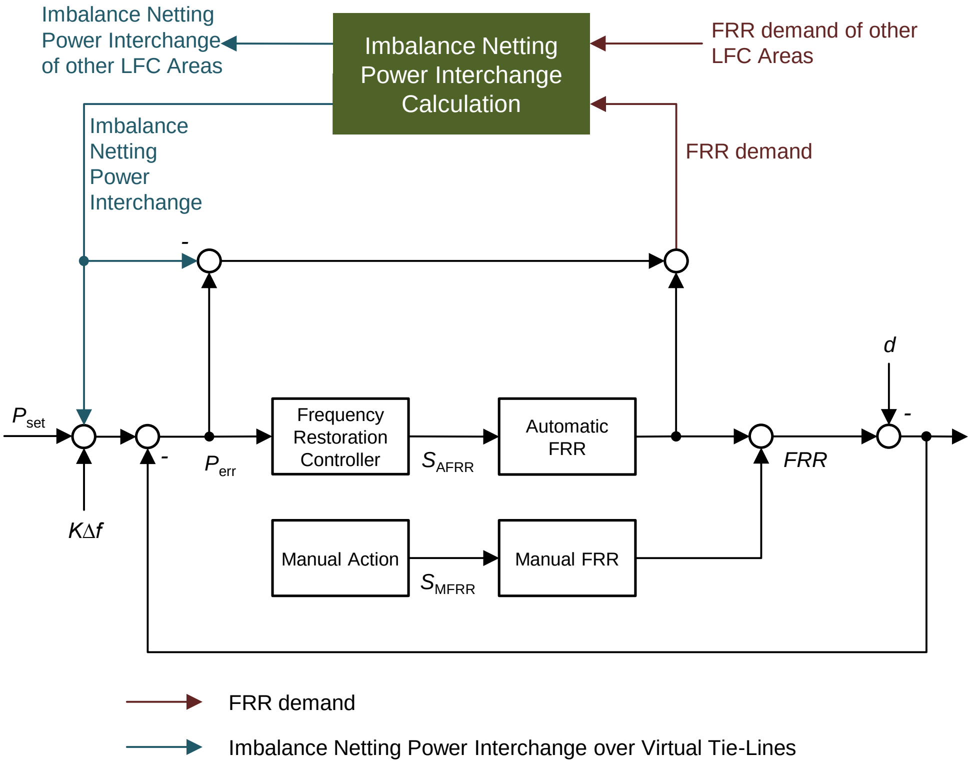


Figure 20: Integration of Imbalance Netting Process into the Frequency Restoration Process

6.2 Reserve Connecting and Reserve Instructing TSO

The roles Reserve Connecting TSO and Reserve Instructing TSO describe two main technical aspects of the relationship between a TSO and a Reserve Providing Unit or a Reserve Providing Group. The terms Reserve Providing Unit and Reserve Providing Group are explained in detail in section 8, for the following explanations it is sufficient to understand that the Reserve Providing Unit and the Reserve Providing Groups are technical installations which provide Active Power Reserves.

The Reserve Connecting TSO is operating the Monitoring Area which the Reserve Providing Unit or the Reserve Providing Group is physically connected to (according to the area hierarchy, a Monitoring Area can correspond to an LFC Area, LFC Block and even a Synchronous Area).

In contrary to the Reserve Connecting TSO which is defined for FCR, FRR and RR, the role of the Reserve Instructing TSO does not require a physical connection of a Reserve Providing Unit or a Reserve Providing Group. The respective relationship is purely operational: The Reserve Instructing TSO triggers the activation of FRR or RR by determining and communicating the according Setpoint value to the provider.

In most cases the Reserve Connecting TSO corresponds to the Reserve Instructing TSO. On the other hand, the Reserve Connecting TSO can appoint a different TSO as the Reserve Instructing TSO. This choice directly results in the implementation of Cross-Border FRR Activation (section 6.3.1) and Cross-Border RR Activation (section 6.3.2).

6.3 Cross-Border Activation of FRR and RR

The Cross-Border FRR Activation Process is designed to enable a TSO to perform the Frequency Restoration Process by activation of FRR connected to a different LFC Area (Frequency Restoration Power Interchange). The NC foresees two basic models for Cross-Border FRR Activation:

- The Reserve Connecting TSO is not the Reserve Instructing TSO (TSO-Provider-Activation).
- The Reserve Connecting TSO is the Reserve Instructing TSO (TSO-TSO-Activation). The Setpoint value for FRR activation is calculated by the Reserve Connecting TSO which is also the Reserve Instructing TSO.

It is important to notice that the NC LFCR describes only the technical implementation of cross-border activation and the respective roles of the TSOs. Both activation models are fully independent from procurement of Reserve Capacity.

6.3.1 Cross-Border FRR Activation Process

Figure 21 and figure 22 show the basic principle for the TSO-Provider-Activation of automated and manual FRR for two LFC Areas illustrated in figure 23 (for easier understanding the Reserve Replacement Process is neglected in this figure):

- The TSO of the LFC Area A is Reserve Connecting TSO for two FRR Providing Units inside his LFC Area (FRR Providing Unit A.1 for automatic FRR and FRR Providing Unit A.2 for manual FRR).

- The TSO of the LFC Area B is Reserve Connecting TSO for two FRR Providing Units inside his LFC Area (FRR Providing Unit B.1 for automatic FRR and FRR Providing Unit B.2 for manual FRR).
- Furthermore, the TSO of the LFC Area A is the Reserve Instructing TSO two FRR Providers connected in LFC Area B (FRR Providing Unit B.3 for automatic FRR and FRR Providing Unit B.4 for manual FRR).

The Setpoints for FRR activation by the FRR Providing Units B.3 and B.4 are calculated directly by the TSO of the LFC Area A (brown arrows). In this example the Frequency Restoration Control Errors are adjusted by subtracting the actual FRR activation is subtracted in LFC Area A and added in LFC Area B (based on the sign conventions in the control diagram) using Virtual Tie-Lines (figure 21). Depending on the arrangement the TSOS can also decide to exchange the required activation by Virtual Tie-Line instead of the actual measured FRR activation.

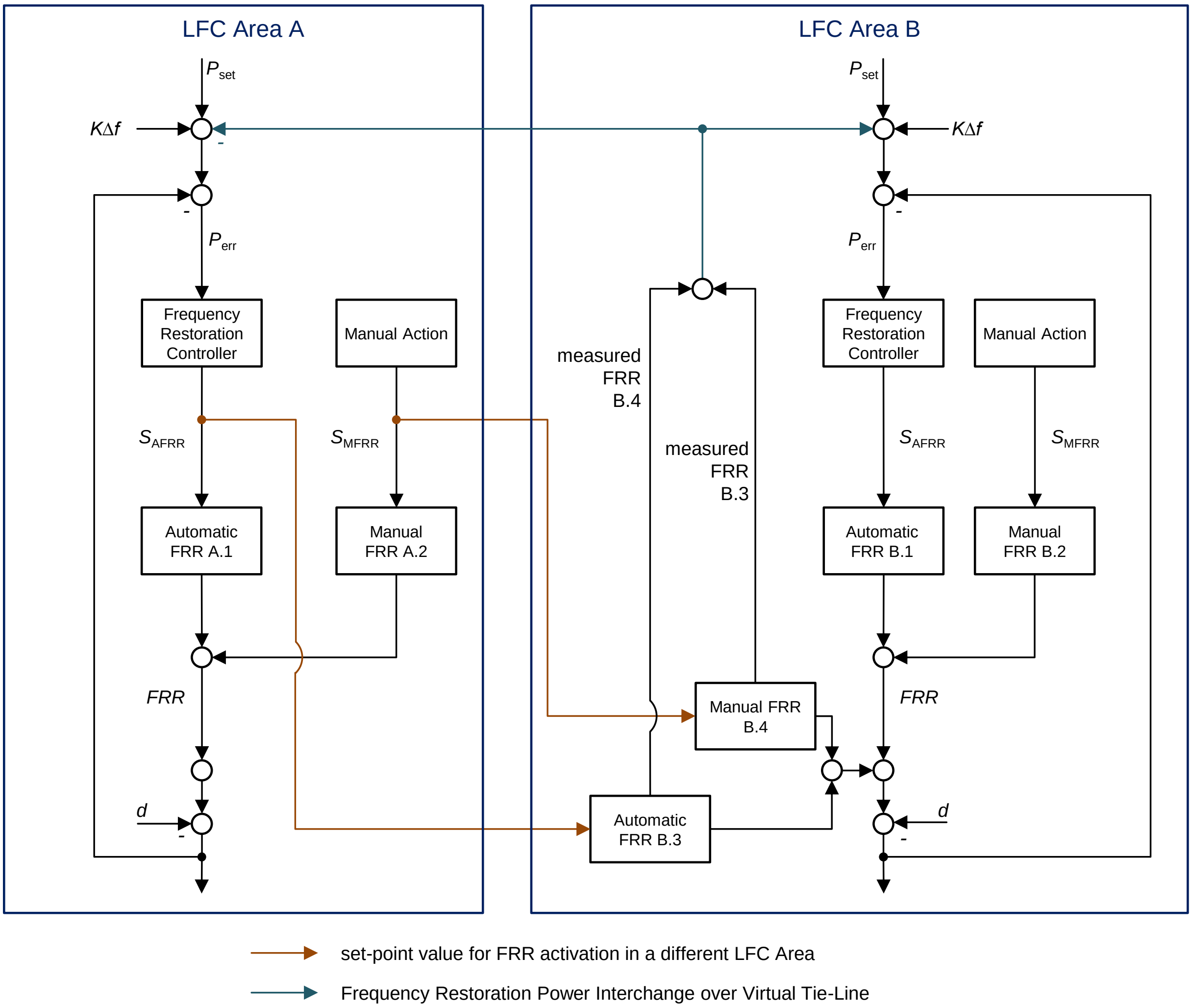


Figure 21: Example for TSO-Provider Activation with Virtual Tie-Lines

Figure 22 illustrates the same principle. The difference lies in the consideration of manual FRR activation which is implemented by the adjustment of the respective schedules for the LFC Areas (purple arrows).

The same principle can be applied for the Cross-Border FRR Activation Process using HVDC links. In this case, the Frequency Restoration Power is exchanged by adjusting the flows over one or more HVDC interconnectors.

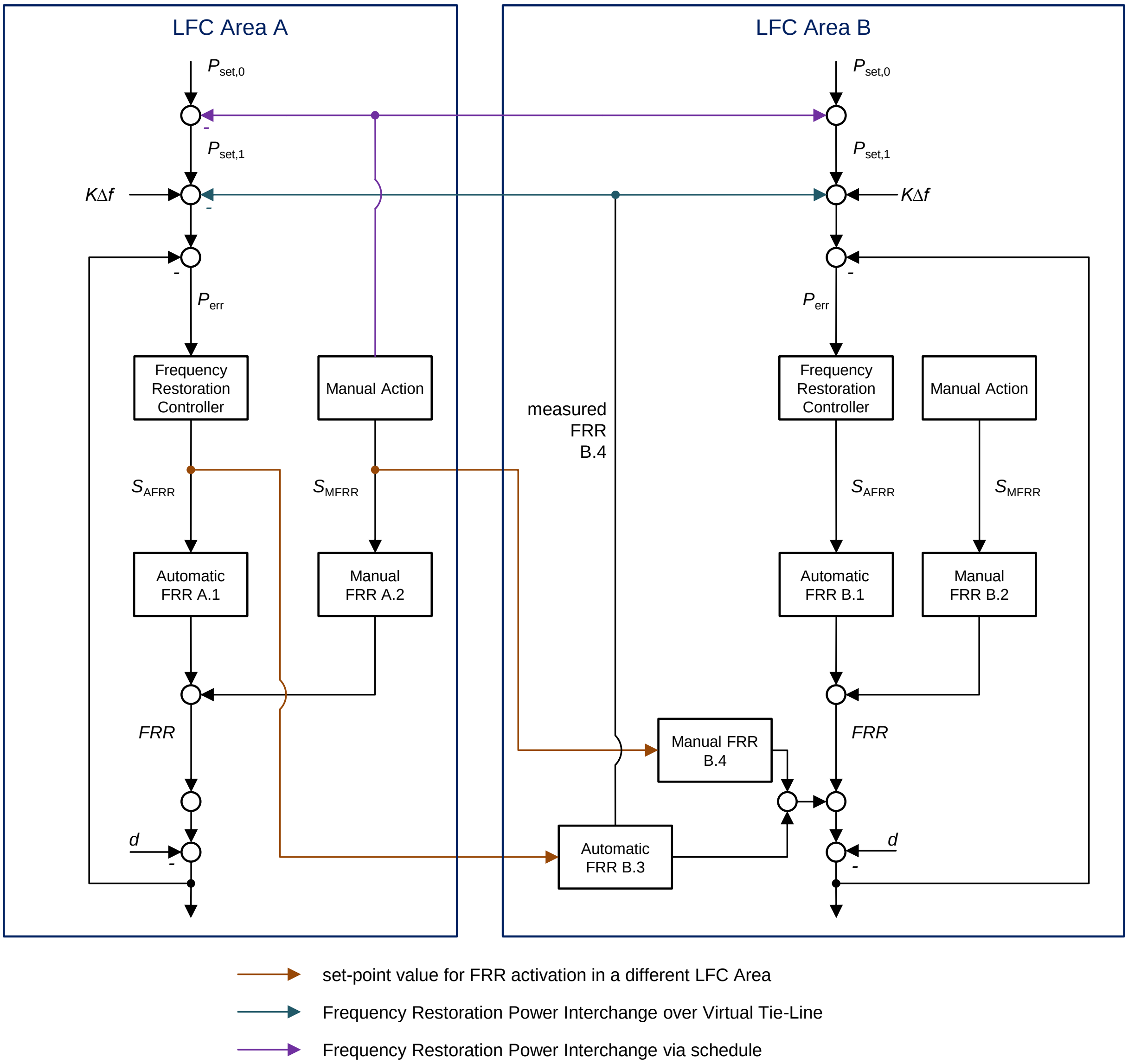


Figure 22: Example for TSO-Provider Activation with Virtual Tie-Lines and schedules

Figure 23 shows the TSO-TSO Activation for automatic FRR. The implementation from the control perspective is identical to the implementation of the Imbalance Netting Process (the implementations can be combined by using an according algorithm for the calculation of the power interchange): The Frequency Restoration Power Interchange for automated FRR is calculated based on the respective FRR demand values and implemented using Virtual Tie-Lines.

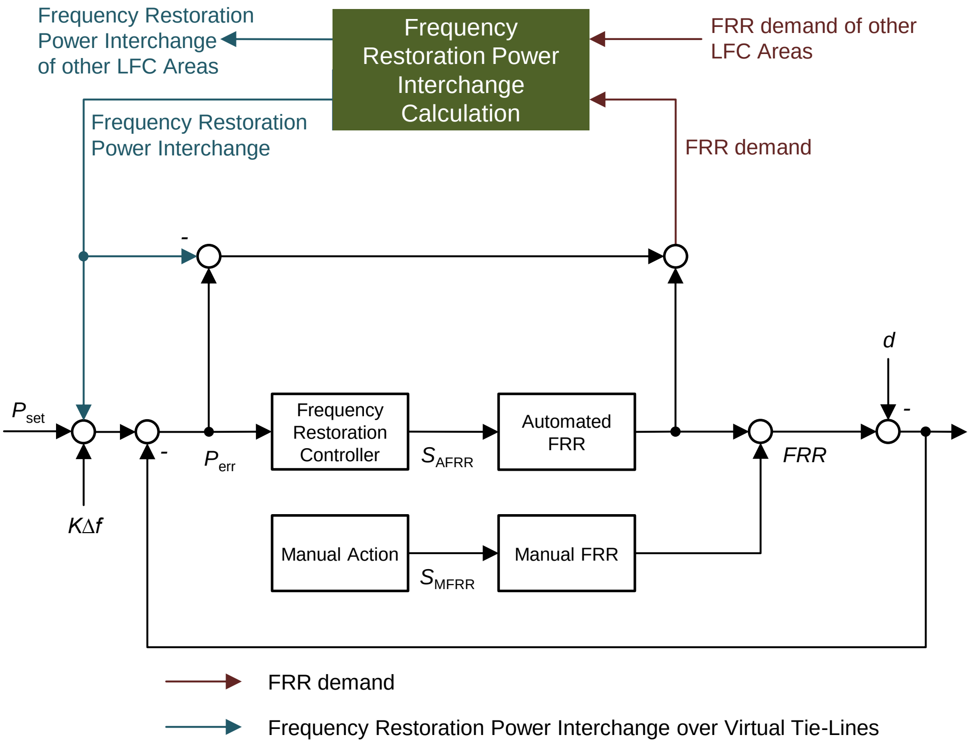


Figure 23: Example for TSO-TSO Activation for automated FRR with Virtual Tie-Lines

Figure 24 shows the TSO-TSO activation for manual FRR. The FRR demand is defined manually by a TSO and is transmitted to a respective algorithm which calculates the according schedules for the adjustment of the Frequency Restoration Control Errors and the FRR amounts which need to be manually activated by the TSOs. The TSO-TSO activation for manual FRR can also be implemented with a Virtual Tie-Line.

Again, the concept is transferable to Frequency Restoration Power Interchange over HVDC links.

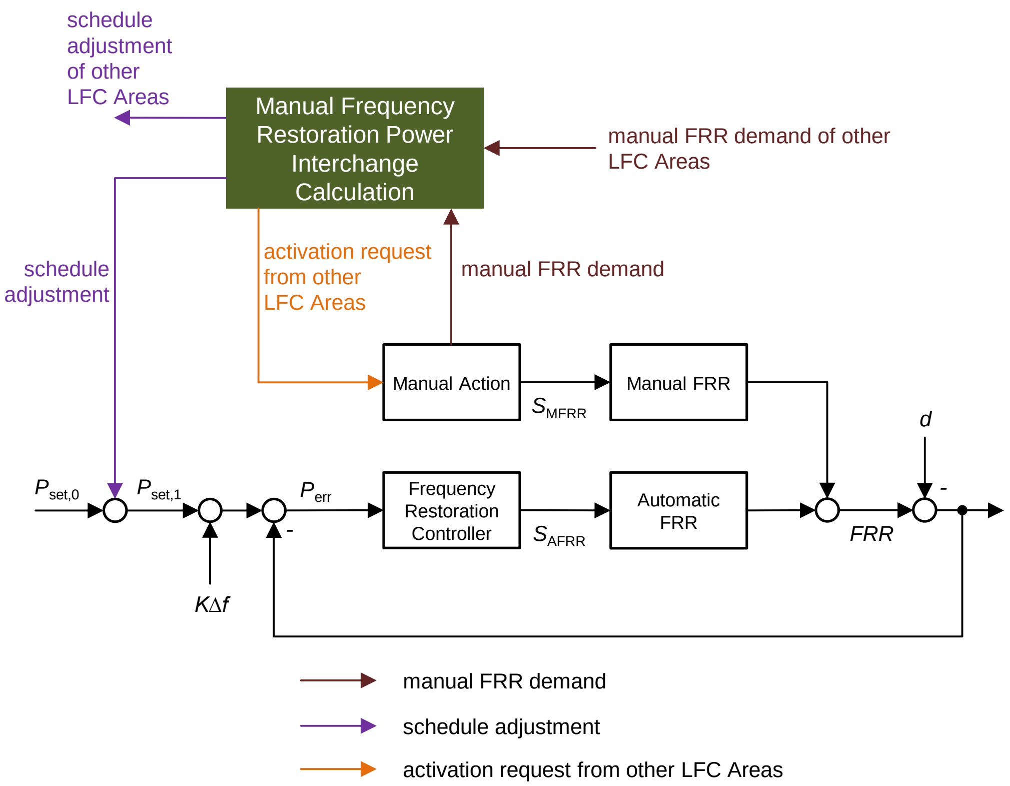


Figure 24: Example for TSO-TSO Activation for manual FRR with schedules

6.3.2 Cross-Border RR Activation Process

The Cross-Border RR Activation Process is designed to enable a TSO to perform the Reserve Replacement Process by activation of RR connected to a different LFC Area (Replacement Power Interchange).

While the requirements for the RR are different from FRR requirements, the implementation can follow the principles for manual FRR which are described in the previous section.

6.4 Operational Security Requirements

For Synchronous Areas consisting of more than one LFC Area the cross-border processes introduce additional interdependencies. Furthermore, the power interchange leads to additional load-flows through the Network which can depending on the direction relief or stress network elements. In order to ensure Operational Security the cross-border processes have to be implemented according to the requirements of the NC LFCR not only related to control schemes but also to operational procedures.

6.4.1 Load-Flows

The Imbalance Netting Power Interchange, Frequency Restoration Power Interchange or Reserve Replacement Power Interchange shall not result in load-flows which lead to violation of Operational Security Limits (cf. Article 36(6), Article 37(5) and Article 38(5)). In order to achieve that goal three components are necessary:

- The physical result in terms of load-flows caused by the Imbalance Netting Process or cross-border activation of FRR or RR must be made transparent in real-time operation in order to enable an understanding of the system state.

- A procedure to limit the interchange between LFC Areas in real-time must be implemented by the TSOs.
- The limits for the interchange must respect ex-ante planned values and observations of the real-time Operational Security Analysis.

6.4.2 Relationship with Dimensioning, Sharing and Exchange

The cross-border Load-Frequency Control processes which are optional in general (cf. table 6) become mandatory in case they are required to meet obligations related to fulfilment of the quality target as well as Exchange of Reserves or Sharing of Reserves (cf. chapter 9).

6.4.2.1 Imbalance Netting and Dimensioning

LFC Areas which form a LFC Block and apply a dimensioning procedure based on the disturbances of the whole LFC Block (i.e. netting the disturbances) are obliged to implement the Imbalance Netting Process, otherwise the basis for dimensioning would not correspond to the real-time operation resulting in higher demand for Reserve Capacity.

For the same reason, prior performing the Imbalance Netting Power Interchange with other LFC Blocks, the imbalances have to be netted inside the LFC Block in order to ensure that the full netting potential which was taken into account for dimensioning is used in real-time (Article 36(9)).

Where the Imbalance Netting Process is implemented for different LFC Blocks, the LFC Blocks shall ensure having sufficient reserves available to meet the respective FRCE Target Parameters regardless of Imbalance Netting Power Interchange (Article 36(11)). In particular, this means that if the Imbalance Netting Power Interchange is set to zero (e.g. due to congestions), each LFC Block shall have a sufficient amount of free Reserve Capacity to offset the disturbances without the Imbalance Netting Process.

In case the Imbalance Netting Process fails due to unforeseen restrictions of transmission capacity or problems with the communication infrastructure, the TSOs shall foresee according fall-back procedures (starting with detection and alarming of the operational staff and ending with limitation or deactivation of imbalance netting).

In GB, IRE and NE where the FRR process is currently based on a single LFC Area and on the frequency for the Synchronous Area, imbalances are netted physically which is an integral part of the control design.

6.4.2.2 Cross-Border Activation of Active Power Reserves, Sharing and Exchange

Although the Cross-Border Activation Processes do not imply Sharing or Exchange:

- the implementation of the Cross-Border FRR Activation Process is a precondition for sharing or exchange of FRR.
- the implementation of the Cross-Border RR Activation Process is a precondition for Sharing or Exchange of RR.

While Imbalance Netting between LFC Blocks can be switched off any time, the failure of Cross-Border FRR Activation or Cross-Border RR Activation due to communication errors or unforeseen restrictions of transmission capacity will lead to unavailability of Reserve

Capacity. The TSOs shall foresee according fall-back procedures to stop the cross-border processes and activate own FRR or RR.

6.4.3 NOTIFICATION

Since the cross-border processes cause additional load-flows which have to be monitored, the TSOs of the Synchronous Area must be notified in advance in case of optional implementation between LFC Blocks.

One or more TSOs which are not participating in this process may declare themselves as Affected TSOs based on the analysis of the Operational Security and require the provision of real-time values for power interchange between LFC Blocks. Furthermore, additional operational procedures can be implemented allowing the Affected TSOs setting a limitation of the interchange between the LFC Blocks in real-time.

6.4.4 GEOGRAPHICAL LIMITS

Since any cross-border activation process by itself does not result in a redistribution of FCR, FRR or RR and, if implemented between LFC Blocks, can be stopped at any time, there is no necessity to define fixed limits. The cross-border activation process relates to power, whereas the Exchange and Sharing of Reserves relate to Reserve Capacity. Therefore, only Exchange and the Sharing of Reserves lead to a redistribution of Reserve Capacity and require a cross-border activation process to be implemented but not vice-versa.

Nonetheless, the implementation has to take limited transmission capacity into account and organise the Interchange accordingly. This will implicitly lead to geographical limits on congested electrical borders. Furthermore, the extent of cooperation may be limited by the ability to implement operational procedures such as the fall-back mechanism. Therefore, the NC LFCR provides an additional possibility to operate the processes in several steps with different cooperation layers by implementation of an according optimisation algorithm.

6.5 ADDED VALUE OF THE NC LFCR

The added value provided by the NC LFCR lies in the harmonisation of terms, methodologies and procedures allowing the maximum degree of cooperation between TSOs on the European level while setting limits with respect to Operational Security.

7 DIMENSIONING OF RESERVES

Imbalances in an interconnected system can have different reasons. The following types of imbalances have to be considered (cf. figure 25):

- Disturbance or full outage of a Power Generating Module, HVDC interconnector or load - this type of imbalance is generally used for the calculation of the Reference Incident of a Synchronous Area or a Dimensioning Incident of a LFC Block;
- Continuous variation of load and generation – stochastic fast (noise) disturbance caused by fast variations of consumption and generation;
- Stochastic forecast errors – stochastic slow disturbances caused by forecast errors of load (e.g. due to untypical weather) and RES generation;
- Deterministic imbalances – a deterministic disturbance caused by the deviation between load and step-shaped schedules which reaches its peak at the time point with the highest change of schedules (mostly visible at the hour shift) and causes deterministic Frequency Deviations.
- Network splitting - these imbalances are generally out of the dimensioning of the Synchronous Area as they lead most likely to an emergency situation in a part or in all of the Synchronous Area, nonetheless the disturbance is taken into account by formulation of geographic constraints (cf. chapter 9).

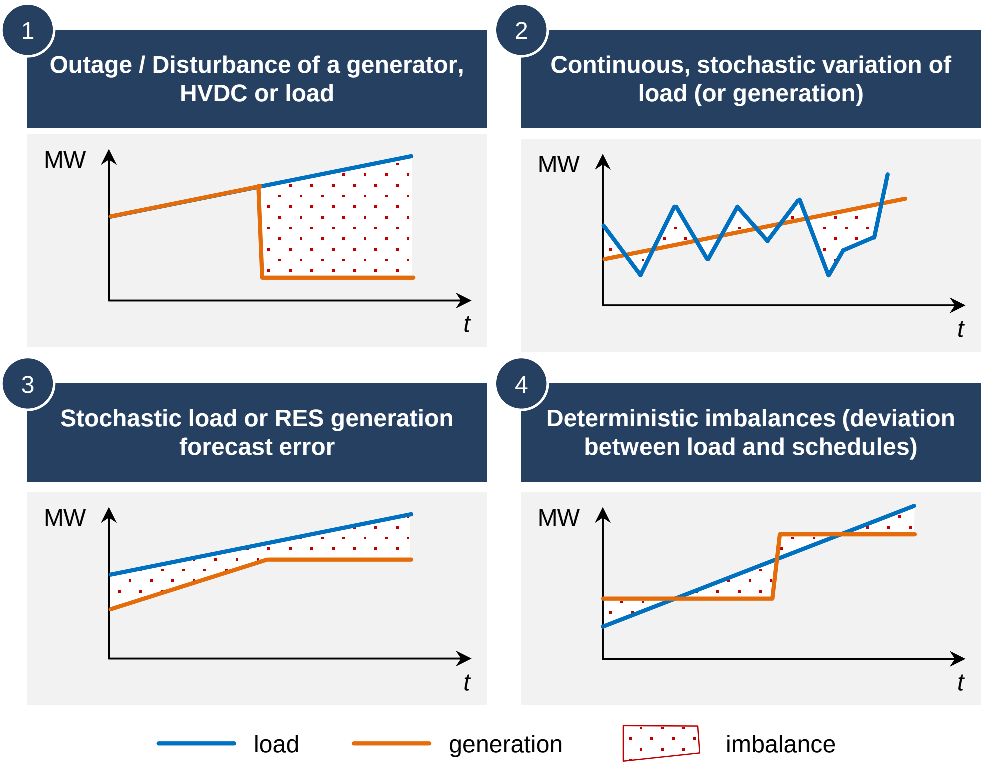


Figure 25: Simplified illustration of imbalance types

Dimensioning of Reserves in general has to take into account all of the corresponding effects and has to respect

- expected magnitude of the imbalance;
- expected duration of the imbalance;

- possible mutual dependency of imbalances; and
- imbalance gradients.

The present section treats the methodologies for dimensioning of FCR, FRR and RR which are activated in the framework of the Load-Frequency Control processes (cf. section 5) and necessary precondition to achieve the required System Frequency quality.

7.1 DIMENSIONING OF FCR

Any imbalance between generation and demand in a synchronously connected grid immediately results in a Frequency Deviation which continuously increases as long as the respective imbalance exists. Without any countermeasure the System Frequency would reach a critical value resulting in the collapse of the synchronously connected grid.

As described in section 5.2, the objective of the Frequency Containment Process is to maintain a balance between generation and consumption within the Synchronous Area and to stabilise the electrical system by means of the joint action of respectively equipped FCR Providing Units and FCR Providing Groups. Appropriate activation of FCR results consequently in stabilisation of the System Frequency at a stationary value after an imbalance in the time frame of seconds.

Whereas the stochastic imbalances and deterministic Frequency Deviations are transient and vanish after some minutes an imbalance caused by a disturbance, outage or even network splitting is persistent and has to be covered for a comparably longer period of time by an appropriate amount of FCR followed by activation of other reserves (see also explanations to FRR, RR).

With regards to persistent power imbalances, the disturbance/outage of generation or load or HVDC interconnector is considered. The basic dimensioning criterion of the FCR is to withstand the Reference Incident in the Synchronous Area by containing the System Frequency within the Maximum Frequency Deviation and stabilizing the System Frequency within the Maximum Steady-State Frequency Deviation.

The Reference Incident has to take into account the maximum expected instantaneous power deviation between generation and demand in the Synchronous Area and can be determined by taking into account at least

- the loss of the largest Power Generating Module;
- loss of a line section;
- loss of a bus bar;
- the loss of the largest load at one Connection Point; as well as
- a loss of a HVDC Interconnector

that may cause the biggest Active Power Imbalance with an N-1 failure.

Over the years, the N-1 criterion has proven itself to be the best practice solution for GB, IRE and NE and was therefore defined in Article 43(5).

In large systems such as CE, the amount of the generating capacity and demand leads to a larger probability of an additional loss of generation, consumption or in-feed before the system has recovered from a previous loss within the design window. Therefore, the dimensioning approach for CE requires a probabilistic assessment for the calculation of the Reference Incident. The performed probabilistic assessment of the Reference Incident calculation [6] confirmed the best-practice approach implemented in CE for decades: An N-2 criterion shall be used to determine the size of the Reference Incident which is currently equivalent to 3000 MW - two biggest nuclear power units of 1500 MW each. Furthermore, the Reference Incident is symmetrical which means that the positive FCR Capacity is equal to the negative FCR Capacity.

In addition to the Reference Incident, the probability of FCR exhaustion can be calculated by combining the probability of forced instantaneous outages and disturbances with the probability of used FCR due to the existing Frequency Restoration Control Error (cf. figure 26). The FCR is then dimensioned based on a defined risk level of insufficient FCR. This approach is implemented in the NC LFCR due to increasing impact of the persisting imbalances, in particular the deterministic imbalances which occur due to optimisation of generation based on energy market rules result in lack of coordination between generation and load (load changes are continuous whereas changes of generation follow the accounting periods, cf. section 4.7)

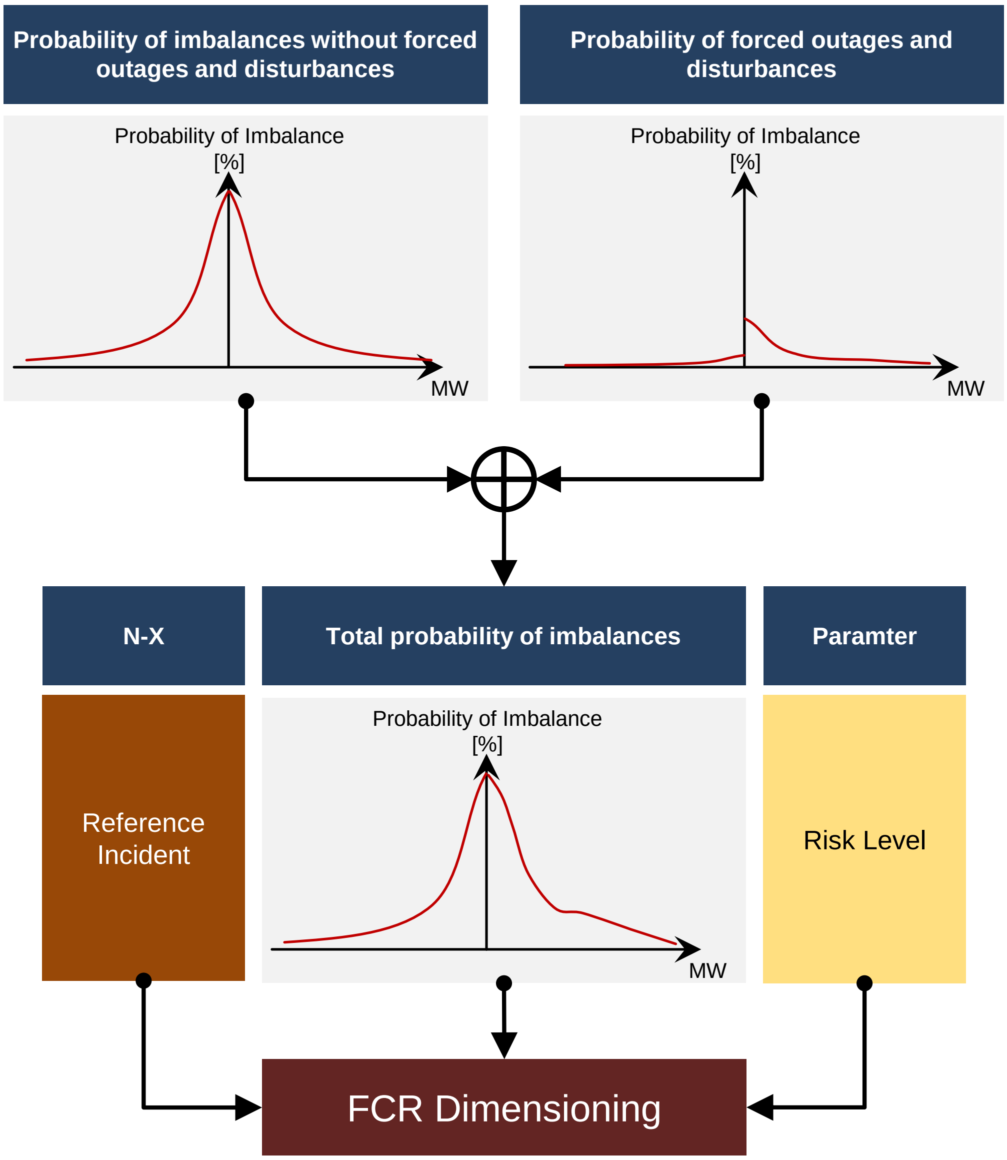


Figure 26: Probabilistic approach for FCR dimensioning

Based on the performed evaluations [6] the risk level “once in 20 years” has been chosen as input for the NC LFCR (cf. Article 43(4)) for CE.

For GB and IRE, due to the higher volatility of the Reference Incident, the FCR is calculated on a continuous basis which does not make the probabilistic approach viable and only the Reference Incident shall apply.

For NE the calculation of the Reference Incident is also performed regularly. Nonetheless, due to recent increase of deterministic imbalances and the resulting Frequency Deviations as well as due to the high number of HVDC Interconnectors, the probabilistic assessment for FCR capacity is required for proper dimensioning.

Figure 27 shows a simple and fictional example for the application of the probabilistic approach and Reference Incident as defined by the NC. Based on a probability density function calculated as the result of figure 26, the FCR Capacity for the Synchronous Area can be obtained by calculating all imbalances which will happen less likely than the allowed risk level (once in 20 years). At the same time, the figure 27 also shows a negative and a positive Reference Incident which can be used for the deterministic dimensioning applied in GB and IRE.

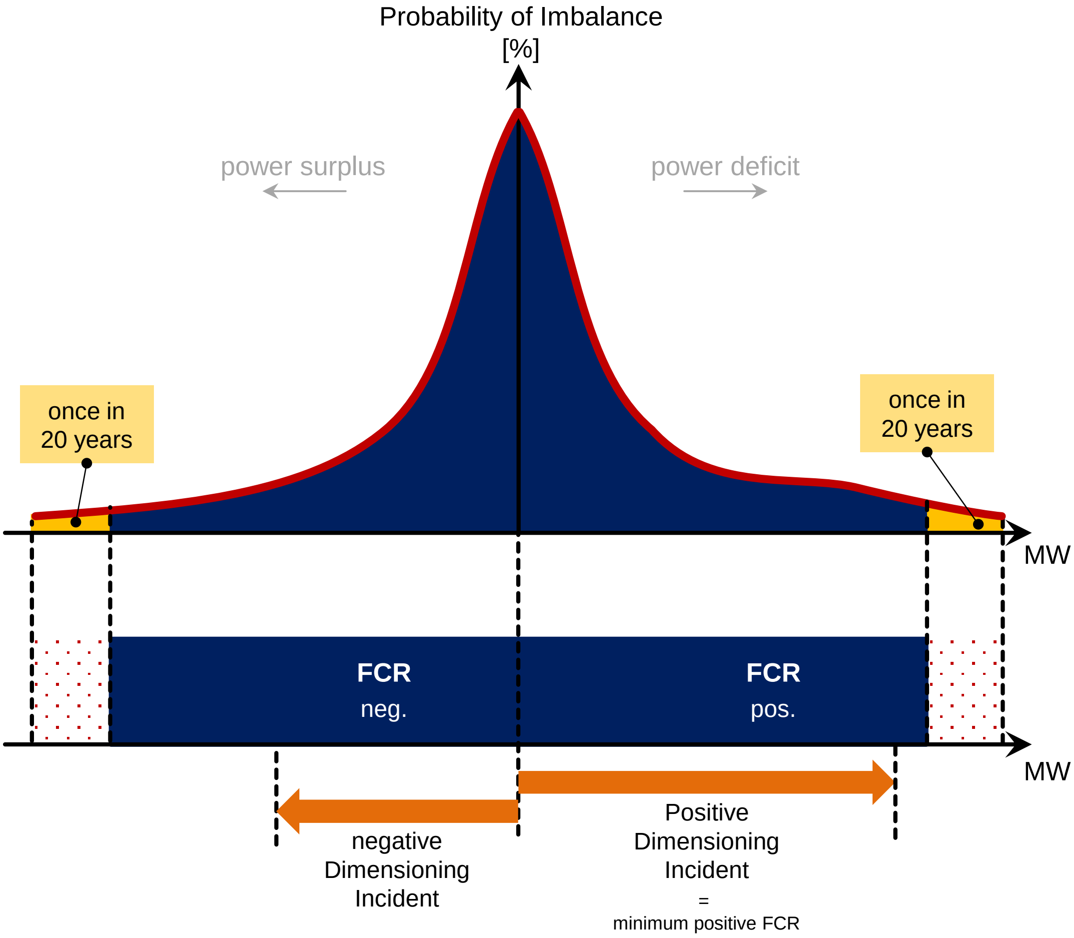


Figure 27: FCR dimensioning – fictional example

The value of FCR determined by the dimensioning approach is the total amount of FCR needed for the whole Synchronous Area. For CE and NE a second calculation step is performed in order to define the responsibility of each TSO to organise the availability (according to national regulations) of a share of the total FCR Capacity.

