European Network of
Transmission System Operators
for Electricity

SUPPORTING PAPER FOR THE LOAD-FREQUENCY AND RESERVES NETWORK CODE

WORKING DRAFT

30.04.2013

DRAFT V3

1 PURPOSE AND OBJECTIVES OF THIS DOCUMENT

1.1 PURPOSE OF THE DOCUMENT

This document has been developed by the European Network of Transmission System Operators for Electricity (ENTSO-E) to accompany the consultation of the Load-Frequency-Control and Reserves Network Code (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.

1.2 STRUCTURE OF THE DOCUMENT

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

Background:

- Section 2 introduces the legal framework within which the system operation Network Codes have been developed as well as the next steps in the process.
- Section 3 explains the approach, which ENTSO-E has taken to develop the Network Code, outlines some of the challenges and opportunities ahead of System Operation as well as concepts used in the NC LFCR are clarified in this section.

Explanatory notes:

- Section 4 complies with the requirements of the Framework Guidelines on System Operation (FG SO [1]) regarding NC LFCR developed by the Agency for the Cooperation of Energy Regulators (ACER).
- Section 5 focuses 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.
- Section 6 describes different approaches in the Synchronous Areas
- Section 7 describes the added value of implementing the technical and operational principles set by the NC LFCR.

Next steps:

- Section 8 summarises next steps in the development of the NC LFCR.

1.3 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.

1.4 RESPONDING TO THE CONSULTATION

The responses to the submissions made during the public consultation will be outlined in a table as an appendix of this supporting document.

2 PROCEDURAL ASPECTS

2.1 INTRODUCTION

This section provides an overview of the procedural aspects of the Network Codes' 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.

2.2 THE FRAMEWORK FOR DEVELOPING 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 Network Codes. This is shown below:

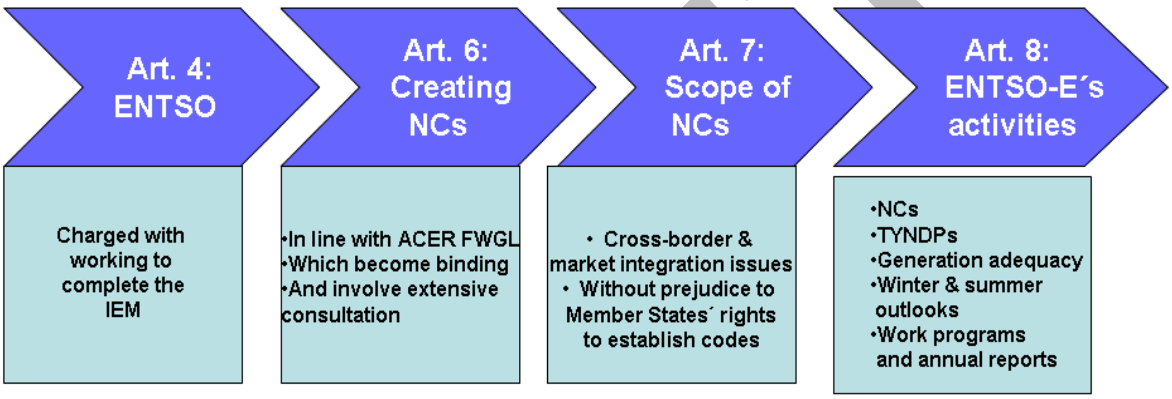


Figure 1: ENTSO-E's legal role in Network Code development according to Regulation (EC) 714/2009.

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

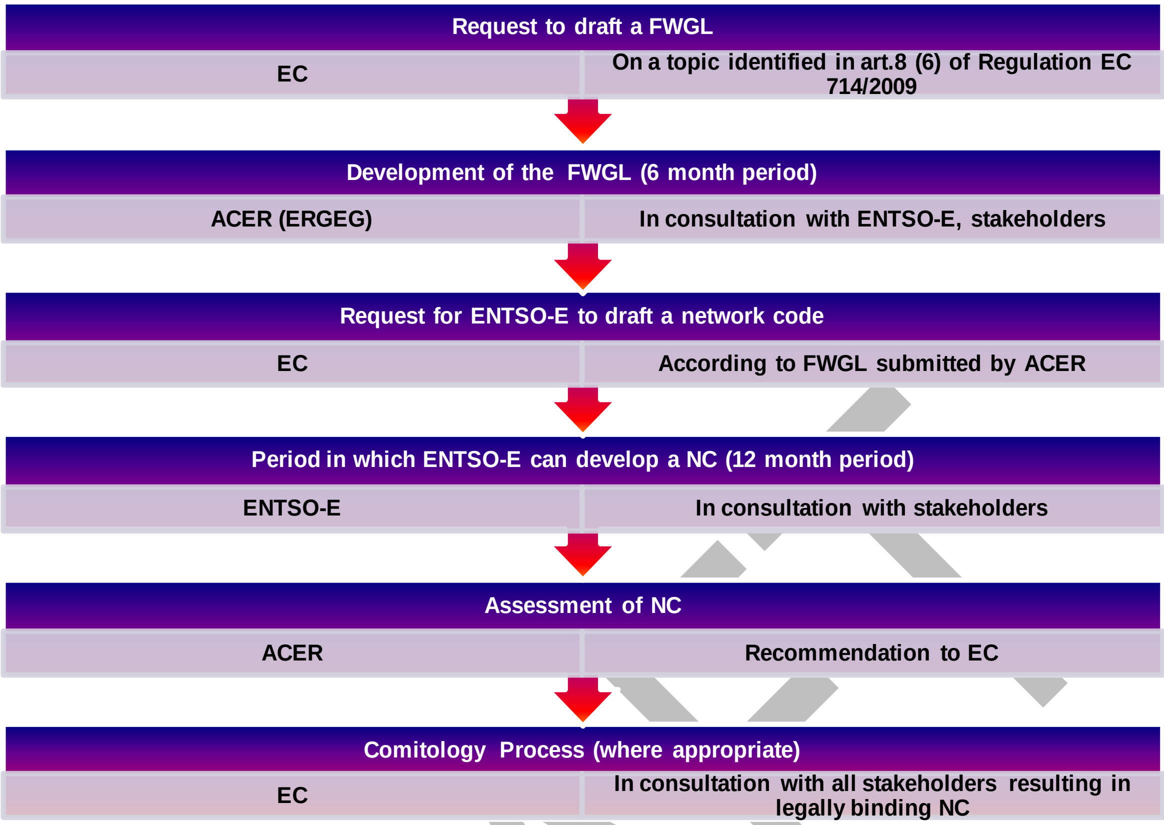


Figure 2: Network codes' development process [Source: ENTSO-E]

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.

2.3 NEXT STEPS IN THE PROCESS

ENTSO-E held a public consultations on NC LFCR. A workshop with the DSOs Technical Expert Group and a public stakeholder's workshop were held on 13 February and 12 March 2013, in order to present the updates done in the draft NC LFCR, taking into account comments from the stakeholders after 1st and 2nd workshops respectively 12 July and 25 September 2012. ENTSO-E has carefully considered all comments which were provided and updated the Network Code in light of them. The new version of the code will be outlined in the 4th Workshop on the NC LFCR planned for the 7th May 2013. Following agreement and approval within ENTSO-E, the Network Code will be submitted to ACER in line with the defined deadline of 1st July 2013.

ACER is then expected to assess the NC LFCR to ensure it complies with the FG SO 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 will eventually transform the NC LFCR into a legally binding integral component of the Regulation (EC) 714/2009.

3 Scope, structure & approach to drafting the NC LFCR

3.1 Background

ENTSO-E has drafted the NC LFCR to define the minimum requirements for TSO and Reserve Providing Units ensuring secure and efficient operation of load-frequency control in order to achieve and maintain a satisfactory level of frequency quality inside each Synchronous Area.

Based on the FG SO and on the Initial Impact Assessment (IIA) provided by ACER, the NC LFCR states the operational planning and scheduling principles in terms of technical needs, considering market solutions compatible and supporting to maintaining the security of supply.

3.2 Guiding Principles

The guiding principles of the NC LFCRs 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 for the provision of reserves to the reserve connecting TSO. These principles are essential for the TSOs of a synchronous area to manage their responsibilities to ensure a sufficient level of frequency quality efficiently.

The main goal of the system operation NCs is to achieve a harmonised and solid technical framework - including the implementation of all necessary processes required for it, taking into account the rapid growth of the Renewable Energy Sources (RES) generation 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 Internal Electricity Market (IEM).

The requirements set out in system operation NCs on TSOs, DNO 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 NCs 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;

- The subject matter – 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 NC’s

- framework must acknowledge and respect the fact that system operation cannot be interrupted and "restarted" –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 NCs 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 NCs, most notably those addressing grid connection, market and regulating power / balancing.

3.3 Background and Structure of NC LFCR

Secure and efficient transmission system operation can be made possible, only if there is an obligation for the Transmission System Operators (TSOs) and the Reserve Providing Units to cooperate and to meet the relevant minimum technical requirements for the load-frequency control operation of the interconnected transmission systems of a synchronous area. Even though each TSO has its own responsibility area, secure and efficient load-frequency control of a synchronous area is a common task:

- All systems inside a synchronous area contribute to the frequency quality; each TSO inside a synchronous area has to support the frequency quality accordingly and a fault in one area will possibly affect the whole synchronous area. Hence, secure load-frequency control requires close coordination and cooperation.
- Efficient system operation requires close collaboration between all stakeholders; the main purpose of the liberalizing and therefore this harmonizing of the electricity sector was efficiency, and utilizing the resources for balancing the system efficient requires close collaboration and coordination on EU level.

Secure and efficient load-frequency control can be made possible only if there is a well-organized structure of load-frequency control and an application of EU-wide harmonised processes based on commonly shared quality targets. It is aimed to have all means necessary to control the system in real time at disposal of the TSO, when it is either subject to normal changes of operation conditions or facing incidents affecting generation, demand or transmission equipment.

NC LFCR provides the basis for these harmonised processes, control structure and quality targets. It defines the minimum process requirements for ensuring an effective and efficient load-frequency control applicable to all TSOs and reserve providing units.

NC LFCR covers the control processes "frequency containment reserve", "frequency restoration reserve" and "replacement reserve". All stakeholders, including TSOs, should respect the common requirements for these control processes and to develop relevant measures required to maintain the quality and stability of the load-frequency control and to support the efficient functioning of the European IEM. These control processes are the basis for the key elements, structure and provisions of this Network Code.

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: harmonising security principles, clarifying and harmonising methods, roles and responsibilities of operators and grid users as well as to enable and ensure adequate data exchange in order to future proof the system for integrating innovative technologies and sustainable energy sources, operate the system in a safe, secure, effective and efficient manner 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 electricity system operation that are 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 [1] 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"*.

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 in the three following levels addressed coherently:

- **European wide level:** Definition of the common control processes "frequency containment reserve", "frequency restoration reserve" and "replacement reserve" and the rules for border-crossing exchange of reserves;

- **Synchronous areas level:** Establishment of the control structure, definition of a common frequency quality target and application of the frequency containment reserve process;

- **LFC Block level:** Definition of a frequency restoration target and application of the frequency restoration reserve process and the replacement reserve process.

Regarding methodologies, the approach adopted is to tune the provisions through a global framework giving high level principles and requirements for detailed specifications to be carried out of the code, in a transparent process 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 FIELD OF APPLICABILITY OF THE NC LFCR

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 small isolated systems and micro isolated systems in accordance with the Article 8(7) of Regulation (EC) N° 714/2009
- In the isolated systems which do not present any cross-border network issues nor market integration issues, in the absence of transmission system.
- Power systems operating under synchronous mode in the 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.

3.6 INTERACTION WITH OTHER NETWORK CODES

The Load-Frequency Control & Reserve Network Code (NC LFCR) is being drafted in parallel with other related Network Codes. Several processes, methodologies and standards provided in NC LFCR are influenced by or would influence these related Network Codes and the coordination of the interactions is an important objective of ENTSO-E. The principal cross-issues with other Network Codes have been dealt with in the following way:

- The Network Codes on *System Operation* – these codes consist of the Operational Security NC (OS NC), the Operational Planning and Scheduling NC (OPS NC) and the NC LFCR. The OS NC can be viewed as the 'umbrella' code of the system operation Network Codes. It therefore sets the overall principles for system operation and reflects on the common issues with the OPS NC and the NC LFCR while those will describe their specific processes in greater detail.

- The connection codes (RfG NC and DCC) – connection codes establish the technical capabilities of the generation and demand units connected to the grid. LFCR references to them in those provisions in which information related to technical characteristics are required. The translation of technical capabilities described in connection codes to operational criteria, particularly with regards to the reserve provision, is done in the OS NC.

- *Future Network Codes* – Particularly challenging is the situation when Network Codes are not yet under official development: the forthcoming NC on Balancing (NC EB) is under scoping discussions. The NC LFCR and the NC EB are closely related. While the LFCR defines the technical requirements for the load-frequency control, the latter will define the reserve products and rules for a common market.