Since in general the behaviour of generation and load is the basis for the needed FCR, the distribution key for the individual TSOs should reflect generation and demand connected in the area of a TSO. The result is the Initial FCR Obligation. Besides, the fair distribution of obligations, the calculation method for the Initial FCR Obligation implicitly results in an even geographic distribution of FCR.

The methodology for calculation of the Initial FCR Obligation is harmonised for CE and NE - obviously, since GB and IRE are operated only by one TSO who is responsible for the total FCR, there is no need to further allocate the total FCR Capacity to constituent TSOs within those Synchronous Areas.

7.2 Dimensioning of FRR and RR

The present section describes the methodology of FRR and RR dimensioning in context of System Frequency quality.

7.2.1 Interdependencies with FCR and Frequency Quality

As explained in section 4, any imbalance between Active Power generation and consumption leads to a persisting rise or fall of System Frequency and therefore to a Frequency Deviation which has to be countered by FCR activation.

Thus, there is a direct physical relationship between the amount of FCR, FRR and RR – any imbalance amount which is not covered by FRR or RR leads to a Frequency Deviation followed by joint and automatic activation of FCR in the whole Synchronous Area. Figure 28 shows this basic interdependency between FRR and RR activation and the impact on FCR and System Frequency quality:

- The cases a) – e) illustrate real-time deviations between aFRR, mFRR and RR activation and a step-shaped imbalance. Depending on the dynamics, the respective deviation changes its size and shape. For instance, the full activation of RR takes longer than the full activation of aFRR or mFRR which results in a higher power imbalance which has to be covered by FCR.
- The case d) shows a scenario with insufficient Reserve Capacity to cover the imbalance which leads to a persisting usage of FCR.

It is obvious that, due to the relationship of FRR and RR with System Frequency, the total reserve amount and the shares of single reserve types will have an impact on the overall Operational Security.

For these reason, the NC LFCR defines minimum requirements for FRR and RR dimensioning based on a combination of a deterministic and probabilistic approach and coherent with the quality requirements.

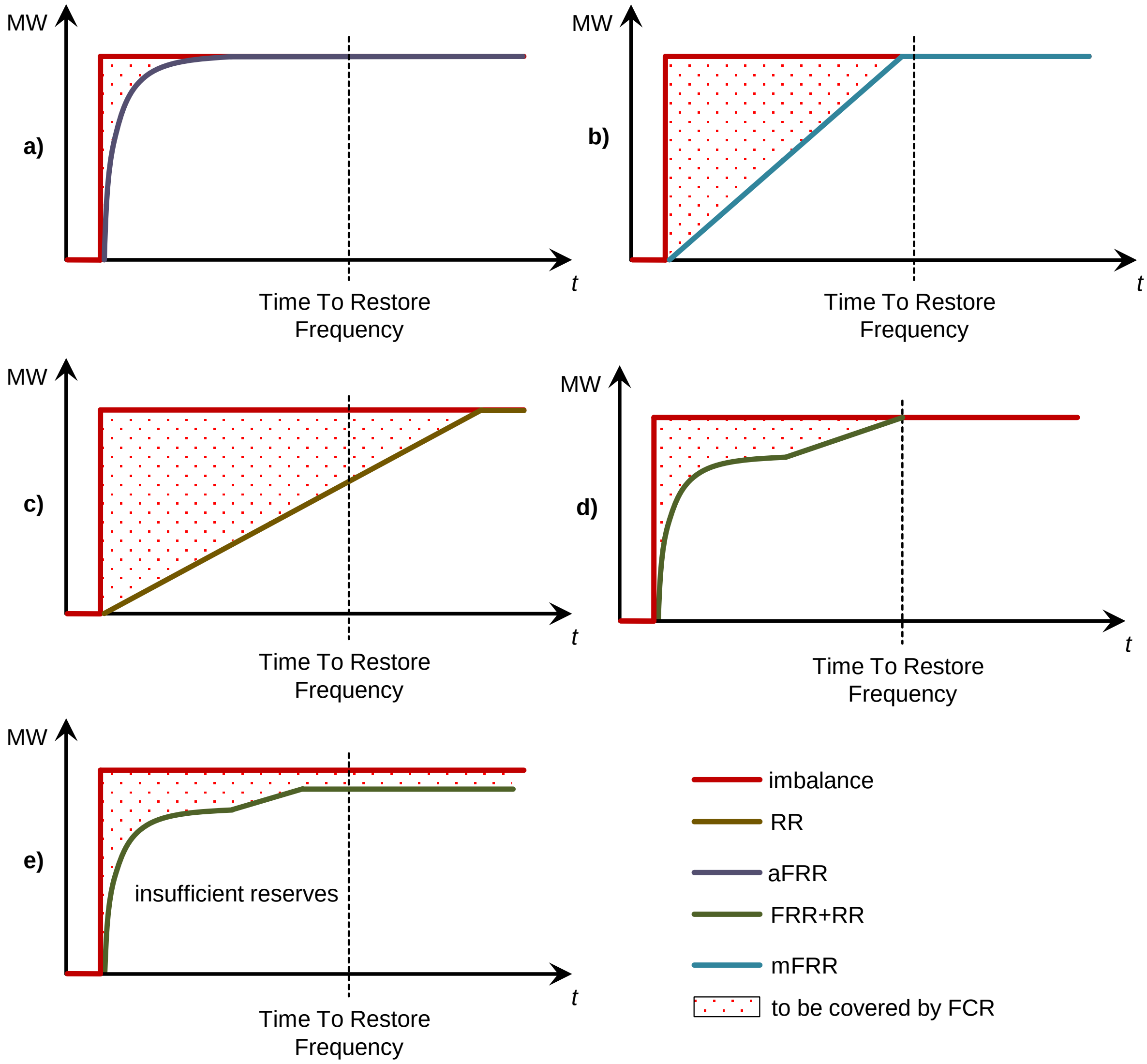


Figure 28: Relationship between FRR and RR activation and FCR

7.2.2 DIMENSIONING METHODOLOGY

This NC LFCR obliges the TSOs to perform a dimensioning of FRR and RR on the level of LFC Blocks. Although, as demonstrated in section 7.2, the dimensioning of FRR and RR has to take into account the requirements in chapter 3 of the NC LFCR, the link between

- the Frequency Quality Target Parameters and Frequency Restoration Control Error Target Parameters; and
- the amounts of aFRR, mFRR and RR

cannot be expressed by a simple mathematical formula. The suitable dimensioning approach differs from LFC Block to LFC Block due the physical sources and patterns of its imbalances – for this reason the NC LFCR intentionally leaves the final choice to the TSOs of the LFC Block. Nonetheless, it is possible to define obligations for TSOs as boundary conditions which enable the TSOs of each LFC Block

- to ensure that the FRR and RR available to the TSOs of the LFC Block are sufficient to guarantee a safe operation;

- to respect quality target of the LFC Block and sub-targets of the single LFC Areas; and
- to contribute to the overall System Frequency quality.

Figure 29 illustrates the components of the FRR Dimensioning Rules (Article 46) and RR Dimensioning Rules (Article 48) based on a simple fictional example. Similar to the dimensioning of FCR, the minimum values for FRR and RR required for CE and NE shall be based on a combination of

- a deterministic assessment based on the positive and negative Dimensioning Incident (Article 46(2).e and Article 46(2).f); and
- a probabilistic assessment of historical records for at least one full year (Article 46(2).a and Article 46.2.b).

The deterministic approach requires that the FRR Capacity shall not be smaller than the Dimensioning Incident (separate for positive and negative direction). In general, this is the tripping of the largest generation unit for the positive direction and the largest demand facility for the negative direction. In certain LFC Blocks an HVDC interconnection might be the determining element for the Dimensioning Incident.

For the probabilistic assessment the NC LFCR defines a minimum value for the sum of FRR Capacity and RR Capacity (Article 46(2).h and Article 46(2).i) which is defined by the 99 % quantile of the LFC Block Imbalances (separate for positive and negative direction).

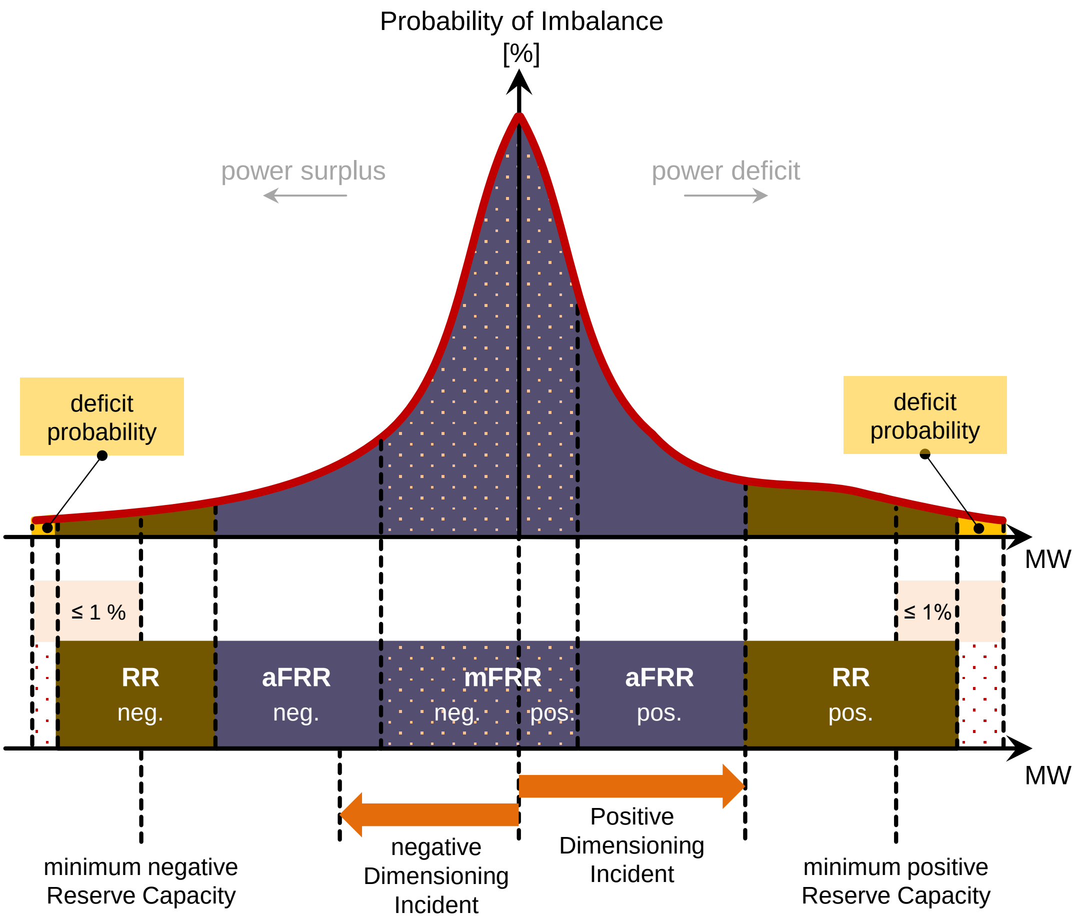


Figure 29: FRR and RR Dimensioning – fictional example

In the example provided by figure 29 the 99 % quantiles are bigger than the respective Dimensioning Incidents and therefore determine the overall sum of FRR Capacity and RR Capacity. The 99 % quantile is a minimum value and thus can be harmonised for all LFC Blocks. At the same time, the example shows that for a specific LFC Block it is in general necessary to exceed the minimum values defined by the NC LFCR

- to comply with FRCE Target Parameters (Article 46(2).b and Article 48(3).c);
- to respect network constraints within a LFC Block (Article 46(2).g); and
- to take all factors into account which may lead to unavailability of FRR or RR (for instance, in case of unavailability of Reserves provided from a different LFC Area or Sharing).

Furthermore, the different response times of aFRR, mFRR and RR must be also considered in the dimensioning and lead to the respective shares (in the example, the share of aFRR and RR is bigger in positive direction). Based on the available transmission capacity a certain distribution and amount of FRR and RR within a LFC Block may be required.

For GB and IRE only the deterministic approach is applied due to the volatility of the systems. Furthermore, the RR Capacity shall be dimensioned not only as support to FRR but also to FCR activation (Article 48(3).b).

For Ireland FRR reserves are dimensioned to exactly cover the Reference Incident which is the largest single infeed. So after 90 seconds the FCR with additional MWs become FRR. As these combined MWs only sum to the largest single infeed it means that for the Reference Incident FRR cannot replace FCR and the TSO must rely on Replacement Reserves to replace the FCR.

The dimensioning principles for FCR, FRR and RR can be, under certain conditions, supplemented by a reduction in Reserve Capacity due to Sharing of Reserves as explained in chapter 9.

7.3 ADDED VALUE OF THE NC LFCR

The added value provided by the NC LFCR lies in the harmonisation of terms, methodologies and procedures for dimensioning while physics that define the peculiarities of the single Synchronous Areas are respected.

The values not defined by the NC LFCR are subject to NRA approval.

8 TECHNICAL REQUIREMENTS FOR RESERVE PROVISION

This chapter describes the technical requirements for provision of FCR, FRR and RR defined by the NC LFCR. The NC RfG and the NC DCC are used as a general reference especially particular to define the relationship between the respective technical concepts of Power Generating Module and Demand Unit on one hand, and the Reserve Providing Unit and the Reserve Providing Group on the other hand. Nevertheless, it has to be taken into account that while the requirements of the NC RfG and NC DCC define fundamental technical capabilities of new technical installations, the requirements of the NC LFCR are defined for all Reserve Providing Units and Reserve Providing Groups to ensure a technically harmonised availability, activation and monitoring of Active Power Reserves.

8.1 RESERVE PROVIDING UNIT AND RESERVE PROVIDING GROUP

In general, Reserves can be provided by adjusting the Active Power generation or consumption. As a consequence, the NC LFCR requirements for the provision of reserves are based on definitions for the Power Generating Module and Demand Unit introduced in the NC RfG and NC DCC respectively. Since these definitions are crucial for understanding the concept of Reserve Providing Unit and Reserve Providing Group and, in particular, aggregation, they are briefly summarised in the first step before the explanation of Reserve Providing Unit and Reserve Providing Group.

8.1.1 POWER GENERATING MODULES AND DEMAND UNITS

Figure 30 illustrates the definition Power Generating Module and Demand Unit.

A Power Generating Module can be either a Synchronous Power Generating Module or a Power Park Module.

A Synchronous Power Generating Module can consist of one or more indivisible generating units connected to a common Connection Point. The same approach is used for storage devices in generation mode. Furthermore, according to the exact definition a Synchronous Power Generating Module can be connected via more than one Connection Point if the generating units cannot be operated independently (e.g. combined-cycle gas turbine facility).

The definition of Power Park Module corresponds to the definition of a Synchronous Power Generating Module with the difference that the generating units of a Power Park Module are connected via power-electronics.

A Demand Unit reflects the definition of a Power Generating Module and means an indivisible set of installations which can be controlled in order to moderate the electricity demand (this includes storage devices in consumption mode).

It is worth mentioning that, in addition, the NC RfG and NC DCC both define facilities (Power Generating Facility and Demand Facility). These definitions are mainly used to define obligations for the respective Facility Owner. Since the technical requirements are stated at the Power Generating Module level and Demand Unit level, these definitions are used for definition of the concepts Reserve Providing Unit and Reserve Providing Group in the NC LFCR.

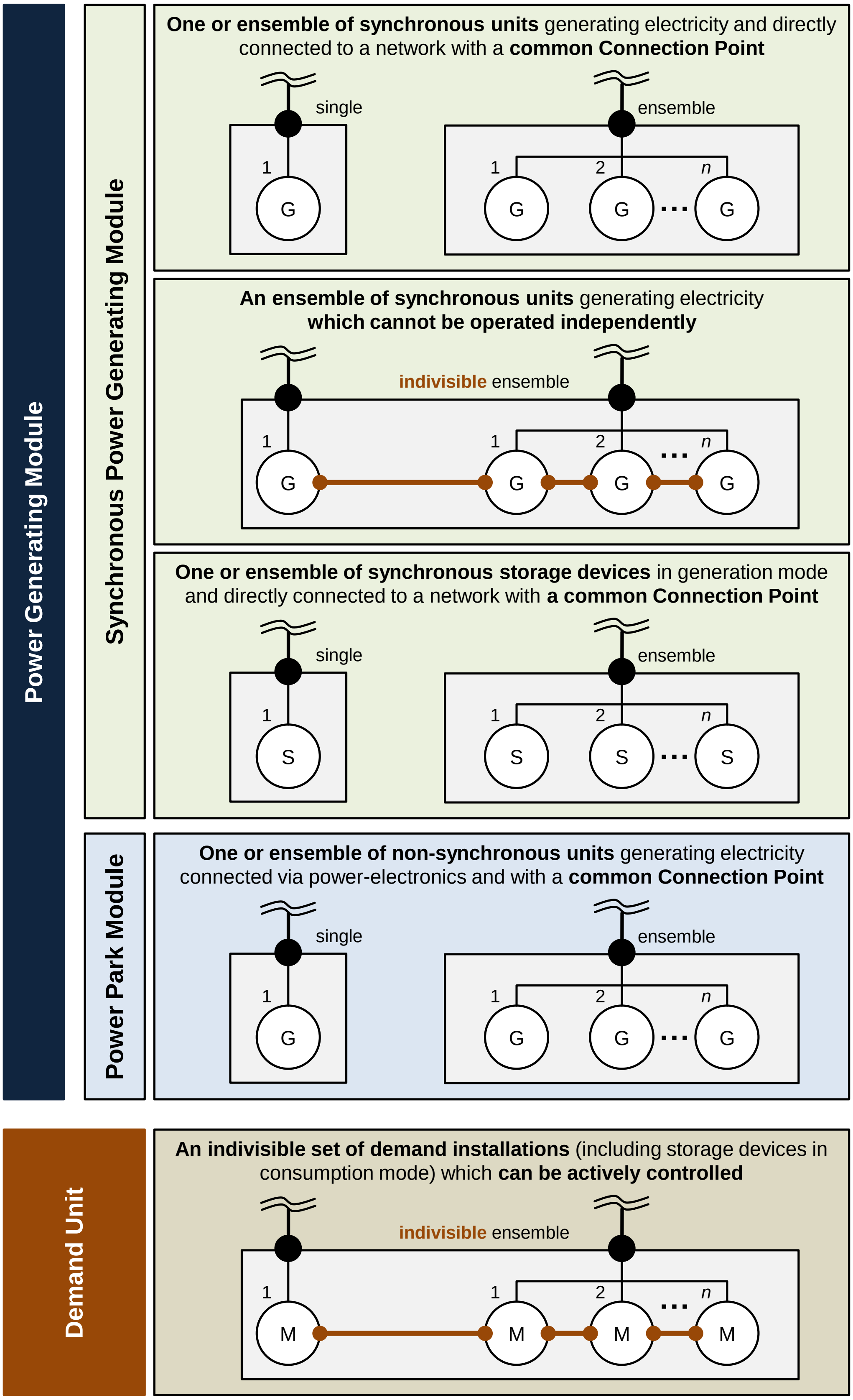


Figure 30: Power Generating Module and Demand Unit

8.1.2 Reserve Providing Unit

The NC LFCR defines a Reserve Providing Unit as follows:

Reserve Providing Unit means a single or an aggregation of Power Generating Modules and/or Demand Units connected to a common Connection Point fulfilling the requirements of FCR, FRR or RR.

As a consequence, the definition for a Reserve Providing Unit already allows aggregation of several generating or consuming devices subject to the condition of a Common Connection Point (as shown in figure 31) and, naturally, subject to the fulfilment of the respective technical requirements.

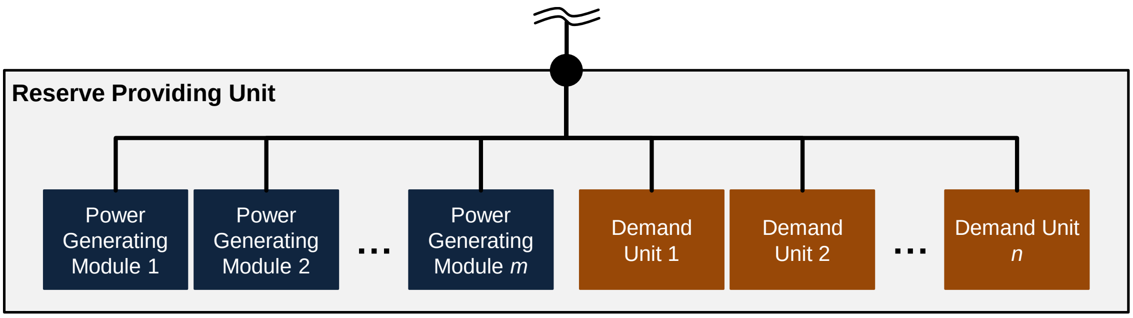


Figure 31: Reserve Providing Unit

Figure 32 shows possible scenarios for Reserve Providing Units which consist of one or more Power Generating Modules and Demand Units. For example, a Reserve Providing Unit could be formed by a controllable installation consisting of solar power plants as Power Generating Modules and a battery.

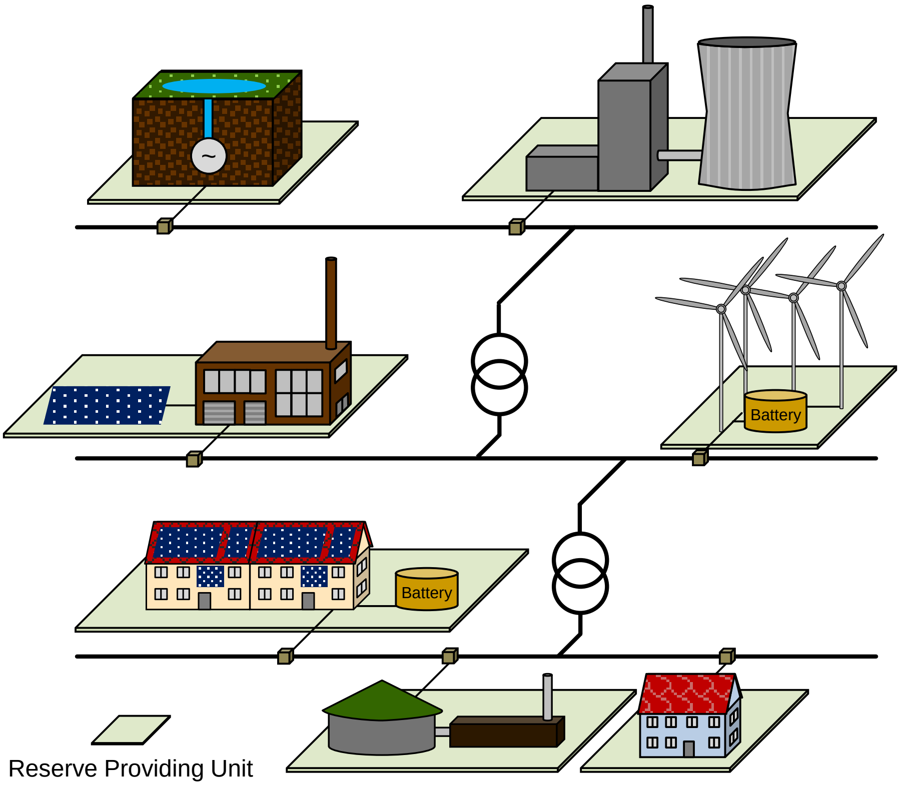


Figure 32: Illustration of possibilities for aggregation within a Reserve Providing Unit

As the examples given by figure 32 demonstrate, the NC LFCR defines a future-proof concept for the provision of Reserves allowing and fostering the integration of RES based generation and demand into the Load-Frequency Control framework.

8.1.3 Reserve Providing Group

The NC LFCR defines a Reserve Providing Group as follows:

> *Reserve Providing Group means an aggregation of Power Generating Modules, Demand Unit and/or Reserve Providing Units connected to more than one Connection Point fulfilling the requirements for FCR, FRR or RR.*

As a consequence, a Reserve Providing Group allows an aggregation of generating and demand installations connected to the network at any point. The definition explicitly states that a Reserve Providing Group can include

- not only Reserve Providing Units which fulfil the technical requirements alone (without further aggregation within a Reserve Providing Group); but also
- Power Generating Modules and Demand Units which fulfil the requirements only as a Reserve Providing Group.

As shown in figure 33, the concept of a Reserve Providing Group is very flexible. In particular, it has to be noted that the definition itself imposes no geographical or any other boundary conditions for the aggregation. Therefore, FCR Providing Groups can be excluded from reserve provision by the Reserve Connecting TSO subject to NRA approval and based on technical arguments related to Operational Security which could be affected by geographical distribution of Reserves.

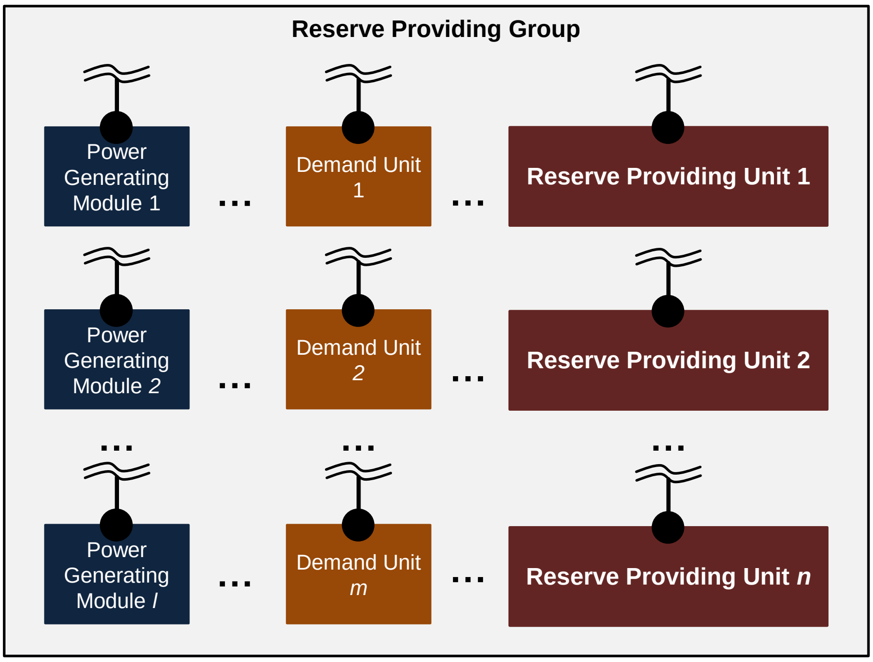


Figure 33: Reserve Providing Group

8.2 FCR Provision and Activation

This section describes the requirements for FCR Providing Units and FCR Providing Groups defined by the NC LFCR including availability and monitoring.

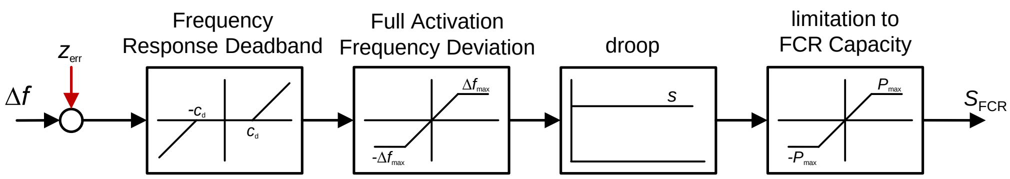
8.2.1 Minimum Technical Requirements

An appropriate activation of FCR is a necessary precondition in order to achieve the required frequency quality. Therefore, Article 44(1) of the NC LFCR determines minimum requirements (FCR Minimum Technical Requirements) for the control accuracy and the dynamic behaviour of FCR Providing Units and FCR Providing Groups.

The accuracy requirements encompass

- the minimum accuracy of System Frequency measurement; and
- inherent Frequency Response Insensitivity and possible intentional Frequency Response Deadband.

The implications of the accuracy requirements are demonstrated in figure 34 on a simplified control scheme for calculation of FCR activation for a FCR Providing Unit or a FCR Providing Group.



Δf – Frequency Deviation
z_{err} – inaccuracy of System Frequency measurement
c_d – intentional Frequency Response Deadband
Δf_{max} – FCR Full Activation Frequency Deviation
s – droop
P_{max} – FCR Capacity
S_{FCR} – set-point value for FCR activation

Figure 34: Implications of accuracy requirements – simplified control scheme

The measurement of the Frequency Deviation is overlapped with a measurement error (z_{err}). Since the measurement error directly impacts the FCR activation, it is crucial to limit its amplitude which is achieved by the requirement to the minimum accuracy of frequency measurement. The NC LFCR defines a harmonised value of ≤10 mHz for all Synchronous Areas.

This value was defined based on comments from the stakeholders during the public consultation and reflects the status of the currently implemented equipment. Due to evolvement of the technology one hand and the increasing challenges to Load-Frequency Control, the NC LFCR includes a requirement to implement the current industrial standard. In particular, this means that the measuring equipment yet to be installed for new FCR Providing Units and FCR Providing Groups should aim at the highest possible accuracy with reasonable costs.

The second requirement of Article 44(1) allows an intentional Frequency Response Deadband (c_d) but at the same time limits its combined effect with the inherent Frequency Response Insensitivity in order to ensure that also small Frequency Deviations are controlled and the Frequency Quality Target Parameters can be fulfilled. Furthermore, the requirement ensures that the activation of FCR does not start too late after a Frequency Deviation. It has to be noted that the limitation of the intentional Frequency Response Deadband does not apply if the according FCR Providing Unit or FCR Providing Group is obliged by the Reserve Connecting TSO to start its activation after a certain Frequency Deviation threshold.

While the intentional Frequency Response Deadband is a control parameter that can be changed, the inherent Frequency Response Insensitivity is part of the fundamental mechanical design, for this reason the values chosen by the NC LFCR correspond to the currently implemented standards.

The Full Activation Deviation defines a requirement for activation in terms of Frequency Deviation and ensures that the Maximum Steady-State Frequency Deviation is not violated.

The Full Activation Time of FCR defines a requirement for activation in terms of time by guarantying a sufficient activation gradient in order to achieve the necessary frequency quality and to ensure that the Maximum Instantaneous Frequency Deviation is not violated.

Moreover, the NC LFCR requires that each FCR Providing Unit or Reserve Providing Group has only one Reserve Connecting TSO which means that aggregation is only possible within one Monitoring Area or LFC Area. This requirement is necessary

- for the assessment of the power interchange and Operational Security; and
- for the calculation of the FRCE for the Frequency Restoration Process if the Synchronous Area contains more than one LFC Area.

8.2.2 AVAILABILITY

Proper FCR activation is crucial for Operational Security and therefore a continuous availability of FCR is very important. Since forced outages of FCR Providing Units or FCR Providing Groups cannot be prevented and might endanger Operational Security, the risk of remarkable reduction of FCR has to be limited. The NC LFCR tackles this risk by setting requirements for

- FCR provision by a single FCR Providing Unit in order to limit the consequences of a loss of a Power Generating Module, Demand Unit or a Connection Point; and
- the ability to activate FCR in case of persisting Frequency Deviations.

For CE, the FCR Capacity which can be provided by a single FCR Providing Unit is limited to 5 % of the total FCR Capacity (currently 150 MW). For GB, IRE and NE due to higher volatility of the systems the loss of a FCR shall be taken into account by the continuous FCR dimensioning.

Regarding the ability to activate FCR three aspects have to be considered:

- expected activation of FRR and corresponding relief of FCR within Time To Restore Frequency;
- possibly limited energy reservoirs in FCR Providing Units and FCR Providing Groups; and
- possibility of time periods with Frequency Deviations occurring mainly in one direction.

The respective requirements in the NC LFCR take all aspects into account by determining the general obligation to activate FCR as long as the Frequency Deviation exists but also by allowing FCR Providing Units and FCR Providing Groups with limited storage as long as certain conditions can be fulfilled (Article 45(6)).

- Each FCR Providing Unit or FCR Providing Group with energy reserves which are not limited (e.g. fossil fuelled power plants) shall activate FCR as long as the Frequency Deviation persists or, as it is the case for GB and IRE, until the same Providing Unit or Providing Group has activated FRR.
- If the energy reservoir is limited, the FCR Providing Unit or FCR Providing Group shall also activate FCR as long as the Frequency Deviation persists or the energy reservoir is exhausted (or in case of GB and IRE until it has activated FRR).

For CE and NE, FCR Providing Units or FCR Providing Groups with limited energy reservoir shall be able to activate full FCR Capacity for at least 30 minutes and refill the reservoir at latest within 2 hours. For GB and IRE, the methodology to determine the requirements for energy availability shall be outlined in the Operational Agreement.

8.2.3 Monitoring

Due to importance of FCR for Operational Security, monitoring of provision and activation of FCR plays an important role in the assessment of correct functioning of Load-Frequency Control. Effective monitoring requires respective data from the providers with a sufficient time resolution to be able to detect non-compliant provision or activation. An example of instantaneous data is given in figure 35.

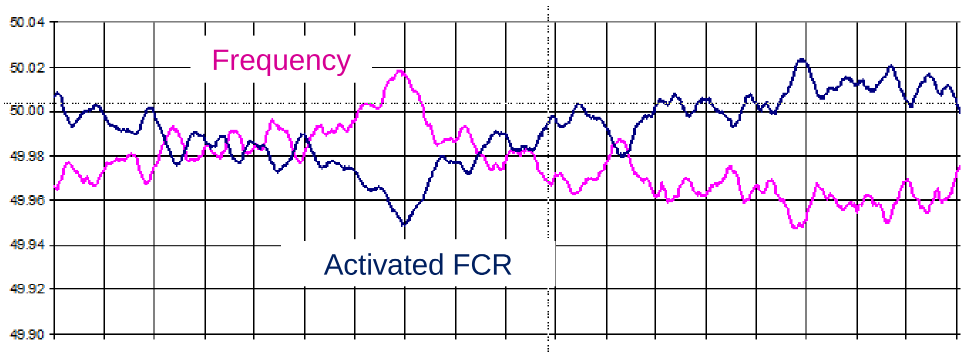


Figure 35: Example for instantaneous data recorded for monitoring purposes.

Furthermore, the NC LFCR defines the necessary data (Article 44(8)) under consideration of the high flexibility for aggregation on the level of FCR Providing Units and FCR Providing Groups and possible implications for the transmission network of the Reserve Connecting TSO. A threshold for aggregation of data provision is set to 1.5 MW, the maximum installed capacity threshold for a Type B Power Generating Module which, according to NC RfG, shall have the capability to provide data for Active Power Output in real-time [4].

8.2.4 Additional Technical Properties

While the FCR Minimum Technical Requirements are fully harmonised with respect to the structure of requirements and partially harmonised with respect to the values for all Synchronous Areas, the determination of additional, more detailed technical properties concerning FCR provision and activation is necessary at the Synchronous Area level and Reserve Connecting TSO level in order to respect the specific physical boundary conditions such as:

- the dynamic behaviour of System Frequency in the Synchronous Area;
- structure and pattern of load and generation including renewables;
- imbalance patterns; and
- the structure of the transmission network operated by the Reserve Connecting TSO.

Additional properties for FCR activation might also be necessary to implement technical concepts which are not yet known or to introduce specific products. The respective additional properties of FCR shall be approved by all NRAs of the Synchronous Area and therefore a transition period and a consultation with FCR Provider shall be foreseen.

These additional technical properties shall:

- ensure Operational Security;
- be based on transparent technical arguments;
- respect the values provider by NC RfG;
- enable efficient FCR monitoring;
- be approved by the responsible NRAs.

The fulfilment of the requirements shall be evaluated during the Prequalification phase.

8.3 FRR and RR Provision and Activation

The present section describes the requirements for FRR and RR Providing Units as well as FRR and RR Providing Groups defined by the NC LFCR including availability and monitoring (Article 47 and Article 49).

8.3.1 FRR Minimum Technical Requirements

The Frequency Restoration Process is implemented at the level of a LFC Area. At the same time the quality target for the Frequency Restoration Process is defined for the according LFC Block (which may correspond to one or more LFC Areas). The NC LFCR explicitly defines two main harmonised requirements for all Synchronous Areas:

- The Full FRR Activation Time shall be at most Time To Restore Frequency (Article 46(2).c);
- the delay for Automatic FRR Activation shall be at most 30 s (Article 47(1).c).

As for FCR and because of different Synchronous Areas, the FRR Minimum Technical Requirements have to take the different boundary conditions of the single LFC Areas and LFC Blocks (structure of generation and load, renewables, typical imbalance patterns) into account. Therefore the NC LFCR defines a harmonised framework for the requirements and leaves room for further details which must be defined on the LFC Block and LFC Area level in order to ensure efficiency.

The FRR Minimum Technical Requirements shall

- ensure Operational Security;
- enable the fulfilment of the FRCE Target Parameters;
- be based on transparent technical arguments;
- respect the values provider by NC RfG;
- enable efficient FRR monitoring;

- be approved by the responsible NRAs.

The fulfilment of the requirements shall be evaluated during the Prequalification phase.

8.3.2 RR Minimum Technical Requirements

As an optional process, RR may be used for replacing and/or supporting the activated FRR in an LFC Area. When RR dimensioned in common with FRR it becomes a part of the Restoration process, therefore, it should also enable the fulfilment of the FRCE Target Parameters.

An LFC Area will choose to implement RRP depending on its operational window, within which BRPs are not able to restore their imbalances. Indeed, the longer this operational window is, the later BRPs will be able to be balanced. In case a LFC Area has only implemented a FRP, the activated FRR will only be replaced one or two hours later, and the Area would not be able to face another imbalance. It can also happen, that imbalances are forecasted during this window. In both cases, using RR is needed either to replace activated FRR or to prevent the activation of FRR.

For all these reasons, the RR Minimum Technical Requirements will depend on each LFC Area design. Therefore, it will be defined in multi-lateral agreements, and shall

- ensure Operational Security;
- enable the fulfilment of the FRCE Target Parameters;
- be based on transparent technical arguments;
- enable FRR (and when applicable FCR) replacement;
- be approved by the responsible NRAs

For GB and IRE, FRR is mostly based on the same capacity as FCR. One unit can provide FCR and FRR but it will be the same MW, their definition will change depending on time. Therefore, in GB and IRE, RR will replace the activated FRR and FCR.

The fulfilment of the requirements shall be evaluated in the prequalification phase.

8.3.3 Availability

In order to respect the provision of the dimensioning process of FRR and RR, TSOs have to define Availability requirements for each type of reserves depending on their design.

Moreover, because these reserves are essential to fulfil the FRCE targets, and to restore the balance of the system waiting before BRPs can do it, Providers have to inform their Instructing TSO of an outage in real time, so that TSOs can take remedial actions if relevant.

8.3.4 Monitoring

The monitoring of FRR and RR provision and activation is highly relevant not only for evaluation of FRR and RR activation, it is also necessary for real-time operation of the Frequency Restoration Process, dimensioning and implementation of the Imbalance Netting Process, Cross-Border FRR Activation Process and Cross-Border RR Activation Process. In order to enable appropriate efficient monitoring and to lay foundation for the cross-border control processes, the NC LFCR defines data provision requirements which are harmonised for all Synchronous Areas.

8.4 PREQUALIFICATION

Any potential Reserve Provider shall have the right to formally apply a combination of Power Generating Modules and/or Demand Units for Prequalification which is defined by the NC LFCR as follows:

> *Prequalification means the process to verify the compliance of a Reserve Providing Unit or a Reserve Providing Group of kind FCR, FRR or RR with the requirements set by the TSO according to principles stipulated in this code.*

Figure 36 shows the basic steps of the Prequalification. Each potential Reserve Provider shall have the right to apply for Prequalification at the Reserve Connecting TSO (in case of Exchange of FRR or Exchange of RR a different TSO may be appointed by the Reserve Connecting TSO to process the Prequalification). The TSO shall evaluate the fulfilment of the technical requirements and declare the Prequalification as passed or propose amendments which can be implemented by the potential Reserve Provider.

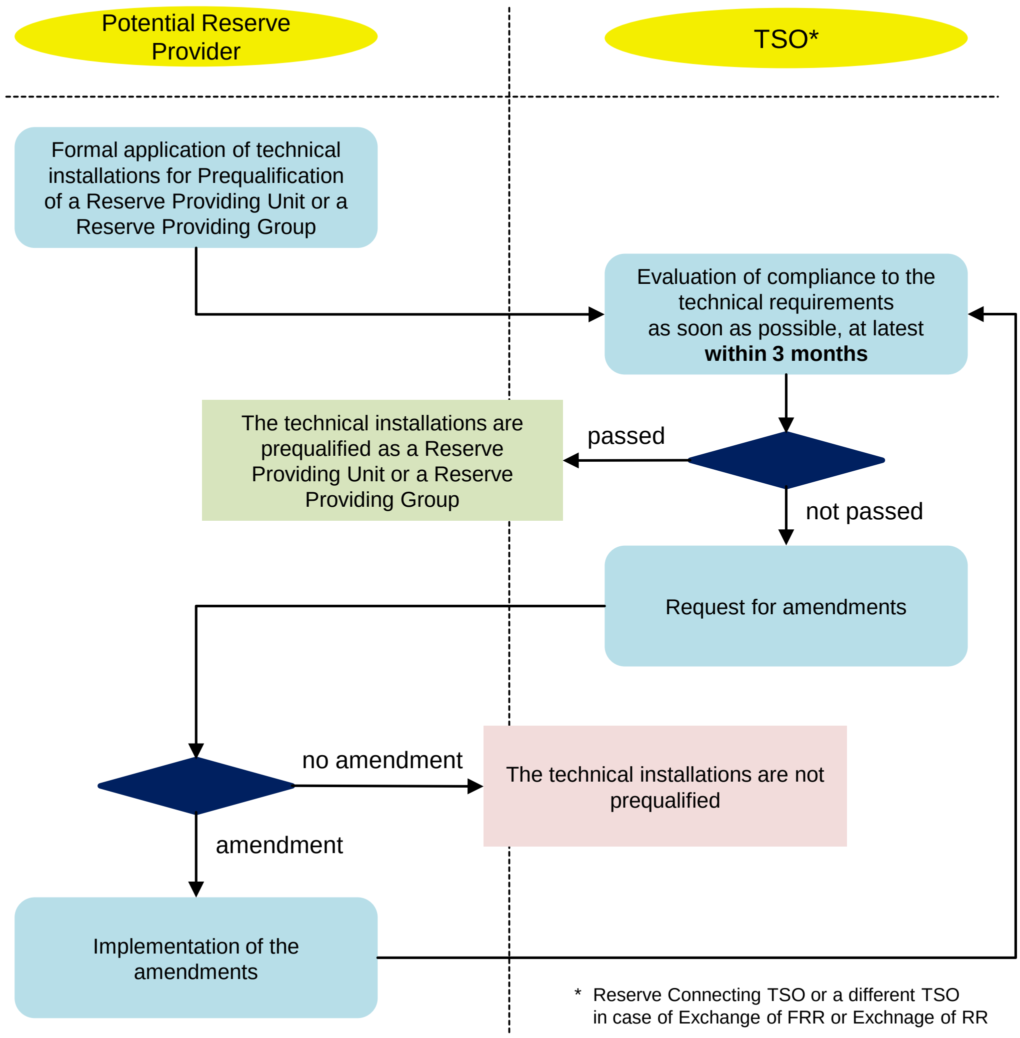


Figure 36: Prequalification Process

8.5 COOPERATION WITH DSOS

As shown in figure 32, a Reserve Providing Unit or a Reserve Providing Group may be connected at any voltage level including distribution networks operated by DSOs. In order to facilitate and enable provision of FCR, FRR and RR from distributed generation, the NC LFCR has to tackle the cooperation with the according DSOs in its role of a Reserve Connecting DSO (Article 68):

> *Reserve Connecting DSO means the DSO responsible for the Distribution System to which a Reserve Providing Unit or Reserve Providing Group, providing reserves to a TSO, is connected.*

The cooperation shall be based on technical arguments and transparent procedures approved by applicable legislation which shall allow a flexible approach for the integration of distributed generation as Reserves by implementation of real-time and ex-ante information exchange as well as the possibility to assess the impact of Active Power Reserves on the distribution grid and to set the according limits if necessary for Operational Security.

The TSO and the Reserve Connecting DSO shall commonly define the applicable procedures for reserve delivery by Reserve Providing Units and Reserve Providing Groups located in Distribution Networks.

8.6 Added Value of the NC LFCR

The NC LFCR provides an added value by harmonising the terms at the European level. Furthermore, the flexibility to aggregate Power Generating Modules and Demand Units in Reserve Providing Units and Reserve Providing Groups facilitates the participation of distributed generating units based on RES as well as controllable demand.

9 EXCHANGE AND SHARING OF RESERVES

A geographically even distribution of reserves and a sufficient amount of reserve capacity in the system are key requisites for ensuring Operational Security. As the Exchange of Reserves impacts the geographical distribution and the Sharing of Reserves impacts the reserve capacity within the system, it is important that the NC LFCR sets technical limits for the Exchange and Sharing of Reserves to maintain Operational Security. The basic principles for Exchange, Sharing and according limits are treated in this chapter.

The aim of the Exchange and Sharing of Reserves is to improve the economic efficiency in performing LFC within the pan-European electricity system thereby maintaining the high standards for Operational Security set forth in the Operational Network Codes. Whereas market and optimisation aspects will be defined in the Electricity Balancing Network Code, the NC LFCR only defines technical limits and requirements to be respected in case of the Exchange and Sharing of Reserves to ensure Operational Security.

9.1 BASIC PRINCIPLES

The present section illustrates the basic principles of Exchange and Sharing.

9.1.1 EXCHANGE OF RESERVES AND GEOGRAPHICAL DISTRIBUTION

The Exchange of Reserves allows TSOs to organise and to ensure the availability of Reserve Capacity (FCR, FRR and RR) resulting from the dimensioning by relying on Reserve Providing Units and Reserve Providing Groups which are connected to an area operated by a different TSO (see Articles 50, 52, 54, 56 inside a Synchronous Area and Article 59, 62 and 64 between two Synchronous Areas).

Figure 37 illustrates the exchange of 200 MW of Reserve Capacity (FCR, FRR or RR) from Area B to Area A.

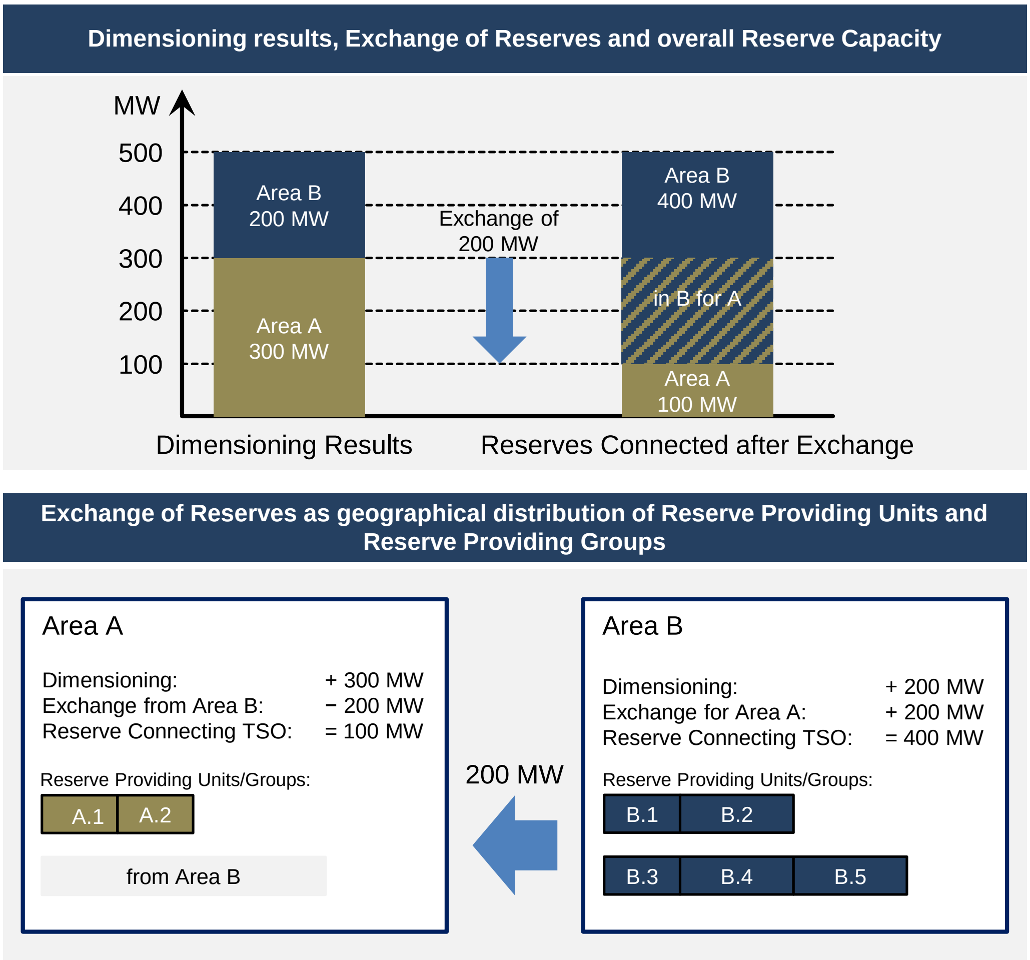


Figure 37: Exchange of Reserves – simple example

Suppose that the Dimensioning Rules result in the need of 300 MW for Area A and 200 MW for Area B. Without the Exchange of Reserves the respective Reserve Capacity has to be provided by Reserve Providing Units or Reserve Providing Groups connected to the Area which means that 300 MW have to be connected in Area A and 200 MW in Area B.

As a result of the Exchange of Reserves of 200 MW from Area B to Area A, 200 MW of Reserve Capacity needed for Area A are now located within Area B, whereas Area A still ensures in addition the availability of the full amount of its own Reserve Capacity.

Although the geographical location of the Reserve Capacity is different from the dimensioning results for each area, the total amount of Reserve Capacity within Area A and B is still 500 MW which is equivalent to the total amount without the exchange.

9.1.2 Sharing of Reserves and the Amount of Reserve Capacity

The Sharing of Reserves allows the TSOs to organise and to ensure the availability of Reserve Capacity (FCR, FRR and RR) which is required by Dimensioning Rules by relying on the same reserves (FCR, FRR and RR) (see Articles 51, 53, 55, 57 inside a Synchronous Area and Article 60, 61, 63 and 65 between two Synchronous Areas).

Figure 38 illustrates the sharing of 100 MW of Reserve Capacity between the TSOs of Area A and the TSOs of Area B.

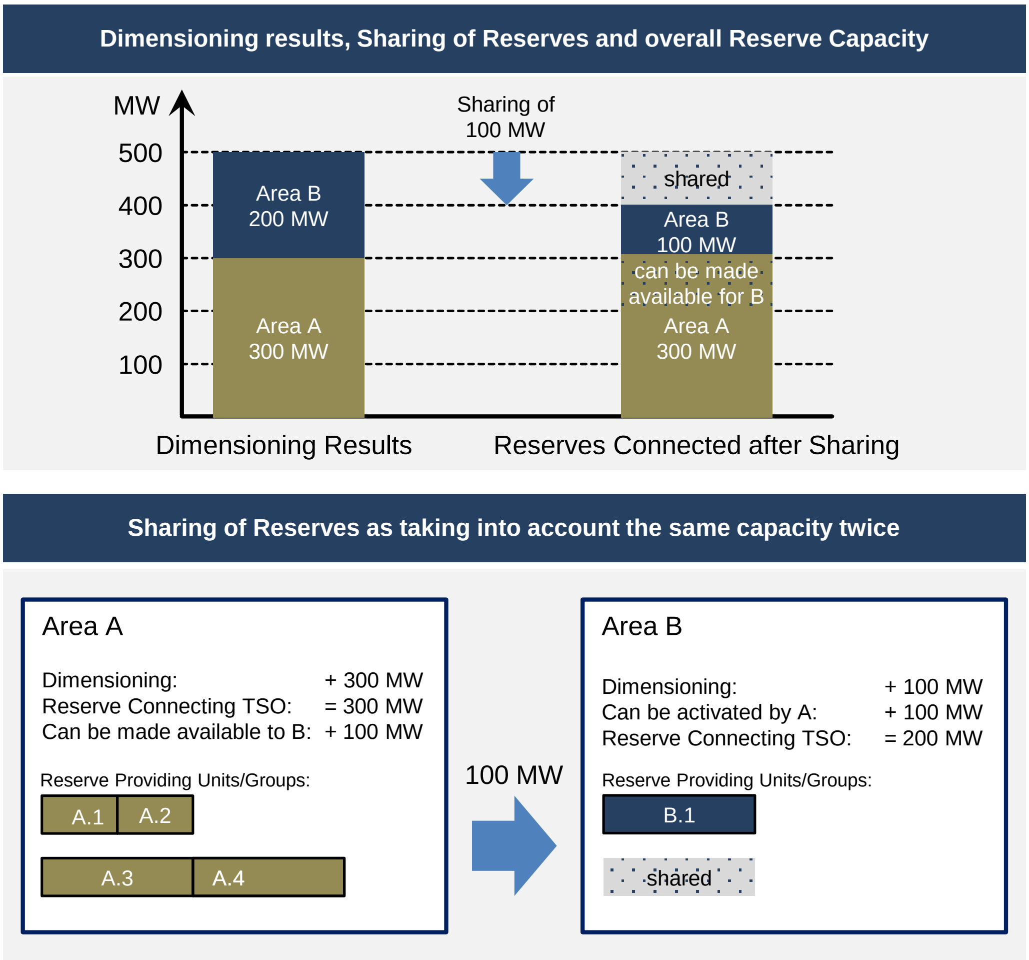


Figure 38: Sharing of Reserves – simple example

Suppose that the Dimensioning Rules for Area A and Area B result in the need of 300 MW FRR for Area A and 200 MW for Area B (same amounts as in figure 37). Without the sharing of reserves the TSOs of Area A and Area B have to ensure the availability of respectively 300 MW and 200 MW.

However, assuming that in some cases it might be very unlikely that both TSOs need to activate the full amount Reserve Capacity at the same time, the TSOs of Area A and Area B can 'share' part of their Reserve Capacity. In practice this means that the TSOs of Area B can make use of e.g. 100 MW of the Reserve Capacity of the TSOs in Area A. Such an arrangement can be unilateral (TSOs of Area B can make use of 100 MW of the Reserve Capacity of the TSOs in Area A but not vice versa) or bilateral (in which case the TSOs of Area A can also access 100 MW of the Reserve Capacity of the TSOs in Area B).

As a result the TSOs of Area A and Area B now need to ensure the availability of 300 MW and 100 MW. The TSOs of Area A now make 100 MW of their own Reserve Capacity also available to the TSOs of Area B. The total amount of the Reserve Capacity within the system is now 400 MW, whereas it was 500 MW without the sharing agreement (leading in this example to reduction of 100 MW of Reserve Capacity in the total system).

In contrast to the Exchange of Reserves which only changes the geographical distribution of Reserve Capacity, the Sharing of Reserves changes the total amount of Active Power Reserves in the Synchronous Area, with an impact on the geographical distribution as an additional implicit effect. The Sharing Agreement defines priority rights to the shared Reserves in the situation where both TSOs have a simultaneous need.

9.2 ROLES OF THE TSOS

Sharing of Reserves is a concept which allows a TSO to take a cross-border activation process into account while organising the availability of the required Active Power Reserves. This means that Sharing of Reserves cannot be technically linked to a specific Reserve Providing Unit or a Reserve Providing Group. Generally speaking, Sharing of Reserves provides a control capability offered by one TSO to another without ensuring the availability of additional corresponding Reserve Capacity. The Exchange of Reserves provides a control capability and additional corresponding Reserve Capacity at the same time.

Furthermore, as explained in section 6 the conceptual definition of Reserve Connecting TSO's role does not automatically require the technical infrastructure or responsibility to instruct Active Power Reserves while, at the same time, an implementation of a Cross-Border FRR Activation Process or a Cross-Border RR Activation Process does not imply Exchange of Reserves or Sharing of Reserves.

In order to define clear and consistent responsibilities for TSOs involved in Exchange of Reserves or Sharing of Reserves, the NC LFCR introduces the respective roles for the involved TSOs. These roles are explained in this section.

9.2.1 RESERVE CONNECTING TSO AND RESERVE RECEIVING TSO

In context of Exchange of Reserves the role of the Reserve Connecting TSO does not change (cf. section 6.2) but is supplemented with an additional meaning:

The Reserve Connecting TSO is still the TSO which operates the Monitoring Area, LFC Area or LFC Block to which a Reserve Providing Unit or a Reserve Providing Group is physically connected to while a certain amount of the Reserve Capacity is required by a different TSO, the Reserve Receiving TSO, to fulfil its dimensioning requirements.

The Reserve Receiving TSO is defined as follows:

> *Reserve Receiving TSO means the TSO involved in an exchange with a Reserve Connecting TSO and/or a Reserve Providing Unit or a Reserve Providing Group connected to another Monitoring or LFC Area.*

In the example given in section 9.1.1 the role of the TSO operating Area A is the Reserve Receiving TSO while the TSO operating Area B is the Reserve Connecting TSO.

9.2.2 CONTROL CAPABILITY PROVIDING AND CONTROL CAPABILITY RECEIVING TSO

The roles of Control Capability Providing TSO and Control Capability Receiving TSO are defined as follows:

> *Control Capability Providing TSO means the TSO which shall trigger the activation of its Reserve Capacity for a Control Capability Receiving TSO under conditions of an agreement for the Sharing of Reserves.*

> *Control Capability Receiving TSO means the TSO calculating Reserve Capacity by taking into account Reserve Capacity which is accessible through*

a Control Capability Providing TSO under conditions of an agreement for the Sharing of Reserves.

Therefore, the respective terms describe the relationship in context of Sharing of Reserves between two TSOs enabling the NC LFCR to directly and explicitly target the respective obligations without inconsistencies with the roles of the Reserve Connecting TSO, the Reserve Receiving TSO and the Reserve Instructing TSO.

The Control Capability Providing and Receiving TSOs shall follow the Notification Process for the Sharing of Reserves.

9.2.3 AFFECTED TSO

In addition to the Reserve Connecting TSO and the Reserve Receiving TSO for the Exchange of Reserves and the Control Capability Providing TSO and Control Capability Receiving TSO for the Sharing of Reserves, any Affected TSO according to section 6.4.3 has the right to refuse respectively the Exchange or Sharing of Reserves in the case the activation of the concerned Reserve Capacity would result in power flows in violation with the Operational Security Limits.

9.3 REQUIREMENTS FOR EXCHANGE OF RESERVES

The NC LFCR lays down provisions for the amount of FCR, FRR and RR required to ensure Operational Security and to respect the frequency quality targets. In order to so, as outlined in section 9.1.1, the TSOs are allowed to implement the Exchange of Reserves which allows them to rely on the Reserve Capacity connected within an area operated by another TSO. The reasons for this can be

- technical, e.g. in case of the required amount of Active Power Reserves cannot be provided within the area of a TSO; and
- economic, e.g. in case that the provision of reserves located within the area of another TSO is economically more efficient.

The Exchange of Reserves therefore can only take place if sufficient Reserve Capacity is available for the involved TSOs to ensure the availability of their required Reserve Capacity resulting from the dimensioning requirements.

An even distribution of Active Power Reserves, both within and between the Synchronous Areas, is critical for ensuring Operational Security and to enable TSOs to perform their tasks according to the requirements set forth in the NC LFCR and other operational Network Codes. The even distribution of Active Power Reserves ensures that location of imbalances is near to the location of reserves (and the reserve activation) and, therefore,

- makes the system more robust in case of network splitting;
- avoids issues of rotor angle stability (even distribution of FCR);
- ensures that the different areas of a Synchronous Area and different Synchronous Areas can operate up to a certain extent more or less independent of each other;
- minimises the risk of power flows exceeding Operational Security Limits thereby restricting the activation of exchanged Reserve Capacity.

The NC LFCR defines

- technical limits for the redistribution of reserves within and between Synchronous Areas by the Exchange of Reserves in order to ensure Operational Security;
- the roles and responsibilities of TSOs and Reserve Providers involved in the Exchange of Reserves; and
- technical requirements for the Exchange of Reserves related to implementation of cross-border activation.

9.3.1 Exchange of FCR within a Synchronous Area

The Initial FCR Obligation ensures the even distribution of FCR within the Synchronous Area. Furthermore the FCR requirements provide limits for the maximum amount of FCR Capacity which can be provided by a single FCR Providing Unit thereby limiting the risk of the instantaneous loss of large amounts of FCR and may also contribute to a more even distribution of FCR (see Article 45(5)).

The redistribution of FCR by the Exchange of FCR has to be limited as to ensure that:

- the flows arising from the activation of exchanged FCR Capacity can be managed and do not exceed Operational Security Limits;
- that sufficient FCR is available in the different grid areas in case of network splitting (figure 39); and
- issues of rotor angle stability shall not occur upon activation of the FCR.

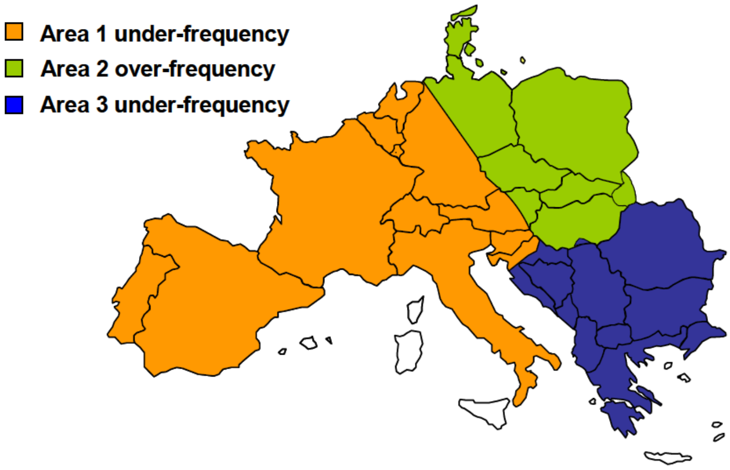


Figure 39: Network splitting in CE in November 2006 [9]

The different nature of the Synchronous Areas, in terms of geographical and electrical size, the organization of the Synchronous Area in Monitoring Areas, LFC Areas and LFC Blocks, network topology and the total amount of FCR, requires that limits for the redistribution of FCR due to exchange are set on different types of areas, constituting the Synchronous Area:

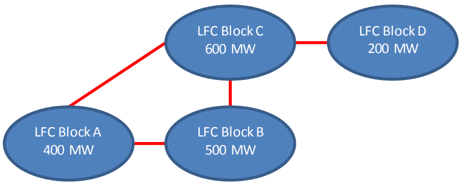
For NE, GB and IRE the limits for the internal redistribution of FCR may be fixed in a Synchronous Area Operational Agreement and are subject to the conditions of [Article 4] in the NC LFCR.

For the CE the limits for the Exchange of FCR are set on the level of LFC Blocks, and, if required on the level of LFC Areas:

- The amount of FCR located within a LFC Block and subject to the Exchange of FCR (delivered to adjacent LFC Block(s) within the same Synchronous Area) is limited to 30% of its total Initial FCR Obligations. This avoids local concentration of FCR in a single LFC Block which can be problematic in case of network splitting (as shown in figure 39) and might cause issues of rotor angle stability. Each LFC Block is allowed to fulfil at least 100 MW of FCR Obligation for adjacent LFC Blocks.
- The minimum amount of FCR to be physically located within each LFC Block is set to 30 % of the total Initial FCR Obligations of the TSOs of the LFC Block in order to ensure the availability of a minimum amount of FCR especially in case of network splitting.
- Ad-hoc limits for the Exchange of FCR between the LFC Areas of an LFC Block to ensure Operational Security can be defined in an LFC Block Operational Agreement and subject to the conditions of Article 4 in the NC LFCR.

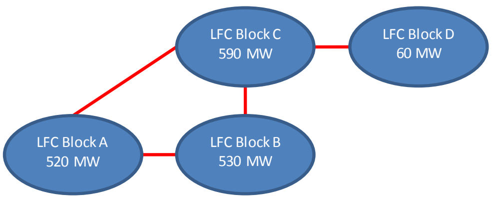
Figure 40 gives an example for the application of the limits for the Exchange of FCR between LFC Blocks within the Synchronous Area of Continental Europe. Simulations show that these limits for the Exchange of FCR ensure an even distribution of FCR throughout the Synchronous Area.

Initial FCR distribution			
	Initial FCR Obligation	Minimum FCR Obligation to remain in LFC Block	Maximum FCR Obligation for adjacent LFC Blocks
LFC Block A	400	120	120
LFC Block B	500	150	150
LFC Block C	600	180	180
LFC Block D	200	60	100



Maximal FCR redistribution towards LFC Block A					
	Initial FCR Obligation	FCR located in			
		LFC Block A	LFC Block B	LFC Block C	LFC Block D
LFC Block A	400	400			
LFC Block B	500	120	380		
LFC Block C	600		150	450	
LFC Block D	200			140	60
Sum	**1700**	**520**	**530**	**590**	**60**

Maximal FCR redistribution towards LFC Block D					
	Initial FCR Obligation	FCR located in			
		LFC Block A	LFC Block B	LFC Block C	LFC Block D
LFC Block A	400	250	150		
LFC Block B	500		420	180	
LFC Block C	600			500	100
LFC Block D	200				200
Sum	**1700**	**250**	**570**	**680**	**300**



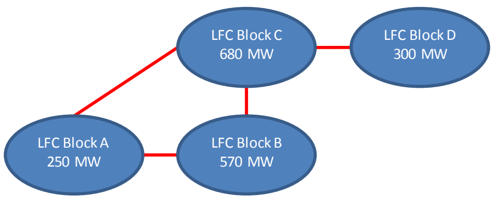


Figure 40: Example for Exchange of FCR in CE

The Reliability Margin accommodates the flows resulting from the activation of FCR throughout the Synchronous Area. FCR is activated simultaneously within the entire Synchronous Area and flows towards the physical location where the imbalance originated. The redistribution of FCR therefore changes the flows resulting from its activation throughout the entire Synchronous Area. Therefore each Affected TSO has to verify whether its

Reliability Margin is sufficient to accommodate the flows resulting from the activation of FCR Capacity caused by the Exchange of FCR.

As Frequency Containment is the joint responsibility of all TSOs of the Synchronous Area, each TSO is responsible for its own FCR Obligation towards the Synchronous Area. The Exchange of FCR has to be seen as a transfer of part of the FCR Obligation from the Reserve Receiving TSO to the Reserve Connecting TSO. As such, the Reserve Connecting TSO becomes technically responsible for the exchanged FCR Capacity.

9.3.2 EXCHANGE OF FCR BETWEEN SYNCHRONOUS AREAS

TSOs of a Synchronous Area may receive part of the FCR required for their Synchronous Area from another Synchronous Area. In such a case the Reserve Connecting TSO(s) of the other Synchronous Area are responsible for ensuring the availability of this exchanged FCR Capacity in addition to their own FCR Obligation within their Synchronous Area. An example of such an Exchange of FCR between Synchronous Areas is shown in figure 41.

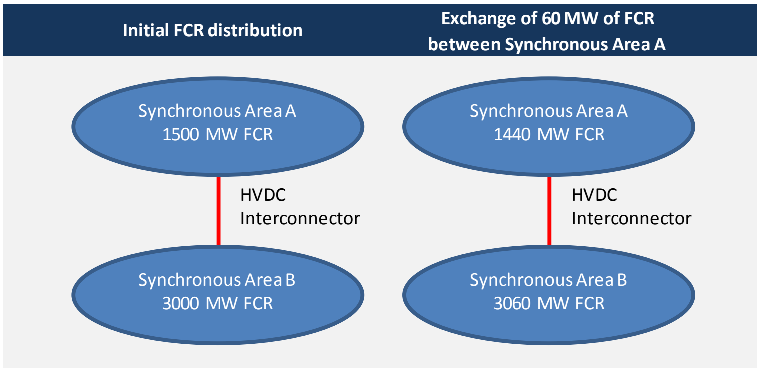


Figure 41: Example for the Exchange of FCR between two Synchronous Areas

FCR is activated by the FCR Providing Units or FCR Providing Groups based on the Frequency Deviation of the Synchronous Area. This introduces some complexity in the Exchange of FCR between Synchronous Area as the exchanged FCR Capacity shall now only be activated in case of a Frequency Deviation in the Reserve Connecting Synchronous Area and not in case of a Frequency Deviation in the Reserve Receiving Synchronous Area.

The HVDC Operator therefore has to operate the HVDC Interconnector based on the instructions of the Reserve Receiving TSO(s). These instructions will reflect the Frequency Deviation of the Reserve Receiving Synchronous Area. In this way the HVDC Interconnector ensures that the HVDC Interconnector injects the amount of required FCR to the Reserve Receiving Synchronous Area by subtracting this power from the Reserve Connecting Synchronous Area.

As the HVDC Interconnector subtracts power from the Reserve Connecting Synchronous Area in case of a Frequency Deviation in the Reserve Receiving Synchronous Area, it introduces an imbalance in the Reserve Connecting Synchronous Area, which results in a Frequency Deviation in this Area. As a result FCR shall be activated by all the TSOs of the Reserve Connecting Synchronous Area as to contain the Frequency Deviation in their Synchronous Area.

The Exchange of FCR between Synchronous Areas impacts the frequency quality of the Reserve Connecting Synchronous Area in case of FCR activation required by the Reserve

Receiving Synchronous Area. Therefore all the TSOs of the Synchronous Area shall agree in a Synchronous Area Operational Agreement on a set of rules, minimum requirements and limits for the Exchange of FCR between Synchronous Areas.

Figure 42 gives an example for the Exchange of 60 MW of FCR between Synchronous Area A and B given by the figure 41. Suppose that there occurs a sudden Frequency Deviation of -50 mHz in the Synchronous Area A requiring the activation of 500 MW of FCR and no Frequency Deviation in Synchronous Area B. In case that the Exchange Agreement requires 20 MW of FCR activation in Synchronous Area B, 480 MW of FCR shall be activated within Synchronous Area A while the HVDC Interconnector shall inject the additional 20 MW to Synchronous Area A by subtracting it from Synchronous Area B. The introduced deficit of 20 MW in Synchronous Area B shall cause a Frequency Deviation which will then be contained by the activation of 20 MW of FCR within Synchronous Area B.

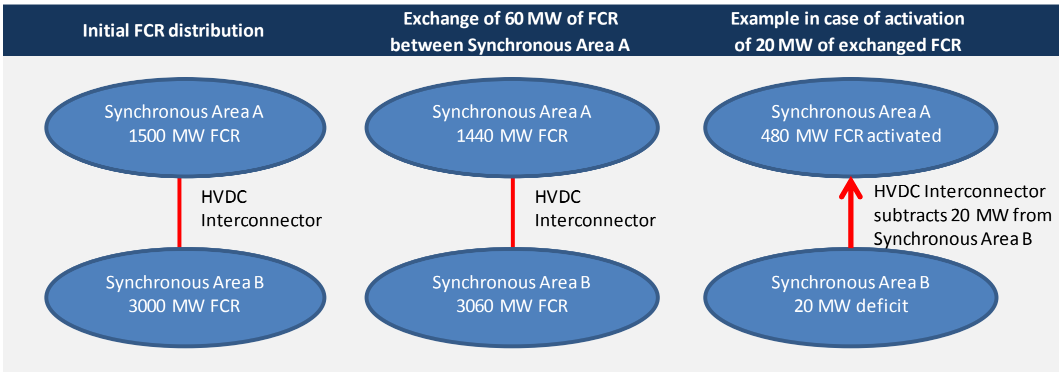


Figure 42: FCR activation between two Synchronous Areas

Furthermore such an Exchange of FCR between Synchronous Areas shall impact the Frequency Restoration Control Error of the LFC Block in the Reserve Connecting Synchronous Area to which the HVDC Interconnector is connected. The injection or subtraction of power by the HVDC Interconnector, based upon the instruction of the Reserve Receiving TSO(s), to deliver the required amount of FCR to the Reserve Receiving Synchronous Area is seen as an imbalance within this LFC Block. The FRP of the LFC Block shall then restore the Frequency Deviation of Synchronous Area B to zero.

The Reserve Receiving TSO shall furthermore ensure that the Exchange of FCR between Synchronous Areas complies with the rules for the maximum loss of FCR due to the failure of a Reserve Providing Unit.

9.3.3 Exchange of FRR and RR within a Synchronous Area

The dimensioning of FRR and RR are performed at the level of the LFC Block and the TSOs of the LFC Block are responsible for ensuring the availability of this amount of FRR and RR and to perform the FRP and RRP for their respective LFC Areas.

An even distribution of FRR/RR in the Synchronous Area is crucial to ensure Operational Security. The even distribution

- ensures that a sufficient amount of FRR/RR is available to all TSOs in case of network splitting;
- allows the LFC Blocks of the Synchronous Area to operate more or less in an independent way (e.g. communication or IT-issues); and

- minimises the risk of power flows exceeding Operational Security Limits thereby restricting the activation of exchanged Reserve Capacity.

The initial dimensioning of FRR/RR on the level of the LFC Blocks ensures implicitly a more or less even distribution of FRR/RR within the Synchronous Area. The Exchange of FRR/RR between LFC Blocks of a Synchronous Area (only applicable for Synchronous Areas with more than one LFC Block) allows a further optimisation of the provision of the required FRR/RR for the LFC Blocks but has an impact on the distribution of FRR/RR within the Synchronous Area. Limits are therefore required to ensure Operational Security.

In order to ensure the even distribution of FRR/RR within the Synchronous Area the TSOs of an LFC Block have to keep a minimum of 50 % of the FRR/RR of the LFC Block physically located within their own LFC Block. Generally this amount of FRR/RR allows the TSOs of the LFC Blocks to operate their LFC Block independently from other LFC Blocks for more than 90 % - 95 % of the time, reducing the risks in case of communication issues etc., while still allowing a significant potential for the optimization of the provision of FRR/RR by Exchanging FRR/RR with other LFC Blocks.

The TSOs of the LFC Areas of the LFC Block have the right to set limits to the amount of FRR/RR that can be located outside of their LFC Area for technical reasons such as power flow issues within the LFC Block in the LFC Block Operational Agreement. Such limits are subject to the provisions of Article 4.

9.3.4 Exchange of FRR and RR between Synchronous Areas

TSOs of a Synchronous Area may receive part of the FRR/RR required for their LFC Block from another LFC Block in another Synchronous Area in an Exchange Agreement.

The TSOs of each Synchronous Area shall agree in a Synchronous Area Operational Agreement on rules, minimum requirements and limits for the Exchange of FRR/RR between Synchronous Areas. These limits shall comply with the limits set for the Exchange of FRR/RR within the Synchronous Area if applicable and are subject to the provisions of Article 4.

The Reserve Connecting and Reserve Receiving TSOs shall define procedures for the case that the Exchange of FRR/RR fails in real-time.

The Exchange of FRR/RR between Synchronous Areas is similar to the Exchange of FRR/RR within a Synchronous Area. The HVDC Interconnector shall control the Active Power Flow over the HVDC Interconnector in accordance with instructions defined by either the Reserve Connecting TSO or Reserve Receiving TSO in accordance with the FRR/RR Technical Minimum Requirements.

The Exchange of FRR/RR between Synchronous Areas shall be agreed by the Reserve Connecting and Reserve Receiving TSOs in an Exchange Agreement.