3.7 CLARIFICATION ON CONCEPTS USED WITHIN THE NC LFCR

The focus of the NC LFCR is based on the following concepts:

- **EU wide harmonised control processes as a basis for load-frequency control:** the control processes "frequency containment reserve", "frequency restoration reserve" and "replacement reserve" set a basis for an efficient and effective load-frequency control in the EU. The frequency containment reserve aims at containing the frequency drop after an incident inside a pre-defined band. The frequency restoration reserve is designed to restore the frequency to its target value 50 Hz. The replacement reserve replaces the activated reserves to restore the available reserves in the system or for economic optimisation;
- **Common control structure inside a synchronous area:** the set up of a proper control structure sets a basis for an efficient and effective load-frequency control in each synchronous area. It bases on the LFC area as core TSO responsibility area. The frequency restoration quality is defined on the level of the LFC Block that may consist of more than one LFC area. The frequency quality is defined on the level of the synchronous area that may consist of more than one LFC Block. This control structure design sets clear rules for TSO responsibilities offering valuable incentives to co-operate on LFC Block or synchronous area level. The

control structure chosen by each synchronous area depends on the number of TSO involved and the complexity of the system in terms of congestion management;

- **Common frequency quality target inside a synchronous area:** The common frequency quality target is designed on synchronous area level. This includes frequency target values as well as frequency evaluation criteria. The frequency containment reserve process is set up on synchronous area level as a common reserve. This includes the amount of reserves needed and the share of reserves per TSO;
- **Frequency restoration quality target for each LFC Block:** The frequency restoration reserve process and the replacement reserve process are set up on LFC Block level. This includes the amount of reserves needed per LFC Block. The individual quality target values for the frequency restoration are defined per LFC Block and derived from the common frequency quality target of the synchronous area;
- **The LFC area / the monitoring area as core TSO responsibility area:** The operation of the load-frequency control as a core TSO responsibility is defined on the level of the LFC area (automatic control) and / or monitoring area (manual control);
- **Framework to determine the amount of reserve needed:** the NC delivers the basis to determine the amount of reserves needed per control process "frequency containment reserve", "frequency restoration reserve" and "replacement reserve" in order to deliver the required quality;
- **Border crossing exchange to enhance efficiency and as a basis to the market:** The efficiency of the load-frequency control is enhanced by border-crossing exchange of reserves. This exchange relates to the control processes "frequency containment reserve", "frequency restoration reserve" and "replacement reserve" as well as to imbalance netting. The border-crossing exchange is treated inside a synchronous area as well as cross synchronous areas. The NC sets restrictions to the border-crossing exchange where needed from a technical point of view.

Based on the above, the following categories of requirements have been established in the NC LFCR as chapters:

- Frequency Quality
- Load-Frequency Control Structure
- Frequency Containment Reserves
- Frequency Restoration Reserves
- Replacement Reserves
- Exchange of Reserves
- Synchronous Time Control
- Co-operation with DNO

These subjects will be described in more detail in chapter 5.

3.7.1 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 Code.

In several cases a system of an Island, belonging to the Responsibility Area of a TSO (like Balearic Islands) or having an 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 being connected to the mainland only through a DC link or for other technical reasons.

As a conclusion, National network code, respecting European legislation, apply to those systems and it is up to the respective TSO to assess if such a system as mentioned before falls under the scope of application of the Code.

Each National Regulatory Authority has to monitor the correct implementation of EU-legislation and therefore of this NC. If a TSO considers that a system or part of its system of its Responsibility Area does not fall under the scope of application of the Code the reasoning has to be given by the TSO. The monitoring of implementation by NRA ensures therefore the correct application of the Network Code.

3.8 Working with Stakeholders & Involved Parties

The legally binding nature of 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 RfG NC, 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 in ENTSO-E webpage under link https://www.entsoe.eu/events/system-operation/ .

In line with suggestions by stakeholder organizations 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.

4 RELATIONSHIP BETWEEN THE NC LFCR & FRAMEWORK GUIDELINES

4.1 THE FRAMEWORK GUIDELINES

The FG SO [1] focuses on three key challenges, which shall be addressed by four objectives as Figure 3shows.

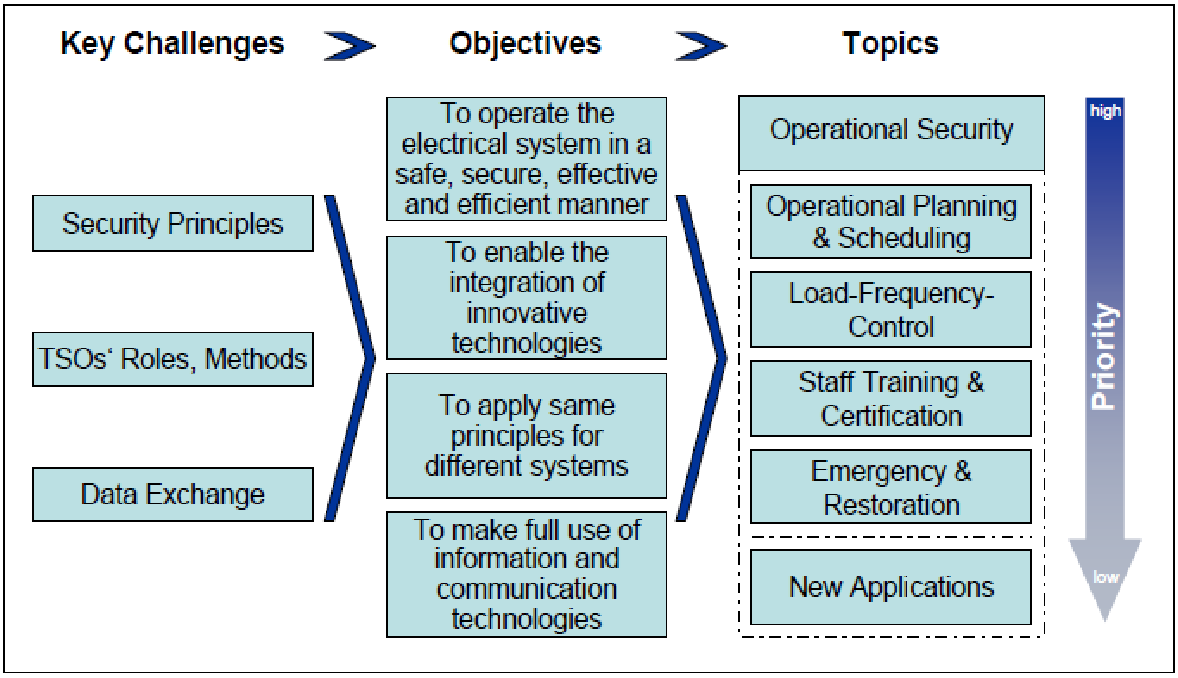


Figure 3: Structure and development flow of the Framework Guidelines on Electricity System Operation.

The overall scope and objectives of the FG SO [1] 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 [1] 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, DNOs and significant grid users.

The requirements described in the NC LFCR have been formulated in line with the FG SO [1] 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.

4.2 FRAMEWORK GUIDELINES FOR NC LFCR

The NC LFCR according to the OS FG defines:

1. Definition of the various terms used in relation to load-frequency control within the different synchronous areas;

2. 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
3. Frequency quality criteria;
4. Appropriate minimum standards and requirements applicable to TSO and reserve providing units;
5. Requirements for TSO with regards to the implementation of e.g. controllable generation, load characterisation and demand side management;
6. The NC shall foresee that TSO 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;
7. Description of principles for exchange of all necessary information between TSO to handle the different load-frequency control activities in a co-ordinated and co-operative manner.

5 NC LFCR: Objectives, Requirements

This chapter describes the structure and the content of the NC LFCR in more detail. The NC LFCR is built up as follows:

- Purpose and objectives (outside chapter numbering)
- Chapter 1: General provisions
  - Subject matter and scope
  - Definitions
  - Regulatory aspects
  - Recovery of costs
  - Confidentially obligations
  - Agreement with bordering TSO
  - TSO Cooperation
- **Chapter 2: Operational Agreements**
- **Chapter 3: Frequency Quality**
- **Chapter 4: Load-Frequency Control Structure**
- **Chapter 5: Operation of Load-Frequency Control**
- **Chapter 6: Frequency Containment Reserves**
- **Chapter 7: Frequency Restoration Reserves**
- **Chapter 8: Replacement Reserves**
- **Chapter 9: Exchange and Sharing of Reserves**
- **Chapter 10: Time Control**
- **Chapter 11: Co-operation with DNOs**
- Chapter 12: Transparency of Information
- Chapter 13: Final Provisions

5.1 Frequency Quality

5.1.1 TSO Co-operation regarding Frequency Quality

In any electric system, the Active Power has to be generated at the same time as it is consumed. Power generated must be maintained in constant equilibrium with power consumed / demanded, otherwise a power deviation occurs. Disturbances in this balance, causing a deviation of the System frequency from its set-point values, will be offset initially by the kinetic energy of the synchronous rotating generating units and motors connected. Due to the transformation of the kinetic energy of the rotating masses to electrical energy in the Power Generating Units the frequency of rotation will change leading to a Frequency Deviation.

Imbalances between generation and demand leading to Frequency Deviations occur due to the following types of reasons:

- Disturbance / outage of generation or load or HVDC interconnector. This type of imbalance is generally the one used for the calculation of the Reference Incident.
- Stochastic imbalances in normal operation. These can occur due to the continuous variations of demand or renewable energy output.
- Deterministic Frequency Deviations – e.g. ramping at the hour shift.
- Network splitting. These imbalances are generally out of the design of the Synchronous Area as they lead most likely to an emergency situation in a part or in all of the Synchronous Area.

The size and duration of these Frequency Deviations with respect to the Nominal Frequency for a sufficiently long period of time are regarded as frequency quality. System Frequency quality is a common good for all the users of the Synchronous Area which shall be properly monitored and maintained. In this regard, the Network Code on Load-Frequency and Reserves in Article 8 defines the processes that shall be performed by all the TSOs of the Synchronous Area in order to evaluate the quality of System Frequency.

5.1.2 Frequency Quality Design Parameters

Each Synchronous Area has been designed in such a way to guarantee that after a disturbance caused by an imbalance between generation and demand the consequences are within reason. In large Synchronous Areas this implies that large imbalances do not lead to under-frequency load shedding and the System Frequency remains within some design values. The design imbalance which the Synchronous Area shall be able to withstand is the Reference Incident. After the occurrence of this Reference Incident the System Frequency will deviate from the Nominal Frequency and there will be a Frequency Deviation. The System Frequency should behave in time as designed by some parameters named Frequency Quality Design Parameters. They described the different limits that are to be set to the System Frequency. They are represented in Figure 4:

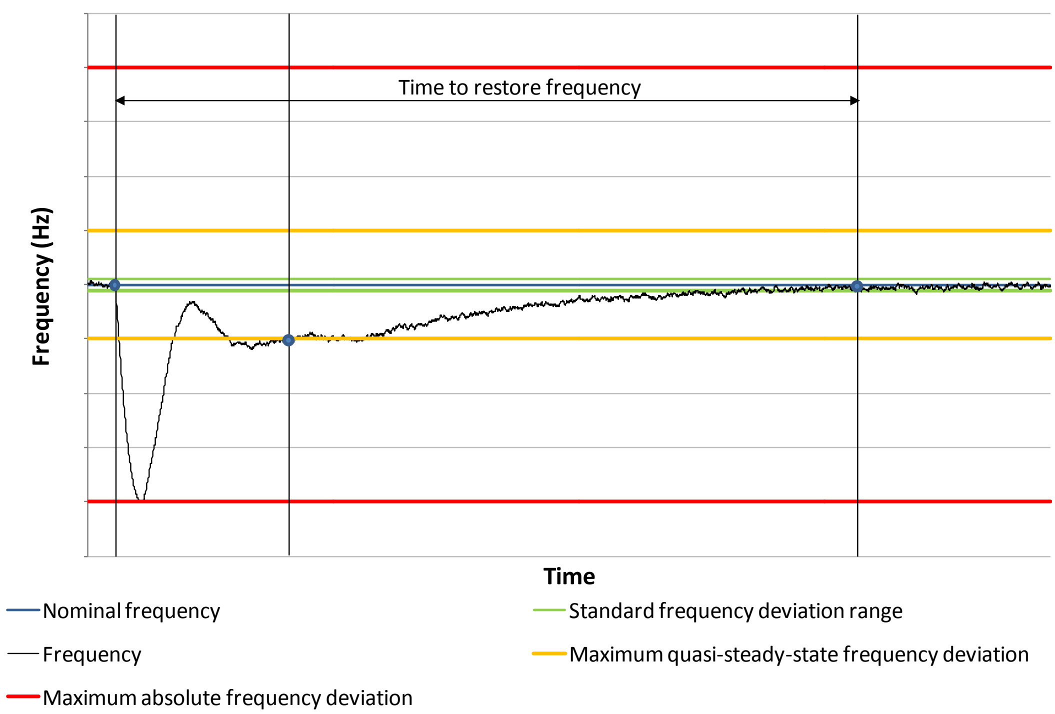


Figure 4: Frequency Quality Design Parameters

The Frequency Quality Design Parameters consist on the following parameters:

- *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. The droop of all reserve providing units participating in FCR should be set in such a way that all the contracted/obligatory FCR are deployed
- *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 Range within Time to Restore Frequency.

  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 Range within Time to Restore Frequency*: Range to which the System Frequency should be restored after the Time to Restore Frequency has elapsed since a Reference Incident occurs.
- *Time To Recover Frequency* (not shown in Figure 4) 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 Maximum Steady State Frequency Deviation;
- *Frequency Range within Time to Recover Frequency* (not shown in Figure 4) means 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

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 be coordinated as well with the requirements that are set to generators and loads, which are included in the NC Requirements for Generators (NC RfG) and in the Demand Connection Code (NC DCC).

The choice of values for each Frequency Quality Design Parameters is highly dependent of each Synchronous Area as these parameters depend heavily on the following Synchronous Area characteristics:

a. 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.

b. Grid structure and/or network topology.

c. The behaviour of the loads and the Power Generating Units, primarily their reaction to Frequency Deviations.

d. For all synchronous areas except GB and Ireland, the currently observed System Frequency quality in order to perform the probabilistic analysis that could lead to an evaluation of the risk of having a total imbalance larger than the Synchronous Area is able to withstand while maintaining the System Frequency within the Frequency Quality Design Parameters. Otherwise it is not guaranteed that the Synchronous area could run into a situation with a

large scale incident as a consequence of load-generation 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.

Therefore, since each Synchronous Area has its own frequency dynamic, it is not possible to fix the same values for the Frequency Quality Design 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 have available. 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 9(2). As stated in Article 9(4), a period in between two revisions not longer than 5 years period seems reasonable.

5.1.3 Frequency Quality Target Parameters

The duration of the total System Frequency deviations is an important parameter as the larger and more persistent appearance of Frequency Deviations, the more likely the Synchronous Area could experience a large unbalance at the time where there is initially a Frequency Deviation leading to an event outside of the design parameters. A common frequency quality model must be set per Synchronous Area as a goal to reach which can assure with reasonable certainty that the risk of an incident or concatenation of imbalance incidents is very low. The frequency quality model of the Synchronous Area implies therefore setting target values to the frequency parameters called Frequency Quality Target Parameters. In Article 9(3) the maximum number of minutes outside the Standard Frequency Range is defined as the minimum Frequency Quality Target Parameters. 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.

In any case, other Frequency Quality Target Parameters can be set by each Synchronous Area in order to set goals corresponding to System Frequency quality.

5.1.4 Frequency Restoration Control Defining Parameters

Synchronous Areas may consist of one or several LFC Blocks. In the case of Synchronous Areas with only one LFC Block i.e. SA Cyprus, Ireland, Great Britain and Northern Europe, the frequency quality is already a measure of the power imbalances. The criteria in the remaining paragraphs of this section defined below will not apply to these synchronous areas.

In the case of Synchronous Areas with several LFC Blocks, as is the case of Continental Europe, System Frequency quality will depend on the combined behaviour of each of the LFC Blocks. The goal of each LFC Block is to maintain the Frequency Restoration Control Error as close as possible to zero. This parameter, which historically has been known as Area Control Error, is a measure of the contribution of the LFC Block to the Synchronous Area frequency quality although its main goal is to maintain power balance within the LFC Blocks to assure system security with the (N-1)-Criterion of the LFC Blocks including the Tie-Lines with other LFC Blocks inside the same Synchronous Area.

In order to achieve the set values of the Frequency Quality Target Parameter it is of the utmost importance that the LFC Blocks keep proper Frequency Restoration Control Error quality. In order to keep the same structure as with frequency quality, there are therefore two Frequency Restoration Control Error Defining Parameters, which are defined in Article 10(1).

In order to define these Frequency Restoration Control Error Defining Parameters it is considered that the Frequency Restoration Control Error behaves like a normal distribution in each of the LFC Blocks and that these normal distributions are independent of each other at any time. With this consideration, and assuming that each of the LFC Blocks behave in similar manner there is a fixed relationship between the standard deviation of the Frequency Restoration Control Error of a LFC Blocks and the standard deviation of the normal distribution of the resulting sum of all of the Frequency Restoration Control Errors of the LFC Blocks within the Synchronous Area [3]:

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

Being K_T the total network power-frequency characteristic of the whole Synchronous Area and K_i the network power-frequency characteristic or K-factor of the LFC Block *i*, This parameters K_i are calculated with the Initial FCR Obligations. The values for each Frequency Restoration Control Error Defining Parameter, which are Level 1 Frequency Restoration Control Error Range and Level 2 Frequency Restoration Control Error Range are not defined in the Network Code, however in order to assure a fair share of the frequency quality targets between the LFC Blocks, these values should be proportional to the square root of the Initial FCR Obligations of the LFC Blocks.

The values of the Level 1 Frequency Restoration Control Error Range and Level 2 Frequency Restoration Control Error Range will be set deriving from the risk level considered in Article 9(4) (d) of once in twenty years.

Since the Level 1 and Level 2 Frequency Restoration Control Error Range of the LFC Blocks depend of the total K-Factor of the Synchronous Area and the contribution coefficients of each LFC Block their values should be revised yearly to take into account the possible changes in the LFC Blocks or in the Synchronous Area. This requirement is stated in Article 10(2).

5.1.5 Frequency Restoration Control Target Parameters

The values of the Frequency Restoration Control Error Target Parameters will be the ones corresponding to the desired behaviour of the distribution of the Frequency Restoration Control Error of the LFC Block and are defined in Article 10(3).

The Frequency Restoration Control Error Target Parameter corresponding to the Level 1 Frequency Restoration Control Error Range is the maximum number of time intervals outside the Level 1 Frequency Restoration Control Error Range within a time interval equal to the Time to Restore Frequency and shall be equal to 30% or 10 512 15-minute time intervals in a year. The value of 30% is used as an approximation of 31,4% (=100%-68.6%) 15-minute intervals that shall be inside the Level 1 Frequency Restoration Control Error Range.

The Frequency Restoration Control Error Target Parameter corresponding to the Level 2 Frequency Restoration Control Error Range is the maximum number of time intervals outside the Level 2 Frequency Restoration Control Error Range within a time interval equal to the Time to Restore Frequency and shall be equal to 5% or 1 752 15-minute time intervals in a year .

The Frequency Restoration Control Error Target Parameters are defined for each LFC Block. However, in case a LFC Block is composed of several LFC Areas the expected quality for each LFC Area of the LFC Block shall be defined in a TSO multi-party agreement as stated in Article 10(4).

5.1.6 Frequency Quality Data Collection

In order to perform the evaluation of the Frequency Restoration Control Error Target Parameters and the Frequency Quality Target Parameters the necessary data shall be gathered and prepared as described in Article 11. The data comprises:

1. Instantaneous Frequency data per Synchronous Area;
2. 1-minute Average Frequency Data per Synchronous Area;
3. 1-minute Average Frequency Deviation Data per Synchronous Area;
4. Instantaneous Frequency Restoration Control Error Data for each LFC Block in Continental Europe;
5. 1-minute Average Frequency Restoration Control Error Data; and
6. 15-minute data of the Frequency Restoration Control Error Data for each LFC Block in Continental Europe.

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 Frequency Restoration Control Error shall be shorter than or equal to 10 seconds as the dynamics of the Frequency Restoration Process are significantly slower compared to the dynamics of the Frequency Containment Process and such small measurement periods are not required in this case.

It is important to assure that the collected data is accurate and thus the minimum accuracy is set to 1 mHz in case of System Frequency data or 10 MW in case of Frequency Restoration Control Error data when measured in MW like in Continental Europe.

The average data shall be calculated using the arithmetic mean:

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

Being n the number of instantaneous samples in the minute or 15 minutes and a_i the value of sample i within n.

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.

5.1.7 Frequency Quality Evaluation Criteria

With the aim of evaluating the frequency quality Article 12 defines the Frequency Quality Evaluation Criteria which area a series of global reliability indicators regarding both the System Frequency quality and the Frequency Restoration Control Error quality in the case of Continental Europe. The Frequency Quality Evaluation Criteria are the indicators that are observed by the TSOs of a Synchronous Area and obtain information about how well the Synchronous Area or the LFC Block behaved. Some Frequency Quality Evaluation Criteria show information about the performance of the Synchronous Area and others show information about the performance of a LFC Block.

Some of these 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 3 months as defined in Article 13(4) whereas the Frequency Quality Target Parameters and Frequency Restoration Control Error Target Parameters are compared yearly.

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 11(2), and the calculation of the different values for each Frequency Quality Evaluation Criteria. This process is defined in Article 12(1).

Apart from the Frequency Quality Evaluation Criteria the NC LFCR requests an assessment of the risk of FCR Exhaustion for each Synchronous Area that should be performed according to Article 12(3) as there is a clear and accountable influence of the relationship between System Frequency quality and the risk that exists in a Synchronous Area of experiencing a situation in which the Frequency Containment Reserve is exhausted, but the imbalance between generation and demand persists. In such a situation the System Frequency will drop further and may reach values in which the automatic under-frequency load-shedding relays may trip leaving partial black-outs within the affected Synchronous Area. This study should be performed annually. A possible methodology is described in Appendix C of [3] (Report of the ENTSO-E AhT Operational Reserve).

The following variables are used in paragraph 5.1.7.1 and 5.1.7.2 to describe the Frequency Quality Evaluation Criteria defined in Article 11(2):

- f_{Av}: average frequency of the 1-minute Average Frequency Data;
- $f_{1\text{-min},i}$: sample *i* of the 1-minute Average Frequency Data;
- $FRCE_{Av}$: average Frequency Restoration Control Error of 15-minute Average Frequency Restoration Control Error Data;
- $FRCE_{15\text{-min},i}$: sample *i* of the 15-minute Average Frequency Restoration Control Error Data;
- n: number of samples in the 3-month period; and
- $\sigma_{f,1min}$: standard deviation of the 1-minute Average Frequency Data.
- $\sigma_{FRCE,15min}$: standard deviation of the 15-minute Average Frequency Restoration Control Error Data.

5.1.7.1 Frequency Quality Evaluation Criteria for the Synchronous Area

There are 5 Frequency Quality Evaluation Criteria defined for the Synchronous Area. The collection of the necessary data and calculation of these Frequency Quality Evaluation Criteria is performed by the Synchronous Area Monitor as described in Article 13. These Frequency Quality Evaluation Criteria are explained in detail along with their calculation formulas if applicable:

- 1-minute Average Frequency Data during a 3-month period for the Synchronous Area (f_{Av});

$$f_{Av} = \frac{1}{n} * \sum_{1}^{n} f_{1min,i}$$

This Frequency Quality Evaluation Criteria shows whether the distribution of the 1-minute Average Frequency Data is centred in the Nominal Frequency. The value for the 3-month period should be almost exactly 50 Hz and it is proportional to the accumulated electrical time deviation during the 3-month period.

- standard deviation of the 1-minute Average Frequency Data during a 3-month period for the Synchronous Area;

$$\sigma_{f,1min} = \sqrt{\frac{1}{n} * \sum_{1}^{n} \left(f_{1min,i} - f_{Av}\right)^2}$$

This Frequency Quality Evaluation Criteria gives information about the frequency quality of the complete set of 1-minute Average Frequency Data by defining the second order distance of the data with respect to the System Frequency average or 50 Hz.

- absolute Frequency Deviation range corresponding to the 95-percentile of the 1-minute Average Frequency Data during a 3-month period for the Synchronous Area;

This Frequency Quality Evaluation Criteria is calculated by ordering the 1-minute Average Frequency Deviation Data f_{1min}-f_n from the lowest to the highest value and obtaining the absolute value of the Frequency Deviation that is surpassed in absolute value by 5% of the 1-minute Average Frequency Deviation Data values during a 3-month period.

This Frequency Quality Evaluation Criteria gives information about the 5% most extreme values of the frequency quality.

- total time during a 3-month period in which the instantaneous Frequency Deviation was greater than the Maximum Instantaneous Frequency Deviation; and

This Frequency Quality Evaluation Criteria is calculated by multiplying the number of data values in which the Instantaneous Frequency Data minus the Nominal Frequency is greater in absolute value than the Maximum Instantaneous Frequency Deviation and multiplying that value by the measurement period of the Instantaneous Frequency Data during a 3-month period.

This Frequency Quality Evaluation Criteria gives information about the amount of time in which the Synchronous Area has been in a severe situation, outside of the design of the Synchronous Area, regarding load-generation unbalances. This value shall be kept to zero.

- number of 1-minute Average Frequency Data values during a 3-month period outside the Standard Frequency Range;

This Frequency Quality Evaluation Criteria is calculated by counting the number of data values in which the 1-Minute Average Frequency Data minus the Nominal Frequency is greater in absolute value than the Standard Frequency Range during a 3-month period.