9.4 Requirements for Sharing of Reserves

The dimensioning procedures for FCR/FRR/RR result in a certain amount of FCR, FRR and RR capacity to be provided by each TSO. However, in some cases it is very unlikely that two TSOs would need to activate their full amount of FCR, FRR or RR at the same time.

Therefore, there is a potential to reduce the amount of Reserve Capacity to be provided by these TSOs and to make common use of part of the reserves (Sharing of Reserves).

The Sharing of Reserves allows for a reduction of the total reserves within the system without performing a common dimensioning for these reserves. The Sharing of Reserves therefore introduces a risk in the system in case the Control Capability Providing and Receiving TSOs simultaneously need to activate the reserves made available for common use. Limits for the Sharing of Reserves are thus required to ensure Operational Security.

It has to be emphasized that, due to the fact that the Sharing of Reserves is allowed without common dimensioning, strict limits will apply for the resulting maximum reduction of Reserve Capacity. In case of common dimensioning (e.g. in case of merging of two LFC Blocks in a single LFC Blocks) the resulting FRR/RR reduction might be higher than the one allowed by the Sharing of Reserves. This is because of the fact that in the common dimensioning of reserves the risk for simultaneous activation of reserves is implicitly taken into account, based on the nature and occurrence of the imbalances, which is not the case for the Sharing of Reserves (generic rules).

9.4.1 Sharing of FCR within a Synchronous Area

Frequency Containment is a joint responsibility of all TSOs of the Synchronous Area, meaning that, in case of an incident/imbalance in the Synchronous Area, FCR is activated simultaneously by all TSOs of the Synchronous Area in order to stabilize the frequency. As a result all FCR is jointly dimensioned for all the TSOs of a Synchronous Area. Therefore no further Sharing of FCR within the Synchronous Area can be considered, as the FCR is already fully shared implicitly (common dimensioning). Further Sharing of FCR within the Synchronous Area would lead to a total amount of FCR being less than the required amount of FCR for the Synchronous Area.

9.4.2 Sharing of FCR between Synchronous Areas

The FCR Dimensioning Process is performed at the level of the Synchronous Area. The resulting amount of FCR ensures that the Frequency can be contained in case of the occurrence of the Reference Incident and ensures that the risk of having insufficient FCR available is limited to an agreed upon value. By this the required FCR amount is already fully shared between the TSOs of a Synchronous Area and it is ensured that total FCR Capacity of the Synchronous Area corresponds with the minimum amount needed for a secure System Operation. As a consequence the resulting required FCR amount for a Synchronous Area is relatively small compared to the total FRR / RR amounts required.

Reducing the FCR amount available in a Synchronous Area below the required FCR amount generally implies a high risk to the System Operation of a Synchronous Area since the FCR is the fastest Reserve available to the TSOs designed to contain the System Frequency. The situation of a high imbalance in combination with an insufficient FCR amount available in the Synchronous Area will immediately result in a sudden System Frequency drop with no proper further countermeasures available to the TSOs to stop it.

The argumentation above implies that in general the Sharing of FCR between TSOs of different Synchronous Areas is not allowed since it would introduce a dependency between the Synchronous Areas in terms of Frequency Containment including the introduction of the risk of a common failure.

The particular case of the relatively small Synchronous Area IRE with its neighbour GB can be regarded as an exception. In this case the required FCR amount is relatively high with regards to the system size and its availability cannot be ensured at any point in time. Thus the Sharing of Reserves between the IRE and GB brings advantages with regards to the availability of the required FCR amount that overrule the operational risk associated with the dependency of the Frequency Containment Processes in the two Synchronous Areas. Furthermore, the probability of such operational risk is lower due to the limited number of network elements in the smaller Synchronous Area.

Therefore, the sharing of FCR between Synchronous Areas is exceptionally allowed between the Synchronous Areas of IRE and GB due to the specific situation of a nearby small and relatively large Synchronous Area and the process has been in place for some time.

9.4.3 Sharing of FRR and RR within a Synchronous Area

The Sharing of FRR within a Synchronous Area allows (small) LFC Blocks, needing a relatively high amount of FRR Capacity to cover their Dimensioning Incident compared to the FRR Capacity required to cover other imbalances, to reduce their FRR Capacity by cooperating with other LFC Blocks. This enhances the economic efficiency as it reduces the amount of FRR in the LFC Blocks required for a rather unlikely event (Dimensioning Incident).

The limits for the Sharing of FRR within a Synchronous Area set forth in the FRR Dimensioning Rules are conceived in a way that limits the risk that the Control Capability Connecting and Receiving TSOs would need to activate the FRR Capacity made available for common use at the same time (as there is no common dimensioning performed). This is achieved in the following way:

- The TSOs of an LFC Block have to ensure at least the availability of 99 % of their required FRR Capacity resulting from the FRR Dimensioning Rules. This ensures that in 99 % of the time the TSOs of the LFC Block have sufficient FRR available without having to access the FRR Capacity subject to a Sharing Agreement; and
- Only TSOs of an LFC Block for which the FRR Capacity required to cover the Dimensioning Incident (positive and negative) exceeds the amount of FRR Capacity required to cover 99 % of the historical (positive and negative) imbalances are allowed to reduce their FRR Capacity by concluding a Sharing Agreement. This means that, in case these TSOs would need to access the common reserves, it is most likely due to the occurrence of the Dimensioning Incident in their LFC Block. This event is considered to be uncorrelated with the imbalances of other LFC Blocks, thereby reducing the risk that more than one TSO needs to access the common reserves at the same time; and
- The maximum FRR reduction for an LFC Block is limited to 30 % of its Dimensioning Incident. This limits the size of the risk in case the Sharing of FRR would fail.

Figure 43 and figure 44 and give an example of the application of the sharing rules for two different LFC Blocks.

- In figure 44 the LFC Block needs 1000 MW of FRR to cover the Dimensioning Incident while it would only need 800 MW of FRR to cover 99 % of the other imbalances in the LFC Block. According to the limits for the sharing of FRR, this LFC

Block can reduce its FRR Capacity, resulting from the FRR Dimensioning Rules with 200 MW by concluding a Sharing Agreement with other LFC Blocks.

- In figure 44 the LFC Block cannot reduce its FRR Capacity by concluding a Sharing Agreement with other TSOs. This is due to the fact that the TSOs of this LFC Block need an amount of FRR Capacity, exceeding the Dimensioning Incident, to cover random imbalances in their LFC Block. As it is not clear whether these imbalances are correlated with the imbalances in other LFC Blocks, a reduction of FRR by Sharing is excluded. However, in case of a common FRR Dimensioning with another LFC Area or LFC Block of the Synchronous Area, such an LFC Block can further optimize the total amount of FRR required.

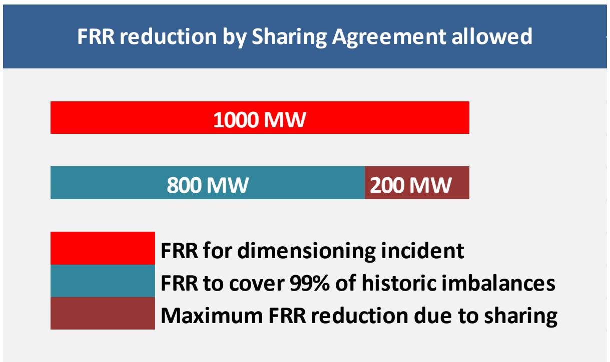


Figure 43: Calculation of maximum FRR reduction by the Sharing of FRR (Case A)

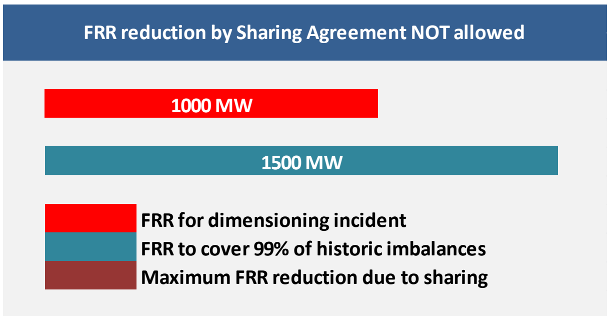


Figure 44: Calculation of maximum FRR reduction by the Sharing of FRR (Case A)

According to the RR Dimensioning Rules the TSOs of the LFC Blocks are allowed under certain conditions to reduce their RR Capacity by concluding a Sharing Agreement for RR with other TSOs of the LFC Block.

The Control Capability Providing and Receiving TSOs shall agree in the Sharing Agreement on procedures to ensure that the activation of the FRR/RR Capacity subject to the Sharing of FRR/RR does not lead to power flows in violation with the Operational Security Limits.

In case of Sharing of FRR or RR within a Synchronous Area it is always the Control Capability Providing TSO that has priority access to the reserves made available for common use. This is because the Control Capability Providing TSO has ensured the provision of this amount of reserves. In case the Control Capability Receiving TSO does not have access to the reserves made available for common use, he shall have to take other measures in order to fulfil its responsibilities with respect to the quality targets.

In case two LFC Areas/Blocks of a Synchronous Area would like to further optimise their total amount of FRR they can perform a common FRR Dimensioning by forming a LFC Block.

9.4.4 SHARING OF FRR AND RR BETWEEN SYNCHRONOUS AREAS

TSOs of a Synchronous Area may receive part of the FRR/RR required for their LFC Block from another LFC Block in another Synchronous Area under the form of a Sharing Agreement.

The TSOs of each Synchronous Area shall agree in a Synchronous Area Operational Agreement on a set of rules, minimum requirements and limits for the Sharing of FRR/RR between Synchronous Areas. These limits shall comply with the limits set for the Sharing of FRR/RR within the Synchronous Area if applicable and are subject to the provisions of Article 4.

The Control Capability Providing and Receiving TSOs shall define procedures for the case that the Sharing of FRR/RR would fail in real-time.

The Sharing of FRR/RR between Synchronous Areas is quite similar to the Sharing of FRR/RR within a Synchronous Area. The HVDC Interconnector shall control the Active Power Flow over the HVDC Interconnector in accordance with instructions defined by either the Control Capability Connecting TSO or the Control Capability Receiving TSO in accordance with the FRR/RR Technical Minimum Requirements.

The Sharing of FRR/RR between Synchronous Areas shall be agreed by the Reserve Connecting and Reserve Receiving TSOs in an Exchange Agreement.

9.5 ADDED VALUE OF THE NC LFCR

The NC LFCR provides a framework of cooperation between TSOs at the European level in order to optimise the provision and availability of Reserve Capacity. At the same it states clear limits motivated by Operational Security. Where limits are not defined in the NC LFCR, they will be approved by the NRAs.

10 Benefits of the NC LFCR

The NC LFCR builds on decades of experience collected by the TSOs and presents a further development of existing operational standards and best practices clarifying the concepts and adjusting them for application across Europe. It is fully compliant to the FG on LFCR [1] and provides a clear and flexible framework for NC EB to define products and cross-border energy balancing.

While deciding on the objectives and major topics to be included in the NC LFCR, a constant screening process with the objectives defined by the FG SO has been carried out. The analytic approach taken for drafting the NC LFCR resulted in the current code structure. Reaching this point and by recognizing that the added values of the code are inherently linked to its objectives of the NC LFCR, the following benefits are to be expected by implementing the operational principles defined in the NC LFCR.

The NC LFCR is part of the Operational Security Code group. The scope of this code is to ensure effective system balancing and frequency management in a harmonised manner across Europe, whilst at the same time leaving room for technical requirements on a national and/or Synchronous Area level.

Figure 45 provides a mapping of the requirements based on three categories:

- **“Base-line”** means that the respective articles reflect values, practices or methodologies which are already implemented by most TSOs.
- **“Harmonisation”** means that the respective articles reflect values, practices or methodologies which are already implemented by some TSOs are harmonised for all Synchronous Areas.
- **“New”** means that the respective articles reflect values, practices or methodologies which are either completely new or are explicitly formulated as binding obligations for the first time.

It can be seen that the harmonisation including use of common language in the NC LFCR allows easier comparison of activities between areas, which in-turn makes it easier for TSOs to cooperate to maximise security across the wider European grid area. New requirements mainly target improved and common reporting methods driving greater transparency of actions at LFC Block as well as Synchronous Area level and making it easier to identify frequency quality problems at all scales.

The NC LFCR includes the core definitions of frequency quality, the measures by which TSOs must regulate and monitor frequency and associated balance. The challenges of decarbonisation and the introduction of new renewable energy generation as well as Demand Side Management calls for much closer cooperation for secure and stable grid operations. The common measures will permit more common monitoring of quality and allow earlier identification of issues in one or more areas of grid operations.

Chapter	Article	Title	Base-line	Harmonisation	New
Chapter 1		**GENERAL PROVISIONS**			
	1	SUBJECT MATTER AND SCOPE			■
	2	DEFINITIONS		■	■
	3	REGULATORY ASPECTS		■	
	4	REGULATORY APPROVALS		■	
	5	REGULATORY NOTIFICATION		■	
	6	RECOVERY OF COSTS	■		
	7	CONFIDENTIALITY OBLIGATIONS	■		
	8	AGREEMENT WITH TSOS NOT BOUND BY THIS NETWORK CODE			■
	9	TSO CO-OPERATION			■
Chapter 2		**OPERATIONAL AGREEMENTS**			
	10	SYNCHRONOUS AREA OPERATIONAL AGREEMENT		■	
	11	LFC BLOCK OPERATIONAL AGREEMENT		■	
	12	LFC AREA OPERATIONAL AGREEMENT		■	
	13	MONITORING AREA OPERATIONAL AGREEMENT		■	
	14	IMBALANCE NETTING AGREEMENT		■	
	15	CROSS-BORDER FRR ACTIVATION AGREEMENT		■	
	16	CROSS-BORDER RR ACTIVATION AGREEMENT		■	
	17	SHARING AGREEMENT		■	
	18	EXCHANGE AGREEMENT		■	
Chapter 3		**FREQUENCY QUALITY**			
	19	FREQUENCY QUALITY TARGET PARAMETERS		■	
	20	FRCE TARGET PARAMETERS			■
	21	CRITERIA APPLICATION PROCESS AND FREQUENCY QUALITY EVALUATION CRITERIA		■	
	22	DATA COLLECTION AND DELIVERY PROCESS	■		
	23	SYNCHRONOUS AREA MONITOR	■		
	24	LFC BLOCK MONITOR	■		
	25	INFORMATION ON LOAD AND GENERATION BEHAVIOUR	■		
	26	RAMPING PERIOD FOR THE SYNCHRONOS AREA		■	
	27	RAMPING RESTRICTIONS FOR ACTIVE POWER OUTPUT ON SYNCHRONOUS AREA LEVEL		■	
	28	RAMPING RESTRICTIONS FOR ACTIVE POWER OUTPUT ON LFC BLOCK LEVEL	■		
	29	MITIGATION	■		
Chapter 4		**LOAD-FREQUENCY CONTROL STRUCTURE**			
	30	BASIC STRUCTURE		■	
	31	PROCESS ACTIVATION STRUCTURE	■		
	32	PROCESS RESPONSIBILITY STRUCTURE		■	
	33	FREQUENCY CONTAINMENT PROCESS (FCP)	■		
	34	FREQUENCY RESTORATION PROCESS (FRP)	■		
	35	RESERVE REPLACEMENT PROCESS (RRP)	■		
	36	IMBALANCE NETTING PROCESS		■	
	37	CROSS-BORDER FRR ACTIVATION PROCESS		■	
	38	CROSS-BORDER RR ACTIVATION PROCESS		■	
	39	GENERAL REQUIREMENT FOR CROSS BORDER CONTROL PROCESSES		■	
	40	TSO NOTIFICATION	■		
	41	INFRASTRUCTURE	■		
Chapter 5		**OPERATION OF LOAD FREQUENCY CONTROL**			
	42	SYSTEM STATES RELATED TO SYSTEM FREQUENCY	■		
Chapter 6		**FREQUENCY CONTAINMENT RESERVES (FCR)**			
	43	FCR DIMENSIONING	■		
	44	FCR TECHNICAL MINIMUM REQUIREMENTS	■		
	45	FCR PROVISION		■	
Chapter 7		**FREQUENCY RESTORATION RESERVES (FRR)**			
	46	FRR DIMENSIONING		■	
	47	FRR TECHNICAL MINIMUM REQUIREMENTS	■		
Chapter 8		**REPLACEMENT RESERVES (RR)**			
	48	RR DIMENSIONING		■	
	49	RR TECHNICAL MINIMUM REQUIREMENTS	■		
Chapter 9		**EXCHANGE AND SHARING OF RESERVES**			
	Section 1	**Exchange and Sharing of Reserves within a Synchronous Area**			
	50	EXCHANGE OF FCR WITHIN A SYNCHRONOUS AREA	■		
	51	SHARING OF FCR WITHIN A SYNCHRONOUS AREA	■		
	52	GENERAL REQUIREMENTS FOR THE EXCHANGE OF FRR AND RR WITHIN A SYNCHRONOUS AREA	■		
	53	GENERAL REQUIREMENTS FOR THE SHARING OF FRR AND RR WITHIN A SYNCHRONOUS AREA			■
	54	EXCHANGE OF FRR WITHIN A SYNCHRONOUS AREA	■		
	55	SHARING OF FRR WITHIN A SYNCHRONOUS AREA			■
	56	EXCHANGE OF RR WITHIN A SYNCHRONOUS AREA	■		
	57	SHARING OF RR WITHIN A SYNCHRONOUS AREA			■
	Section 2	**Exchange and Sharing of Reserves between Synchronous Areas**			
	58	GENERAL REQUIREMNTS		■	
	59	EXCHANGE OF FCR BETWEEN SYNCHRONOUS AREAS		■	
	60	SHARING OF FCR BETWEEN SYNCHRONOUS AREAS	■		
	61	GENERAL REQUIREMENT FOR SHARING AND EXCHANGE BETWEEN SA			■
	62	EXCHANGE OF FRR BETWEEN SYNCHRONOUS AREAS			■
	63	SHARING OF FRR BETWEEN SYNCHRONOUS AREAS			■
	64	EXCHANGE OF RR BETWEEN SYNCHRONOUS AREAS.		■	
	65	SHARING OF RR BETWEEN SYNCHRONOUS AREAS			■
	Section 3	**Cross-Border Activation Process of FRR /RR**			
	66	CROSS-BORDER ACTIVATION PROCESS OF FRR / RR		■	
Chapter 10		**TIME CONTROL PROCESS**			
	67	TIME CONTROL PROCESS	■		
Chapter 11		**CO-OPERATION WITH DSOs**			
	68	RESERVE PROVIDING UNITS CONNECTED TO THE DSO GRID	■		
Chapter 12		**Transparency of Information**			
	69	GENERAL TRANSPARENCY REQUIREMENTS			■
	70	INFORMATION ON OPERATIONAL AGREEMENTS		■	
	71	INFORMATION ON FREQUENCY QUALITY			■
	72	ANNUAL REPORT ON LOAD-FREQUENCY CONTROL			■
	73	INFORMATION ON THE LOAD-FREQUENCY CONTROL STRUCTURE			■
	74	INFORMATION ON FCR			■
	75	INFORMATION ON FRR			■
	76	INFORMATION ON RR			■
	77	INFORMATION ON SHARING AND EXCHANGE			■
Chapter 13		**FINAL PROVISIONS**			
	78	AMENDMENT OF CONTRACTS AND GENERAL TERMS AND CONDITIONS			■
	79	ENTRY INTO FORCE			■

Figure 45: NC LFCR – base-line, harmonisation and new requirements

The code develops three processes of reserves required to contain and restore frequency disturbances as well those required to replace them and ensure longer-term balance between supply and demand for electricity. In each case and for each Synchronous Area there are common dimensioning requirements and common minimum technical requirements. The common language defined around the basic power system balancing function, permits products to be defined within these broader categories for various technologies.

These categories form the basis of defining technical requirements for use in market initiatives to permit further coupling and integration of markets, and permitting greater cross-border and inter-area activities, reducing barriers to trade for balancing service providers whether they are generators or demand-side.

The code has a strong focus on security of supply; the code recognises the need to reach an optimal position which enables improved economies of scale, while limiting the risks of failure and capacity constraints which are becoming increasingly important as the length of the power delivery path increases.

The code identifies the opportunities and mechanisms for transfer of balancing services between LFC-Blocks through defining broad mechanisms defined as imbalance netting, exchange or sharing of Reserve Capacity thereby reducing the amounts of reserves activated as well as opening-up the market and thereby increasing competition between balancing service providers. This will thus create a means for the NC EB to develop tools that will reduce the average consumer bills for balancing costs across Europe.

However the transmission system capacity is finite, and so the code sets limits to the degree to which reserves can be exchanged and shared. TSOs should also have the rights to restrict the provision or receipt of reserve power where transmission security limits would be breached. This fundamental requirement to ensure security of supply and provide firm limits to markets preventing brittle solutions which would endanger customer supplies becomes a key aspect of the code.

The benefits mentioned above cover the ability to maintain the high system security standard as it is nowadays and as it is appreciated by European citizens. With these benefits the TSOs lay a robust basis for facing the new energy transition challenges. A further quantification of the added values of implementing the requirements of the NC LFCR would require complex studies subject to multiple factors and hypothesis that depend strongly on scenarios per region and are subject to numerous fluctuating parameters.

In addition to the benefits described above, the code contributes significantly towards the efforts of meeting the energy policy targets of the European Union

- in maintaining and developing security of supply;
- in facilitating greater integration and the opening of the single electricity market;
- in providing a sound framework for the future, to deal with the challenges and opportunities that arise from the changing sources of energy and increasing drive towards smart-demand participation in achieving a low-carbon, energy-efficient economy.

A key goal of the NC LFCR is to achieve as much as possible a harmonised and solid technical framework for Interconnected System Load-Frequency Control taking into account the rapid growth of the (volatile) Renewable Energy Sources (RES) generation and their impact on system operation in general and on frequency specifically. Consequently, the requirements have been designed in order to ensure a Load-Frequency Control that meets the objectives of a secure Interconnected System operation and the effective development of the IEM.

The requirements set out in the NC LFCR build on a long history of existing common and best practices, lessons learned and operational needs throughout the European Transmission Systems.

REFERENCES

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[8] UCTE: Operation Handbook Policy 1. March 2009

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APPENDIX A: CURRENT PRACTICES OF ELECTRICAL TIME CONTROL

Since 1926, after the invention of the electric clock driven by a synchronous motor, the largest Synchronous Areas have implemented system frequency control for long time periods, keeping electrical time accuracy. The network operators control the daily average frequency and use best endeavours so that electrical clock deviations stay within a few seconds. In practice, for long time corrections of system frequency average errors from its nominal value, the TSOs raise or lower the Setpoint frequency by a specific percentage to maintain synchronization of electrical time to UTC.

Taking into consideration the Synchronous Area size and the value of nominal frequency, there are different values regarding the electric time control as it is shown by the following examples:

- The accuracy of frequency adjustment:
  - ±0.02 % for system with 50 Hz as nominal frequency = 0.01 Hz (Continental Europe)
  - ±0.033 % for system with 60 Hz as nominal frequency = 0.02 Hz (NERC)
- Correction duration:
  - 1 day - Continental Europe and Nothern Europe
  - ¼ h – GB, NERC
- Allowed range:
  - [-30 s;+30 s] - Continental Europe, NE
  - [-10 s;+10 s] – GB, East NA
  - [-2 s;+2 s] - West NA
  - [-3 s;+3 s] - West NA
- Range of started correction actions:
  - [-20 s;+20 s] - Continental Europe
  - [-15 s;+15 s] – NE

In CE, the deviation between electrical time and UTC (based on International Atomic Time) is calculated at 08:00 each day in the control centre in Switzerland (Laufenburg).

The target frequency (in the FRR process) is then adjusted by up to ±0.01 Hz (±0.02%) from 50 Hz as needed, to ensure a long-term frequency average of exactly 50 Hz × 60 s × 60 minutes × 24 hours = 4’320’000 voltage cycles per day.

The time error corrected by a frequency offset of 0.01 Hz during 1 day is:

0.01 Hz / 50 Hz *24*60*60 s = 17.28 s

That justifies the adopted range of 20 seconds as the range to start the corrective actions inside CE system. The value of 0.01 Hz adopted for frequency correction is coherent with the insensitivity of governors.

In North America, whenever the electrical time error exceeds 10 seconds for the East Interconnection, 3 seconds for Texas, or 2 seconds for the West Interconnection, a correction of ±0.02 Hz (0.033 %) is applied. Time error corrections start and end either on the hour or on the half hour. The correction is provided also in the FRR process.

The time error corrected by a frequency offset of 0.02 Hz during 30 minutes is:

0.01 Hz / 60 Hz *30*60s = 0.6 s

APPENDIX B: MAPPING OF FCR, FRR AND RR TO PRODUCTS

Table 7 provides a mapping of the Active Power Reserves according to the NC LFCR to terms which are currently used in the Synchronous Areas as product definitions.

Table 7: Mapping Processes to Products

Sync. Area	Process	Product	Activation	Local / Central	Dynamic / Static	Full deviation	Full activation
IRE	FCR	Primary operating reserve	A	L	D / S	>±200 mHz	5 s
IRE		Secondary operating reserve	A	L	D / S	±200 mHz	15 s
NE		FNR (FCR N)	A	L	D	±100 mHz	120 s -180 s
NE		FDR (FCR D)	A	L	D	±500 mHz	30 s
CE		Primary Control Reserve	A	L	D	±200 mHz	30 s
GB		Frequency response dynamic	A	L	D	variable	variable
GB		Frequency response static	A	L	S	variable	variable
IRE	FRR	Tertiary operational reserve 1	A/M	L / C	D / S	n.a.	90 s
IRE		Tertiary operational reserve 2	M	C	S	n.a.	5 minutes
IRE		Replacement reserves	M	C	S	n.a.	20 minutes
NE		FRRA	A	C	D	n.a.	2 min
NE		Regulating power	M	C	S	n.a.	15 minutes
CE		Secondary Control Reserve	A	C	D	n.a.	15 minutes
CE		Tertiary Control Reserve	M	C	S	n.a.	15 minutes
GB	RR	Various Products	M	n.a.	D / S	n.a.	variable
IRE		Replacement reserves	M	C	S	n.a.	20 minutes
NE		Regulating power	M	C	S	n.a.	15 minutes
CE		Tertiary Control Reserve	M	C	S	n.a.	individual
GB		Various Products (mainly STOR)	M	n.a.	D / S	n.a.	variable

(M)	manual activation	(C)	Instructed by the Reserve Instructing TSO
(A)	automatic activation	(L)	Local activation triggered by the Reserve Providing Unit or Reserve Providing Group

APPENDIX C: GREAT BRITAIN SYNCHRONOUS AREA

The Great Britain Synchronous Area is an area where the Synchronous Area, LFC Block, and LFC Area are one. Although there are several TSOs, the GB NRA appoints one TSO as designated GB system operator (GBSO). The GBSO is the only operator of the HV transmission system and therefore has the sole responsibility for maintaining frequency quality by balancing demand with generation. The other TSOs act only in the roles of Transmission Owner, not as System Operator. They could be said to be a monitoring area. GB is joined to other Synchronous Areas by HVDC links to Eire, Northern Ireland, France and The Netherlands. As the Synchronous Area consists of one structure throughout, the frequency quality is maintained by keeping the frequency as close as possible to nominal which is 50 Hz. The frequency deviation is a measure of the power imbalance. As part of historical design there is no Automatic Generation Control (i.e. no automatic FRR).There is the capability for various FCR, manual FRR, and RR services on the HVDC links Reserve sharing with Ireland is in place, and there is reserve exchange with Continental Europe (for FCR, FRR an RR). The services in place vary but are dependent on the bilateral contracts in place between the GBSO and the TSO at the other end of the HVDC link.

The required frequency quality for GB Synchronous Area is outlined in GB legislation in the Electricity Supply regulations and the “National Electricity Transmission System Security and Quality of Supply Standards” (SQSS). These requirements have been drawn up to meet the historical design of the GB transmission network. The GBSO has to meet these requirements and the requirements of the Network Code are written to take account of the operation and design of this Synchronous Area.

DIMENSIONING

In GB there are two aspects to dimensioning that have to be considered. These are dimensioning as a consequence of the connection conditions and system conditions in real time.

The largest unit that may be connected to the Transmission network is set by the NRA after consultation with stakeholders. This sets the general dimensioning requirements. There may be occasions in real time when the dimensioning incident that has to be covered is greater than the connection size, this may be due to reasons such as network topology changes. A full cost and risk assessment is carried out in these situations whether to cover this requirement or apply restrictions and bring the dimensioning requirement down to the connection limit size or below.

There is a statutory limit of 50.5 to 49.5. For a normal loss (defined in the SQSS) the frequency deviation must not exceed the statutory limit. In the code this is referred to as the maximum steady state frequency deviation. For an abnormal loss (defined in the SQSS) the frequency deviation (referred to in the code as maximum instantaneous frequency deviation) may fall to less than 49.5 Hz but in this situation the frequency must return to the statutory limit within 60 seconds. To ensure these limits are met there is an operational limit of 49.8 to 50.2 Hz (referred to in the code as the standard frequency range). If the frequency falls to the statutory limit it must return to the operational limit with 10 minutes.

FREQUENCY REQUIREMENTS

The objectives of the GBSO response/reserve holding policy shall be to provide assurance, that with reasonably foreseeable levels of generation failure, shortfall, and demand forecast error and credible generation or demand loss do not cause us to invoke involuntary demand disconnection. In so doing the GBSO shall endeavour to adopt a response/reserve holding strategy that maintains the prevailing level of short-term supply security.

In real time the frequency requirement is met by ensuring there is enough reserve on the system so that there is enough reserve on the system to provide frequency response. RR and contingency reserve are used to always ensure FCR and FRR requirements are met.

The reserve for response requirements (FCR) are set by simulation studies that ensure the GBSO meets the SQSS principles (normal & abnormal loss max frequency deviations and ensuring return back to ±0.5 in 1 minute).There is calculated amount of FCR and FRR needed to meet the required dimensioning requirements which is dependent on the demand level. To meet this criteria there is also a limit of 1500 set for the number of occasions outside the ±200 mHz. This is the basis of the value in table 3 within the code.

The Security Standard is subject to periodic review based on such factors as a change in the relationship between risks and margins or significant changes in generation or demand characteristics. There is no obligation in the GB Transmission Licence to work to a Generation Security Standard but the GBSO states to the NRA a 1:365 dimensioning is worked to.

Operationally the Frequency Restoration reserve (FRR) levels and Replacement reserve levels (RR) are set as a joint requirement. The GBSO does not separate the overall requirement into 2 parts, but ensure there is a proportion of the requirement that meets the FRR criteria. It determines FRR+RR requirement by using statistical analysis of half hourly data from previous years (since the inception of GB Trading Arrangements were initiated in 2005). The analysis estimates historic generator unreliability and plant failure statistics (URE) and combines them with demand forecast error (DFE) and wind generation forecast error (WFE) statistics to determine a combined historic imbalance known as Short Term Error (STE) at a particular timescale. This is the imbalance (aggregated over half an hour or Settlement Period) and represents the combined losses observed on the GB transmission system between a particular timescale and that real time settlement period. The data is also grouped into time periods associated with peaks and troughs of the National Demand. URE and DFE and WFE statistics are collated at 24hrs, 18hrs, 12hrs, 6hrs and 4hrs ahead of real time, where 4 hrs ahead is considered the final time at which the control room would be able to complete their final system operating plan. These dataset of combined imbalances are ordered as below such that a 1 in 365 probability (99.73%) imbalance level is set at the short term reserve requirement for each timescale.

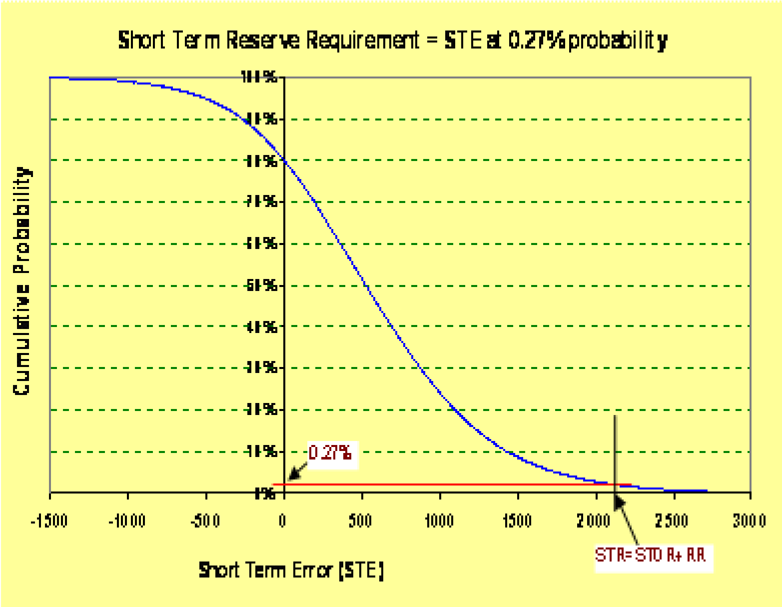

Figure 46: Short term reserve requirement probability for GB

The values in the Network Code in tables 1 and 2 have been defined based on this methodology.

CONTINUOUS DIMENSIONING

The GBSO continuously assesses the frequency requirement to meet the dimensioning criteria. To maintain the SQSS there cannot be a shortfall of response. Online tools are used to continuously display the reserve requirements for the required dimensioning at that current demand level. The GBSO is continuously dimensioning over the entire GB system.

RESERVE MARKET

The GB SO instructs reserve providers to provide FCR and FRR based on a number of factors including reserve price, bid-offer price, reserve requirement, reserve provision, provider parameters, and transmission congestion.

The GBSO will always know the location of the reserve provision and so will always ensure the dimensioning requirements are met. To restrict holding on a node (as in some other Synchronous Areas) would restrict the operation of the GB market and increase costs to consumers. For this reason there is no specific nodal restriction on FCR.

The requirements for reserve providers to replace unavailable units and recover energy reservoirs have not been added to GB, as the GBSO replaces unavailable units by requesting another unit itself in the market instead of mandating reserve providers to replace unavailable units themselves. The reserve contracts and prequalification takes account of any energy reservoir limitations so a replacement requirement is not required

TIME CONTROL

The GB Grid Code specifies that the TSO will endeavour (in so far as it is able) to control electric clock time to within plus or minus 10 seconds by specifying changes to Target Frequency, by accepting bids and offers in the Balancing Mechanism. Errors greater than plus or minus 10 seconds may be temporarily accepted at GBSO's reasonable discretion. For GB there is no statutory requirement to monitor and control clock error.

CHANGES INTRODUCED BY THE NETWORK CODE

The Network Code does not bring about any new requirements in terms of structure, and frequency quality. Changes and new items bought about by this code are publishing requirements, alert states (although already GB has a process in place for warning market participants of frequency issues and operating reserve issues). The code outlines any restrictions between GB and the other Synchronous Areas in sharing and exchange.

APPENDIX D: IRELAND SYNCHRONOUS AREA

From the perspective of load – frequency control and reserves the island of Ireland constitutes a single Synchronous Area, a single LFC Block and a single LFC Area [3]. Both EirGrid and SONI act together as the TSO to ensure the required frequency quality is maintained through joint scheduling, dispatch and maintaining of the required level of reserves on a Synchronous Area level. Central dispatch as opposed to self-dispatch is the current market design. With central dispatch the TSO determines the dispatch values and issues instructions directly to generators or demand. The TSO determines the dispatch instructions based on prices and technical parameters provided by the participating parties in order to minimise the system production cost while meeting security requirements. This is currently combined with centralised unit commitment scheduling in the SEM market. In a centrally dispatched market participants are given their position based on a central decision.

Since the introduction of the Single Energy Market (SEM) in November 2007, the generation of power on the island of Ireland has been scheduled and dispatched based on bids provided by conventional generators, interconnector capacity holders, demand side load blocks and the priority dispatch must-run principle. EirGrid and SONI are charged with the scheduling (in advance) and dispatch (in real-time) of electricity on the transmission system.

A number of the key features of the Single Electricity Market on the island of Ireland are:

- mandatory gross Pool;
- day-ahead and an additional intra-day complex bidding;
- ex-post System Marginal Price (SMP) pricing (which excludes transmission, reserve and other constraints), with a single island-wide price for each Trading Period;
- central dispatch.

Participation in the pool is mandatory for licensed generators and suppliers save for generators which have a maximum export capacity of less than 10 MW (the de minimis threshold) for whom direct participation is voluntary. As a consequence, almost all electricity generated has to be sold into/purchased from the pool. Under the pool arrangements, the sale and purchase of electricity is conducted on a gross basis, with all generators/suppliers receiving/paying the same price for the electricity sold into/bought via the pool. Bilateral financial contracting (e.g. contracts for differences) can still occur, but the arrangements for doing so are separate from and not covered within the Trading and Settlement Code.

Participants are required to submit Offers, technical and commercial, into the pool in respect of each Generator or Demand Unit for each Trading Day with an additional intra-day gate opening. The data contained within Offers applies equally for all Trading Periods within the relevant Trading Day (Interconnector Units are an exception to this rule. Interconnector Units are able to submit individual Offers to apply for each Trading Period in order to enable effective interaction with interconnected markets).

Technical Offer Data relates to the technical capabilities of the Generator or Demand Unit and consists of parameters such as ramp rates, start-up times.

Commercial Offer Data consists of:

- No load cost

- Start-up costs
- MW price (up to 10 price quantity pairs)

Under the Single Electricity Market, dispatchable Generator or Demand Units are dispatched centrally by the TSOs, rather than autonomously through self-dispatch by the Generator Unit operator. The TSO produces a schedule for each half hour based on the technical and commercial offer data submitted by the market participants, using a unit commitment and economic dispatch tool.

The market schedule determined by the MSP Software, actual dispatch patterns are in principle based upon economics, and it is a reasonable expectation that the cheapest generation will scheduled to run first, whilst respecting the technical capabilities of the Generator or Demand Units. However, while the MSP Software produces a market schedule on the assumption of an unconstrained system, ignoring the impact of, for example, transmission constraints, voltage and reserve requirements, the TSOs must dispatch Generator or Demand Units taking system constraints and reserve requirements into account (and must also consider real-time issues on the system such as unplanned outages). Therefore, the actual dispatch schedule followed is likely to deviate from the market schedule produced by the MSP Software.

The Reserve Constrained Unit Commitment package is normally run three times, but can be run as required, with in the relevant trading day to account for any changes such as unit trips or changes in system demand or wind output.