The addition of the four values of this Frequency Quality Evaluation Criteria is to be compared to the Frequency Quality Target Parameter defined in Article 9(3).

5.1.7.2 Frequency Quality Evaluation Criteria for the LFC Block

There are 7 Frequency Quality Evaluation Criteria defined for each of the LFC Block in which the Synchronous Area consists. The collection of the necessary data and calculation of these Frequency Quality Evaluation Criteria is performed by the LFC Block Monitor as described in Article 13. These Frequency Quality Evaluation Criteria are explained in detail along with their calculation formulas if applicable:

- average during a 3-month period of the values corresponding to the average within a time interval equal to Time To Restore Frequency of the Frequency Restoration Control Error of the LFC Block;

$$FRCE_{Av} = \frac{1}{n} * \sum_{1}^{n} FRCE_{15min,i}$$

  This Frequency Quality Evaluation Criteria shows whether the distribution of Average Frequency Restoration Control Error is centred in zero (in this example measured for 15-minute intervals being the Time to Restore Frequency of the Synchronous Area Continental Europe). If the LFC Blocks decide that the compensation of the past imbalances is performed by returning the imbalance energy of the LFC Block the value for the 3-month period should be almost exactly 0 mHz.

- standard deviation during a 3-month period of the values corresponding to the average within a time interval equal to Time To Restore Frequency of the Frequency Restoration Control Error of the LFC Block;

$$\sigma_{FRCE,15min} = \sqrt{\frac{1}{n} * \sum_{1}^{n} \left(FRCE_{15min,i} - FRCEf_{Av}\right)^2}$$

  This Frequency Quality Evaluation Criteria gives information about the Frequency Restoration Control Error quality of the complete set of 15-minute Average Frequency Restoration Control Error by defining the second order distance of the data with respect to the 0 mHz.

- absolute Frequency Restoration Control Error range corresponding to the 95-percentile of the values corresponding to the average within a time interval equal to Time To Restore Frequency of the Frequency Restoration Control Error of the LFC Block during a 3-month period;

  This Frequency Quality Evaluation Criteria is calculated by ordering the 15-minute Average Frequency Restoration Control Error $FRCE_{15min,i}$ from the lowest to the highest value and obtaining the absolute value of the Frequency Restoration Control Error that is surpassed in absolute value by 5% of the 15-minute Average Frequency Restoration Control Error values during a 3-month period. This value is given in MW.

  This Frequency Quality Evaluation Criteria gives information about the 5% most extreme values of the Frequency Restoration Control Error and should be lower than the Level 2 Frequency Restoration Control Error Range.

- number of time intervals of a period equal to Time To Restore Frequency in which the average of the Frequency Restoration Control Error of the LFC Block is outside the Level 1 Frequency Restoration Control Error Range during a 3-month period;

  This Frequency Quality Evaluation Criteria is calculated by counting the number of data values in which the 15-minute Average Frequency Restoration Control Error is greater in absolute value than the Level 1 Frequency Restoration Control Error Range during a 3-month period.

  The addition of the four values of this Frequency Quality Evaluation Criteria is to be compared to the Frequency Restoration Error Target Parameter defined in Article 10(3)(a).

- number of time intervals of a period equal to Time To Restore Frequency in which the average of the Frequency Restoration Control Error of the LFC Block is outside the Level 2 Frequency Restoration Control Error Range during a 3-month period;

This Frequency Quality Evaluation Criteria is calculated by counting the number of data values in which the 15-minute Average Frequency Restoration Control Error is greater in absolute value than the Level 2 Frequency Restoration Control Error Range during a 3-month period.

The addition of the four values of this Frequency Quality Evaluation Criteria is to be compared to the Frequency Restoration Error Target Parameter defined in Article 10(3)(b).

- number of events in which, after the minute at which the positive 1-minute Average Frequency Restoration Control Error of a LFC Block is larger than 60% of the FRR Capacity of the LFC Block, the 1-minute Average Frequency Restoration Control Error of the LFC Block is not returned to 15% of the FRR Capacity of the LFC Block or the negative 1-minute Average Frequency Restoration Control Error of a LFC Block is lower than 60% of the FRR Capacity of the LFC Block the 1-minute Average Frequency Restoration Control Error of the LFC Block is not returned to 15% of the FRR Capacity of the LFC Block within the Time to Restore Frequency during a 3-month period compared to the number of times in which the absolute 1-minute Average Frequency Restoration Control Error of a LFC Block exceeds 60% of the FRR Capacity during the same three month period.

This Frequency Quality Evaluation Criteria is calculated by counting the number of time in which the following happens (Figure 5):

i. there is an upward crossing of the positive 60% of the minimum FRR Capacity of the LFC Block as described in Article 30(2) of the 1-minute Average Frequency Restoration Control Error Data;

ii. there is not a downward crossing of 15% of the positive of the minimum FRR Capacity of the LFC Block as described in Article 30(2) in the 1-minute Average Frequency Restoration Control Error Data until a time longer than the Time to Restore Frequency starting from the minute of the upward crossing of the positive 60% of the minimum FRR Capacity of the LFC Block.

or

i. there is a downward crossing of the negative 60% of the minimum FRR Capacity of the LFC Block as described in Article 30(2) of the 1-minute Average Frequency Restoration Control Error Data;

ii. there is not an upward crossing of 15% of the of the minimum FRR Capacity of the LFC Block as described in Article 30(2) n the 1-minute Average Frequency Restoration Control Error Data until a time longer than the Time to Restore Frequency starting from the downward crossing of the negative 60% of the minimum FRR Capacity of the LFC Block.

This Frequency Quality Evaluation Criteria is the equivalent of the trumpet curve method that has been in use in Continental Europe [4]. It shows the number of times in the 3-month period in which the TSOs of the LFC Block to which the data corresponds where not able to return the Frequency Restoration Control Error to a value close to zero. This number should be relatively low. It is expected to be typical that there are several events of this type due to imbalances due to different reasons that happen within a time frame of 15 minutes.

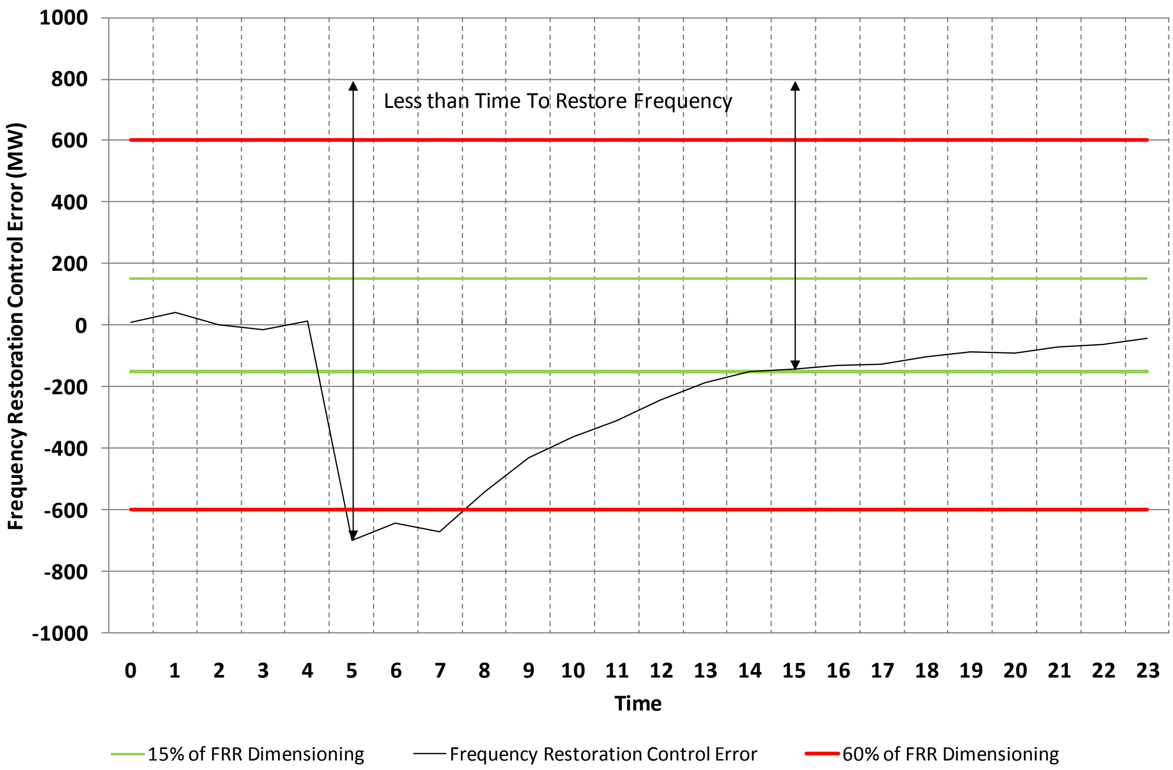


Figure 5: Description of an event to be counted by the Frequency Quality Evaluation Criteria described in Article 11(2)(b)(vii) which applies to Synchronous Areas with more than one LFC Block.

5.1.8 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 cause factors that have influenced the quality of System Frequency or of Frequency Restoration Control Error and propose to their respective NRAs and/or ACER the proposal to solve this deficiency.

Article 15 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 6 and Figure 7).

In Figure 6 it can be observed at 6, 16, 17, 20, 21 and 22 how there is a Deterministic Frequency Deviation associated with the change of the hour. Figure 7 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.

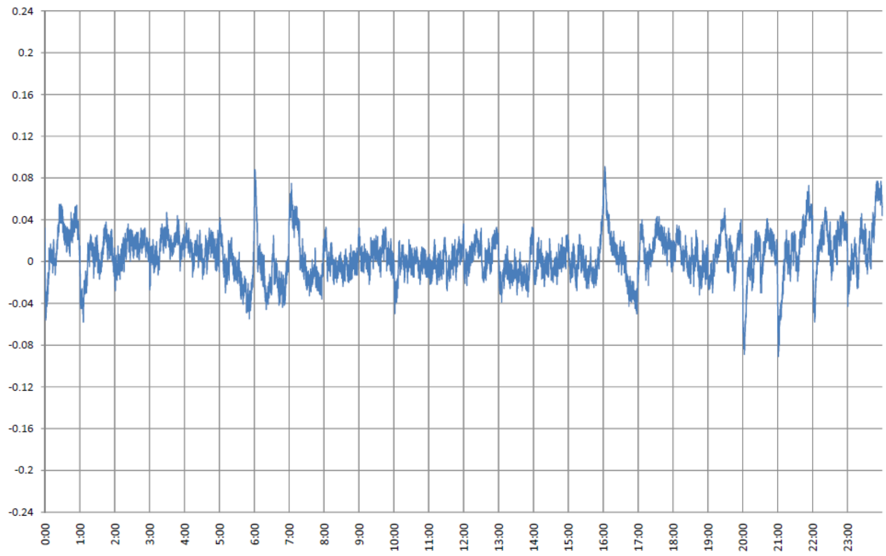


Figure 6: Deterministic Frequency Deviations in CE on December 17th 2012.

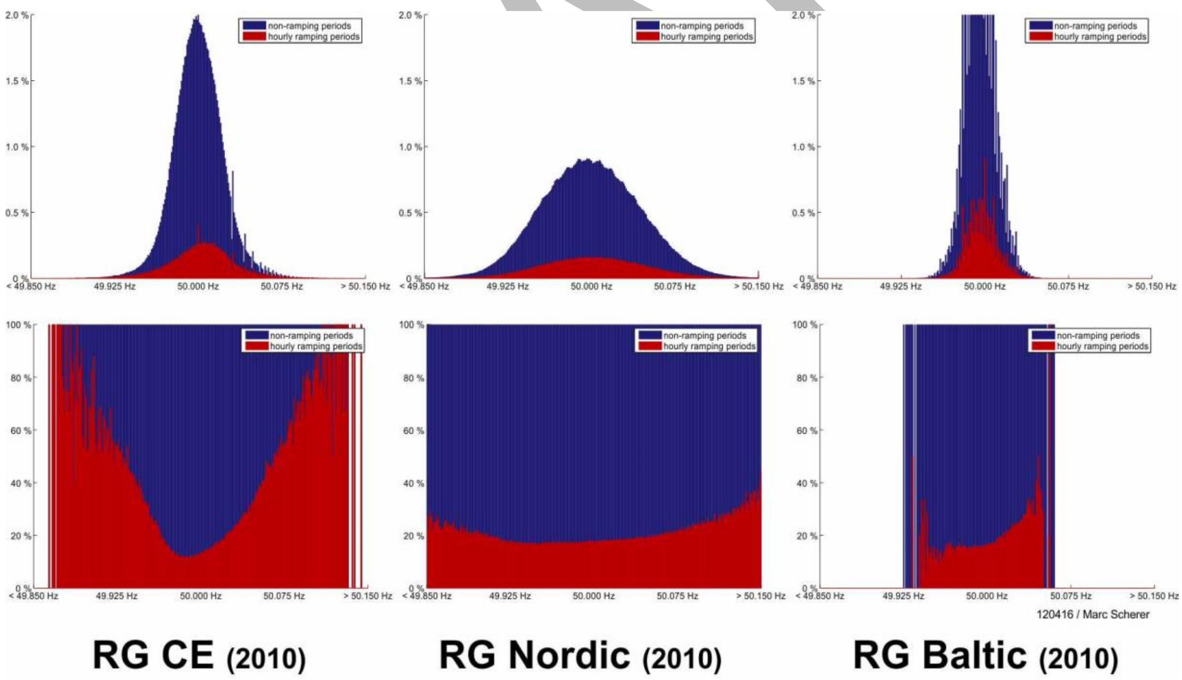


Figure 7: Distribution of Frequency Deviations in CE, Northern Europe and Baltic for 2010 distinguishing all minutes and the minutes around the change of the hour.

Apart for modification of market rules in the markets, including balancing markets, other measures should be taken even ex-ante in order to fulfil the Frequency Quality Target Parameters or the Frequency Restoration Control Error Target Parameters. One efficient measure, especially in smaller Synchronous Areas is to introduce restrictions on the rate of change in the power output or input of Generating Units, HVDC interconnectors and Demand Facilities connected to the TSO network.

These types of limits can be significantly important in the case of rate of change of HVDC interconnectors between LFC Blocks or Synchronous Areas as their output can change rapidly as a result of a program change at the change of the scheduling period.

5.2 Load-Frequency-Control Structure

The continuous maintenance of the power balance is a necessary precondition for achieving the required frequency quality and, therefore, for stable and secure power system operation. This task is performed by a set of Load-Frequency-Control processes which have to be implemented and operated by the TSOs. 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.
- The third part of the chapter deals with the implementation of Imbalance Netting and cross-border reserve activation.
- The fourth part of the chapter provides additional requirements related to Imbalance Netting and cross-border reserve activation in context of area process obligations.

5.2.1 Operational Reserves

5.2.1.1 Frequency Containment Reserves (FCR)

Objectives

Frequency containment aims at the operational reliability of the synchronous area by stabilizing the system frequency in the time-frame of seconds at an acceptable stationary value after a disturbance or incident; it does not restore the system frequency to the set point. The common activation of Frequency Containment Reserve (FCR) in the whole synchronous area modifies the balance between generation and load at the scale of each TSO and hence consequently the power exchanges between the TSOs are varying from their set point.

Means

Frequency containment depends on reserve providing units (e.g. generating units, controllable load resources and HVDC cables) made available to the system in combination with the physical stabilizing effect from all connected rotating machines. As generation resource it is a fast-action, automatic and decentralized function e.g. of the turbine governor, that adjusts the power output as a consequence of the system frequency deviation.

Hierarchy

Frequency containment reserves are activated locally and automatically at the site of the reserve providing unit, independently from the activation of other types of reserves.

5.2.1.2 Frequency Restoration Reserves (FRR)

Objectives

Frequency restoration aims to restore the system frequency in the time frame defined within the synchronous area by releasing system wide activated frequency containment reserves. For large interconnected systems, where a decentralized frequency restoration control is implemented, frequency restoration also aims to restore the balance between generation and load for each TSO, and consequently restore power exchanges between TSOs to their set point.

Means

Frequency restoration depends on reserve providing units made available to the TSOs independently from FCR. Activation of Frequency Restoration Reserve (FRR) modifies the Active Power set points / adjustments of reserve providing units in the time-frame of seconds up to typically 15 minutes after an incident.

Hierarchy

In each LFC Area FRR are activated centrally at the TSO control centre, either automatically or manually.

Frequency restoration must not impair the frequency containment that is operated in the synchronous area in parallel.

5.2.1.3 Replacement Reserves (RR)

Objectives

TSOs need replacement reserves (RR) to prepare for further imbalances in case FCR / FRR has already been activated up to a certain extent, e.g. when market participants have no possibility (neutralisation lead-time) or not the necessary information to compensate by themselves their forecast uncertainties on load, renewable generation, etc.

This amount needed and the time window during which the TSO is restoring the balance on behalf of the market players is highly depending on the market design of each country.

Replacement reserves are activated manually and centrally at the TSO control centre in case of observed or expected sustained activation of FRR and in the absence of a market response. TSO can also use RR to anticipate on expected imbalances.

Means

Replacement reserves depend on reserve providing units made available to the TSOs, independently from FCR or FRR.

Hierarchy

It is used to release FCR and FRR or to prevent its activation in normal operation.

5.2.1.4 Mapping of Processes to Products

Sync. Area	Process	Product	Activation	Local / Central	Dynamic / Static	Full deviation	Full activation
Baltic		Primary Reserve	A	L	D	±200 mHz	30 s
CY		Primary Reserve	A	L	D	±100 mHz	20 s
IRE		Primary operating reserve	A	L	D / S	>±200 mHz	5 s
IRE		Secondary operating reserve	A	L	D / S	±200 mHz	15 s
NE	FCR	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	10 s / 30 s
GB		Frequency response static	A	L	S	variable	variable
Baltic		Secondary emergency reserve	M	C	S	n.a.	15 minutes
CY		Secondary Control Reserve	A/M	L / C	D / S	n.a.	5 minutes
Ireland		Tertiary operational reserve 1	A/M	L / C	D / S	n.a.	90 s
Ireland		Tertiary operational reserve 2	M	C	S	n.a.	5 minutes
Ireland	FRR	Replacement reserves	M	C	S	n.a.	20 minutes
NE		Regulating power	M	C	S	n.a.	15 minutes
CE		Secondary Control Reserve	A	C	D	n.a.	15 minutes
CE		Direct activated Tertiary Control Reserve	M	C	S	n.a.	15 minutes
GB		Various Products	M	n.a.	D / S	n.a.	variable
Baltic		Tertiary (cold) reserve	M	C	S	n.a.	12 h
CY		Replacement reserves	M	C	S	n.a.	20 minutes
IRE		Replacement reserves	M	C	S	n.a.	20 minutes
NE		Regulating power	M	C	S	n.a.	15 minutes
CE	RR	Schedule activated Tertiary Control Reserve	M	C	S	n.a.	individual
CE		Direct activated Tertiary Control Reserve	M	C	S	n.a.	individual
GB		Various Products (mainly STOR)	M	n.a.	D / S	n.a.	from 20 minutes to 4 h

Table 1: Mapping Processes to Products; manual (M) or automatic (A) activation; activated centrally by the TSO (can be manual or automatic) (C) or activation directly at a local reserve provider (L)

5.2.2 Process Activation and Responsibility Structure

The Process Activation Structure defines:

- mandatory control processes which have to be implemented and operated by the 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:

- the division of the Synchronous Area into LFC Blocks, LFC Areas, and Monitoring Areas;
- the hierarchical relationship between these different areas (area hierarchy); and
- area process obligations, including control processes, quality targets, and reserve dimensioning, which must be fulfilled by the TSOs that belong to each type of area.

The area hierarchy is illustrated in Figure 8. Each Synchronous Area is divided into one or more LFC Blocks, each LFC Block is divided into one or more LFC Areas and each LFC Area is divided into one or more Monitoring Areas. Figure 9 shows a stylised example for a possible area hierarchy of a Synchronous Area with three LFC Blocks.

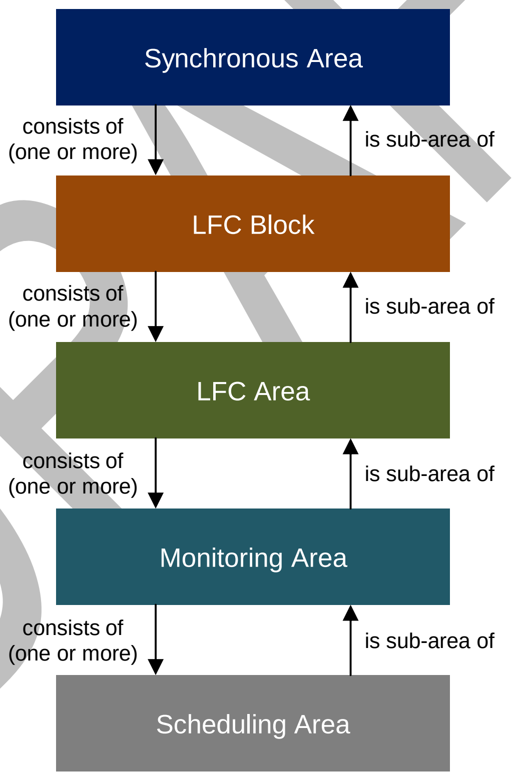


Figure 8: Interdependencies between areas (area hierarchy)

It is worth mentioning that NC LFCR does not formulate detailed requirements for TSOs operating a Scheduling Area. These requirements are established in NC OPS. Nonetheless, the Schedules provided for a Scheduling Area are a precondition for the Frequency Restoration Process when there is more than one LFC Area in the Synchronous Area.

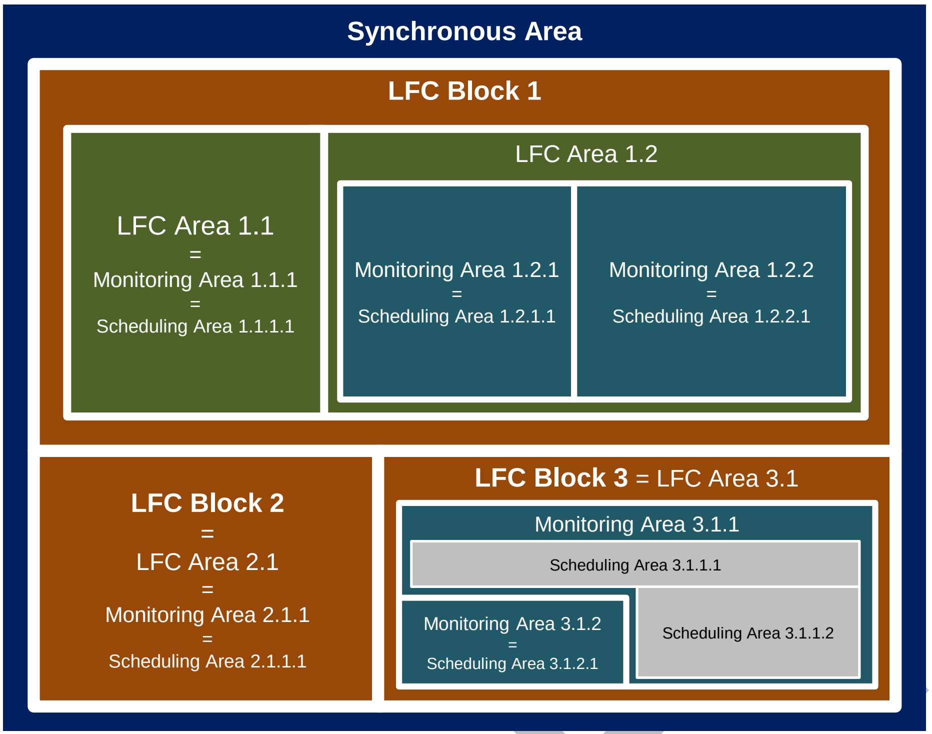


Figure 9: Stylised example for an area hierarchy

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 10 and Figure 11). For example:

- the Synchronous Areas of Ireland, Northern Europe and GB currently consist of exactly one LFC Block and LFC Area;
- CE currently consists of many LFC Blocks as shown in **Error! Reference source not found.**. 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, as shown in Figure 10, 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, Energinet.dk TenneT Germany and TransnetBW.;
- Northern Europe has currently implemented several Scheduling Areas and Monitoring Areas, as shown in Figure 11.