The output of the Reserve Constrained Unit Commitment package (RCUC) includes a unit commitment schedule, a set of discrete MW set points for each unit at 30 minute intervals, a reserve schedule and a tie-line flow schedule. The Control room operators use the output of the Reserve Constrained Unit Commitment package to guide them in the real time dispatch of the generation units. Actual dispatch is achieved through the issue of Dispatch Instructions throughout the Trading Day.

As mentioned above the TSO must ensure that sufficient additional generation output, or demand relief, is scheduled in order to maintain supply to customers in the event of rapid loss of a largest generation in-feed. This can be termed as Active Power reserve.

The following is a description of the current Active Power reserve products available to EirGrid. Primary Operating Reserve and Secondary Operating Reserve are products which comply with the requirements of the FCR process. Tertiary Operating Reserve 1 and 2 are products that comply with the FRR process and Replacement Reserves comply with the RR process. These reserve categories are characterised principally by different required response times and duration of response and are defined in the Grid Codes [3].

Current Frequency Containment Process products:

- Primary Operating Reserve (POR): The additional MW output (or reduction in demand) at the frequency nadir compared to the pre-Incident output (or demand), where the nadir occurs between 5 and 15 seconds after the event. If the actual frequency, nadir is before 5 seconds or after 15 seconds after the event, then for the purposes of POR monitoring the nadir is deemed to be the lowest frequency which did occur between 5 and 15 seconds after the event.

- Secondary Operating Reserve (SOR): The additional MW output (or reduction in demand) compared to the pre-incident output (or demand), which is fully available and sustainable over the period 15 to 90 seconds following the event.

Current Frequency Restoration Process products:

- Tertiary Operating Reserve 1 (TOR1): The additional MW output (or reduction in demand) compared to the pre-incident output (or demand), which is fully available and sustainable over the period 90 to 300 seconds following the event.
- Tertiary Operating Reserve 2 (TOR2): The additional MW output (or reduction in demand) compared to the pre-incident output (or demand), which is fully available and sustainable over the period 300 to 1200 seconds following the event.

Current Replacement Reserve Process products:

- Replacement Reserve: The additional MW output (and/or reduction in demand) required compared to the pre-incident output (or demand) which is fully available and sustainable over the period from 20 minutes to 4 hours following an event. The purpose of this category of reserve is to restore primary reserve within 20 minutes including restoring any interruptible load shed.

The provision of a minimum level of reserves by Generating Units is required by the Grid Code. Reserve in addition to the minimum level can be contracted. The following describes the Grid Code required level of reserves.

POR not less than 5 % Registered Capacity to be provided, at a minimum, at MW outputs in the range from 50 % to 95 % Registered Capacity, with provision in the range of 95 % to 100 % Registered Capacity to be not less than that indicated by a straight line with unity decay from 5 % of Registered Capacity at 95 % output to 0 at 100 % output.

SOR not less than 5 % Registered Capacity to be provided, at a minimum, at MW Outputs in the range from 50 % to 95 % Registered Capacity, with provision in the range of 95 % to 100 % Registered Capacity to be not less than that indicated by a straight line with unity decay from 5 % of Registered Capacity at 95 % output to 0 at 100 % output.

TOR1 not less than 8% Registered Capacity to be provided, at a minimum, at MW Outputs in the range from 50 % to 92% Registered Capacity, with provision in the range of 92 % to 100 % Registered Capacity to be not less than that indicated by a straight line with unity decay from 8 % of Registered Capacity at 92 % output to 0 at 100 % output.

TOR2 not less than 10 % Registered Capacity to be provided, at a minimum, at MW Outputs in the range from 50 % to 90 % Registered Capacity, with provision in the range of 90 % to 100 % Registered Capacity to be not less than that indicated by a straight line with unity decay from 10 % of Registered Capacity at 90 % output to 0 at 100 % output.

It is important to point out that due to the relatively small number of units on the system, that each unit provides POR, SOR, TOR1, TOR2 and RR, if dispatched at the appropriate level. The same Active Power reserve MWs that a unit provides as POR become SOR after 15 seconds and these same MWs, with at least an additional 3 %, become TOR1 at 90 seconds. As described in the following section FRR (TOR1 and TOR2) reserves are dimensioned to exactly cover the Reference incident which is the Largest Single Infeed (LSI).

So after 90 seconds the FCR (POR and SOR) with additional MWs become FRR. As these combined MWs only sum to the Largest Single Infeed it means that for the reference incident FRR cannot replace FCR and the TSO must rely on Replacement Reserves to replace the FCR. For energy limited reserve providers due to the size of the system, number of units and market design it is more appropriate for the TSO depending on system conditions and cost, to work on a case by case basis with the energy limited reserve providers to manage the energy recovery time. If another contingency occurs within the time period of 0 to 20 minutes, automatic under frequency load shedding is used to secure the power system.

The TSO using the Reserve Constrained Unit Commitment package schedules units to provide reserve for the island at minimum system cost based on individual unit reserve characteristics respecting:

- A jurisdictional minimum primary reserve holding for SONI;
- A jurisdictional minimum primary reserve holding for EirGrid;
- A total island reserve requirement determined from a fixed percentage of the Largest Single Infeed (LSI);
- Tie line flow limits after reserve execution in either jurisdiction; and
- A minimum requirement for dynamic reserve in both jurisdictions.

The jurisdictional minimum primary reserve holding for SONI and EirGrid values are fixed and are to:

- permit control of the tie line flows; and
- to avoid uncontrollable frequency falls in the event of system separation i.e. if the tie lines should trip.

Based on a deterministic approach, for each half hour period a total island reserve requirement is determined from a fixed percentage of the Largest Single Infeed (LSI) and for FCR (POR and SOR) allowing for the inclusion of self-regulation of load. The loss of the LSI is the event planned for when quantifying reserve provision. As the LSI could change for each half an hour there is a constant re-dimensioning of the required level of reserves. This makes publication in advance of anything other than an indicative reserve requirement figure extremely difficult. The LSI includes the interconnector import. If reserve is being carried on the LSI, this reserve is not included in reserve totals. The TSO can and will reduce the output of the LSI source if it is a cheaper solution than providing additional reserve. The balance of the reserve requirement (total minus jurisdictional minima can be optimised and scheduled in either jurisdiction).

Present values are:

- Primary 75 % of the Largest Single Infeed (in addition self-regulation of load)
- Secondary 75 % of the Largest Single Infeed (in addition self-regulation of load)
- Tertiary Reserve 1 100 % of the Largest Single Infeed
- Tertiary Reserve 2 100 % of the Largest Single Infeed

A minimum requirement for dynamic reserve is required in both jurisdictions. The interconnectors allow reserve from NGC to flow into the power system when the frequency falls below 49.6 Hz. This reserve provides no system regulating capability, which is provided from the Primary reserve holding. If all the primary reserve was static, system frequency control would not be possible. RCUC respects the desired Static / dynamic requirements when optimising.

Dynamic Reserve (inertia and governor action during frequency transient)

- Synchronised units operating at less than maximum output
- Pump storage synchronised and generating

Static Reserve (output change initiated by system frequency falling through a pre-set activation threshold)

- Pump storage in pump mode
- Interconnectors
- Interruptible Load

The static reserve facility on the interconnectors allows the sharing of reserves between Synchronous Area GB and Synchronous Area Ireland. The ability of each TSO to provide static reserve is available to be armed unless transfers on the interconnector prevent this or it is specifically withdrawn by either of the TSO. The volume of frequency response available will also vary depending on the real time transfer on the interconnector and will not lead to a transfer greater than the NTC. There is also an emergency instruction facility for system security issues and emergency assist facility when one of the parties foresees a difficulty in maintaining security on its transmission system.

The TSO operates such that the frequency can recover to 49.5 Hz within one minute of the loss of the Largest Single Infeed. In addition the Regulator currently applies a system performance incentive related to frequency control. EirGrid is incentivised to maintain the system frequency within a target operating range for a required percentage of time over the course of a year.

The delivery of FCR (POR and SOR) and FRR (TOR1 and TOR2) categories of reserve is assessed in light of the response of the contracted unit to a frequency event (that is, a fall in the system frequency to 49.5 Hz or below). In this instance, the TSO calculates the response expected under the Ancillary Services Agreement, taking into account the size and length of the frequency drop, the response delivered by the unit, and the unit technical data (for example, governor Droop characteristics). The TSO also assesses the delivery of Replacement Reserves, taking account of the timing of dispatch instructions.

There are a number of factors that influence the setting of the Frequency Quality Defining Parameters of a small Synchronous Area relative to a large Synchronous area. In a small Synchronous Area the imbalances due to the loss of individual elements tend to be large in comparison to the system size. This can be particularly pronounced at low system demand. The rate at which frequency changes tends to be high as the system inertial is lower. With lower inertia the system is more sensitive to disturbances with a greater likelihood of a large frequency excursion as an imbalance is large with respect to the size of the system. Also reserve is shared over a small number of units. The combination of these factors leads to the requirement to have wider ranges for the Frequency Quality Defining Parameters.

There is currently no automatic generation control (AGC) in operation in the Synchronous Area Ireland and hence no Automatic FRR. The TSO operators manually issue instructions to the units, allocating the required Active Power between them cost effectively, to maintain the system frequency at nominal.

The time error shall not in normal circumstances exceed ±10 seconds. Within the range of ±10 seconds system frequency should be controlled, through the normal generator dispatch process, such as to return the time error to zero. When the time error exceeds ±10 seconds the consideration should be given to resetting the target frequency as appropriate.

APPENDIX E: NORTHERN EUROPE SYNCHRONOUS AREA.

The Northern Europe Synchronous Area (comprises the countries of Finland, Sweden, Norway and Eastern Denmark) is an area where the Synchronous Area, LFC Block, and LFC Area are currently one. Although each country is the responsibility of a single TSO licensed to as the national system operator (SO). The national SO is the only operator of the HV transmission system including cross border flows and therefore has the sole responsibility. System frequency quality is managed by balancing demand with generation for the whole Synchronous Area. The SO of Norway and Sweden coordinate the activation of manual reserves that is necessary to achieve balance based on a common merit order stack. However all the SO are responsible to be able to balance their national system. Finland is connected to other Synchronous Areas by HVDC links to Russia and Estonia, Norway by HVDC links to Denmark West and Netherlands, Sweden with HVDC links to Poland and Germany and Denmark East to Germany and Denmark West.

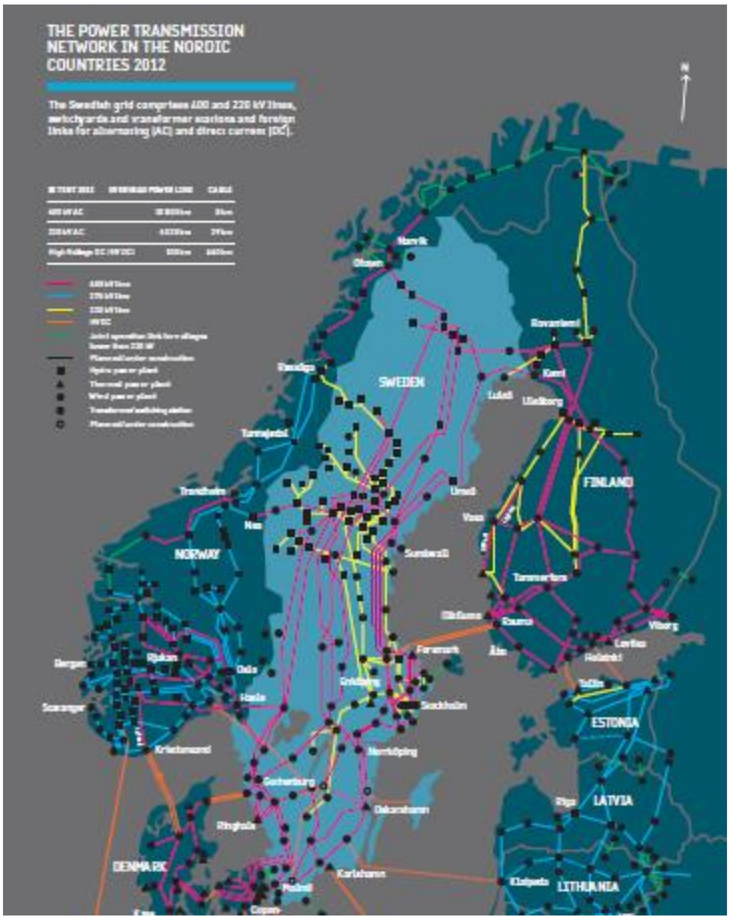

Figure 47: Northern Europe Transmission System

As the Synchronous Area consists of one structure throughout, the frequency quality is maintained by keeping the frequency as close as possible to nominal which is 50 Hz. The frequency deviation is a measure of the power imbalance. FCR reserves are distributed in the system currently based on the annual consumption as a percentage of the total for the Synchronous Area. FCR is defined as two response rates one for the normal operating range and one for disturbance. Automatic FRR has been introduced in the Synchronous Area in

2013 to improve frequency quality performance. Manual regulation is predominant FRR, and RR resources services on the HVDC links. There is RR exchange with Continental Europe.

The required frequency quality for NE Synchronous Area is agreed by the TSOs and documented in the Synchronous Area Operational Agreement (SOA) [7] and reported weekly based on minutes outside the normal operating range. This approach has been consistently applied since 1995 and shows the impact of efficient energy market.

Dimensioning

In NE there are two aspects to dimensioning that have to be considered. These are dimensioning as a consequence of the connection conditions and system conditions in real time.

The largest generation unit loss in the Synchronous Area that may occur in the transmission network is identified by the TSOs. This sets the general dimensioning requirements currently. With HVDC interconnection increasing it is feasible that this will become the largest loss in the system in the future due to reasons such as network topology changes. The definition of dimensional incident and frequency parameters is defined in the SOA.

There is currently a limit of 50.5 to 49.5 for the frequency deviation which must not be exceeded. In the code this is referred to as the maximum steady state frequency deviation.

Frequency requirements

The objectives of the SO in terms of response/reserve holding policy is defined nationally by the NRA or other Authorities shall be to provide assurance, that with reasonably foreseeable levels of generation failure, shortfall, and demand forecast error and credible generation or demand loss do not cause us to invoke involuntary demand disconnection. In so doing the SO shall endeavour to adopt a response/reserve holding strategy that maintains the prevailing level of short-term supply security. Capacity arrangements for manual reserves (RR) exist in all countries however they vary in arrangement and legal structure.

In real time the frequency requirement is met by ensuring there is enough reserve on the system to provide frequency response. The TSOs have a common information system where the available reserves and plan flows are displayed. This is used to monitor and ensure that sufficient RR and FRR are available to replace activated FCR.

The reserve for response requirements (FCR) are set by dynamic simulation studies at NE level, ensuring the SOs meets their collective obligations. Monitoring of delivery is done nationally. In Norway there is a mandatory delivery of FCR from providers over 10 MW of generation and a market to contract additional volume. In the other countries only market mechanism are in place. There is calculated amount of FCR and FRR needed to meet the required dimensioning requirements which are dependent on the dimensioning incident and the market induced imbalances. To meet this criterion there is also a limit of number of minutes outside the normal operating range of ±100 mHz defined in table 2.

Operationally the Frequency Restoration reserve (FRR) levels and Replacement reserve levels (RR) are currently not set jointly as FFR has only been introduced in 2013 in the whole Synchronous Area.

The values in the network code in tables 1 and 2 have been defined based on this levels defined in the SOA and agreed additional values in Northern Europe.

Reserve Market

The NE SOs have a currently National markets for FCR and FRR automatic reserves and allow exchange of these reserves up to a third of the importing SO obligation according to the SOA. Providers to provide FCR and FRR based on a number of factors including reserve price, bid-offer price, reserve requirement, reserve provision, provider parameters, and transmission congestion.

The SO will always know the location of the reserve provision and so will always ensure the dimensioning requirements are met. The prequalification arrangements are conducted by the National SO discression and consideration to geographic distribution. National shares of reserves are defined annually based on dimensioning criteria and allocation keys of the previous year's consumption. This distribution keys are used for FCR and FRR reserves and define national obligations.

The requirements for reserve providers to replace unavailable units and recover energy reservoirs have not been the practice, as the SO replaces unavailable units by requesting another unit itself in the market instead of mandating reserve providers to replace unavailable units themselves. The reserve contracts, general market requirements and prequalification takes account of any energy reservoir limitations so a replacement requirement is not required.

Changes Introduced by the Network Code

The Network Code does not bring about any new requirements in terms of structure, and frequency quality. Changes and new items bought about by this code are publishing requirements, additional frequency monitoring and alert states and a clear dimensioning methodology. The code outlines any restrictions between NE and the other Synchronous Areas in sharing and exchange.

APPENDIX F: CONTINENTAL EUROPE SYNCHRONOUS AREA

Within the Continental Europe (CE) Synchronous Area, the individual control actions and the reserves are organised in a decentralized structure consisting on LFC Areas and LFC Blocks. The goal is to keep the frequency as close as possible to the nominal value, which is 50 Hz and to keep the LFC Areas and LFC Blocks balanced by keeping the power exchange values between them to their scheduled values. The respective procedures are defined in the Operation Handbook Policy 1 [8].

The Synchronous Area of CE consists of multiple interconnected LFC Blocks, each of them with centralised control. Each LFC Block may divide up into LFC Areas that operate their own underlying control, as long as this does not jeopardise the interconnected operation. The present hierarchy of the control is represented in the following figure:

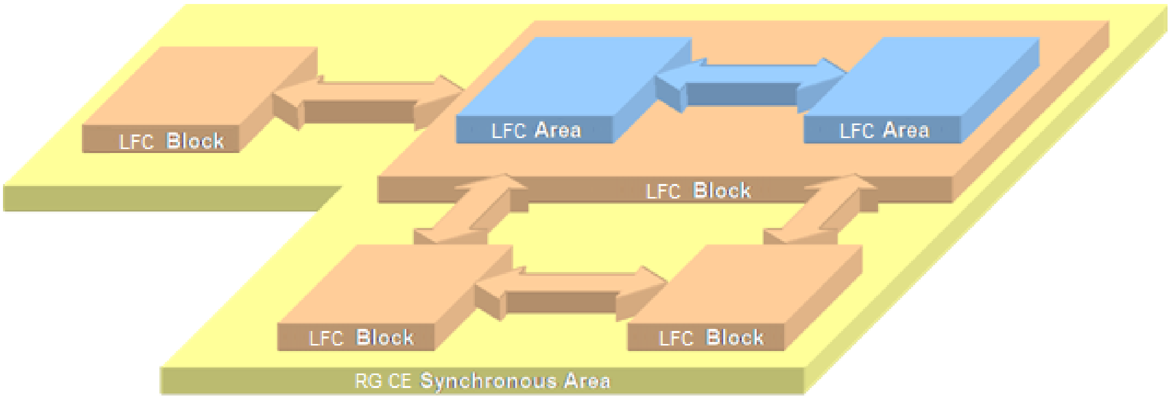

Figure 48: Hierarchy of the decentralized control in CE

Control actions are performed in different successive steps, each with different characteristics and qualities, and all depending on each other:

- Frequency containment is a joint responsibility distributed among all TSOs of CE with the goal of stabilizing the frequency in the time-frame of seconds. In CE its control structure is proportional and a steady-state error appears. The Frequency Containment Process is internally called primary control and starts within seconds as a joint action of all TSOs involved.
- Frequency Restoration is a local responsibility of each TSO for the imbalance in its LFC Area or LFC Block. In CE, the Frequency Restoration Process consists of Secondary Control which is automated and directly activated tertiary control which is a manual process. The goal of FRR activation is to recover the System Frequency and to replace primary control.
- Replacement Reserves are referred as Scheduled Activated Tertiary Reserves in CE and are manual reserves that are used to free up a LFC Area or LFC Block's FRR after the imbalance has been compensated and the system has settled to steady-state with the System Frequency value close to 50 Hz.
- Time Control is used in CE and corrects global time deviations of the synchronous time in a longer time frame as a joint action of all TSOs.

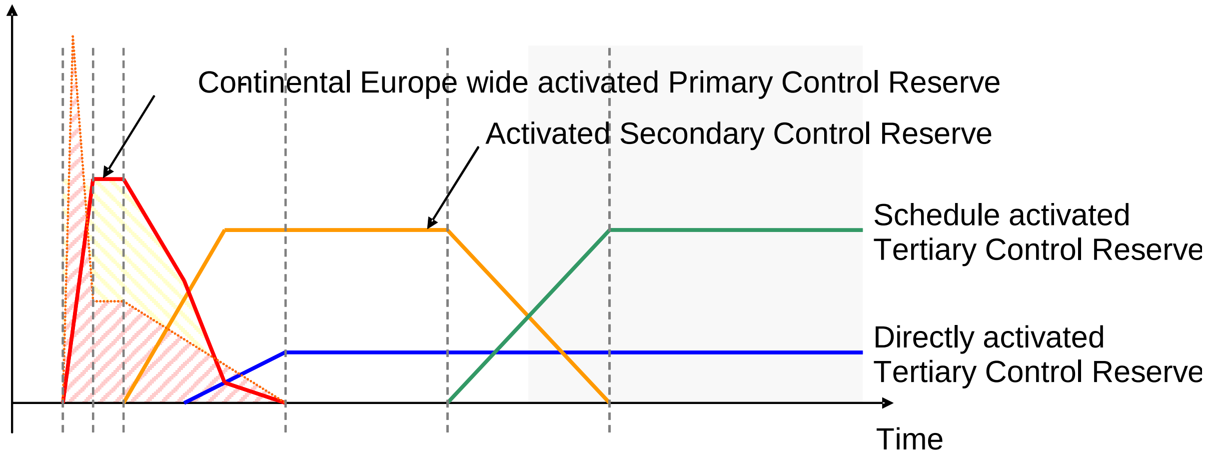

Figure 49: Principle frequency deviation and subsequent activation of reserves in CE

Frequency Containment Reserves or Primary Control

The total primary control reserve for the entire CE is determined taking account operational experience and theoretical considerations. An N-2 criterion is currently used adding to a Reference Incident of 3000 MW as the sum of the two largest nuclear power units connected in the same power plant as there is a risk that these units can trip one after the other before the frequency is returned to its nominal value and the FCR are replaced.

Each LFC Block must contribute to the correction of an imbalance with the providers of this service with obligations to the LFC Block. The overall primary reserve of the whole Synchronous Area is shared between LFC Blocks in accordance with their respective contribution coefficient to primary control. These contribution coefficients are calculated on a yearly basis for each LFC Block taking into account the net generated electricity in the LFC Block for a whole year (including electricity production for export and scheduled electricity production from jointly operated units, without deducting the generation consumed by the pumping of reversible hydro units) compared to the total electricity production in the whole CE for the same whole year.

The shares of primary control reserves of the LFC Blocks are defined by multiplying the determined total primary control reserve for CE and the contribution coefficients of the LFC Block.

The deployment time of the primary control reserves of the various LFC Blocks should be as similar as possible, in order to minimise dynamic interaction between LFC Blocks as a consequence of anticipated performance rather than the logic of controllers.

The primary control reserve of each LFC Block must be fully activated within 15 seconds in response to disturbances in which the power deviation is less than 1500 MW. If the value of the power deviation is between 1500 and 3000 MW the maximum primary control response time rises linearly from 15 to 30 seconds. In this case, the activated primary control power should behave linearly as much as possible, until the balance between power generation and consumption has been restored.

Automatic FRR: Secondary Control

The function of Secondary Control, also known in CE as load-frequency control, is to keep or to restore the power balance in each LFC Block and, consequently, to keep or to restore the

System Frequency to its Setpoint value of 50 Hz and the power interchanges with adjacent LFC Areas to their programmed scheduled values, thus ensuring that the full reserve of primary control power activated will be made available again. Secondary Control may not impair the action of the Primary Control. These actions of Secondary Control will take place continually, both in response to minor deviations and in response to major discrepancies between production and consumption.

Whereas all LFC Blocks provide mutual support by the supply of primary control power during the primary control process, only the LFC Block affected by a power unbalance is required to undertake secondary control action for its correction. Consequently, only the controller of the LFC Block in which the imbalance between generation and consumption has occurred will activate the corresponding secondary control power within its LFC Block. Parameters for the secondary controllers of all LFC Areas need to be set such that, ideally, only the controller in the zone affected by the disturbance concerned will respond and initiate the deployment of the requisite secondary control power.

Within a given LFC Block, in order to maintain this balance, generation or demand capacity for use as secondary control reserve must be available to cover power plant outages and any disturbances affecting production, consumption and transmission. Secondary control is applied to the selected provider units comprising the control loop. Secondary control operates for periods of several minutes, and is therefore timely dissociated from primary control. This behaviour over time is associated with the PI (proportional-integral) characteristic of the secondary controllers. Secondary control makes use of measurements of the system frequency and active power flows on the tie-lines of the LFC Block. A secondary controller computes power Setpoint values of selected Providing Units for control and the transmission of these Setpoint values to the respective Providing Units.

The Frequency Restoration Control Error is termed Area Control Error in CE. The Area Control Error must be kept close to zero in each LFC Block. If a LFC Block has more than one internal LFC Areas, the LFC Block organises the internal secondary control.

The Dimensioning Incident of each LFC Area or LFC Block is calculated in using an N-1 criterion taking into account the largest generation unit, load or HVDC interconnector of the LFC Area or the LFC Block.

Manual FRR and RR: Tertiary Control

Tertiary control is a change in the Setpoints of generations or loads participating, in order to guarantee the provision of secondary control reserves at the right time and distribute the secondary control power to the various generations in the best possible way.

Tertiary Control is divided between directly activated tertiary control which can be activated at any time, independent from a time-frame of exchange schedules and it is part of the Frequency Restoration Process and scheduled activated tertiary control which is activated in relation to the predefined time-frame of schedules, normally between 15 minutes to one hour. The scheduled activated tertiary control is part of the Replacement Process.

Time Control

If the mean system frequency in the synchronous zone deviates from the nominal frequency of 50 Hz this results in a discrepancy between synchronous time and Universal Coordinated

Time (UTC). A discrepancy between synchronous time and UTC is tolerated in CE within a range of ±20 seconds without need for time control actions.

An entity is appointed within CE as the time monitor. The time monitor is responsible for the calculation of synchronous time and the organisation of its correction. Correction involves the setting of the Setpoint frequency for secondary control in each LFC Block and LFC Area at 49.99 Hz or 50.01 Hz, depending upon the direction of correction, for full periods of one day (from 0 to 24 hours).

Hourly ramps of scheduled programs

The algebraic sum of the agreed hourly exchange programs of cross-border exchange transfers between LFC Blocks and LFC Areas and the adjacent LFC Blocks or LFC Areas constitutes the power interchange set point for the areas' secondary controller. In order to reduce fluctuations on interconnections when program changes occur and deterministic Frequency Deviations, it is necessary that this change is converted to a ramp lasting 10 minutes in total, starting 5 minutes before the agreed change of the exchange program and ending 5 minutes later (see figure below), regardless of the scheduling time-step (one hour, 30 minutes or 15 minutes).

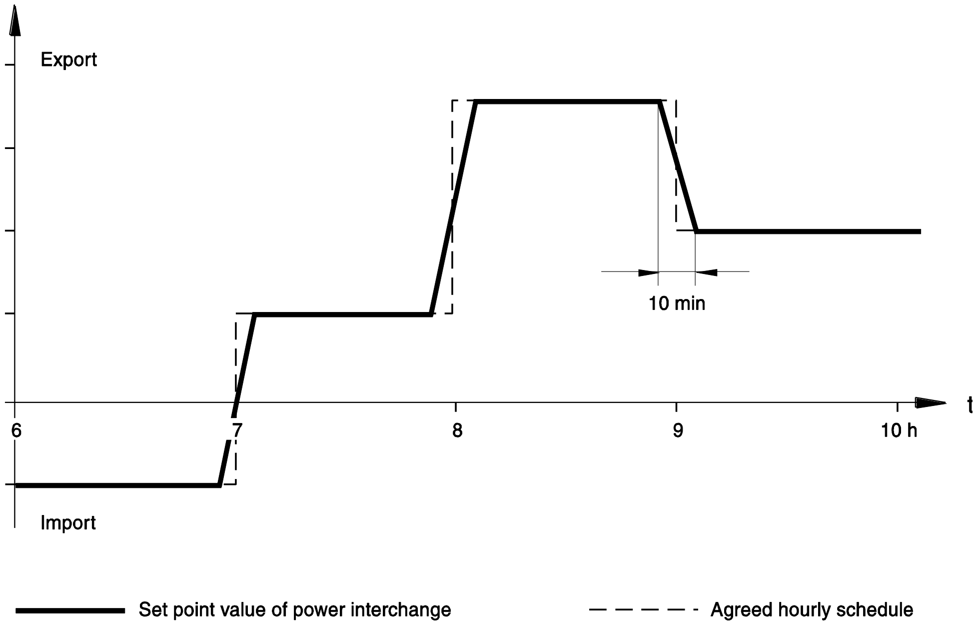

Figure 50: Example of ramping between LFC Blocks in CE

Changes Introduced by the Network Code

The LFCR Network Code does not bring any new requirements in terms of structure. The main changes and new items introduced in this code are improved frequency quality monitoring and increased publishing of requirements. The code outlines any restrictions between CE and the other Synchronous Areas in sharing and exchange that were within CE not clearly defined before.

APPENDIX G: LIST OF REFERENCES TO PROVIDERS

For the readability and convenience of all parties who are interested in or who can be considered as 'providers' as defined in the NC LFCR (excluded the 'whereas' section), we compiled two lists, one where the term 'provider(s)' appears in the NC and one where the term 'providing unit(s)' or 'providing group(s)' appears.

PROVIDER

Chapter 1 General Provisions
Subject Matter and Scope
Article 1(1)
Definitions
Article 2
'Provider'
Regulatory Notification
Article 5(1)f,g
Confidentiality Obligations
Article 7(1)
Chapter 6 Frequency Containment Reserves
FCR Technical Minimum Requirements
Article 44(2)
Article 44(3)
Article 44(5)
Article 44(8)
FCR Provision
Article 45(4)
Article 45(5)
Article 45(6)
Chapter 7 Frequency Restoration Reserves
FRR Technical Minimum Requirements
Article 47(1)e,h
Article 47(6)
Article 47(7)
Chapter 8 Replacement Reserves
RR Technical Minimum l Requirements
Article 49(1)f
Article 49(6)
Article 49(7)

PROVIDING UNIT AND PROVIDING GROUP

Chapter 1 General Provisions
Definitions
Article 2
'Prequalification'
'Provider'
'Reserve Instructing TSO'
'Reserve Connecting DSO'
'Reserve Connecting TSO'
'Reserve Providing Group'
'Reserve Providing Unit'
'Reserve Receiving TSO'
Regulatory approvals

Article 4(2)a,b,d,f
Regulatory Notification
Article 5(1)g
Chapter 6 Frequency Containment Reserves
FCR Technical Minimal Requirements
Article 44(1)
Article 44(3)
Article 44(4)
Article 44(5)
Article 44(6)
Article 44(7)
Article 44(8)
Article 44(8)c
FCR Provision
Article 45(3)b
Article 45(4)
Article 45(5)a
Article 45(6)
Chapter 7 Frequency Restoration Reserves
FRR Technical Minimal Requirements
Article 47(1)a,b,d,e,f,g,i
Article 47(2)
Article 47(3)
Article 47(4)
Article 47(5)
Article 47(6)
Article 47(7)a,b
Article 47(8)
Chapter 8 Replacement Reserves
RR Technical Minimal Requirements
Article 49(1)
Article 49(1)a,b,d,e,f,g
Article 49(2)
Article 49(3)
Article 49(4)
Article 49(5)
Article 49(6)
Article 49(7)a,b
Article 49(8)
Chapter 9 Exchange and Sharing of Reserves
Section 1 Exchange and Sharing of Reserves within a Synchronous Area
Exchange of FCR within a Synchronous Area
Article 50(8)
Chapter 11 Co-operation with DSOs
Reserve Providing Units connected to the DSO Grid
Article 68(1)
Article 68(2)a,c,d
Article 68(3)
Chapter 12 Transparancy of Information
Information on FCR
Article 74(3)

APPENDIX H: GLOSSARY

Active Power - is the real component of the Apparent Power at fundamental Frequency, expressed in watts or multiples thereof (e.g. kilowatts (kW) or megawatts (MW)). (from [NC RfG])

Active Power Reserve means the Active Power which is available for maintaining the frequency; (from [NC OS])

Adjacent LFC Areas means LFC Areas having a common electrical border (from [NC LFCR])

Adjacent LFC Blocks means LFC Blocks having a common electrical border (from [NC LFCR])

Affected TSO means the TSO for which information on the Exchange of Reserves and/or Sharing of Reserves and/or Imbalance Netting Process and/or Cross-Border Activation Process is needed for the analysis and maintenance of Operational Security (from [NC LFCR])

Agency means the Agency for the Cooperation of Energy Regulators as established by Regulation (EC) No 713/2009 (from [NC CACM])

Alert State means the System State where the system is within Operational Security Limits, but a Contingency from the Contingency List has been detected, for which in case of occurrence, the available Remedial Actions are not sufficient to keep the Normal State; (from [NC OS])

Alert State Trigger Time means the time until Alert State becomes active (from [NC LFCR])

Area Control Error (ACE) means the sum of the instantaneous difference between the actual and the Setpoint value of the measured total power value and Control Program including Virtual Tie-Lines for the power interchange of a LFC Area or a LFC Block and the frequency bias given by the product of the K-Factor of the LFC Area or the LFC Block and the Frequency Deviation (from [NC OS])**Automatic FRR** means FRR that can be activated by an automatic control device (from [NC LFCR])

Automatic FRR Activation Delay means the period of time between the setting of a new Set point value by the frequency restoration controller and the start of physical Automatic FRR delivery (from [NC LFCR])

Automatic FRR Full Activation Time means the time period between the setting of a new Set point value by the frequency restoration controller and the corresponding activation or deactivation of Automatic FRR (from [NC LFCR])

Average FRCE Data means the Set of data consisting of the average value of the recorded instantaneous FRCE of a LFC Area or a LFC Block within a given measurement period time (from [NC LFCR])

Connecting TSO means the TSO in whose Responsibility Area a Power Generating Module, Demand Facility, non-TSO owned Interconnector, or grid element is connected to the Network at any Voltage level (from [NC OPS])

Connection Point means the interface at which the Power Generating Module, Demand Facility, Distribution Network or Closed Distribution Network is connected to a Transmission System, Distribution Network or Closed Distribution Network (from [NC LFCR])

Control Capability Providing TSO means the TSO which shall trigger the activation of his Reserve Capacity for a Control Capability Receiving TSO under conditions of an agreement for the Sharing of Reserves (from [NC LFCR])

Control Capability Receiving TSO means the TSO calculating Reserve Capacity by taking into account Reserve Capacity which is accessible through a Control Capability Providing TSO under conditions of an agreement for the Sharing of Reserves (from [NC LFCR])

Control Program means the Setpoint value, also called schedule, for the netted power interchange of a LFC Area over Interconnectors (from [NC OS])

Criteria Application Process means the process of calculation of the target parameters for the Synchronous Area, the LFC Block and the LFC Area based on the data obtained in the Data Collection and Delivery Process (from [NC LFCR])

Cross-Border FRR Activation Process means a process agreed between the TSOs participating in the process that allows for activation of FRR connected in a different LFC Area by correcting the input of the involved FRPs accordingly (from [NC LFCR])

Cross-Border RR Activation Process means a process agreed between the TSOs participating in the process that allows for activation of RR connected in a different LFC Area by correcting the input of the involved RRP accordingly (from [NC LFCR])

Data Collection and Delivery Process means the Process of collection of the set of data necessary in order to perform the Frequency Quality Evaluation Criteria (from [NC LFCR])

Demand Facility means a facility which consumes electrical energy and is connected at one or more Connection Points to the Network. For the avoidance of doubt a Distribution Network and/or auxiliary supplies of a Power Generating Module are not to be considered a Demand Facility (from [NC DCC])

Demand Side Response Active Power Control (DSR APC) means demand within a Demand Facility or Closed Distribution Network that is accessible for modulation by the Relevant Network Operator, which results in an Active Power modification (from [NC DCC])

Demand Side Response System Frequency Control (DSR SFC) means reduction or increase of the demand of electrical devices in response to Frequency fluctuations, made by an autonomous response to temperature targets of these electrical devices to diminish these fluctuations (from [NC DCC])

Demand Side Response Very Fast Active Power Control (DSR VFAPC) means demand within a Demand Facility or Closed Distribution Network that can be modulated very fast, i.e. within 2 seconds, in response to a Frequency deviation, which results in a very fast Active Power modification; (from [NC DCC])

Demand Unit means an indivisible set of installations which can be actively controlled by a Demand Facility Owner or Distribution Network Operator to moderate its electrical energy demand. A storage device within a Demand Facility or Closed Distribution Network operating in electricity consumption mode is considered to be a Demand Unit. A hydro pump-storage unit with both generating and pumping operation mode is excluded. If there is more than one unit consuming power within a Demand Facility, that cannot be operated independently from each other or can reasonably be considered in a combined way, then each of the combinations of these units shall be considered as one Demand Unit (from [NC DCC])

Dimensioning Incident means the highest expected instantaneously occurring Active Power Imbalance within a LFC Block in both positive and negative direction (from [NC LFCR])

Distribution Network means an electrical Network, including Closed Distribution Networks, for the distribution of electrical power from and to third party[s] connected to it, a Transmission or another Distribution Network (from [NC DCC])

Droop - is the ratio of the steady-state change of Frequency (referred to nominal Frequency) to the steady-state change in power output (referred to Maximum Capacity). (from [NC RfG])

Electrical Time Deviation means the time discrepancy between synchronous time and Universal Time Coordinated (UTC) (from [NC LFCR])

Emergency State means the System State where Operational Security Limits are violated and at least one of the operational parameters is outside of the respective limits; (from [NC OS])

Exchange of Reserves means a concept for a TSO to have the possibility to access Reserve Capacity connected to another LFC Area, LFC Block or Synchronous Area to comply with the amount of required reserves resulting from its own reserve dimensioning process of either FCR, FRR or RR. These reserves are exclusively for this TSO, meaning that they are not taken into account by any other TSO to comply with the amount of required reserves resulting from their respective reserve dimensioning processes (from [NC LFCR])

FCR Full Activation Frequency Deviation means the rated value of Frequency Deviation at which the FCR in a Synchronous Area is fully activated (from [NC LFCR])

FCR Full Activation Time means the time period between the occurrence of the Reference Incident and the corresponding full activation of the FCR (from [NC LFCR])