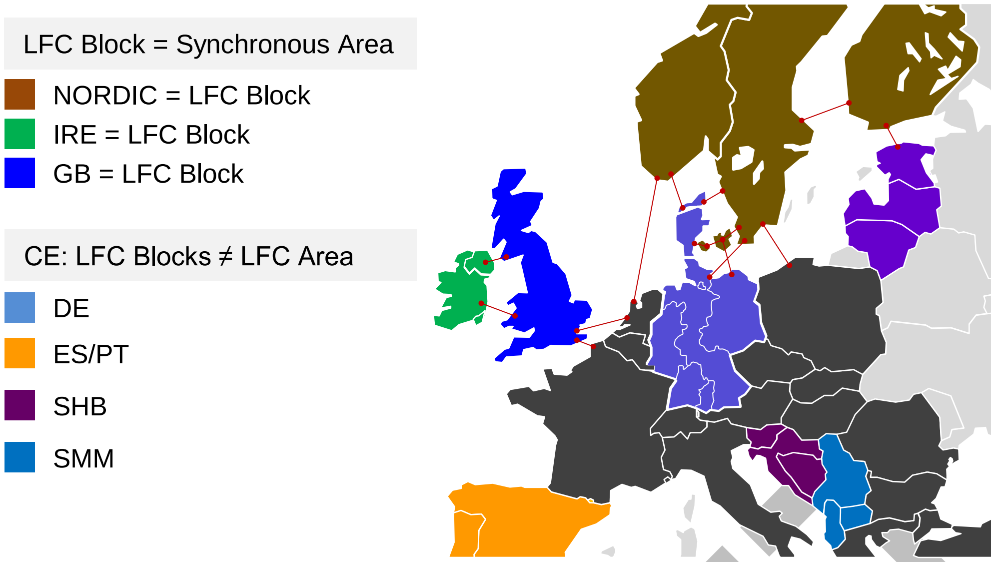


Figure 10: Synchronous Areas, LFC Blocks and LFC Areas

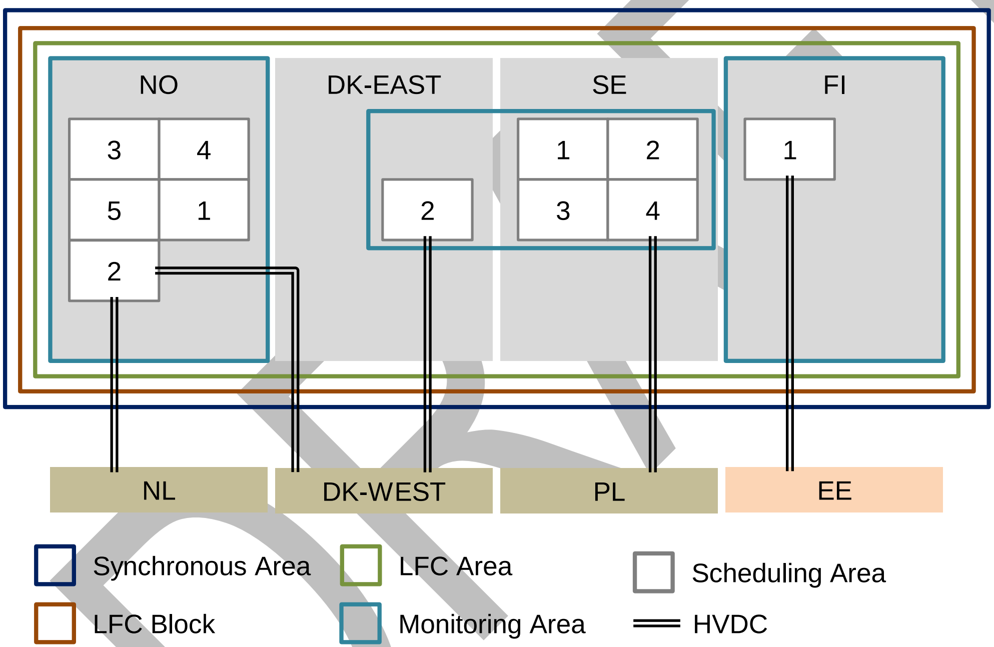


Figure 11: Area hierarchy in Northern Europe

The area hierarchy and the according area process obligations represent the general framework for organisation of Load-Frequency-Control in a Synchronous Area. Table 2 summarizes the different area process obligations defined in NC LFCR. For instance, a TSO operating an LFC Area has the obligation to collect and calculate the Schedules for the area, to perform an online calculation and monitoring of the actual power interchange and the Frequency Restoration Error as well as 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 and 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, an LFC Block, an 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 as described in Article 18. 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.

It has to be noted that some optional control processes can become 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 can be found in paragraph 5.2.5. Furthermore, a control process which is optional from the technical perspective of NC LFCR may become mandatory according to provisions of another NC, such as NC EB.

The added value of different area types and area process obligations formulated in this NC 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. 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.

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			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

Table 2: Area Process Obligations

5.2.3 Frequency Containment, Restoration and Reserve Replacement

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.

Figure 12 illustrates the interdependencies between the Frequency Containment Processes, Frequency Restoration Process and Reserve Replacement Process:

- 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 within the whole Synchronous Area.
- The Frequency Restoration Process within SA CE controls the frequency to its set-point value 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 the FCR in some Synchronous Areas (this process can also support the FRR activation). The Reserve Replacement Process is triggered by the disturbed LFC Area.

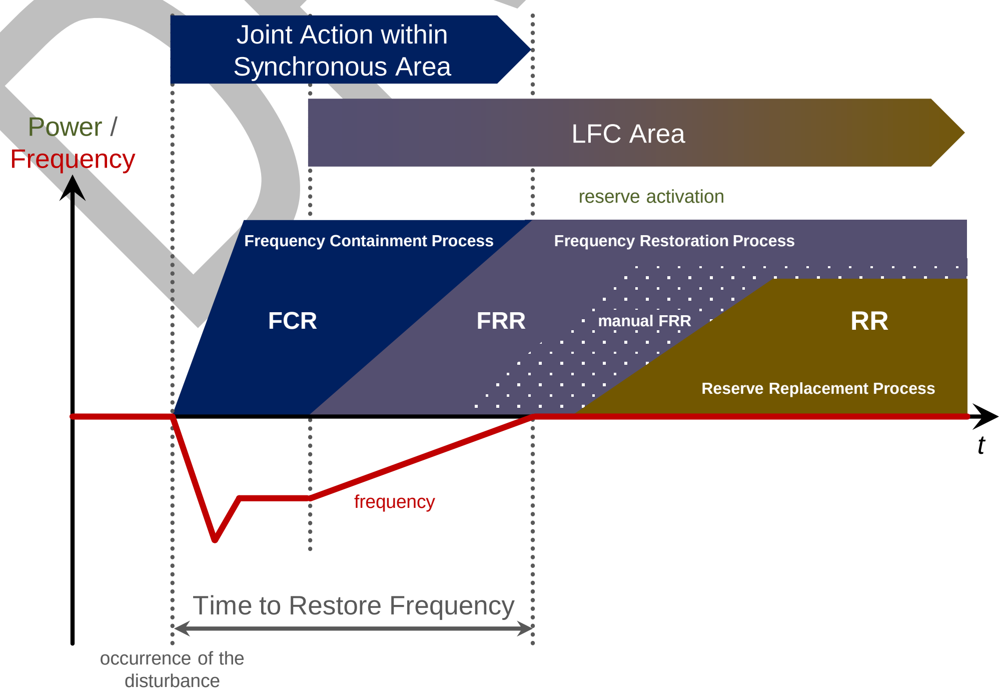


Figure 12: Load-Frequency-Control: Basic process structure

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.

5.2.3.1 Frequency Containment Process

The FCR is activated by a joint action of FCR Providing Units within the whole Synchronous Area with respect to the Frequency Deviation (Frequency Containment Control Error).

Depending on the best practices for a Synchronous Area the activation requirements for single FCR Providing Units may differ, nonetheless, the overall behaviour shall follow two principles which are illustrated in Figure 13:

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

The NC provides a European harmonization of Frequency Containment Process design and the according terms while allowing the necessary flexibility for different Synchronous Areas and types of

FCR Providers. Particularly, it enables FCR provision by demand units and different activation ranges.

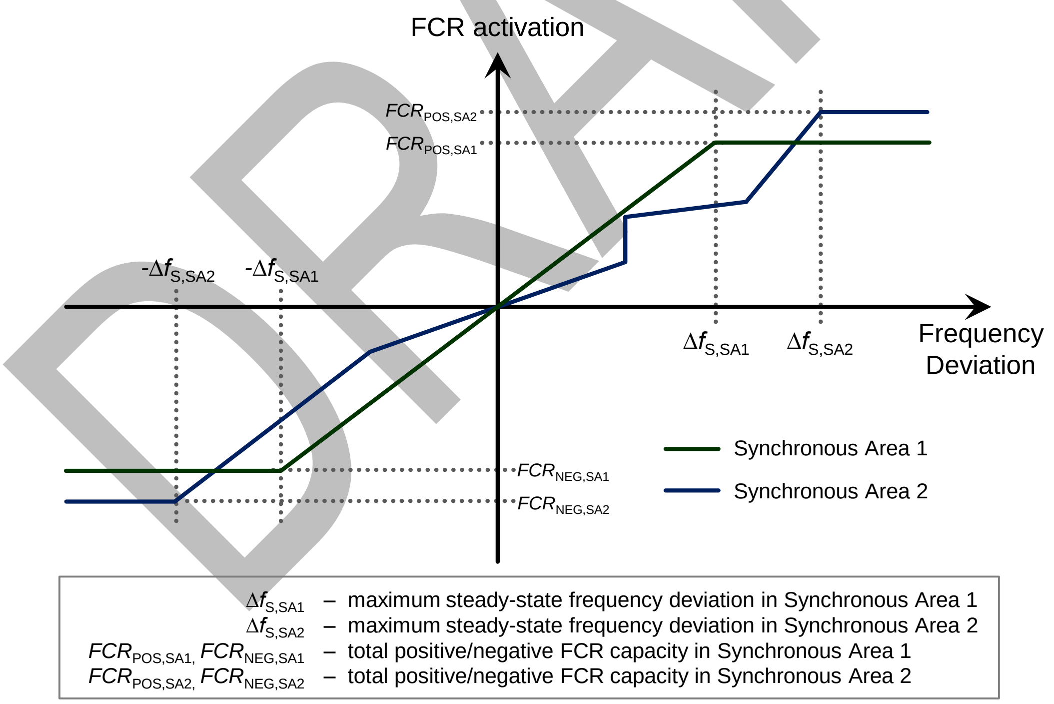


Figure 13: Example for FCR design in two different Synchronous Areas

5.2.3.2 Frequency Restoration and Reserve Replacement Process

The Frequency Restoration Process is designed to control the Frequency Restoration Control Error to zero by activation of manual and automated FRR within Time to Restore Frequency. In this way, the frequency is controlled to its set-point 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 set-points for FRR and RR activation are calculated by the TSOs. Figure 14 shows the implementation of the Frequency Restoration and Reserve Replacement Process from control perspective of a LFC Area.

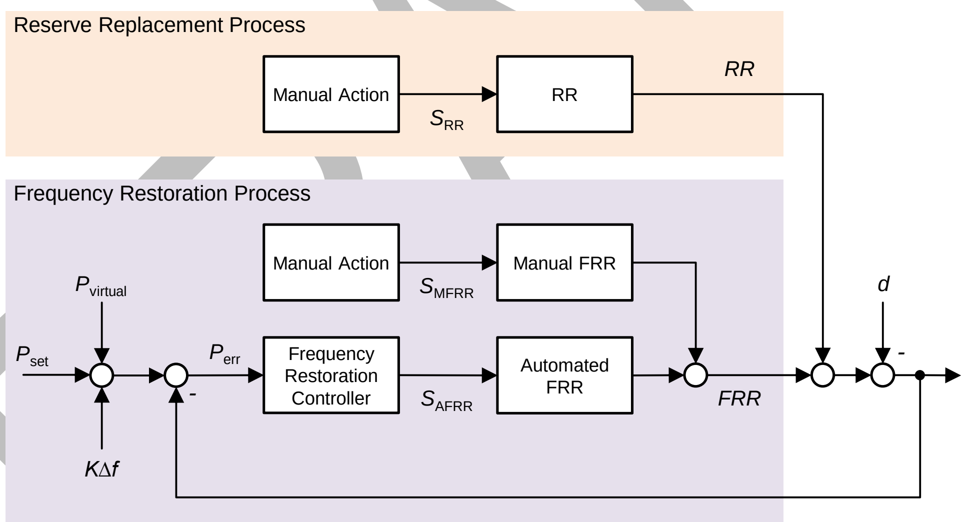
Where a Synchronous Area contains more than one LFC Area the Frequency Restoration Control Error (P_{err}) or Area Control Error (ACE) is calculated from the deviation between the scheduled and actual power interchange of a LFC Area (including Virtual Tie-Lines if any) corrected by the frequency

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 set-point value for FRR activation can be calculated manually (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 set-point 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.

Furthermore, the implementation of automated Frequency Restoration Process is not obligatory: Depending on physical properties of the Synchronous Area as well as different power plant dispatch models manual actions may be sufficient to achieve the necessary frequency quality.



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}	–	set-point value for automated FRR activation
S_{MFRR}	–	set-point value for manual FRR activation
S_{RR}	–	set-point value for RR activation

Figure 14: Frequency Restoration and Reserve Replacement Processes

The added value provided by the NC 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.

5.2.4 Imbalance Netting and Cross-Border Reserve Activation

The NC LFCR provides requirements for cross-border reserve activation and Imbalance Netting. The general technical framework relies on the concept of Virtual Tie-Lines as well as adjustment of control programs or adjustment of the Active Power flows over HVDC links.

The added value provided by the NC lies in the harmonization 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.

5.2.4.1 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. Ireland, GB or Northern Europe), the Imbalance Netting Process is implemented implicitly in the control error calculation.

Figure 15 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. 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 according to the requirements of the NC. 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 Imbalance Netting Power Interchange can also be implemented by adjusting the Active Power flow over one or more HVDC interconnectors.

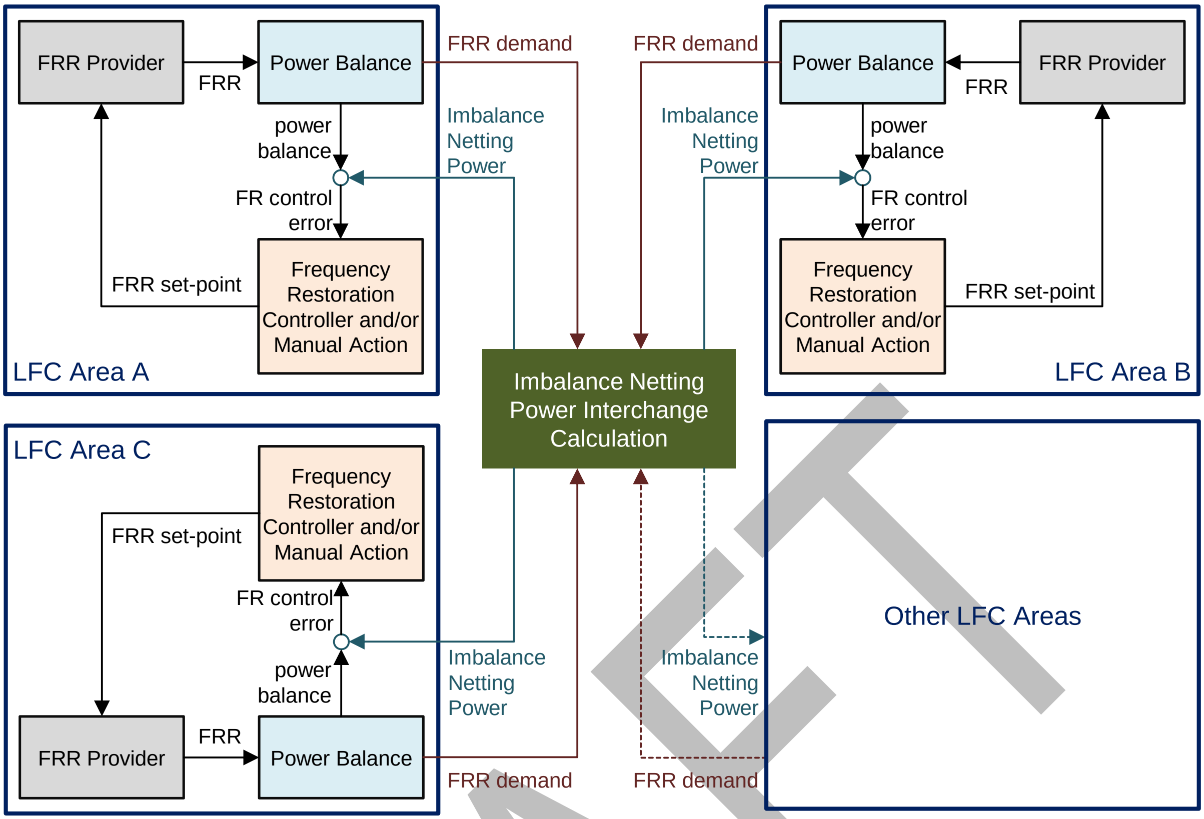


Figure 15: Imbalance Netting Process – basic principle

Figure 16 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 15 (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).

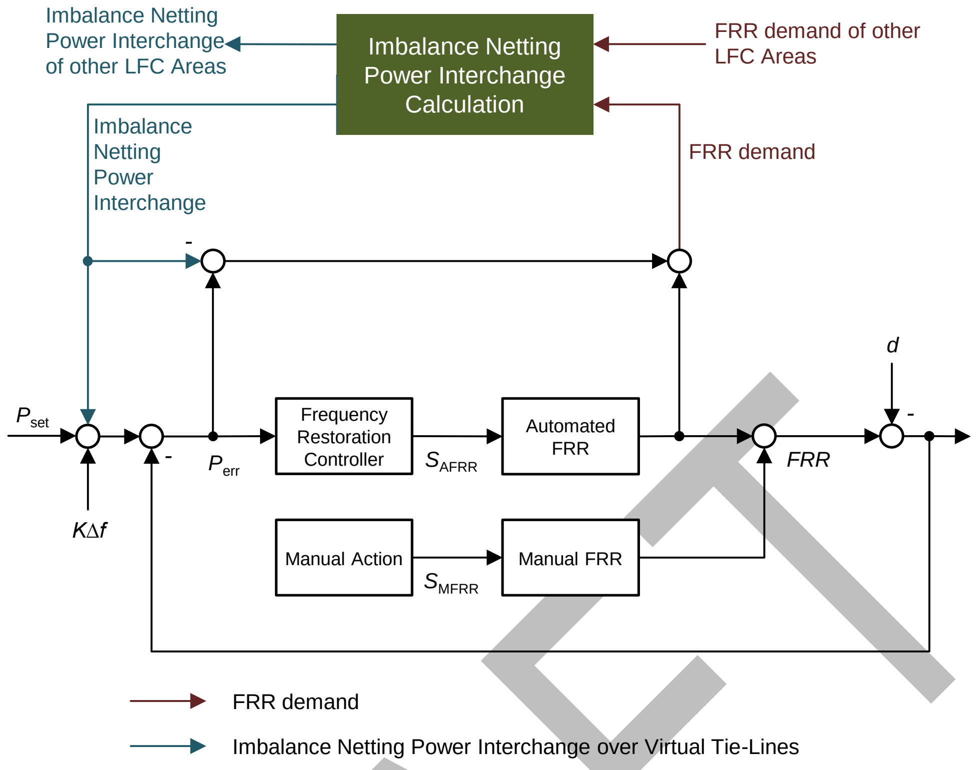


Figure 16: Integration of Imbalance Netting Process into the Frequency Restoration Process

5.2.4.2 Cross-Border FRR Activation Process

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:

- A TSO calculates directly the set-point value for the FRR activation in a different LFC Area directly (TSO-Provider Activation). The Frequency Restoration Power Interchange and the adjustment of the Frequency Restoration Control Error are calculated on the basis of actual FRR measurements (and/or schedules for manual FRR).
- A TSO (or an algorithm) calculates directly the required Frequency Restoration Power Interchange between participating LFC Areas which is used to adjust the Frequency Restoration Control Error (TSO-TSO Activation). The set-point value for FRR activation is calculated by the Reserve Connecting TSO.

Figure 17 and Figure 18 show the basic principle for the TSO-Provider Activation of automated and manual FRR for two LFC Areas illustrated in Figure 19 (for easier understanding the Reserve Replacement Process is neglected in this figure):

- The TSO of the LFC Area A has contracted two FRR Providers inside his LFC Area (FRR Provider A.1 for automated FRR and FRR Provider A.2 for manual FRR).
- The TSO of the LFC Area B has contracted two FRR Providers inside his LFC Area (FRR Provider B.1 for automated FRR and FRR Provider B.2 for manual FRR).
- Furthermore, the TSO of the LFC Area A has contracted two FRR Providers connected in LFC Area B (FRR Provider B.3 for automated FRR and FRR Provider B.4 for manual FRR).

The set-points for FRR activation by the FRR Providers B.3 and B.4 are calculated directly by the TSO of the LFC Area A (brown arrows). In order to adjust the Frequency Restoration Control Errors 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 17).

Figure 18 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.

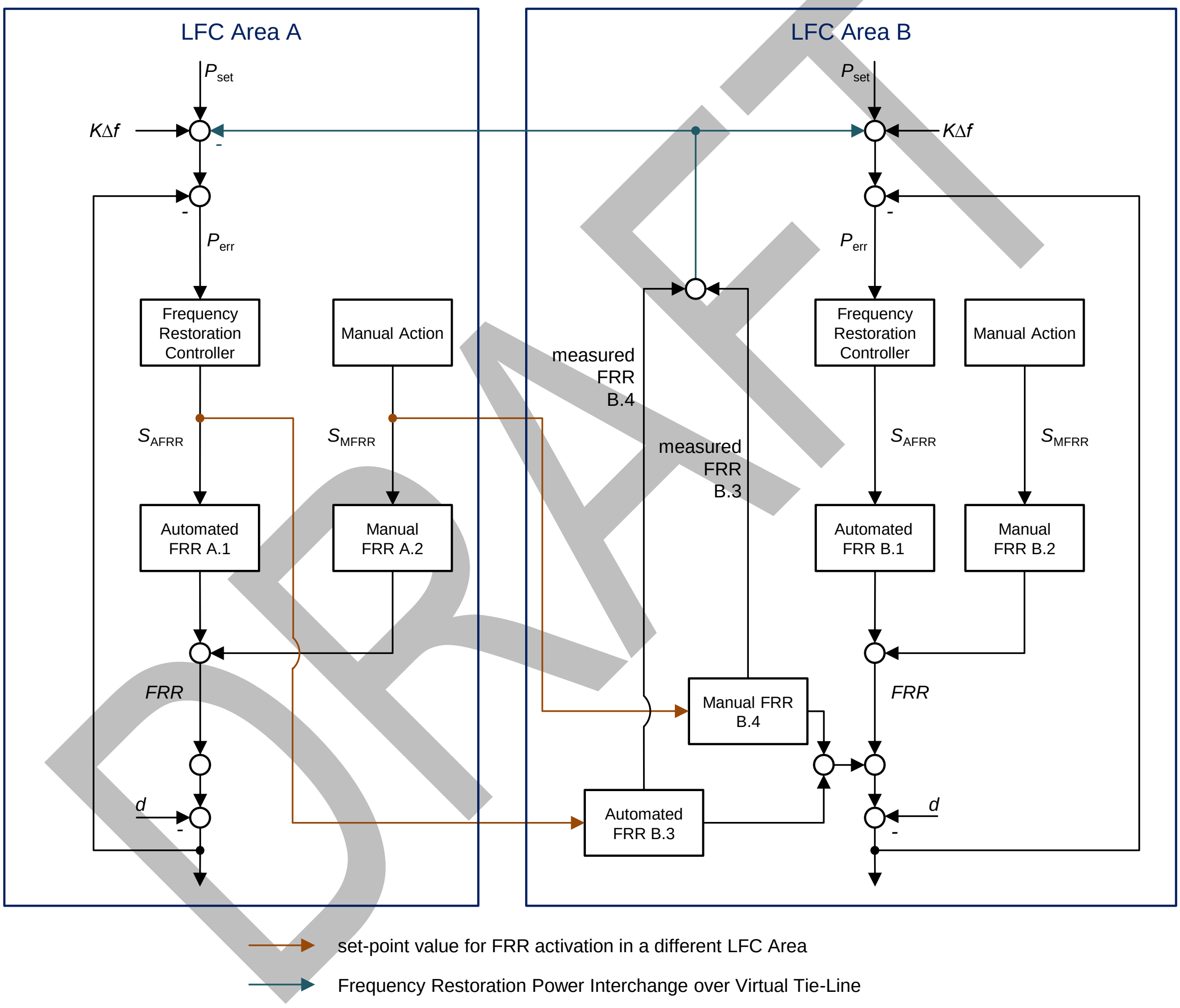


Figure 17: Example for TSO-Provider Activation with Virtual Tie-Lines

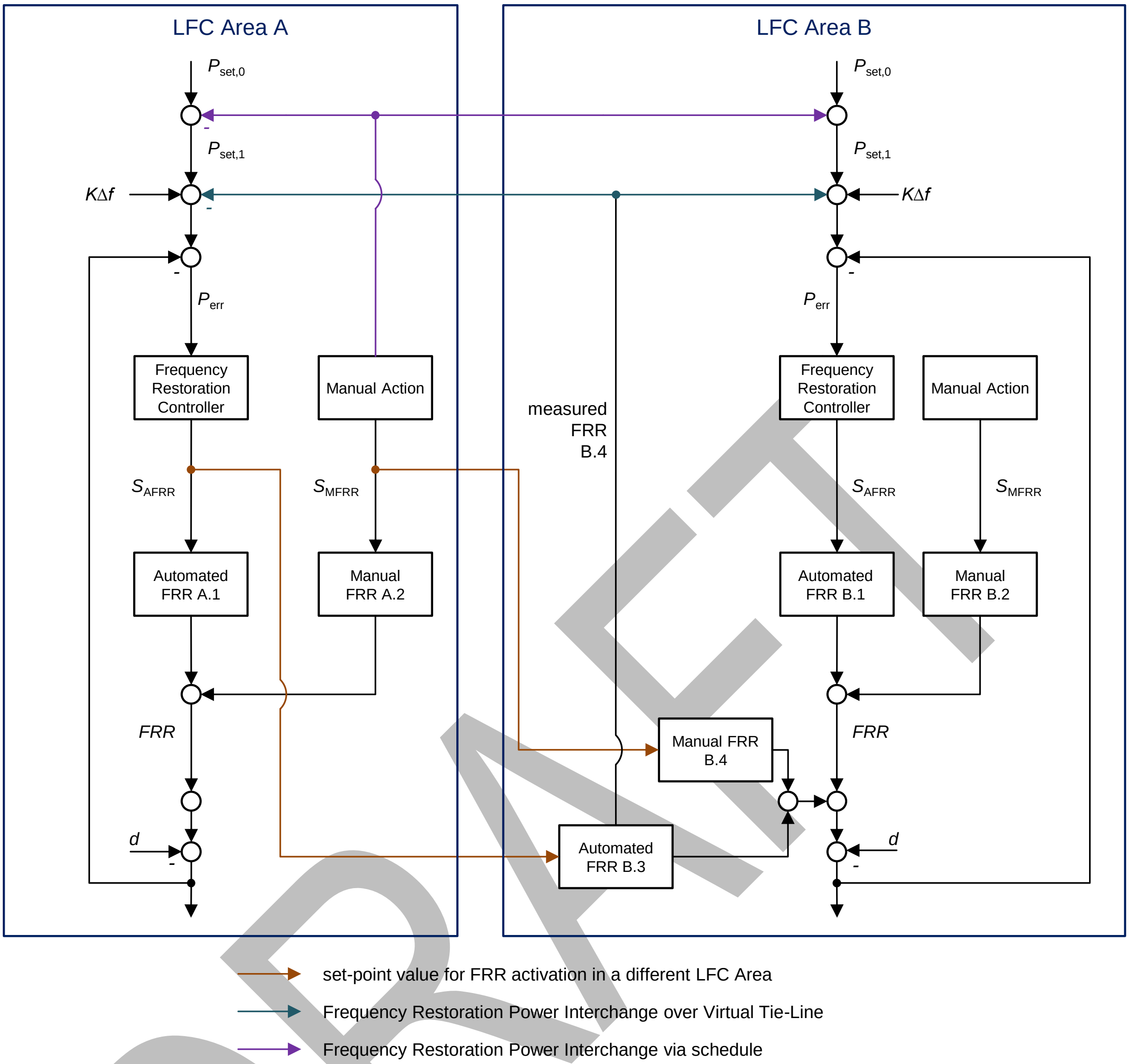


Figure 18: Example for TSO-Provider Activation with Virtual Tie-Lines and schedules