FCR Obligation means the part of all of the FCR that falls under the responsibility of a TSO (from [NC LFCR])

Forced Outage means the unplanned removal from service of Relevant Assets for any urgency reason that is not under the operational control of the respective operator (from [NC OPS])

FRCE Target Parameters means the target main LFC Block variables on basis of which the dimensioning criteria for FRR and RR of the LFC Block are determined and evaluated. These parameters reflect the LFC Block behaviour in normal operation (from [NC LFCR])

Frequency - is the Frequency of the electrical power system that can be measured in all Network areas of the synchronous system under the assumption of a coherent value for the system in the time frame of seconds (with minor differences between different measurement locations only); its nominal value is 50 Hz. (from [NC RfG])

Frequency Containment Process (FCP) means a process that aims at stabilizing the frequency by compensating imbalances by means of appropriate reserves (from [NC LFCR])

Frequency Containment Reserves (FCR) means the Operational Reserves activated to contain System Frequency after the occurrence of an imbalance (from [NC OS])**Frequency Deviation** means the difference between the actual System Frequency and the Nominal Frequency of the Synchronous Area which can be negative or positive (from [NC OS])

Frequency Quality Defining Parameters means the main System Frequency variables that define the principles of Frequency Quality (from [NC LFCR])

Frequency Quality Evaluation Criteria means a set of calculations using System Frequency measurements that allow the evaluation of the quality of the System Frequency against the Frequency Quality Target Parameters (from [NC LFCR])

Frequency Quality Evaluation Data means the set of data that allows the calculation of the Frequency Quality Evaluation Criteria (from [NC LFCR])

Frequency Quality Target Parameter means the main System Frequency target variables on basis of which the behaviour of FCR, FRR and RR activation processes is evaluated in Normal State (from [NC LFCR])

Frequency Recovery Range means the System Frequency range to which the System Frequency is expected to return in the Synchronous Areas GB and IRE after occurrence of an imbalance equal to or less than the Reference Incident within the Time To Recover Frequency (from [NC LFCR])

Frequency Response Deadband - is used intentionally to make the Frequency Control not responsive. In contrast to (in)sensitivity, deadband has an artificial nature and basically is adjustable. (from [NC RfG])

Frequency Response Insensitivity - is the inherent feature of the control system defined as the minimum magnitude of the Frequency (input signal) which results in a change of output power (output signal). (from [NC RfG])

Frequency Restoration Control Error (FRCE) means the control error for the FRP which is equal to the ACE of a LFC Area or is equal to the Frequency Deviation where the LFC Area geographically corresponds to the Synchronous Area (from [NC OS])

Frequency Restoration Power Interchange means the Power which is interchanged between LFC Areas within the Cross-Border FRR Activation Process (from [NC LFCR])

Frequency Restoration Process (FRP) a process that aims at restoring frequency to the Nominal Frequency and for Synchronous Area consisting of more than one LFC Area power balance to the scheduled value (from [NC OS])

Frequency Restoration Reserves (FRR) means the Active Power Reserves activated to restore System Frequency to the Nominal Frequency and for Synchronous Area consisting of more than one LFC Area power balance to the scheduled value (from [NC LFCR])

Frequency Restoration Range means the System Frequency range to which the System Frequency is expected in the Synchronous Areas GB, IRE and NE to return after the occurrence of an imbalance equal to or less than the Reference Incident within the Time To Restore Frequency (from [NC LFCR])

Frequency Set point means the Frequency target value used in the FRP defined as the sum of the Nominal System Frequency and an offset value needed to reduce an Electrical Time Deviation (from [NC LFCR])

FRR Availability Requirements means a set of requirements defined by the TSOs of a LFC Block regarding the availability of FRR (from [NC LFCR])

FRR Dimensioning Rules means the specifications of the FRR dimensioning process of a LFC Block (from [NC LFCR])

Imbalance Netting Power Interchange means the power which is interchanged between LFC Areas within the Imbalance Netting Process (from [NC LFCR])

Imbalance Netting Process means a process agreed between TSOs of two or more LFC Areas within one or more than one Synchronous Areas that allows for avoidance of simultaneous FRR activation in opposite directions by taking into account the respective FRCEs as well as activated FRR and correcting the input of the involved FRPs accordingly (from [NC LFCR])

Inertia - is the fact that a rotating rigid body such as an Alternator maintains its state of uniform rotational motion. Its angular momentum is unchanged, unless an external torque is applied. In the context of this code, this definition refers to the technologies for which Alternator speed and system Frequency are coupled. (from [NC RfG])

Initial FCR Obligation means the amount of FCR allocated to a TSO on the basis of a general sharing key (from [NC LFCR])

Instantaneous FRCE Data means a set of data of the FRCE for a LFC Block with a measurement period equal to or shorter than 10 seconds used for System Frequency quality evaluation purposes (from [NC LFCR])

Instantaneous Frequency Data means a set of data measurements of the overall System Frequency for the Synchronous Area with a measurement period equal to or shorter than 1 second used for System Frequency quality evaluation purposes (from [NC LFCR])

Instantaneous Frequency Deviation means a set of data measurements of the Frequency Deviation with a measurement period equal to or shorter than 1 second (from [NC LFCR])

Interconnector means equipment used to link electricity systems (from Directive 2009/72/EC)

K-Factor means a factor used to calculate the frequency bias component of the ACE of a LFC Area or a LFC Block; (from [NC OS])

Level 1 FRCE Range means the first range used for System Frequency quality evaluation purposes on LFC Block level within which the FRCE should be kept for a specified percentage of the time (from [NC LFCR])

Level 2 FRCE Range means the second range used for System Frequency quality evaluation purposes on LFC Block level within which the FRCE should be kept for a specified percentage of the time (from [NC LFCR])

LFC Block Imbalances means the sum of the FRCE, FRR Activation and RR Activation within the LFC Block and the Imbalance Netting Power Exchange, the Frequency Restoration Power Interchange and the Replacement Power Interchange of this LFC Block with other LFC Blocks (from [NC LFCR])

LFC Block Monitor means a TSO responsible for collecting the Frequency Quality Evaluation Criteria Data and applying the Frequency Quality Evaluation Criteria for the LFC Block (from [NC LFCR])

LFC Block Operational Agreement means a multi-party agreement between all TSO of a LFC Block if the LFC Block consists of more than one TSO; if a LFC Block consists only of one TSO it means a formal declaration of obligations (from [NC LFCR])

Limited Frequency Sensitive Mode – Overfrequency (LFSM-O) - is a Power Generating Module operating mode which will result in Active Power output reduction in response to a change in System Frequency above a certain value. (from [NC RfG])

Limited Frequency Sensitive Mode – Underfrequency (LFSM-U) - is a Power Generating Module operating mode which will result in Active Power output increase in response to a change in System Frequency below a certain value. (from [NC RfG])

Load-Frequency Control Area (LFC Area) means a part of a Synchronous Area or an entire Synchronous Area, physically demarcated by points of measurement of Interconnectors to other LFC Areas, operated by one or more TSOs fulfilling the obligations of a LFC Area (from [NC OS])

Load-Frequency Control Block (LFC Block) means a part of a Synchronous Area or an entire Synchronous Area, physically demarcated by points of measurement of Interconnectors to other LFC Blocks, consisting of one or more LFC Areas, operated by one or more TSOs fulfilling the obligations of a LFC Block (from [NC OS])

Load-Frequency Control Structure means the basic structure considering all relevant aspects of Load- Frequency Control in particular concerning respective responsibilities and obligations (Process Responsibility Structure) as well as types and purposes of Active Power Reserves (Process Activation Structure) (from [NC LFCR])

Manual FRR Full Activation Time means the time period between the set point change and the corresponding activation or deactivation of manual FRR (from [NC LFCR])

Maximum Instantaneous Frequency Deviation means the maximum expected absolute instantaneous Frequency Deviation after the occurrence of an imbalance equal or less than the Reference Incident, beyond which emergency measures are activated (from [NC LFCR])

Maximum Steady-State Frequency Deviation means the maximum expected Frequency Deviation after the occurrence of an imbalance equal or less than the Reference Incident at which the System Frequency is designed to be stabilized (from [NC OS])

Monitoring Area means a part of the Synchronous Area or the entire Synchronous Area, physically demarcated by points of measurement of Tie-Lines to other Monitoring Areas, operated by one or more TSOs fulfilling the obligations of a Monitoring Area (from [NC LFCR])

Netted Area AC Position means the netted aggregation of all AC-external Schedules of an area (from [NC OPS])

Network Operator - is an entity that operates a Network. These can be a TSO, a DSO, a DSO or CDSO (from [NC RfG])

Nominal Frequency means the rated value of the System Frequency (from [NC OS])

Normal State means the System State where the system is within Operational Security limits in the N-Situation and after the occurrence of any Contingency from the Contingency List, taking into account the effect of the available Remedial Actions; (from [NC OS])

Operational Security means the Transmission System capability to retain a Normal State or to return to a Normal State as soon and as close as possible, and is characterised by thermal limits, voltage constraints, short-circuit current, frequency limits and stability limits (from [NC LFCR])

Operational Security Analysis means the entire scope of the computer based, manual and combined activities performed in order to assess Operational Security of the Transmission System, including but not limited to: processing of telemetered real-time data through State Estimation, real-time load flows calculation, load flows calculation during operational planning, Contingency Analysis in real-time and during operational planning, Dynamic Stability Assessment, real-time and offline short circuit calculations, System Frequency monitoring, Reactive Power and voltage assessment (from [NC OS])

Operational Security Limits means the acceptable operating boundaries: thermal limits, voltage limits, short-circuit current limits, frequency and Dynamic Stability limits (from [NC CACM])

Power Generating Module - is either a Synchronous Power Generating Module, or a Power Park Module (from [NC RfG])

Prequalification means the process to verify the compliance of a Reserve Providing Unit or a Reserve Providing Group of kind FCR, FRR or RR with the requirements set by the TSO according to principles stipulated in this code (from [NC LFCR])

Process Activation Structure means the structure to categorize the processes concerning the different types of Active Power Reserves in terms of purpose and activation (from [NC LFCR])

Process Responsibility Structure means the structure to determine responsibilities and obligations with respect to Active Power Reserves based the control structure of the Synchronous Area (from [NC LFCR])

Provider means a legal entity with a legal or contractual obligation to supply FCR, FRR or RR from at least one Reserve Providing Unit or Reserve Providing Group (from [NC LFCR])

Ramping Period means a period of time defined by a fixed starting point and a length of time during which the input and/or output of Active Power will be increased or decreased (from [NC LFCR])

Ramping Rate means the rate of change of Active Power by a Power Generating Module, Demand Facility or DC Interconnector (from [NC OS])

Reference Incident means the maximum instantaneously occurring power deviation between generation and demand in a Synchronous Area in both positive and negative direction considered in the FCR dimensioning (from [NC OS])

Regional Security Coordination Initiative (RSCI) means regional unified scheme set up by TSOs in order to coordinate Operational Security Analysis in a determined geographic area; (from [NC OS])

Reliability Margin means the margin reserved on the permissible loading of a Critical Network Element or a Bidding Zone Border to cover against uncertainties between a capacity calculation timeframe and real time, taking into account the availability of Remedial Actions (from [NC CACM])

Replacement Power Interchange means the power which is interchanged between LFC Areas within the Cross-Border RR Activation Process (from [NC LFCR])

Replacement Reserves (RR) means the reserves used to restore/support the required level of FRR to be prepared for additional system imbalances. This category includes operating reserves with activation time from Time to Restore Frequency up to hours (from [NC LFCR])

Reserve Capacity means the amount of FCR, FRR or RR that needs to be available to the TSO (from [NC LFCR])

Reserve Connecting DSO means the DSO responsible for the Distribution System to which a Reserve Providing Unit or Reserve Providing Group, providing reserves to a TSO, is connected (from [NC LFCR])

Reserve Connecting TSO means the TSO responsible for the Monitoring Area to which a Reserve Providing Unit is connected to (from [NC LFCR])

Reserve Instructing TSO means the TSO responsible for the instruction of the Reserve Providing Unit or the Reserve Providing Group to activate FRR and/or RR (from [NC LFCR])

Reserve Providing Group means an aggregation of Power Generating Modules, Deman Unit and/or Reserve Providing Units connected to more than one Connection Point fulfilling the requirements for FCR, FRR or RR (from [NC LFCR])

Reserve Providing Unit means a single or an aggregation of Power Generating Modules and/or Demand Units connected to a common Connection Point generating fulfilling the requirements for FCR, FRR or RR (from [NC LFCR])

Reserve Receiving TSO means the TSO involved in an exchange with a Reserve Connecting TSO and/or a Reserve Providing Unit or a Reserve Providing Group connected to another Monitoring or LFC Area (from [NC LFCR])

Reserve Replacement Process (RRP) means a process to restore activated FRR and additionally for GB and Ireland to restore the activated FCR (from [NC LFCR])

RR Availability Requirements means a set of requirements defined by the TSOs of a LFC Block regarding the availability of RR (from [NC LFCR])

RR Dimensioning Rules means the specifications of the RR dimensioning process of a LFC Block (from [NC LFCR])

Set point - is a target value for any parameter typically used in control schemes. (from [NC RfG])

Sharing of Reserves means a mechanism in which more than one TSO take the same Reserve Capacity, being FCR, FRR or RR, into account to fulfil their respective reserve requirements resulting for their reserve dimensioning processes (from [NC LFCR])

Significant Grid User means the existing and new Power Generating Facility and Demand Facility deemed by the TSO as significant because of their impact on the Transmission System in terms of the security of supply including provision of Ancillary Services; (from [NC OS])

Standard Frequency Deviation means the absolute value of the Frequency Deviation that limits the Standard Frequency Range (from [NC LFCR])

Standard Frequency Range means a defined interval symmetrically around the Nominal Frequency within which the System Frequency of a Synchronous Area is supposed to be operated (from [NC LFCR])

Steady State Frequency Deviation means the absolute value of Frequency Deviation after occurrence an imbalance, once the System Frequency has been stabilized (from [NC LFCR])

Synchronous Area means an area covered by interconnected TSOs with a common System Frequency in a steady operational state such as the Synchronous Areas Continental Europe (CE), Great Britain (GB), Ireland (IRE) and Northern Europe (NE) (from [NC LFCR])

Synchronous Area Monitor means a TSO responsible for collecting the Frequency Quality Evaluation Criteria Data and applying the Frequency Quality Evaluation Criteria for the LFC Block (from [NC LFCR])

Synthetic Inertia - is a facility provided by a Power Park Module to replicate the effect of Inertia of a Synchronous Power Generating Module to a prescribed level of performance. (from [NC RfG])

System Frequency means the electric frequency of the system that can be measured in all parts of the Synchronous Area under the assumption of a coherent value for the system in the time frame of seconds, with only minor differences between different measurement locations; (from [NC OS])

System Security means the ability of the power system to withstand unexpected disturbances or contingencies (from [NC CACM])

System State means the operational state of the Transmission System in relation to the Operational Security Limits: Normal, Alert, Emergency, Blackout and Restoration System States are defined; (from [NC OS])

Tie-Line means a transmission line that connects different areas excluding HVDC interconnectors (from [NC LFCR])

Time Control Process means a process for time control, where time control is a control action carried out to return the Electrical Time Deviation between synchronous time and UTC time to zero (from [NC LFCR])

Time to Recover Frequency means, for the Synchronous Areas GB and IRE, the maximum expected time after the occurrence of an imbalance smaller than or equal to the Reference Incident in which the System Frequency returns to the Maximum steady state Frequency Deviation (from [NC LFCR])

Time to Restore Frequency means the maximum expected time after the occurrence of an imbalance smaller than or equal to the Reference Incident in which the System Frequency returns to the Frequency Restoration Range for Synchronous Areas with only one LFC Area; for Synchronous Areas with more than one LFC Area the Time to Restore Frequency is the maximum expected time after the occurrence of an imbalance of an LFC Area within which the imbalance is compensated (from [NC LFCR])

Transmission System means the electric power network used to transmit electricity over long distances within and between Member States. The Transmission System is usually operated at the 220 kV and above for AC or HVDC, but may also include lower voltages (from [NC CACM])

Transmission System Operator means a natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the transmission system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the transmission of electricity (from Directive 2009/72/EC)

Virtual Tie-Line means an additional input of the controllers of the involved areas that has the same effect as a measuring value of a physical Tie-Line and allows exchange of electric energy between the respective area (from [NC LFCR])

APPENDIX I: RESPONSE TO PUBLIC CONSULTATION

The following tables provide the summary of comments received during public consultation and overview over the ENTSO-E response.

WHEREAS

Summary	5 legal comments:
	• General comment on update / modification to the NC (general comment with no specific recommendation for adaptation)
	• Comment on references in NC (general comment not specific to specific content of the whereas section)
	• General comment regarding the importance of ensuring that the legal framework will encourage all partners to fulfil their duty in delivering the services. No specific recommendation for adaptation.
	• Comment on proposed modification to whereas 8), 9), 14) (EWEA):
	  ○ **Whereas 8**: suggestion to delete "economic optimization"
	  ○ **Whereas 9**: add at the end that <u>a process for reviewing the delimitation of LFC block or SA areas is established in the NC</u>
	  ○ **Whereas 14**: request for change "<u>limited amounts of</u> (words added) cross-border exchanges, sharing and activation of reserves" enhance efficiency + add "<u>provided that this will not affect operational security.</u> + suppress reference to imbalances netting process while also specifying that restrictions to cross-border exchanges aim at ensuring operational security is maintained at the same level.
	• Comment on whereas 14: specify reference to <u>technical</u> efficiency (limit efficiency to technical aspects).

Changes made	No legal changes NC updated by DT regarding references. Whereas 14: word "technical" added.
Explanation for change or no change	EWEA comments: were "to be checked separately".

Article 1 - SUBJECT MATTER AND SCOPE

Summary	26 comments were made, 4 comments to specify providers, 1 comment to clear up the voluntary of providing reserve service, 2 comments to have a specific chapter for providers, 5 comments to concentrate on efficient load-frequency control instead of efficient utilisation, 3 comments on isolated systems, 1 comment on predictable and observable frequency deviations with new requirement to TSO, 1 comment to change Prequalification to "Qualification", 1 comment to approve additional requirements by NRA, 1 comment about requirements for existing providers, 1 comment to justify the definition of limits for exchange and sharing reserves in supporting paper and 1 comment about the use of endeavour instead of shall.
Changes made	Para 1: Replace "Providers" with "Reserve Providers" Para 2(a): Change to "a) achieving and maintaining a satisfactory level of frequency quality and an efficient process for load frequency control"; Para 3 about Isolated systems shall be deleted New article 4, add approval for really new requirements to Reserve Providers
Explanation for change or no change	- The code is applicable for Reserve Providers; the use of Providers is too general. - If the provision of reserves is voluntary or mandatory is defined in the national legal framework and there is no need to change national rules in this part. - A specific chapter for Reserve Providers is not necessary and with a restructuring of the NC other problems would occur, in supporting paper there will be given an overview. - TSO shall effectively strive at managing their operation efficiently and not managing the resources of the market participants - Isolated Systems have no cross-border impact and need therefore not to be excluded,

	further explanation can be found in the supporting paper - The term “Prequalification” is used in the sense that a qualification has to be made before a contract for providing reserves is made. The Prequalification allows offering reserves. - The prequalification process needs to list the requirements a potential provider has to fulfil. A change or an addition of requirements can only be done for security reasons. If a Reserve Provider does not agree to the new requirements, it can claim against the new requirements by the NRA. For really new requirements, an approval should be added in the new article 4 - The requirements of the NC shall be a general framework to all Reserve Providers, the exception for existing providers would lead to a discrimination of new providers. - The Explanation for the chosen limits of exchange or sharing of reserves will be found in the supporting paper - In some cases a TSO cannot ensure a result. In that case the TSO has to undertake all possible and reasonable measures but without guaranty of success. Therefore it shall endeavour.

Article 2 - DEFINITIONS

Summary	1. Several request to delete references to other NC definitions. 2. Request to definitions defined in other NC. 3. Update definition for K-Factor according to UCTE OH. 4. Update Operational Reserves. 5. Update ATC definition. 6. FCR, FRR and RR definitions questioned. 7. High and Elevated Synchronous Area Alert State questioned. 8. Balancing Services Provider according to NC EB. 9. Replace Tie Line by Physical Tie Line 10. Harmonisation issues, NRA approval, transparency. 11. Typos.
Changes made	1. No changes made. Some references are necessary to ensure transparency. Furthermore all Definitions of exiting network codes and regulations apply to this code as well. 2. We adopted some of the exiting definitions. 3. A valuable comment, we therefore adopted the existing definition. 4. “Operational reserves” is a term used several times. However, it is not as precise as Active Power Reserves. 5. We changes the definition used in this code. 6. No changes made. This terminology has already been established. 7. We aligned the states to other documents by renaming it to normal, alert and emergency. 8. No changes made to underline the difference between NC EB and NC LFCR. 9. No changes made. See below for explanations. 10. This has been addressed several times in the public consultation; see other comments and changes below. 11. Yes, typos have been corrected.
Explanation for change or no change	1. Common practice. 2. Several definitions have updated to be consistent with other codes. 3. Definition has been updated. 4. Deleted Operational Reserves and used Active Power Reserves instead. 5. This definition could have been misleading which is why it has been adjusted. 6. This new terminology has already been introduced and commonly used by ACER and ENTSO-E. 7. Harmonised with NC OS: Normal, Alert and Emergency. The NC LFCR now describes the frequency ranges used for the states in the NC OS. 8. The NC LFCR only deals with reserve providers, balancing services provider are not in the scope of this code. 9. This has been defined differently in the NC OS which is why it has been adjusted in the NC LFCR. 10. We appreciate your comments. 11. Typos corrected.

Article 3 – REGULATORY ASPECTS

Summary	32 Comment was received on this article. Three themes emerged several times: 1) NRA involvement. 2) Transparency. 3) Principle of optimisation.
Changes made	New article 4 with the collection of the approvals of NRA foreseen in this NC is added.
Explanation for change or no change	A new article has been added in the first section of the Network Code (Article 4). This directly refers to the powers of regulators as mentioned in the Third Energy Package and specifically in Directive 2009/72/EC. It presents a consistent set of timings and clarifies the role of regulatory authorities. To enhance clarity, ENTSO-E has explicitly listed all cases where Regulatory Approvals are foreseen and at which level the respective approval should take place (e.g. pan-European, Synchronous Area level or national regulatory authorities). Transparency market issue are dealt with in the European transparency guidelines. Not all information should be available close to real time. Even so, Article 3(1) imposes that all requirements under this Network Code are also to be established under the principle of transparency. Therefore, this principle - substantiated in the transparency guidelines - is fully respected. The principle of optimisation has also to be respected for Load Frequency Control and the provisions of Reserves. Optimisation means here in particular efficiency of the processes and reasonable numbers of needed reserves to hinder to high costs of reserves to be provided.

Article 4 (new Article 6) – RECOVERY OF COSTS

Summary	10 legal comments: • **Paragraph 1):** 4 comments suggesting replacement of the term "regulated Transmission System Operators" by "regulated ~~Transmission~~ ~~System~~ Network Operators". • **Paragraph 2):** 2 comments requesting adding reference to "efficiently incurred costs" as is the case in other NCs • **Paragraph 3):** 3 comments requesting replacement of the term "regulated Transmission System Operators" by "regulated ~~Transmission~~ ~~System~~ Network Operators".".""". (consistency with para 1). • **1 general comment** re. the reference to efficiently incurred costs (any definition of efficiently incurred costs must be approved and overseen by the NRA)
Changes made	In NC LFCR (dated 30/04, version V_3 3 of 25/04): • **Paragraphs 1) and 3)** → "regulated Transmission System Operators" is already changed by "regulated ~~Transmission System~~ Network Operators". • **Paragraph 2)** → ref. to efficiently incurred costs is already included.
Explanation for change or no change	• All system operators included in the scope of the provision on cost recovery • Ensuring consistency of wording with other NCs (cf. adding word "efficiently" in para. 2). • Ref. to the term "economic" → not included.

Article 5 (new Article 7) – CONFIDENTIALITY OBLIGATIONS

Summary	2 comments were made concerning the possibility of using confidential information for other purposes than they were disclosed for.
Changes made	Para 3 is deleted
Explanation for change or no change	Information disclosed under this NC shall be used only to fulfil the respective tasks.

Article 6 (new Article 8)– Agreement with TSOs not bound by this Network Code

Summary	3 comments received that all criticize the lack of legal binding of this provision.
Changes made &	The only change that is needed is that it should be implemented the phrase "shall endeavour" to

explanation	achieve consistency with NC OS and NC OPS because a synchronous Area Agreement can only be implemented if the other TSOs of a Synchronous Area agree. There is no alternative to this "soft clause" in view of the fact that provisions of EU legislation like this NC shall be cannot settle legal obligations to TSOs of states which are not bound by this legislation. Anyway, the clause is necessary to show the target of the NC LFCR to settle operational rules for whole Europe.

Article 7 (new Article 9) - TSO COOPERATION

Summary	12 comments received that find faults with two main topics: 1) the item touches NRA involvement and so should be part of Art 3 par 3. 2) the wording is not legally binding, so the phrase "cooperate loyally", contained in Art 7 par 1 should be deleted.
Changes made & explanation	No need of a change. The question of TSO cooperation regarding to adopting decisions has been discussed broadly, also within LRG. The margin for a more structured and/or binding cooperation model seems to be very limited because of the lack of legal basis for involvement of ENTSO-E and/or ACER as decision making body regarding to litigations between TSOs. The lowest common factor which is possible to be settled in the NC seems to be the requirement to cooperate loyally. So, at least, an individual proceeding of single TSOs that do not take into account their fellow TSOs is formally out of bounds. A general involvement of NRAs how suggested by transferring Art 7 to Art 3 is undue because of the lack of a legal basis for a general requirements that settles the role of NRAs regarding to the adoption of decisions in accordance with the NC LFCR.

Article 8 – TSO CO-OPERATION (**This article has been deleted.)**

Summary	15 comments were received on old article 8. The followings topics emerged several times: 1. The Frequency Quality Target Parameters are already defined in the NC so there should be not amended by TSOs themselves without a consultation and an approval process. 2. The title of the Article is different of the content. 3. Proposal for old Article 8(1): Within XXX months from the entry into force of this network all TSOs of a Synchronous Area shall define the following Quality Target Parameters: a) the Frequency Quality Target Parameters and the Frequency Quality Defining Parameters in accordance with old Article 9 (new art. 19). 4. Include in old Article 8(1): Regulators shall approve the definition in line with the (revised) Article 3(3). 5. Proposed new paragraph in old Article 8(2): Unless in an emergency situation as defined in the Operational Security network code, TSO shall only use the Operational Reserve products FCR, FRR, RR to meet the requirements on new Articles 19 and 20 6. Proposed new paragraph in old Article 8(1): (g) Unless there is an emergency situation as defined in the OS network code, TSOs shall act to meet the Target Parameters in old Articles 9 and 10 (new Articles 19 and 20) using only the Operational Reserve products specified in this network code
Changes made	The article 8 has been deleted. The structure of the Frequency Quality process will be explained in the Supporting Document.
Explanation for change or no change	1. All TSOs of each Synchronous Area shall establish a Synchronous Area Operational Agreement that shall at least include the Frequency Quality Defining Parameters and the Frequency Quality Target Parameter in accordance with Article 19(6). Based on this agreement, TSOs will be able to modify the value of the Frequency Quality Defining Parameters or the Frequency Quality Target Parameter after consultation with stakeholders and NRA approval. 5. TSOs may re-dispatch units to maintain Operational Security using Operational Reserve bids other than in emergency situations as there may not be specific bids for real-time re-dispatching. 6. TSOs may rely on many elements of the system to achieve adequate frequency quality before entering into an emergency situation.

Article 9 – FREQUENCY QUALITY DEFINING AND TARGET PARAMETERS →NEW ART. 19 FREQUENCY QUALITY TARGET PARAMETERS

Summary	49 comments were received on former Article 9, (new article 19). The followings topics emerged several times: 1. Proposed new Frequency Defining Parameter: h) Frequency Standard Deviation. 2. According to NC Requirements for Generators Art. 8(1)(b) the value for the Maximum Instantaneous Frequency Deviation should be 1000 mHz. 3. Proposal to fix that Maximum Instantaneous Frequency Deviation for the NE area equal to 1000 mHz 4. Justification of the values for the Frequency Quality Defining Parameters, established in Table 1 5. Frequency quality parameters should comply with the current issue of the ENTSO-E Operation Handbook. 6. Please define narrower bands for Frequency deviation. Especially for Maximum Instantaneous Frequency Deviation (e.g. +/- 400 mHz). 7. A regulatory oversight should be introduced in old Article 9(2). Those TSO decisions require NRA/ACER approval and stakeholder involvement. 8. Quality defining parameters shall match with quality evaluation criteria. 9. TSOs of a Synchronous Area shall use the Frequency Quality Defining Parameters listed in (1) whose corresponding values are in Table 1 and shall publish at least annually their performance against each of these parameters in terms of all variances. 10. Clarify and justify "Not used" and "Not applicable" reference applied to some parameters 11. The Frequency Quality Target Parameter set by former article 9.3 (new art. 19.4) risks being inadequate to reflect the actual level of frequency quality since it does not take in due account the amplitude of the considered frequency deviations nor the number of the events. 12. To modify The Frequency Quality Target Parameter by adding the number of occurrences per year (cycles outside the standard frequency range), and the maximum rate of frequency change 13. Fill in values of Maximum number of minutes outside the Standard Frequency Range. 14. The value for the maximum number of minutes outside the Standard Frequency Range for RG CE should be 30/9500 min/year. 15. Additional Frequency Quality Target Parameters are required to match established industry practices in terms of equipment specifications. Usually, voltage and frequency operating ranges are defined in a single U/f diagram divided into zones. Each zone is limited in terms of: - time of operation in the zone (for each excursion in that zone) - frequency of occurrence of excursions to the zone (which is different from the cumulative time of operation within the zone). 16. The requirement set up in the Table 2 (maximum number of minutes outside the Standard Frequency Range) is limited only in time. A limit for the amplitude of the deviation outside the parameters described in Table 1 is not included. 17. Typo in old Article 9(4) 18. TSOs shall collaborate with the other TSOs of the same Synchronous Area to monitor and analyze the effects of decreasing inertia in the system in consultation with other stakeholders (specifically involving generating module manufacturers). 19. Questions and deletion proposal of old Article 9(4)(d). Why are IRE and GB excluded 20. And why is Cyprus excluded? 21. Subparagraph to be added to old Article 9(4): "e) Targets shall be technically feasible and agreed in consultation with Stakeholder if other NC for example RfG NC are affected." 22. A regulatory oversight should be introduced in old Article 9(4). Those TSO decisions require NRA/ACER approval and stakeholder involvement. 23. In order to avoid an excessive regulatory uncertainty on the evolution of Frequency Quality Defining Parameters and Frequency Quality Target Parameters, the Network Code should clearly limit the frequency of amendment of these provisions, e.g. not more often than every five years, and introduce a transparent amendment process subject to a thorough cost-benefit analysis and to consultation of the involved stakeholders (e.g. FCR and FRR providers and system users). 24. Typos in old Article 9(4)
Changes made	3. Rewording of old Article 9(4), now Article 19(6) but the Maximum Instantaneous Frequency Deviation for the NE remains unchanged. 7. Rewording of old Article 9(4), now Article 19(6). 13. Values for the Frequency Quality Target Parameters have been filled in. 14. Values for the Frequency Quality Target Parameters have been filled in. 17. Typo have been corrected 21. Subparagraph added to old Article 9(4) or new Article 19(6). 22. Rewording of old Article 9(4), now Article 19(6). 23. Rewording of old Article 9(4), now Article 19(6). 24. Typos have been corrected.
Explanation for change or no change	1. Defining Parameters should be assessed in real-time. The standard deviation is already in the current version of the code a Frequency Quality Criteria. 2. The ranges given in NC RfG Article 8(1)(b) Table 2 ranges in which a Power Generating Module must be able to stay connected for the specified time period which are coordinated with the values for the Maximum Instantaneous Frequency Deviation as the

	ranges in NC RfG are wider assuring that no generator will trip if the System Frequency is confined to the Maximum Instantaneous Frequency Deviation. 3. The Frequency Quality Defining Parameters or the Frequency Quality Target Parameter, with the exception of the Nominal Frequency, shall be revised every 5 years or whenever a significant change occurs. In the case of RG NE the current value is 800 mHz, but could be revised in the future if deemed necessary. 4. Supporting document has been extended to provide more detail on the Frequency Quality Defining Parameters and the values shown in Table 1 5. In the ENTSO-E RG CE OH Policy 1 the 20 mHz range is the activation range of primary control so it can't be guaranteed according to the OH that Primary Control will be activated within this range. The Standard Frequency Range shall be wider than this activation range and the value chosen has been 50 mHz 6. After the occurrence of a Reference Incident in CE the instantaneous frequency might exceed 800 mHz as explained in ENTSO-E RG CE OH Policy 1 Appendix. 7. All TSOs of each Synchronous Area shall establish a Synchronous Area Operational Agreement that shall at least include the Frequency Quality Defining Parameters and the Frequency Quality Target Parameter. Based on this agreement, TSOs will be able to modify the value of the Frequency Quality Defining Parameters or the Frequency Quality Target Parameter, after consultation with stakeholders and NRA approval. 8. Frequency Quality Parameters are already consistent with Frequency Quality Defining Parameters. 9. This proposal was already included in new Article 21, in the Criteria Application Process and Frequency Quality Evaluation Criteria and performance indicators in NC OS. Publishing of these Frequency Quality Evaluation Criteria is established in Chapter 12: Transparency of information. 10. Supporting document has been extended to provide more detail on the Frequency Quality Defining Parameters and the values shown in Table 1 and Table 2. 11. Frequency Quality Target Parameters shall be easily understood, easy to interpret and compare. If the level of Frequency Quality Deteriorates it will be captured in the values calculated for the Frequency Quality Criteria. The information on the number of events is captured in the performance indicators of NC OS. 12. Frequency Quality Target Parameters shall be easily understood, easy to interpret and compare. The mentioned pattern should arise in the Frequency Quality Criteria. 13. The values for the Frequency Quality Target Parameters were missing. 14. 30 or 9500 min/year are values too strict. The value chosen is explained the Supporting Document. 15. U/f ranges given in NC RfG Article 8(1)(a)(1), Article 11, Article 13 and Article 16 not in the NC LFCR. 16. Frequency Quality Target Parameters shall be easily understood, easy to interpret and compare and show the evolution of the system frequency with regard to the distribution of Frequency Deviations. The information on the number of events is captured in the performance indicators of NC OS. 17. - 18. The issue of system inertia is covered in the NC OS Article 15 8. 19. This subparagraph has been deleted. 20. Cyprus will be excluded from the NC as it is a small isolated system. 21. It is the TSO's concern that the changes affecting Power Generator Modules are coordinated with the requirements of NC RfG. 22. All TSOs of each Synchronous Area shall establish a Synchronous Area Operational Agreement that shall at least include the Frequency Quality Defining Parameters and the Frequency Quality Target Parameter. Based on this agreement, TSOs will be able to modify the value of the Frequency Quality Defining Parameters or the Frequency Quality Target Parameter after consultation with stakeholders and NRA approval. 23. Frequency Quality Defining Parameters and Frequency Quality Target Parameters shall be revised when a significant change to the Synchronous Area with impact on Frequency Quality occurs. 24. -

Article 10 – FREQUENCY RESTORATION CONTROL ERROR TARGET PARAMETERS → NEW ART. 20 FRCE TARGET PARAMETERS

Summary	31 comments were received on old article 10 (new art. 20). The followings topics emerged several times: 1. The reference to the "square root of the Initial FCR Obligations" needs to be clearly justified. 2. Typos in old Article 10(1), new Article 20(1). 3. The TSOs of a Synchronous Area shall define, make publicly available on ENTSO-E website and use the following Frequency Restoration Control Error Target Parameters for each LFC Block of a Synchronous Area for the next year with the goal of respecting the provisions of old article 10 §3 a) and b): a) Level 1 Frequency Restoration Control Error Range and b) Level 2 Frequency Restoration Control Error Range 4. Definitions of "Frequency Restoration Control Error Defining Parameters" needs to be

	provided in order to assess whether CBAs and/or NRA implication is required in the revision process. 5. Introduce regulatory involvement in old Article 10(1), new article 20(1). 6. Introduce in old Article 10(1) :Within a period defined for entry into force of this code and thereafter on an annual basis the TSOs of a Synchronous Area shall define and use the following Frequency Restoration Control Error Target Parameters for each LFC Block of a Synchronous Area for the next year with the goal of... 7. Typos in old Article 10(2), new Article 20(2). 8. Introduce regulatory involvement in old Article 10(2). 9. Examples of value for Level 1 & 2 Frequency Restoration Control Error Range should be included. 10. Define parameters regarding the Time To Recover Frequency 11. Typos in old Article 10(3), new Article 20(3). 12. Control Block is not defined in the code. 13. Multi-party agreement should be publicly available and under NRA approval and market parties consultation. 14. Reword old Article 10(4), new article 20(3) to "Where a LFC Control Block consists of more than one LFC Area, all TSOs of the LFC Block shall, within a period defined for entry into force of this code define the Frequency Restoration Control Error Target Parameters for each LFC Area complying with old Article 10(1) and Article 10(2) and in line with the process in [revised] Article 3(3)."
Changes made	2. Typos have been corrected. 4. The definition of Frequency Restoration Control Error Defining Parameter has been included. 5. New wording for article 10(1), new 20(1). 7. Typos have been corrected. 10. Introduction of a new Frequency Quality Evaluation Criteria to take into account the Time to Recover Frequency. 11. Typos have been corrected. 12. Wording has been changed to LFC Block in old Article 10(4).
Explanation for change or no change	1. The explanation for this reference is explained in the Supporting Document. 2. – 3. According to Chapter 12 the Frequency Restoration Target Parameters will be publicly available. 4. Definition has been included in Chapter 1(2). 5. All TSOs of each Synchronous Area shall establish a Synchronous Area Operational Agreement that shall at least include for Synchronous Areas CE and NE the Frequency Control Error Target Parameters for each LFC Block in accordance with Article 20(1). 6. Entry into force of Frequency Restoration Control Error Target Parameters can begin with the entry into force of the NC as there are no significant developments involved that could not be carried out between the approval and the entry into force. 7. – 8. All TSOs of each Synchronous Area shall establish a Synchronous Area Operational Agreement that shall at least include for Synchronous Areas CE and NE the Frequency Control Error Target Parameters for each LFC Block in accordance with Article 20(1). 9. Examples will be given and explained in more detail in the Supporting Document as they change every year. 10. Improvement of the Frequency Quality Evaluation process and criteria. 11. – 12. The typological error shall be corrected. 13. The relevant multi-party agreements are defined in new Chapter 2 and don't require NRA involvement and supervision. 14. Entry into force of Frequency Restoration Control Error Target Parameters can begin with the entry into force of the NC as there are no significant developments involved that could not be carried out between the approval and the entry into force.

Article 11 – DATA COLLECTION AND DELIVERY PROCESS → NEW ART. 22

Summary	11 comments were received on former article 11 (new art. 22). The followings topics emerged several times: 1. "Instantaneous Frequency Data" reference needs to be clarified. 2. Submission to NRA approval of the Frequency Quality Evaluation Data. 3. Explicitly indicate in the article that the minimum accuracy is applicable to the operation and monitoring of the control center only (status of the art for prime movers accuracy is equal or lower than +/-10 mHz for example +/- 15 mHz). 4. TSOs should record data at the shortest available time resolution (1 second intervals record) in order to provide the best picture of frequency quality. This should be the resolution used for the instantaneous data. 5. Submission to NRA approval of the measurement, calculation and information exchange parameters for the Frequency Quality Evaluation Data.

Changes made	1. Definition of Instantaneous Frequency Data slightly modified 3. Wording has been changed in old Article 11(3), new Article 22(3). 4. Rewording of old Article 11(3)(a), new Article 22(3)
Explanation for change or no change	1. Avoidance of misunderstandings. 2. Modification of Frequency Quality Evaluation Data doesn't require an NRA involvement and supervision, as those are parameters for monitoring Frequency Quality Parameters and Frequency Restoration Control Error used by TSO's 3. Avoidance of misunderstandings. 4. In Chapter 1(2), in the definition of Instantaneous Frequency Data, the measurement period equal to or shorter than 1 second is used. 5. The measurement, calculation and information exchange parameters for the Frequency Quality Evaluation Data are processes well established, and don´t require an NRA involvement.

Article 12 – CRITERIA APPLICATION PROCESS AND FREQUENCY QUALITY EVALUATION CRITERIA→ NEW ART. 21

Summary	24 comments were received on former article 11 (new art. 21). The followings topics emerged several times: 1. "1-minute average" data, smoothing the deviation of the frequency from its nominal value, cannot be considered as adequate criteria to assess the frequency quality. If the frequency is being recorded at better than 10s resolution, all subsequent statistical calculations should be based from the original instantaneous data set and not from an "1 minute" averaged data set. 2. The standard deviation of the 1-minute Average Frequency Data during a 3-month period should be of: 20mHz 3. Please clarify the definition of these criteria and the related values for each Synchronous Area. 4. Introduce a new Frequency Quality Evaluation Criteria: (iv) total time and number of events during a 3-month period in which the instantaneous Frequency Deviation was greater than the Maximum Instantaneous Frequency Deviation; 5. A stakeholder promotes the addition to a new criterion based on lower but still significant frequency deviation threshold (ex: 75 mHz for CE) as a more relevant indicator of the deviations due to undesirable operating problems (deterministic deviations) 6. Introduce a new Frequency Quality Evaluation Criteria: FCR control mileage and FRR control mileage 7. Introduce a new Frequency Quality Evaluation Criteria: total time and number of events [...] is not returned to 10% of the Level 2 Frequency Restoration Control Error Range within the Time to Restore Frequency during a 3-month period; 8. Introduce a new Frequency Quality Evaluation Criteria: The frequency control response should be maintain within a "trumpet curve" pathway; 9. Typos in old Article 12(2)(b), new Article 21(2)(b). 10. Publish the results of the Frequency Quality Evaluation Criteria 11. Submission to NRA approval the methodology to assess the risk and the evolution of the risk of FCR exhaustion in the Synchronous Area. 12. The methodology to assess the risk and the evolution of the risk of FCR exhaustion in the Synchronous Area shall be publicly available. 13. An article to analyze data is completely missing. It needs to be stated that those products described are foreseen for unpredictable incidents and deviations. The frequency needs to be analyzed in order to eliminate predictable effects and to find out possible root causes of the deviations.
Changes made	1. Rewording of old Article 12(2), new Article 21(2) 8. Rewording of old Article 12(2)(b), new Article 21(2)(b) 9. Typos have been corrected. 11. Introduction of NRA involvement in old Article 12(3), new Article 21(3). 12. Introduction of publication of this methodology in Chapter 12.
Explanation for change or no change	1. Instantaneous data is to be used in order to prevent any filtering, especially for the smaller Synchronous Areas. 2. In the ENTSO-E RG CE OH Policy 1 the 20 mHz range is the activation range of primary control so it can't be guaranteed according to the OH that Primary Control will be activated within this range. The Standard Frequency Range shall be wider than this activation range and the value chosen has been 50 mHz. 3. Supporting document has been extended to provide more detail on the Frequency

	Quality Evaluation Criteria. 4. NC LFCR considers only normal operation. If the level of Frequency Quality Deteriorates it will be captured in the values calculated for the Frequency Quality Evaluation Criteria. The information on the number of events is captured in the performance indicators of NC OS This new Frequency Quality Evaluation Criteria has been included. 5. It is considered that adding the same analysis for 75 mHz does not provide relevant information for the additional effort. 6. Term mileage not understood in this context. 7. Duration is considered in the number of time intervals outside the Level 1 or Level 2 FRCE ranges also in other Frequency Quality Evaluation Criteria for the LFC Block. 8. When the frequency is not restored to its nominal value within time to restore frequency old Article 12(2)(b)(vii), new Article 21(2)(b), will count an event in all LFC Blocks that did not restore FRCE within the time to restore frequency. 9. – 10. Chapter 12 states that the values of the Frequency Quality Evaluation Criteria will be published. 11. The methodology to assess the risk and the evolution of the risk of FCR exhaustion in the Synchronous Area should not be modified by TSOs themselves without NRA involvement and supervision 12. The methodology to assess the risk and the evolution of the risk of FCR exhaustion shall be publicly available. 13. This analysis is considered in new Article 29, old Article 15.

Article 13 – SYNCHRONOUS AREA MONITOR→NEW ART. 23

Summary	8 comments were received on former article 13 (new art. 23). The followings topics emerged several times: 1. No role is defined for ENTSO-E as this would then be counter part of contracts. 2. Submission to NRA approval the appointment of the Synchronous Area Monitor. 3. The Synchronous Area Monitor shall collect the Frequency Quality Evaluation Data regarding the Synchronous Area and perform the Criteria Application Process in compliance with the lists and the methodologies adopted in old Article 11 (plus 12).
Changes made	1. Old Article 13, new Article 23 has been rewritten. 3. Old Article 13, new Article 23 has been rewritten.
Explanation for change or no change	1. The possibility that ENTSO-E is the Synchronous Area Monitor has been excluded. 2. The appointment of the Synchronous Area Monitor is an internal appointment of the TSOs of a Synchronous Area with no impact on the process or on any aspects related to stakeholders. 3. For further clarity.

Article 14 – LFC BLOCK MONITOR→NEW ART. 24

Summary	8 comments were received on former article 14 (new art. 24). The following topic emerged: 1. Submission to NRA approval the appointment of the LFC Block Monitor.
Changes made	
Explanation for change or no change	1. The appointment of the LFC Block Monitor is an internal appointment of the TSOs of a LFC Block with no impact on the process or on any aspects related to stakeholders.

Article 15 – MITIGATION PROCEDURES→NEW ART. 29

Summary	46 comments were received on former article 15 (new art. 29). The followings topics emerged several times: 1. The current language is too broad and opens the door for the TSOs to obtain wide rights of review of the behaviour of market participants. 2. It is not acceptable to have a reference to ancillary services markets which is not defined neither described in this code. It should be left for the network code on electricity balancing. It is also not acceptable to refer to rules for the behaviour market participants. 3. TSOs must not impose arbitrary restrictions on market participants unless it is an Operational Security issue and then it should be in the Operational Security or Emergency network code. 4. Submission to NRA approval of all possible Mitigation Procedures. 5. Cost recovery for affected parties should be addressed. 6. Corporate rules for TSOs within the Synchronous Area should be introduced. 7. The way in which the article is written appears, to a large extent, to exonerate TSOs from their balancing requirements

	8. All TSO's shall have same obligations and all Grid Users shall have same rights despite of in which country they are situated. 9. The criteria application process establishes the period to calculate the real values of the target parameters (3 months) but for how long should these values be outside limits to allow TSOs to start a mitigation procedure? 10. Different type of actions should be successively covered in the article : - collaboration between TSOs : One important factor in balancing supply & demand is the inter TSO coordination and the relevance of the forecast performed by TSOs. This article should include actions to identify and correct TSOs inadequate activities in terms of communication and forecast. 11. The inclusion of a right to amend the market rules as a result either of a defect on the part of the TSOs or a deliberate attempt on the part of the TSOs not to have to do something themselves undermines investor confidence. As a minimum such a change can only be made with NRA approval following, of course, full stakeholder consultation as the consequences of such a change to the market rules can be profound. The wording with respect to 'behavior of market participants' should be deleted. Market participant behavior is covered in other EU legislation, not this NC. 12. The RfG has established the principle that retrospective application to existing facilities can only occur after a CBA has been undertaken. This principle must apply here as well.
Changes made	Old Article 15, new Article 29 has been rewritten.
Explanation for change or no change	**5.** Cost recovery for market participants should be internalized in the different market bids **6.** Comment outside of the scope of NC LFCR. **8.** Full harmonization is not possible as Regional specificities shall be taken into account in the Network Codes as specified also in the FG.

Article 16 – BASIC STRUCTURE – NEW ARTICLE 30

Summary	Comments received: 5 Recurring topics: NRA approval and publication.
Changes made	New Article 4 ("Regulatory Approval").
Explanation for change or no change	The NRA approval is tackled in Article 4 ("Regulatory Approval"). Since the chapter provides the full definition of requirements related to control processes (i.e. TSO obligations), the topics to be approved are related to the approval of the Process Responsibility Structure (i.e. Monitoring Areas, LFC Areas and LFC Blocks). The LFC structure is going to be published according to the transparency requirements of the NC.

Article 17 – PROCESS ACTIVATION STRUCTURE -> NEW ARTICLE 31

Summary	Comments received: 16 Recurring topics: Optional control processes (e.g. Imbalance Netting Process) should be made mandatory instead of "optional"
Changes made	No changes.
Explanation for change or no change	While some of the optional control processes might be mandatory due to other NCs (EB NC) or regulations, NC LFCR deals only with technical requirements. From technical perspective, the implementation of the control processes in question is not a precondition for the maintenance of operational security in each case. In case of exchange and/or sharing of reserves or joint dimensioning for several LFC Areas the implementation of the respective cross-border activation processes is required explicitly.

Article 18 – PROCESS RESPONSIBILITY STRUCTURE -> ARTICLE 32

Summary	Comments received: 5 Recurring topics: • NRA approval and publication • make the obligation to fulfil the Frequency Restoration Control Error Target Parameters more constraining (delete "endeavour") • optimization of LFC Areas and LFC Blocks • typo

Changes made	New Article 4 ("Regulatory Approval"). The "maximum size of the LFC Block" is deleted. Typos were corrected.
Explanation for change or no change	• The Process Responsibility Structure Article (i.e. Monitoring Areas, LFC Areas and LFC Blocks) shall be approved by NRAs. The Process Responsibility Structure is going to be published according to the transparency requirements of the NC. • Since physical disturbances cannot be avoided or exactly forecasted, the TSOs cannot ensure that all quality criteria shall be met at every time. The word "endeavour" is used to express this fact, while the endeavours are made by complying with the NC LFCR. • The optimization of the Process Responsibility Structure is out of scope of this NC. In any case the Process Responsibility Structure shall be defined according to national law including NRA approval.

Article 19 – FREQUENCY CONTAINMENT PROCESS (FCP) – NEW ARTICLE 33

Summary	Comments received: 7 Recurring topics: Clarification of overall FCR characteristic
Changes made	Wording was changed to clarify the meaning of the requirement to "The control target of the FCP shall be […]" instead of "The FCP shall be designed to […]"
Explanation for change or no change	• The article describes the general technical characteristics of a Frequency Containment Process (FCP) from control perspective. The former formulation "The FCP shall be designed to" was misleading since the configuration of the control process is fully described in the NC (i.e. the control design is already provided). Therefore the NRA approval is given by accepting the NC. • The requirement for the overall FCR characteristic in this article is a general requirement for control design from the Synchronous Area perspective and describes the overall control process behaviour (cf. supporting document).

Article 20 – FREQUENCY RESTORATION PROCESS (FRP) – NEW ARTICLE 34

Summary	Comments received: 5 Recurring topics: • NRA approval and publication • Approval of the "Setpoint value" by NRAs / clarification of Setpoint value • wrong reference / typo
Changes made	• Reference was corrected. • Wording was changed to clarify the meaning of the requirement to "The control target of the FRP shall be […]" instead of "The FRP shall be designed to […]" • Definition of Setpoint was added • Cycle time was deleted (too much detail)
Explanation for change or no change	• The article describes the general technical characteristics of a Frequency Restoration Process (FRP) from control perspective. The former formulation "The FRP shall be designed to" was misleading since the configuration of the control process is fully described in the NC (i.e. the control design is already provided). Therefore the NRA approval is given by accepting the NC. • The Process Responsibility Structure is going to be published according to the transparency requirements of the NC. • The term "Setpoint" is a well-known technical term and describes a desired value for a controlled physical variable, in this case, the desired value for FRR activation. Obviously, in order to operate the system the TSOs need to calculate this Setpoint value by a controller (aFRR) or define it manually (mFRR) in real-time. In the second step, the Setpoint is "communicated" to the FRR Providing Unit or Group which physically activates FRR. The corresponding control diagram is shown in the supporting document.

Article 21 – RESERVE REPLACEMENT PROCESS (RRP)- NEW ARTICLE 35

Summary	Comments received: 10 Recurring topics: • NRA approval and publication • Approval of the "Setpoint value" by NRAs / clarification of Setpoint value • Disruption of the intra-day markets
Changes made	• Wording was changed to clarify the meaning of the requirement to "The control target of the RRP shall be […]" instead of "The RRP shall be designed to […]" • Definition of Setpoint was added
Explanation for change or no change	• The article describes the general technical characteristics of a Reserve Replacement Process (RRP) from control perspective. The former formulation "The RRP shall be designed to" was misleading since the configuration of the control process is fully described in the NC (i.e. the control design is already provided). Therefore the NRA approval is given by accepting the NC. • The term "Setpoint" is a well-known technical term and describes a desired value for a controlled physical variable, in this case, the desired value for RR activation. Obviously, in order to operate the system the TSOs need define it which is done manually. In the second step, the Setpoint is "communicated" to the RR Providing Unit or Group which physically activates RR. The corresponding control diagram is shown in the supporting document. • The comment on disruption of the intra-day markets is out of scope of this NC.

Article 22 – IMBALANCE NETTING PROCESS – NEW ARTICLE 36

Summary	Comments received: 30 Recurring topics: • NRA approval and publication • mandatory implementation of the Imbalance Netting Process • clarification of transmission capacity • clarification of fall-back mechanism • replace "Virtual Tie-Line" by physical tie-line • insert reference to financial settlement • wrong reference / typo
Changes made	• Wording was changed to clarify the meaning of the requirement to "The control target of the Imbalance Netting Process shall be […]" instead of "The Imbalance Netting Process shall be designed to […]" • the term "available transmission capacity" was replaced by the reference to Operational Security Limits • typos were corrected
Explanation for change or no change	• The article describes the general technical characteristics of an Imbalance Netting Process from control perspective. The former formulation "The Imbalance Netting Process shall be designed to" was misleading since the configuration of the control process is fully described in the NC (i.e. the control design is already provided). Therefore the NRA approval is given by accepting the NC. • While some of the optional control processes might be mandatory due to other NCs (EB NC) or regulations, NC LFCR deals only with technical requirements. From technical perspective, the implementation of Imbalance Netting is not a precondition for the maintenance of operational security in each case. • The term "available transmission capacity" was replaced by the reference to Operational Security Limits in order to better describe the requirement which refers to the Operational Security as the actual and global system state while CACM deals with the planning and allocation of transmission capacity in terms of energy trade. • The fall-back mechanism does not imply that the Imbalance Netting Process shall be stopped permanently by the TSOs but is a "switch" which turns off Imbalance Netting Power Interchange in case of unplanned disturbances such as malfunctioning of the communication, unplanned network constraints or network splitting. Therefore, the requirement is an obligation to have technical fall-back procedures for time periods when for the process cannot be operated in a safe way. • For clarification on Virtual Tie-Lines please refer to the supporting document. • Financial settlement for Imbalance Netting is clearly out of scope of this NC.

Article 23 – CROSS-BORDER FRR ACTIVATION PROCESS – NEW ARTICLE 37

Summary	Comments received: 21 Recurring topics: • NRA approval and publication • mandatory implementation of the Cross-Border FRR Activation Process • clarification of transmission capacity • clarification of fall-back mechanism • replace "Virtual Tie-Line" by physical tie-line • wrong reference / typo
Changes made	• Wording was changed to clarify the meaning of the requirement to "The control target of the Cross-Border FRR Activation Process shall be […]" instead of "The Cross-Border FRR Activation Process shall be designed to […]" • the term "available transmission capacity" was replaced by the reference to Operational Security Limits • typos were corrected
Explanation for change or no change	• The article describes the general technical characteristics of a Cross-Border FRR Activation from control perspective. The former formulation "The Cross-Border FRR Activation shall be designed to" was misleading since the configuration of the control process is fully described in the NC (i.e. the control design is already provided). Therefore the NRA approval is given by accepting the NC. • While some of the optional control processes might be mandatory due to other NCs (EB NC) or regulations, NC LFCR deals only with technical requirements. From technical perspective, the implementation of Cross-Border FRR Activation is not a precondition for the maintenance of operational security in each case. • The term "available transmission capacity" was replaced by the reference to Operational Security Limits in order to better describe the requirement which refers to the Operational Security as the actual and global system state while CACM deals with the planning and allocation of transmission capacity in terms of energy trade. • The fall-back mechanism does not imply that the Cross-Border FRR Activation Process shall be stopped permanently by the TSOs but is a "switch" which turns off Frequency Restoration Power Interchange in case of unplanned disturbances such as malfunctioning of the communication, unplanned network constraints or network splitting. Therefore, the requirement is an obligation to have technical fall-back procedures for time periods when for the process cannot be operated in a safe way. • For clarification on Virtual Tie-Lines please refer to the supporting document.

Article 24 – CROSS-BORDER RR ACTIVATION PROCESS – NEW ARTICLE 38

Summary	Comments received: 18 Recurring topics: • NRA approval and publication • mandatory implementation of the Cross-Border RR Activation Process • clarification of transmission capacity • clarification of fall-back mechanism • replace "Virtual Tie-Line" by physical tie-line • wrong reference / typo
Changes made	• Wording was changed to clarify the meaning of the requirement to "The control target of the Cross-Border RR Activation Process shall be […]" instead of "The Cross-Border RR Activation Process shall be designed to […]" • the term "available transmission capacity" was replaced by the reference to Operational Security Limits • typos were corrected
Explanation for change or no change	• The article describes the general technical characteristics of a Cross-Border RR Activation from control perspective. The former formulation "The Cross-Border RR Activation shall be designed to" was misleading since the configuration of the control process is fully described in the NC (i.e. the control design is already provided). Therefore the NRA approval is given by accepting the NC. • While some of the optional control processes might be mandatory due to other NCs (EB NC)

	or regulations, NC LFCR deals only with technical requirements. From technical perspective, the implementation of Cross-Border RR Activation is not a precondition for the maintenance of operational security in each case. • The term "available transmission capacity" was replaced by the reference to Operational Security Limits in order to better describe the requirement which refers to the Operational Security as the actual and global system state while CACM deals with the planning and allocation of transmission capacity in terms of energy trade. • The fall-back mechanism does not imply that the Cross-Border RR Activation Process shall be stopped permanently by the TSOs but is a "switch" which turns off Reserve Replacement Power Interchange in case of unplanned disturbances such as malfunctioning of the communication, unplanned network constraints or network splitting. Therefore, the requirement is an obligation to have technical fall-back procedures for time periods when for the process cannot be operated in a safe way. • For clarification on Virtual Tie-Lines please refer to the supporting document.

Article 25 – ADDITIONAL REQUIREMENTS RELATED TO DIFFERENT AREA RESPONSIBILITIES NEW ARTICLE 39

Summary	Comments received: 7 Recurring topics: • NRA approval and publication • mandatory implementation of Imbalance Netting and Cross-Border FRR/RR Activation Processes • general clarification
Changes made	Wording changes were made to make it clearer when the implementation of cross-border control processes is required from technical perspective.
Explanation for change or no change	• NRA approval is treated by Article 4. • From technical perspective o the implementation of Imbalance Netting is a precondition to a joint dimensioning in a LFC Block. o the implementation of Cross-Border FRR/RR Activation is a precondition to exchange or sharing of these reserves

Article 26 – MEASUREMENTS AND INFRASTRUCTURE – NEW ARTICLE 41

Summary	Comments received: 9 Recurring topics: • NRA approval and publication • Clarification of application to network users
Changes made	The wording was changed to align with OS NC.
Explanation for change or no change	• NRA approval is treated by Article 4. • This article represents general technical requirements for TSO infrastructure. The requirements related to Reserve Providers are treated in the respective chapters.

Article 27 – FCR DIMENSIONING --> new Article. 43

Summary	24 comments were received on this Article: 1) Reference incident /dimensioning: consistency with dimensioning, historical data should not be a basis, should also cover forecast errors (7) 2) Typo (6) 3) Dimensioning: NRA involvement (3) 4) Definition of a small area to be inserted (2) 5) Publishing of values (2) 6) Dimensioning: inertia to be added (1) 7) Exchange of FCR – take network splitting into account (1) 8) Regulatory process / Transition Period:– Determination of FCR within a period defined in the code (see CACM NC) (1)

	9) Reference to DCC (1)
Changes made	• To 4) small Synchronous Area deleted • To 6): Inertia added in Par.2
Explanation for change or no change	• To 1): Forecast errors are not covered by FCR and therefore there is no need to include them in dimensioning; the reference incident is the maximum expected instantaneous imbalance in the SA – typically a generation outage. Such an imbalance has to be covered in any case (see formulation “at least”). Nevertheless the dimensioning approach could result in a higher FCR when applying the determined dimensioning approach that takes into account not only the Reference Incident but also all other kinds of imbalances, e.g. Market Induced Imbalances; in any case, historical data is needed to base the calculation on real conditions • To 3): NRA involvement is generally considered for a number of requirements – however, this is not the case concerning FCR dimensioning, since the process is already defined in the code and doesn’t need further approval • To 4): Small areas have a specific status because their individual conditions vary significantly from larger SAs and require individual solutions for Reserves. --> This NC only applies to those Synchronous Areas which are stated in the definition. • To 5): Publishing of values are already in a separate chapter; values of Reference Incident for GB and IRE vary too frequently between too wide ranges (because of the specific implementation) to make sense for publishing them • Ad 6): in general inertia is an aspect that should be taken into account • Ad 7): Possible network splitting is already covered by limits for XB FCR • Ad 8): Transition period for implementation is a general topic

Article 28 – FCR TECHNICAL MINIMUM REQUIREMENTS --> *new Article 44*

Summary	84 comments were received on this Article: 1) Additional Properties: delete possibility for TSOs to define – all requirements in the NC; harmonisation necessary; need for approval, coordination with RFG (26) 2) Additional requirements for Reserve Providing Groups: to be in line with RFG, approval by NRA, to be harmonized, management of Reserve Providing Groups up to the FCR Provider; involve DSOs in the process, delete right to exclude (6) 3) Monitoring: delete time-stamped instantaneous power without FCR activation, already in the scope of RFG, include a power threshold for data, cancel on line values, time resolution too strict, delete request for droop, requirements should be part of a defined prequalification process in the NC, define a power threshold for monitoring data, delete possibility to request online data; what is the area monitored by a TSO? (15) 4) Prequalification: time period for evaluation requested, process to be harmonized, process in the Code / to be approved by NRA, not needed because of RFG, requirement concerning implementation of a prequalification process defined twice (7) 5) Consideration of domestic homes /fridges – data provision (7) 6) Accuracy of frequency measurements/ insensitivity - too strict (7) 7) “controller” instead of “governor” (3) 8) Table 3: values for IRE missing (2) 9) Dimensioning process – to be approved by NRA (3) 10) FCR Activation should be obligatory only in contracted units (2) 11) Distinguish between “inherent insensitivity” and “intentional dead-band” (2) 12) Ensuring activation profile is TSO’s responsibility (1) 13) Add “proportional-<u>integral</u> governor”, since it is used that way in the Nordic (1) 14) Droop of the governor for hydro power plants “could put them (i) in breach of national and EU environmental obligations and (ii) be a danger to the public.” (1) 15) “Activation time” should be more thoroughly described (1)

Changes made	• To 1) Additional requirements: transition period upon consultation with affected FCR Providers and NRA approval added.
	• To 3) Monitoring:
	    ○ Data list adapted by replacing b), c) and d) with “time-stamped active power data needed to verify FCR activation. This data shall include, but is not limited to time-stamped instantaneous power”
	    ○ possibility to aggregate small units up to a common power of 1 MW provided that clear verification of FCFR activation is possible added
	• To 4) Prequalification
	    ○ Description of the process added

	◦ new formulation to cover request for defined evaluation time:"… within 3 months after provision of all the required information by the FCR Provider to the Reserve Connecting TSO…." • To 6): accuracy requirement changed to 10 mHz (additional requirement to apply industrial standard in case they are better than 10 mHz) • To 8): values added • To 11) distinction/clarification made in table 3
Explanation for change or no change	• To 1): Additional properties: ◦ Definition of additional properties might be necessary to cover future needs that are not known yet. This might be especially true for special kinds of FCR Providing Units like batteries that have not been considered on large scale as potential FCR Providing units yet. ◦ A transition period for implementation, respective consultation of the providers and approval makes sense. • To 2): Requirements for Reserve Providing Groups will strongly depend on the individual concepts ◦ RFG does not reflect requirements for FCR for combinations of units; ◦ management of Reserve Providing Groups is clearly in responsibility of the FCR Provider, nevertheless there might be superimposed requirements concerning the FCR provision with respect to the needs and individual situation of the Connecting TSO; ◦ Involvement of DSOs is a general topic covered in a separate chapter ◦ Evaluation happens in the course of prequalification • To 3): Effective monitoring is essential for ensuring quality of FCR; ◦ since concepts of generation/load vary in a wide range, it is left open, which kind of time-stamped active power data is requested – anyway, time-stamped instantaneous power data is always requested; in case the set point of the unit changes rapidly the active power output may provide too little information to monitor FCR activation (see also RFG) ◦ Aggregation for small units makes sense up to some limit as long as clear verification of activation is possible; ◦ RFG does generally not apply to existing units; data needed for monitoring have to be defined; ◦ For effective monitoring and respective counter measures online data might be needed (see also RFG; Art. 10./2./f) ◦ FCR shall be activated within very short time (e.g. in CE: 30s); for effective monitoring of FCR a time resolution above 10 s does not make sense • To 4): Prequalification: ◦ Consideration of already verified requirements reduces efforts in the prequalification. ◦ 1) RFG basically covers only new units (with possible exceptions). The LFCR requirements have to be applied to ALL Reserve Providing Units/Groups 2) RFG does not cover Reserve Providing Group requirements. 3) Prequalification will include more aspects than RFG. ◦ Process description can be only general ◦ Defined time period for evaluation makes sense • To 5): Domestic homes / fridges will not be taken into account since they are not considered as reserve in terms of controllability and verification. • To 6): Accuracy of 1 mHz is difficult to achieve; 10 mHz should be sufficient for the time being – nevertheless if new industrial standards exist the requirement should be adapted accordingly. • To 7): "governor" is used as a very general term • To 8): - • To 9): NRA approval not necessary since the framework of the process is defined in the NC • To 10): formulation says: "shall activate the AGREED FCR by means of….."….."''….." • To 11): - • To 12) FCR Provider responsible to comply; prequalification (and monitoring) covers the compliance • To 13) Information is not correct • To 14) Only information about droop is required - not a possibility to adjust it by the TSO • To 15) Definition is sufficient

Article 29 – FCR PROVISION --> new Article 45

Summary	54 comments were received on this Article: 1) Availability/unavailability:, adapt formulation concerning information to the TSO, for replacement of an outage 12 hours are too long, replacement of an outage should be responsibility of the TSO, replacement of an outage should be according to the contact – delete requirement at all; delete exception for an outage; "commercial" exceptions should be possible based on the contract; exception for planned outages as well; delete for small units requirement for information to the TSO as long as availability of the provider is not affected, add lack of primary energy as possible excuse not to be available to allow wind/solar power to offer FCR (14) 2) Limits for concentration of FCR (3%/6%): criteria missing, numbers too low, delete limits at all, existing 50 MW-reserves would be excluded in future(4) 3) K factor: unclear (impact on units), NRA approval, deletion, better definition (4) 4) Limited storage: delete recovery of exhausted storage, allow recovery of exhausted storage with energy from the grid, delete possibility of having limited storage, 30 minutes too long/ not in accordance with RFG; GB and IRE – shall be approved by NRA, (23) 5) Question: "Application" of self-regulation (1) 6) Change term "unplanned" to "forced" according to OPS (1) 7) Counter measures for persisting frequency deviations: measures to be described in the NC, NRA approval (2) 8) Domestic homes/fridges: information about unavailability not possible (1) 9) Dispute processes: which (1) 10) Typo/wording (3)

Changes made	• To1) Availability/Unavailability:
	  ○ Requirement connected to obligation to provide FCR
	  ○ Information requirement limited to FCR Providing Unit/Group "that is considered to be relevant according to the results of Prequalification without undue delay";
	  ○ According to continuous availability "during the time period in which it [the FCR Providing Unit] is obliged to provide FCR" was added
	  ○ Responsibility for replacement of unavailable FCR --> New formulation in 5: " Each TSO shall ensure or shall require from its FCR Providers to ensure…."
	  ○ Requirement for replacement in case of a forced unavailability harmonized; requirement for replacement as soon as technically possible and according to the conditions that shall be defined by the Reserve Connecting TSO.
	• To 2) limit per unit raised to 5 %, limit for the electrical node deleted
	• To 4): GR and IRE: approval of methods added,
	2 hours (for all other SAs): "…as soon as possible but at least…." added
	• To 6): "unplanned" replaced by "forced"
	• To 7): Counter measures added and put in the Operation chapter

Explanation for change or no change	• To 1): Availability plays a crucial role in FCR Provision
	  ○ Basic requirements cannot be subject to the contract since there have to be a harmonized effect all over the SA
	  ○ Out of operation situations (e.g. resulting from commercial considerations or maintenance) cannot be accepted to justify unavailability – except where FCR provision is an obligation
	  ○ Information about a forced unavailability must be given to the TSO as soon as possible – nevertheless some delay is acceptable
	  ○ In case of forced unavailability small units can be aggregated for information to the TSO according to their effect – to be clarified in detail in the course of Prequalification
	  ○ Responsibility for replacement of unavailable FCR can lie with the TSO or the FCR provider; solution depends on Reserve concept
	  ○ Replacement possibilities strongly depend on the kind of FCR Providing Units; new formulation on one hand enables some flexibility for TSOs and FCR Providers and on the other hand reduces the risk of subsequent outages before replacement could be organized
	  ○ Lack of primary energy cannot be accepted as an excuse for unavailability
	  ○ Sensible size limit for unavailability information will depend on individual conditions and is therefore up to the Prequalification results
	  ○ To cover the possible case of general FCR obligation for FCR Providing Units (already applied in some MSs) the connection between "obligation" and "continuous availability" makes sense.
	• To 2): limits came from operation Handbook, basis is FCR for the SA (--> 50 MW are not a problem); limit per unit raised to cover current situation – from the system security

	point of view based on experience the 5 % are sensible taking into account the requirement to replace unavailable Reserves as soon as technically possible • To 3) ○ K factor cannot been approved by NRA – it is a system parameter resulting from the behaviour of generators and load ○ K factor has no direct impact on Reserve Providing Units • To 4): possibility of limited storage can be tolerated under certain conditions ○ 30 minutes reflect 1) possibility of a subsequent outage/imbalance, 2) not sufficient activation of FRR within 15 minutes for whatever reason and 3) possible continuous activation of FCR prior to the outage due to a mean value of frequency deviation deviating from zero over a remarkable period of time (result can be some gradual exhaustion of storages); current observations of frequency as well as respective simulations support this requirement ○ New formulation more specific • To 5): self-regulation cannot be "applied"; it is an system-immanent effect • To 6): - • To 7): Counter measures covered in Art 41; they depend on system states and will be coordinated among TSOs; • To 8): domestic homes / fridges are NOT considered as reserves but as demand response that cannot be controlled / monitored at all. • To 9): dispute processes are not part of the NC • To 10): -

Article 30 – FRR DIMENSIONING – NEW ARTICLE 46

Summary	39 comments were given to this Article, the main points of concern were: 1) It was requested to make the dimensioning approach and the results subject to NRA approval. In addition it was requested, that the methodology to arrive to the ratio of automatic and manual FRR shall be justified to and approved by the NRA. 2) It was requested to make the allocation of responsibilities within a LFC Block subject to NRA approval. 3) It was requested transparency with regard the data set for FRR dimensioning. 4) Several comments referred to the changing electricity and market systems and argued that a dimensioning based on historical data is not sufficient. 5) Several remarks challenged the 99 % quantile approach and requested a more strict percentage (e.g. 99.9 %) 6) One remark was given, that sharing shall not be allowed, because it defeats the object of separation of LFC Blocks. Others requested an explanation of the 30 % rule. 7) Several remarks regarding clarity and definitions
Changes made	Changes: 1) No change needed 2) No change needed 3) No change needed 4) No change needed 5) No change needed 6) No change needed 7) Small changes
Explanation for change or no change	Explanation 1) It shall be made clear in the Supporting Document that the dimensioning methodology is already subject to NRA approval and that the determination of automatic and manual FRR is hence part this methodology. The results shall not be subject to approved by the NRA as the methodology has been approved. 2) The LFC Block Operational Agreement was introduced in the new version of the code which is subject to NRA approval. Hence no change is needed. 3) A transparency with regard to the used data is seen as not relevant for the stakeholders. 4) It shall be explained in the Supporting Paper that the term "significant expected changes" refers to the possibility to incorporate the expected changes. 5) It shall be explained in the Supporting Paper, that the 99% is a minimum value and that the goal of the dimensioning is to achieve the FR quality target. 6) It shall be explained in the Supporting Paper, that the Sharing is strictly limits the sharing of FRR and hence guarantees an independent operation. Also the 30 % rule

	shall be reasoned.

Article 31 – FRR TECHNICAL MINIMUM REQUIREMENTS – NEW ARTICLE 47

Summary	41 comments were given to this Article, the main points of concern were: 1) The specifications regarding real-time measurement supply and the reference power production are unclear. [10] 2) It was requested to supply on-line measurement data to the Reserves Connecting DSO.[1] 3) It was requested to make any complementary requirement subject to NRA approval and to promote European harmonization; furthermore it was remarked that these requirements shall be consistent to the NC RFG [11] 4) Several comments were made that the FRR provision is based on a voluntary basis. 5) Remarks regarding lack of clarity, definitions and typos.[5] 6) General remarks regarding NRA approval or additional Transparency. [9]
Changes made	Changes: 1) It was specified, that the measurement is primarily relevant from the Connection Point perspective, but that further information for a Group can be necessary 2) The obligation for data delivery to Reserve Connecting DSOs is catered in the DNO Chapter.. 3) The additional requirements were reduced to availability requirements, control quality and connection requirements. 4) Clearer definitions were introduced, will be explained in Supporting Paper
Explanation for change or no change	Explanation: 1) Will be explained in Supporting Document. 2) No need for change as covered in DSO chapter.. 3) As an individual approach per LFC Blocks and per TSO is necessary, a full European harmonization is not possible. The freedom may be limited to an acceptable range by the introduction of ranges.. 4) A new definition of Provider and Unit and Group was introduced clarifying this relationship.

Article 32 – FRR OPERATION – NEW ARTICLE 42

Summary	31 comments were given to this Article, the main points of concern were: 1) Several requests were made to fact that the relation to the OS NC and to other NC shall be clarified.[12] 2) Many remarks were given, that the instruction of generating and demand facilities shall only be applied if NRA approval is given and if cost compensation is guaranteed for these cases. Further ones questioned the LFCR Code the right place to regulate this, but would expect a reference to the Emergency Code [3] 3) Remarks regarding lack of clarity, definitions and typos.[8] 4) General remarks regarding NRA approval or additional Transparency. [8]
Changes made	Changes: The complete chapter was rewritten now forming Chapter 5. For this the remarks were taken into account in the following way: 1) The relation to the OS NC was clarified; no references to other NC were introduced. 2) The NRA Approval for the actions was introduced; a reference to the Emergency Code was omitted.
Explanation for change or no change	Explanation: 1) The relation was clarified, that only the Normal State and the Alert State with regard to System Frequency are covered by this code. 2) For actions beyond Active Power Reserves a NRA involvement is needed. There is no

	connection to the Emergency Code.

Article 33 – RR DIMENSIONING – NEW ARTICLE 48

Summary	28 comments were received on this article. The main issues are the following : 1. Make clear reference to EB NC, as Reserves are contracted, and procurement should be harmonized (7) 2. Define common Dimensioning rules (1) 3. Explain the difference of use of RR between CE and GB/IRE (2) 4. Reference to the illiquidity of the market (6) 5. NRA approval of the TSO multi-party agreement for the definition of roles and responsibilities within a LFC Block (5) 6. Transparency of the Dimensioning rules (1) 7. Publication of TSO multi-party agreement (2) 8. Typo (4)
Changes made	1. No changes 2. No changes 3. No changes 4. Reformulation of the requirement to delete reference to the market 5. No changes 6. No changes 7. No publication of TSO multi-party agreements 8. Corrections in the article
Explanation for change or no change	1. NC LFCR deals only with technical requirements, EB NC will deal with the market issue 2. The dimensioning rules are defined in the code, and in a mutli-party agreement, but RRP is optional, so dimensioning depends on the need of a LFC Block 3. Develop the explanation in the supporting paper 4. Requirement was not clear 5. There is no need for NRA approval of TSO organization 6. Already in the transparency chapter 7. TSO multi party agreements may contain confidential information, and are therefore not public.

Article 34 – RR TECHNICAL MINIMUM REQUIREMENTS – NEW ARTICLE 49

Summary	67 comments where received on this article. The main issues are : 1. Activation of RR should be reasonable (2) 2. Additional requirements: all the requirements should be included in the code (4). 3. Activation of RR should not distort the market, make reference to EB NC (11) 4. Real-time measurement issue (7) 5. NRA approval (9) 6. Qualification process to accept more facilities (2) 7. RR operation article is missing (7) 8. Technical clarification about full activation time (4) 9. Typo (12) 10. There is no need to inform the Connecting TSO about unavailability or limitation, since all facilities have to publish this information on REMIT platform according to Transparency Regulation (8)
Changes made	1. No changes 2. No changes 3. No changes 4. No change for the measurement requirement, but clarification in the article for reference power production 5. Adapt the article case by case 6. Minimum size has been added 7. New article on operation 8. The article has been modified 9. Corrections have been made in the article 10. No changes
Explanation for change or no change	1. activation depends on the imbalances of an LFC Area, and will be consistent with the technical requirements 2. it is not possible to include all the requirements in the code. The system is moving,

	TSOs may need to change the requirements or add new ones to fit with new facilities 3. explanation in the supporting paper 4. it is a strong requirement to be able to monitor in real time the activation of RR 5. add NRA approval where it is needed 6. a minimum size has been added for RR providing units 7. common operation article for Reserves is better than one article in FRR and RR chapters. 8. 9. 10. REMIT is not a real time database. For security considerations, each TSO requires real-time information to meet their obligations

Article 35 – EXCHANGE OF FCR WITHIN A SYNCHRONOUS AREA – NEW ARTICLE 50

Summary	37 comments were made. Following topics emerged: 1) The right for BSPs to participate in each TSO tender for FCR (5 comments); 2) The fact that TSOs shall allow for the exchange of FCR ⇔ have the right to perform the transfer of FCR (2 comments); 3) NRA involvement to assess costs in case of exchange of FCR (1 comment); 4) Add reference to NC on Electricity Balancing for the exchange of FCR (1 comment); 5) Limits for the exchange of FCR (12 comments); a. Clearer formulation; b. No export limit for FCR to ensure liquid market; c. Rules for import and export should be identical; d. No internal limits for exchange of FCR within an LFC Block; e. NRA involvement for limits (2 comments); f. Explain the 100 MW limit; g. Make formulation on network splitting and internal congestions more clear 6) Agreement between Connecting, Receiving and Affected TSOs on the Exchange of FCR subject to NRA approval (1 comment). 7) Definition of and approval for the common threshold to apply as Affected TSO (10 comments); a. Require NRA involvement and public consultation of the threshold. 8) Reliability margin (6 comments) a. No reservation of XB capacity to allow for the exchange of FCR; b. Add reference to NC CACM for the Reliability Margin; c. Cost benefit analysis for any increase in RM to enable the exchange of FCR; d. Transparency on changes in RM for the exchange of FCR. 9) Responsibility of the FCR provider towards the Reserve Connecting TSO: a. Delegation of the activation from the Connecting to the Receiving TSO should be possible.
Changes made	1) The NC is rewritten in a way that it only covers technical limits for the exchange of FCR. The market organization of the exchange itself shall be described in the NC on Electricity Balancing. 5) The formulation of the limits was made more clear. NRA involvement was added where the exact limits are not set in the NC. The limits proposed in the NC LFCR (both for import and export) are maintained as they ensure an even distribution of FCR throughout the Synchronous Area, and are therefore important to ensure Operational Security, as well as an even distribution of FCR in case of network splitting. 6) This article was reformulated and states now that the Exchange of FCR can only be refused in case the exchange of FCR could lead to flows exceeding the Operational Security Limits. 7) The common threshold was deleted from the NC. It is stated now that a TSO can declare itself as Affected TSO in case the Exchange of FCR affects its Operational Security parameters. 8) A more thorough link with NC CACM was put in place. The NC LFCR only deals with technical issues and not with costs (cost benefit analysis).
Explanation for change or no change	1) (Change) The NC LFCR deals only with technical issues. For the exchange of FCR these issues are: a. Ensuring an even distribution of FCR throughout the Synchronous Area (limits for the exchange); b. Organization of the transfer, ensure the correct functioning of exchange; c. Ensuring that the operational security is guaranteed in case of exchange (Reliability Margin). The NC LFCR shall not decide on market design issues (TSO – BSP, TSO – TSO) while ensuring also not to exclude a priori any of those designs to develop (NC EB).

	2) (No change) The NC LFCR sets forth technical limits (boundaries) for the exchange of reserves. The market organization itself shall be discussed in the NC EB. The latest wording of the NC LFCR does not exclude exchange of FCR to take place. 3) (No change): the technical limits for the exchange of FCR are clearly defined in the NC (or require NRA involvement if determined on ad-hoc basis). Therefore no NRA involvement on technical matters is required as long as those rules are respected. Any considerations with respect to provision of reserves and according costs will be considered in the NC on EB. 4) (No change): although the exchange of FCR shall be further elaborated in the NC on EB, from a legal point it is not possible to refer to a NC that is not elaborated yet. Therefore the NC on EB shall have to refer back to the NC LFCR. 5) (Partially changed) a. (Change) Formulation was made more clear b. (Change) NRA involvement was added in case the exact limits are not mentioned in the NC itself. c. (No change) The proposed limits are maintained as simulations show that they ensure an even distribution of FCR throughout the Synchronous Area, which is required for Operational Security. A limit for export is required to avoid large-scale concentration of FCR within an LFC Block. 6) As the technical limits for the exchange of FCR are already within the NC or subject to NRA involvement, there is no need further need for NRA involvement for the Exchange of FCR respecting those technical rules. Aspects of market design, costs,… shall be considered in the NC on Electricity Balancing. 7) Additional restrictions on the Exchange of FCR should be justified on the basis of Operational Security Analysis. 8) (Partially changed) A clear link with NC CACM is required for the sake of clarity. The Reliability Margin itself should be sufficient to avoid overloading of transmission lines in case of FCR activation. The NC LFCR does not deal with market issues as cost-benefit analysis, reservation of transmission capacity etc. The article was made clearer in the sense that the Affected TSOs shall verify whether their Reliability Margin is sufficient for the Exchange of FCR. Issues of cross-border capacity for the exchange of reserves shall be dealt with in the NC on EB. 9) (No change) As the Exchange of FCR invokes also the exchange of FCR Obligation, the Reserve Connecting TSO becomes per definition responsible for the activation of the Exchanged FCR. FCR is activated on the basis of a local frequency measure, so there is no delegation of an activation Setpoint as such.

Article 36 – SHARING OF FCR WITHIN A SYNCHRONOUS AREA – NEW ARTICLE 51

Summary	1 comment was made: 1) Wording should be made more strict (1 comment).
Changes made	1) Wording was adjusted: *‚It is prohibited for a TSO to share any part of its FCR Obligation with other TSOs in the Synchronous Area, in order to reduce the total amount of FCR of the Synchronous Area as defined in accordance with Article 27(1)*
Explanation for change or no change	1) Clearer wording for the Article.

Article 37 – GENERAL REQUIREMENTS FOR THE EXCHANGE OF FRR AND RR - NEW ARTICLE 52

Summary	28 comments were made. Following topics emerged: 1) *‘The Reserve Connecting TSO shall give its prior consent in case of a direct relationship between the Reserve Receiving TSO and the Reserve Providing Unit or Group*.’ A TSO should not be able to block a TSO – BSP model. A mitigation procedure for lack of reserves should be sufficient (5 comments). 2) Cross-border capacity for the exchange of FRR/RR (12 comments). a. Delete that the Reserve Connecting and Receiving TSO shall define the identity of the TSO responsible for ensuring sufficient transmission capacity to be available (role of NC EB) b. Delete the article that sufficient cross-border capacity must be available (role of NC EB) c. Require NRA involvement for this Article; d. Publication of TSO multi-party agreement to define the identity of the TSO responsible for ensuring sufficient transmission capacity to be available

	e. No ex-ante reservation of capacity for the Exchange of FRR/RR. f. Reference to NC EB 3) Add NRA involvement for the definition of the Synchronous Area Agreement on the roles and responsibilities of the Reserve Connecting, Receiving and Affected TSOs. 4) Publication of volumes of planned exchange of FRR/RR, duration of the agreement, expected power flows due to the exchange and price paid for FRR/RR in absence of the possibility of a (economical) TSO-BSP model. 5) Make role of Reserve Connecting TSO clearer. 6) Remove Art. 37.6 as it is already covered in Article 39.2 and 41.2
Changes made	1) The article was rewritten to focus only on the technical relationships and requirements for the good functioning of the Exchange of FRR/RR. A mitigation procedure for the case that the Exchange of FRR/RR leads to insufficient volumes was added. 2) Wording was changed to focus only on technical issues. 4) No changes made. 5) Role is made clearer throughout the NC by defining the different topics to be considered when defining roles and responsibility of Connecting and Receiving TSO. 6) Article was deleted (already in other Articles 39.2 and 41.2).
Explanation for change or no change	1) (Change) The NC LFCR only deals with technical requirements. It is of key importance that the Reserve Connecting TSO is at least notified in case of a direct relationship between the Reserve Receiving TSO and the Reserve Providing Unit or Group. Furthermore such a relationship should not lead to insufficient volumes of FRR/RR capacity to be available for the Reserve Connecting TSO. 2) (Partial change) The NC LFCR only deals with technical issues. Therefore the NC LFCR states now that Operational Security may not be endangered by the exchange of FRR/RR (cfr. overloading of lines) and that the Reserve Connecting TSO and Reserve Receiving TSO shall define procedures to avoid this from happening. Any reservation or use of transmission capacity, along with required transparency, shall be considered in the NC on Electricity Balancing. 3) (No change) The DT stresses that these technical responsibilities are required to ensure the proper functioning of the exchange of FRR/RR. They however do not affect market parties nor the market for the exchange of reserves and are therefore not subject to NRA approval. Market aspects will be defined in the NC EB, requiring possible NRA approval. 4) The NC LFCR does not exclude a priori any market model. Publication of prices and market deals does not fall under the scope of the NC LFCR as this does not relate to technical matters. Furthermore the publication for the Exchange of FRR/RR is already foreseen in Chapter 11 (Transparency). 5) The Network Code was made clearer on the role of the Reserve Connecting TSO. 6) Double reference.

Article 38 – GENERAL REQUIREMENTS FOR THE SHARING OF FRR AND RR NEW ARTICLE 53

Summary	21 comments were made. Following topics emerged: 1) Reference to Article 30 with limits for the sharing of FRR/RR capacity (2 comments) 2) Total combined limit for the sharing and exchange of FRR/RR Capacity; 3) Each TSO shall remain responsible to cope with incidents and imbalances in its own LFC Block in case the shared FRR/RR aren't available. This is not an optimal situation as already transmission capacity can be reserved for this purpose (1 comment) 4) Requirement for sufficient transmission capacity for the sharing of FRR/RR and reference to NC EB (7 comments) a. No reservation of capacity b. Cross-referencing to NC EB (article on use, allocation and reservation of cross-zonal capacity for balancing reserves' 5) Synchronous Area Agreement on roles and responsibilities of the Control Capability Providing and Receiving and Affected TSOs needs to be subject to NRA involvement. (2 comments) 6) The consent of any Affected TSO cannot unreasonably be withheld. (1 comment) 7) Transparency on information related to sharing (1 comment)
Changes made	2) The limits for the exchange were adjusted in order to reflect the fact that the 50 % limit for FRR/RR relates to the total amount of FRR/RR before any reduction due to sharing. 6) It is now stated that an Affected TSO can refuse the sharing in case the flows exceed the Operational Security Limits.
Explanation for change or no change	1) (No change) Reference is made in Article 40 dealing specifically with limits for the Sharing of FRR. Therefore the NC LFCR is consistent. 2) (Change) The 50 % limit for the exchange of FRR/RR is included in the NC to ensure an even distribution of reserves as to ensure that the TSOs are still able to control most

	imbalances even if the exchange would fail (network splitting, communication failure,…).,…).).,…). Therefore the same rules should apply for all LFC Blocks, regardless the sharing of reserves. **3)** (No change) Per definition a TSO remains responsible to balance its LFC Block. Furthermore this Network Code only states that transmission capacity must be available to activate the shared reserves (flows do not exceed Operational Security Limits). How this is ensured shall be discussed in the NC EB (reservation of capacity, probabilistic methodology,…).,…).).,…). **4)** (No change) The NC LFCR only deals with technical matters. Therefore the NC only states that the activation of the shared FRR/RR may not endanger operational security. Aspects considering transmission capacity shall be dealt with in the NC on EB (reservation of capacity, probabilistic approach, only sharing if free remaining capacity,…). As the NC on EB is not elaborated yet it is from a legal point of view impossible to make reference to it. The NC on EB shall therefore have to include a reference to NC LFCR. **5)** (No change) The DT stresses that these technical responsibilities are required to ensure the proper functioning of the sharing of FRR/RR. They however do not affect market parties nor the market for the sharing of reserves and are therefore not subject to NRA approval. Market aspects will be defined in the NC EB, requiring possible NRA approval. **6)** (Change) The sharing of FRR/RR can only be refused in case the resulting flows would exceed Operational Security Limits. This makes the NC clearer and stipulates that refusals can only be based on operational security aspects. **7)** (No change) Transparency of technical data is ensured in Chapter 11. Information on market arrangements,… shall be considered in NC on EB.

Article 39 – EXCHANGE OF FRR WITHIN A SYNCHRONOUS AREA - NEW ARTICLE 54

Summary	17 comments were made. Following topics emerged: 1) The right for BSPs to participate in the tender of FRR for the exchange of FRR (7 comments) 2) The exchange of FRR should be subject to NRA involvement in order to avoid that costs are passed from one TSO to another. (1 comment) 3) Limits for the exchange of FRR (7 comments) a. Exchange of FRR should not be limited to much to ensure liquid market (keep less than 50 % FRR inside the LFC Block). b. Current limits are not strict enough (keep more FRR inside the LFC Block) c. Exchange should be limited more to avoid the use of cross-zonal transmission capacity and keep integrity of LFC Blocks. 4) Explanation on supplementary FRR Capacity (1 comment) 5) Make limits for the exchange of FRR due to internal congestions more and network splitting more clear (1 comment)
Changes made	1) The NC is rewritten in a way that it only covers technical limits for the exchange of FRR. The market organisation of the exchange itself shall be described in the NC on Electricity Balancing. 4) Supplementary FRR Capacity was removed from this NC. 5) Wording in the NC was made more clear.
Explanation for change or no change	1) (Change) The NC LFCR deals only with technical issues. For the exchange of FRR these issues are: a. Ensuring an even distribution of FRR throughout the Synchronous Area (limits for the exchange) b. Organization of the transfer, ensure the correct functioning of exchange c. Ensuring that the operational security is guaranteed in case of exchange. The NC LFCR shall not decide on market design issues (TSO – BSP, TSO – TSO) while ensuring also not to exclude a priori any of those designs to develop (NC EB). 2) (No change) As the technical limits for the exchange of FRR are clearly put forward in the NC or require NRA involvement in case of ad-hoc limits, no further NRA involvement for technical matters is required. Market arrangements and costs will be treated in the NC on EB and are not considered in the NC LFCR. 3) (No change) The limit to keep 50 % inside the LFC Block ensures an even distribution of FRR which is required for Operational Security reasons. The limit of 50 % of FRR Capacity enables the TSOs to cover already most of the imbalances in its LFC Block and therefore reduces the risk in case of failure of the exchange or network splitting. 4) (Change) The 99% used in the FRR Dimensioning Article refers to the minimum amount of FRR Capacity. A TSO might need more FRR Capacity to fulfil its obligations set forth in this NC. 5) Wording was made clearer.

Article 40 – SHARING OF FRR WITHIN A SYNCHRONOUS AREA - NEW ARTICLE 55

Summary	2 comments were made. Following topics emerged: 1) Reference missing towards the limits on exchange of FRR. 2) NRA involvement for the sharing of FRR is required in order to avoid one TSO to pass costs on a second TSO.
Changes made	1) Reference was added.
Explanation for change or no change	1) (Change) The volume of 'shared' FRR is also not procured inside the own LFC Area/Block and is therefore also subject to the limits on exchange of FRR. 2) (No change) The technical limits for the sharing of FRR are clearly put forward in this NC. Therefore no further NRA involvement is required. The market arrangements and costs shall be discussed in the NC on EB and are therefore not in the scope of this NC.

Article 41 – EXCHANGE OF RR WITHIN A SYNCHRONOUS AREA - NEW ARTICLE 56

Summary	19 comments were made. Following topics emerged: 1) Wrong numbering (no Article 41(1)) (3 comments) 2) The right for BSPs to participate in the tender of RR for the exchange of RR (6 comments) 3) Limits for the exchange of RR (7 comments) a. Exchange of RR should not be limited too much to create a liquid market b. The exchange of RR should be limited more as to ensure the integrity of the LFC Block and avoids use of cross-zonal capacity 4) The Exchange of RR should be subject to NRA involvement to avoid one TSO to pass costs to another TSO 5) Make limits for the exchange of FRR due to internal congestions more and network splitting more clear (1 comment)
Changes made	1) Numbering was corrected. 2) The NC is rewritten in a way that it only covers technical limits of the exchange of RR. The market organisation of the exchange itself shall be described in the NC on Electricity Balancing. 5) Wording in the NC was made clearer.
Explanation for change or no change	1) (Change) Numbering was corrected. 2) (Change) The NC LFCR deals only with technical issues. For the exchange of RR these issues are: a. Ensuring an even distribution of RR throughout the Synchronous Area (limits for the exchange) b. Organization of the transfer, ensure the correct functioning of exchange c. Ensuring that the operational security is guaranteed in case of exchange. The NC LFCR shall not decide on market design issues (TSO – BSP, TSO – TSO) while ensuring also not to exclude a priori any of those designs to develop (NC EB). 3) (No change) The limit to keep 50 % inside the LFC Block ensures an even distribution of RR which is required for Operational Security reasons. The limit of 50 % of RR Capacity enables the TSOs to cover already most of the imbalances in its LFC Block and therefore reduces the risk in case of failure of the exchange or network splitting. 4) (No change) As the technical limits for the exchange of RR are clearly put forward in the NC or require NRA involvement in case of ad-hoc limits, no further NRA involvement for technical matters is required. Market arrangements and costs will be treated in the NC on EB and are not considered in the NC LFCR. **5)** Wording in the NC was made more clear

Article 42 – SHARING OF RR WITHIN A SYNCHRONOUS AREA - 57

Summary	11 comments were made. Following topics emerged: 1) The sharing of RR should be subject to NRA involvement in order to avoid one TSO passing costs to another TSO. (1 comment) 2) The notion of 'very unlikely to happen' is too vague for a EU NC.
Changes made	2) Rewording of the limits for the sharing. They are now included in the RR Dimensioning Rules. NRA approval should be added as no strict limits are defined in the NC.
Explanation for change or no change	1) (No change) The technical limits for the sharing of RR are within the NC and subject to NRA involvement. Market arrangements and costs will be discussed in the NC on EB and are out of scope of the NC LFCR. 2) Article was reworded and NRA approval will be added.

Article 43 – EXCHANGE AND SHARING OF RESERVES BETWEEN SYNCHRONOUS AREAS - SECTION 2

Summary	2 comments 1. The provision of FCR exchange and FRR and RR sharing or exchange on HVDC interconnectors shall be subject to contract between TSO and HVDC interconnector. 2. A lot of transmission capacity will be reserved for this purpose that isn't available anymore for commercial purposes.
Changes made	None.
Explanation for change or no change	The NC LFCR defines technical capability but not the allocation of capacity which will be subject to social welfare justification in line with the FG Balancing. Therefore these questions are not in the scope of the NC LFCR.

Article 44 – EXCHANGE OF FCR BETWEEN SYNCHRONOUS AREAS NEW ARTICLE 59

Summary	20 comments 1. TSO multi-party agreement should be publicly available and under NRA approval and market parties consultation (18). 2. HVDC interconnectors cannot remedy faults outside its design capability. (1) 3. Stakeholder should be informed of contracted reserves and prices (1).
Changes made	1. NRA involvement has been reviewed 2. None. 3. None.
Explanation for change or no change	1. Change made to Article 3.3 2. Article only refers to the existing design capability. 3. Contracted reserves are a transparency issue. The NC LFCR does not describe how the contracting is done; this is covered in the NC Balancing.

Article 45 – SHARING OF FCR BETWEEN SYNCHRONOUS AREAS - NEW ARTICLE 60

Summary	No comments.
Changes made	None.
Explanation for change or no change	There are no comments.

Article 46 – EXCHANGE OF FRR BETWEEN SYNCHRONOUS AREAS - NEW ARTICLE 62

Summary	18 comments. 1. Excluding the possibility for a TSO-BSP model would be in contradiction with the internal market rules (2). 2. TSO multi-party agreement should be publicly available and under NRA approval and market parties consultation (6). 3. Several typing errors, e.g. cross-references (6). 4. Stakeholder should be informed of contracted reserves and prices (1). 5. The rules and minimum requirements shall cover at least a) the operational impact between the Synchronous Areas; and b) the impact on the frequency quality of the involved Synchronous Areas. Exchange of FRR shall not exceed 20 % of the dimensioning incident (1). 6. The TSOs must comply with both the REMIT and Transparency Guideline obligations (1). Exchange between Synchronous Areas is based on a TSO-TSO model.
Changes made	1. BSP to TSO model facilitated. 2. NRA involvement has been reviewed 3. Corrected, 4. None.

	5. The part of the FRR Capacity which is exchanged shall be provided within an LFC Block of the second Synchronous Area in addition to the FRR Capacity of this LFC Block of the second Synchronous Area has been modified to enable TSO to assess the risk to system security 6. None.
Explanation for change or no change	1. Changes made. 2. Change made to Article 3.3 3. Change made. 4. Contracted reserves are a transparency issue. The NC LFCR does not describe how the contracting is done; this is covered in the NC Balancing. 5. Change made to A 46.2 6. Contracted reserves are a transparency issue. The NC LFCR does not describe how the contracting is done; this is covered in the NC Balancing.

Article 47 – SHARING OF FRR BETWEEN SYNCHRONOUS AREAS - NEW ARTICLE 63

Summary	6 comments 1. The cross-references are not correct (6).
Changes made	1. Change made.
Explanation for change or no change	1. Corrected

Article 48 – EXCHANGE OF RR BETWEEN SYNCHRONOUS AREAS - NEW ARTICLE 64

Summary	6 Comments 1. Such contract will take into account Article 3 (3) and without prejudice to the exemptions granted under Regulation (EC) No 1228/2003 and Regulation (EC) No 714/2009 (4). 2. Excluding the possibility for a TSO-BSP model would be in contradiction with the internal market rules (1). 3. Only free and secured (n-1) transmission capacity can be used for these operational security relevant products (1). Exchange between Synchronous Areas is based on a TSO-TSO model.
Changes made	1. Change made to Article 3.3 2. None. 3. None.
Explanation for change or no change	1. Change made to Article 3.3 2. There is no BSP-TSO model arrangement for the exchange between Synchronous Areas currently in place and a BSP-TSO model does not facilitate a CMO as required in the FG Balancing. 3. The network code draft was neutral in terms of how the capacity was made available.

Article 49 – SHARING OF RR BETWEEN SYNCHRONOUS AREAS - NEW ARTICLE 65

Summary	2 comments 1. The cross-references are not correct (1). 2. TSOs could agree to pass costs / obligations from TSO 1 to TSO 2 which may not be in the interest of those stakeholders who pay the TSO 1 costs.
Changes made	1. The cross-references have been corrected. 2. None.
Explanation for change or no change	1. Corrected. 2. The pricing of the RR transfer is not in the scope of the NC LFCR but NC Balancing.

Article 50 – CROSS-BORDER ACTIVATION PROCESS OF FRR AND RR FOR OPTIMIZATION PURPOSES - NEW ARTICLE 66

Summary	27 comments were made. Following topics emerged: 1) Make cross-border activation an obligatory process for TSOs as TSOs are required to

	share/exchange reserves (1 comment) 2) Inappropriate reference to optimization purposes (8 comments) 3) The cross-border activation for optimization should only be allowed to the extent that it not endangers grid quality and operational security (4 comments) 4) A link should be made towards the limits on the sharing and exchange of FRR/RR Capacity; limits for exchange/sharing should be duly justified; exchange and sharing will be transparent (6 comments); 5) Inappropriate referencing towards optimization purposes (NC on EB) (8 comments); 6) Article should be deleted as it allows TSOs to override the control structure and processes in the code 7) Overlap with Article 23 and 24 (1 comment). 8) Typo: Reserve Replacement Process (1 comment) 9) Add transparency on cross-border activation (1 comment)
Changes made	1) Cross-border activation shall be allowed by the NC LFCR as long as it doesn't interfere with operational security. 2) Reference to optimization purposes was deleted. The NC LFCR now only states that the cross-border activation of FRR/RR is allowed subject to some constraints in the XB FRR/RR activation processes in the control structure chapter. 7) Article 50 was merged with article 23 and 24; the article was made clearer. 8) Typo was corrected
Explanation for change or no change	1) (Partial change) Cross-border activation shall be allowed by the NC LFCR. Performing cross-border activation is only for optimization purposes and shall therefore be further considered in the NC on EB (no obligatory process in NC LFCR). Cross-border activation of FRR/RR relates to activation (energy) of all available reserves, whereas the sharing and exchange of reserves relates to reserve capacity (MW). Therefore there is no link between the sharing and exchange and the cross-border activation process as such. On the other hand a cross-border activation process must be implemented to proceed to the sharing and exchange of reserves. **2)** (Change) Optimization in terms of activation of FRR/RR shall be considered in the NC on EB. **3)** (No change) The NC LFCR states clearly that the cross-border activation process may not endanger operational security, nor endanger frequency quality (see articles on XB FRR/RR activation process in the control structure chapter). **4)** (No change) The limits for the sharing and exchange of FRR/RR ensure sufficient reserve capacity to be available in the system with an appropriate distribution. The activation of these available reserves however can be optimized in a more global way. There is no direct link between the sharing and exchange of reserves and the limits for the cross-border activation process as such. However sharing and exchange of reserves requires a cross-border activation process to be implemented. **5)** (Change) Reference to optimization purposes was deleted from Art. 50. **6)** (No change) The Article 50 does not allow overriding the control structure. The limits for the sharing and exchange of reserves define the amount of reserve capacity and distribution. Cross-border activation allows using the most efficient reserves for activation and will be described in the NC on EB. 7) (Change) The article was merged with Article 23 and 24 and made more clear 8) (Change) Typo corrected **9)** (Partial change) The market aspects of the cross-border activation of reserves shall be considered in the NC on EB.

Article 51 – TIME CONTROL PROCESS - NEW ARTICLE 67

Summary	5 comments were received on this chapter, dealing with the following key issues: 1. 2 comments ask to eliminate the chapter or the table with the overview on the ranges which need frequency set point corrections; 2. 1 comment asks for cost recovery for generators during this process; 3. 1 comment asks for NRA approval; 4. 1 comment regards typos;
Changes made	1 The chapter was rewritten and the table was removed; 2. The generators cost recovery is not in the aim of this chapter; 3. NRA involvement has been reviewed but the chapter 8 requirements are not subject of NRA approval.
Explanation for change or no change	In order to clarification and harmonization, the chapter refers at time control actions during as part or not in FRR process activation.

Article 52 (new Article 54)– RESERVE PROVIDING UNITS CONNECTED TO THE DSO GRID - NEW ARTICLE 68

Summary	23 comments have been received on this Article, addressing the following topics: 1. Affected DSOs (DSOs positioned between the Reserve Connecting DSO and the TSO) (1 comment); 2. Limiting reserve provision after prequalification (7 comments). 3. 5 comments dealt with obtaining more time for the Connection DSO to deliver information. 4. Retitle the chapter to be clearer on the content (1 comment) 5. DSOs requested real time information on Reserve Providing Groups (2 comments) 6. 1 comment asked for TSOs to be the ones to inform DSOs about potential Reserve Providing Units/Groups. 7. 3 comments addressed the rights and responsibilities of DSOs, stating that the drafted Article gave too much freedom to DSOs to impose limits on reserves located within their network, and stating that references to Article 3(3) were inconsistent. 8. 1 comment addressed DSO operational security in general, requesting real-time information and the ability to set temporary limits, stating that real time information would help to eliminate the need for temporary limits on DSO delivery of reserves. 9. 2 Comments suggested that DSOs should only be allowed to request structural information once unless it has changed, and that only operational information should be given repeatedly upon request.
Changes made	1. Affected DSO will be included. 2. The request for review by the connected DSO, of the possibility of a provider connected to its grid will be honoured by: temporary limits can be set in accordance with national legislation, even after Prequalification 3. No change 4. The title has been changed to better reflect the content of the Chapter. 5. Article reworded: TSO shall agree with its Reserve connected DSO on information exchange (this automatically includes real time information when the parties agree to do so). 6. Article reworded: TSO shall agree with its Reserve connected DSO on information exchange 7. The Article has been redrafted to ensure proportionality and consistency. 8. Article reworded: TSO shall agree with its Reserve connected DSO on information exchange (this automatically includes real time information when the parties agree to do so). 9. Article reworded: TSO shall agree with its Reserve connected DSO on information exchange.
Explanation for change or no change	1. The remarks about Affected DSOs make sense from an operational communication point of view. 2. Request is reasonable, due to changing conditions of the grid, that the Reserve Connected DSO can review the responsibilities of a provider. 3. Potential Providers are asked to comply with a waiting period of three months. In this waiting period the DSO has two months to perform their analyses. The request for more time for the DSO cannot be granted because TSOs need the final month for their own analyses. 4. Request for clarification the title is reasonable. 5. The new formulation that the TSO shall agree with its Reserve connected DSO on information exchange, enables flexibility that allow for respecting national practices. 6. Correct information exchange is important 7. Request is reasonable. 8. Correct information exchange is important. 9. Correct information exchange is important

Article 53 - GENERAL TRANSPARENCY REQUIREMENTS -> NEW ARTICLE 69

Summary	6 comments were received on this Article, dealing with the following key issues: 1. 5 comments dealt with rights and responsibilities of TSOs, asking to warrant the correctness of information and to be more specific on the conditions under which TSOs can deviate from publication timeframes. 2. 1 comment asked to establish the location for publication here rather than repeat it in all other articles.
Changes made	The right for TSOs to deviate from publication timeframes has been deleted. The paragraphs in Article 68 dealing with correctness of information and information has been adapted to be more specific, namely specifying exactly to which information the paragraphs shall apply. The location of publication, now the central information transparency platform of ENTSO-E established in accordance with the Transparency regulation, has been centralised within Article 68.
Explanation for change or no change	When changes need to be implemented on short term, a requirement to publish these changes far in advance could be detrimental to Operational Security. However, the current timeline was deemed sufficient for TSOs to introduce necessary changes.

	TSOs cannot always warrant the correctness of large data sets, as they can be caused by all sorts of technical issues, such as measurement errors. However, the old formulation was too inclusive, and the responsibility of the TSO to provide correct data has been sharpened in order to be clear on what the TSO should and should not be responsible for. With the placement of reference to the location of publication here, the NC is more readable and less repetitive.

Article 54 - INFORMATION ON FREQUENCY QUALITY -> NEW ARTICLE 71

Summary	12 comments were received on this Article, dealing with the following key issues: 1. 2 comments asked for more transparency, requesting TSOs to publish raw frequency data and add the publication of frequency versus time profiles for the sake of generator design. 2. 8 comments requested information to be published on the central information platform of ENTSO-E established through the Transparency guidelines. 3. 2 comments dealt with typos and references.
Changes made	Article 68 now includes a reference to the publication location, which is now the central information platform of ENTSO-E established through the Transparency guidelines. Typos and references have been fixed.
Explanation for change or no change	Providing and publishing the requested additional data would require TSOs to implement new processes and deal with technical issues of which the costs do not outweigh the benefits of publishing the information. NC RfG deals with requirements for generation in order to safely connect to the Network. The criteria defined in Chapter 3 on Frequency Quality are sufficient. For these reasons the publication of the requested additional information will not be included in NC LFCR.

Article 55 - INFORMATION ON LOAD-FREQUENCY CONTROL STRUCTURE -> NEW ARTICLE 73

Summary	11 comments were received on this Article, dealing with the following key issues: 1. 4 comments dealt with the timing of publications, requesting to publish material further in advance in order to give stakeholders more time to adapt. 2. 4 comments requested information to be published on the central information platform of ENTSO-E established through the Transparency guidelines. 3. 3 comments dealt with typos and references.
Changes made	The deadlines for publication of the Process Responsibility Structure and the Process Activation Structure have been changed to three months in advance. Article 61 now includes a reference to the publication location, which is now the central information platform of ENTSO-E established through the Transparency guidelines. Typos and references have been fixed.
Explanation for change or no change	

Article 56 INFORMATION ON FCR -> NEW ARTICLE 74

Summary	11 comments were received on this Article, dealing with the following key issues: 1. 8 comments dealt with the timing of publications, requesting to publish material further in advance in order to give stakeholders more time to adapt. 2. 3 comments dealt with typos and references.
Changes made	The deadline for publication of FCR Properties has been extended to three months before they become effective. Typos and references have been fixed.
Explanation for change or no change	The deadline for publication of material in accordance with Article 54(1) has remained at one month because this material is created in an annual process, and it would become too restrictive for TSOs if much more time was reserved for publication purposes. However, the deadline

	publication of FCR Properties has been extended to 3 months ahead, in order to allow stakeholders time to adapt to the change.

Article 57 – INFORMATION ON FRR -> NEW ARTICLE 75

Summary	18 comments were received on this article, dealing with the following key issues: 1. 3 comments asked for more transparency, asking TSOs to publish outlooks on FCR and FRR activation, information relating to procurement, and H+1 data on activation of FRR. 2. 12 comments dealt with the timing of publications, requesting to publish material further in advance in order to give stakeholders more time to adapt. 3. 3 comments dealt with typos and references.
Changes made	The deadlines for publication of the FRR Technical Minimum Requirements, FRR Availability Requirements and the FRR Dimensioning Rules in Article 67 have been changed to three months in advance. Typos and references have been fixed.
Explanation for change or no change	It is possible and reasonable to give stakeholders more time to adapt to new information, especially when it concerns new technical requirements. Therefore the deadline for publication has been changed to three months before the applicability of the new information. Information about procurement is dealt with within NC EB and is out of scope of NC LFCR. Information on activation on FRR on H+1 basis is unnecessary for a transparent market, is not possible for TSOs, and would lead to market distortion. For these reasons the publication of the requested additional information will not be included in NC LFCR.

Article 58 - INFORMATION ON RR -> NEW ARTICLE 76

Summary	13 comments were received on this Article, dealing with the following key issues: 1. 8 comments dealt with the timing of publications, requesting to publish material further in advance in order to give stakeholders more time to adapt. 2. 3 comments asked for more transparency, requesting TSOs to publish information related to procurement of RR, information on activation on RR on D+1 basis, and asking GB and IRE who do not use RR to publish their equivalent information. 3. 2 comments dealt with references.
Changes made	The deadlines for publication of the RR Technical Requirements, RR Availability Requirements and the RR Dimensioning Rules in Article 68 have been changed to three months in advance. References have been fixed.
Explanation for change or no change	It is possible and reasonable to give stakeholders more time to adapt to new information, especially when it concerns new technical requirements. Therefore the deadline for publication has been changed to three months before the applicability of the new information. Using RR reserves is optional. It might be unnecessary due to market reasons, or all necessary reserves may be included within FRR. There are no other related technical issues that replace RR reserves in GB or IRE that require publication. Information about procurement is dealt with within NC EB and is out of scope of NC LFCR. Information on activation on RR on D+1 basis is unnecessary for a transparent market. For these reasons the publication of the requested additional information will not be included in NC LFCR.

Article 59 - INFORMATION ON SHARING AND EXCHANGE -> NEW ARTICLE 77

Summary	6 comments were received on this Article, dealing with the following key issues: 1. 3 comment dealt with consistency with the transparency regulation, requesting information to be published in accordance rather than just in accordance with national legislation. 2. 1 comment dealt with internal consistency, stating that sharing of FCR is not allowed. 3. 1 comment requested information to be published on the central information platform of ENTSO-E established through the Transparency guidelines. 4. 1 comment dealt with a typo.
Changes made	
Explanation for change	The information published here is not mentioned within the Transparency guidelines, and therefore

or no change	a reference to the Transparency guidelines here would not make sense. Publication of all necessary information in accordance with the Transparency guidelines will of course still occur. Sharing of FCR is allowed between SA IRE and GB. Therefore the publication requirement is consistent with the allowances in Chapter 7.

Article 60 - AMENDMENT OF CONTRACTS AND GENERAL TERMS AND CONDITIONS New Article 78

Summary	1 general comment has been made regarding the NC.
Changes made	No modification.
Explanation for change or no change	The comment made is general and not specific to Art. 60 (the comment calls for closer TSO/DSO work and considers that the NC LFCR allows for TSO intervention in the DSO grid without the DSO being aware).

Article 61 – ENTRY INTO FORCE - NEW ARTICLE 79

Summary	4 comments were made: • Request to extend the delay within which the NC requirements should be implemented and Synchronous Area agreements concluded from 12 months to 24 months. • General remark • Absence of retroactive application should be clearly specified. Requirement to apply to new units only should be explicitly mentioned. • comment: suggestion to specify the provisions regarding the conclusion of Synchronous Area agreements and TSO multiparty agreements.
Changes made	References to Articles on Synchronous Area, LFC block agreements added in the provision (see attached suggestion). NC OPS: provides that some provisions apply from the date of entry into force whereas some others apply at the same date as Art. 35 NC OS at minimum 18 months after entry into force). Delete second, third and fourth paragraphs: add instead: “With the exception of Chapter 2 and Article 70, which shall apply as from the entry into force, this Network Code shall apply as from [date – the same as in Article 35 NC OS – at minimum 18 months after entry into force]. Add at the end: “This Network Code shall be binding in its entirety and directly applicable in all Member States.” As is the case in NC OS and NC OPS, the NC LFCR should provide that it shall apply minimum 18 months after entry into force.
Explanation for change or no change	Specifying the relevant NC provisions improves clarity. Request for extension to 24 months: not included (only one comment made in that respect)