Figure 19 shows the TSO-TSO Activation for automated 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 20: Example for TSO-TSO Activation for manual FRR with schedules 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.

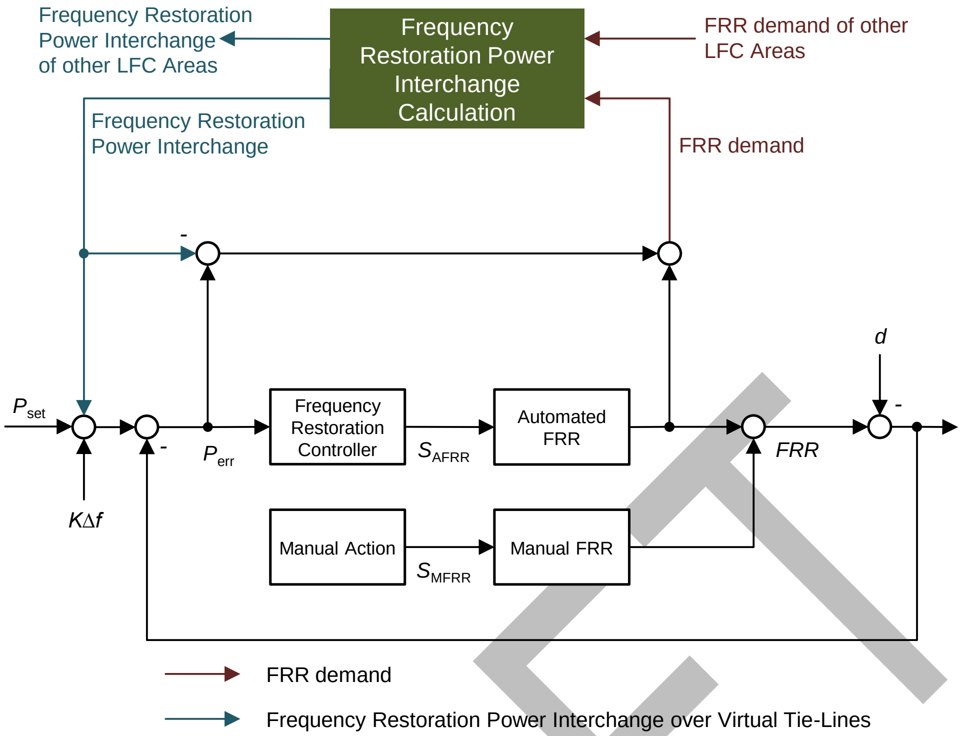


Figure 19: Example for TSO-TSO Activation for automated FRR with Virtual Tie-Lines

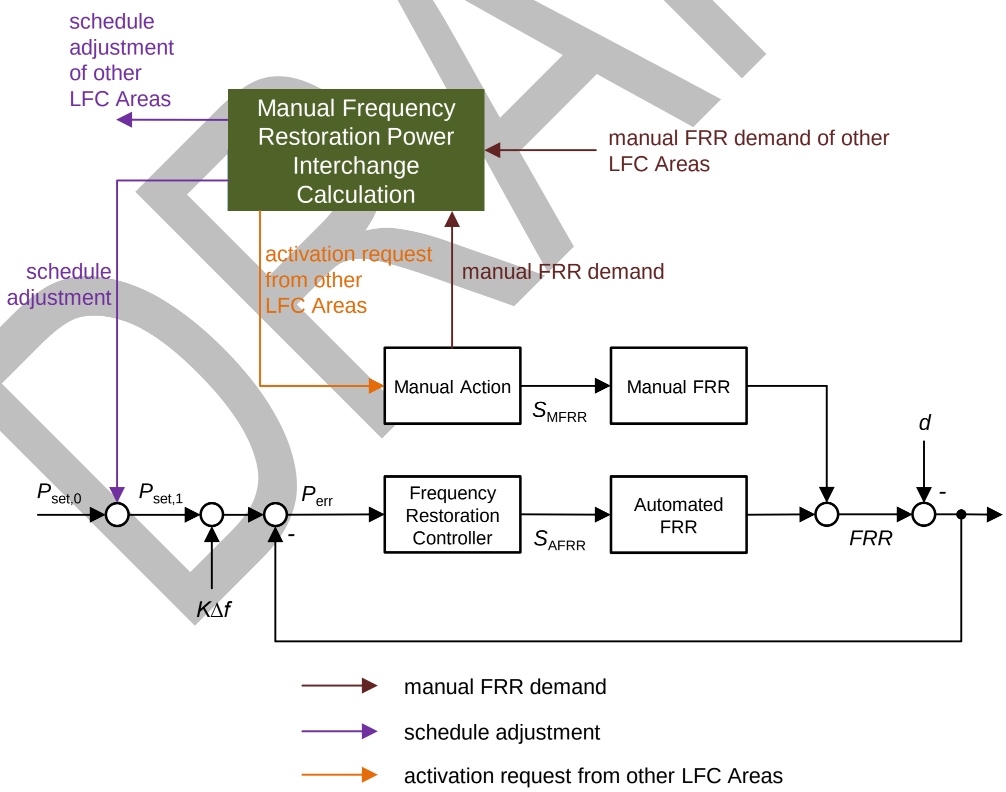


Figure 20: Example for TSO-TSO Activation for manual FRR with schedules

5.2.4.3 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.

5.2.4.4 Operational Security

The NC defines limits for power interchange between the involved LFC Areas: The Imbalance Netting Power, the Frequency Restoration Power and the Replacement Power Interchange shall not exceed the Available Transmission Capacity which is determined based on Operational Security assessment.

5.2.5 Additional Requirements related to Area Types

Processes which are optional in general (cf. Table 2) can be mandatory depending on local implementation factors. Considerations which might make aspects mandatory are exemplified below (other conditions may also exist):

- 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 (as in dimensioning). Furthermore, prior performing the Imbalance Netting Power Interchange with other LFC Blocks, the imbalances have to be netted inside the LFC Block.
- Where the Imbalance Netting Process is implemented for different LFC Blocks, the LFC Blocks shall ensure having sufficient reserves available to meet the respective Frequency Restoration Quality Target Parameters regardless of Imbalance Netting Power Interchange. 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 reserves to offset the disturbances without the Imbalance Netting Process.
- 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.
- If one of the cross-border processes is implemented between LFC Areas of different LFC Blocks, all TSOs of the Synchronous Area have to agree on this implementation. 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 a limitation of the interchange between the LFC Blocks in real-time.

5.2.6 Measurements and Infrastructure

The NC defines basic requirements for measurements and infrastructure in the ENTSO-E. The details shall be defined within a multi-party agreement on a Synchronous Area level.

5.3 Frequency Containment Reserves

Any imbalance between generation and demand in a synchronously connected grid (Synchronous Area) 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.

The objective of frequency containment is to maintain a balance between generation and consumption within the synchronous area and thus to stabilize the electrical system by means of the joint action of respectively equipped providers.

Appropriate activation of FCR results consequently in stabilization of the system frequency at a stationary value after an imbalance in the time frame of seconds. As a matter of fact due to the principle of activation FCR cannot restore system frequency (and power exchanges between areas) to their reference values.

5.3.1 FCR Dimensioning

Imbalances in an interconnected system can have different reasons. The following types of reasons for system frequency deviations have to be separated / considered (see also explanations to Frequency Quality):

- Disturbance / outage of generation or load or HVDC interconnector. This type of imbalance is generally the one used for the calculation of the Reference Incident.
- Stochastic imbalances in normal operation. These can occur due to the continuous variations of demand or renewable energy output.
- Deterministic Frequency Deviations – e.g. ramping at the hour shift.
- Network splitting. These imbalances are generally out of the design of the Synchronous Area as they lead most likely to an emergency situation in a part or in all of the Synchronous Area.

Dimensioning of FCR 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
- Limits / thresholds for Frequency Deviations

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 operational 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 Frequency Containment Reserve (FCR) is to withstand the Reference Incident in the synchronous area by containing the system frequency within the maximum system frequency deviation and stabilizing the system frequency within the maximum steady-state system frequency deviation.

The Reference Incident has to take into account the maximum expected instantaneous power deviation between generation and demand in the synchronous area. In large systems such as the Synchronous Area Continental Europe an N-2 scaling criterion (outage of the two biggest generation / consumption / in-feed units is considered to scale the risk of multiple outages within the recovery window of the system. This concept is supported by a probabilistic assessment for the calculation of the Reference Incident.

The reference incident shall be sized taking into account at least the loss of the largest power generation / consumption unit or the loss of a line section, bus bar or HVDC interconnector that may cause the biggest imbalance with an N-1 failure[1]. In larger systems such as in the Continental Europe with many units there is 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.

A probabilistic assessment for the calculation of the reference incident is required as well as the use of historic data to determine which the largest generation loss was in 20 years. In very large systems such as CE an N-2 scaling criterion of the two biggest generation / consumption / in-feed units shall be used for dimensioning the reference incident to scale the risk of multiple outages within the recovering window of the system.

As an example, in the CE Synchronous Area an N-2 criterion shall be used leading to determine the size of the reference incident in 3000 MW which is the equivalent to two nuclear power units of 1500 MW, the biggest there are in the system. Such a probabilistic assessment was performed (see Ad-hoc Team Operational Reserves report).

Stochastic Imbalances and Deterministic Frequency Deviations (resulting from market optimization) occur independently from outages of generation / load and can be estimated by using statistical analysis.

For dimensioning of FCR the different effects have to be combined by using statistical data from the past with the aim to limit the likelihood of insufficient FCR. Thus, dimensioning of FCR has to take into account resulting imbalances that happen with a certain probability.

The value of FCR thereby determined is therefore the needed total FCR per Synchronous Area. FCR is per se a shared portion of the reserve of the total FCR which has to be distributed between TSOs in the Synchronous Area using a distribution key. 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.

5.3.2 FCR Minimum Technical Requirements

To guarantee appropriate activation of FCR the determination of minimum requirements for the providers are necessary. These requirements encompass the basic parameters

- Accuracy of Frequency measurement – to be able to detect Frequency Deviations exceeding a certain size
- Maximum Insensitivity of the governor of FCR providing Units – to avoid too late activation of FCR
- Full activation time of FCR – to harmonize activation in terms of time and to guarantee a sufficient activation gradient
- Full Activation Deviation – to harmonize activation in terms of Frequency Deviation

Nevertheless determination of additional detailed requirements concerning provision and activation must be possible to be able to react on changing boundary conditions with respect to structure and pattern of load and generation including renewables. . These parameters as well as any other additional parameter shall be set respecting the provisions of NC RfG Article 10 (2) (b). Respective

[1] It may be necessary in the future to verify the definition of the reference incident because of the changes of the transmission and generation systems (development of dispersed generation).

additional requirements encompass also specifications for Reserve Providing Groups - e.g. with respect to appropriate monitoring.

In general monitoring of provision and activation of FCR plays an important role in the concept of FCR. Effective monitoring requires respective data from the providers with a sufficient time resolution to be able to detect non-compliant provision or activation

One of the main parameters for defining the behaviour of an FCR Providing Unit is the Droop. The Droop of the FCR Providing Unit shall be such that after a large unbalance leading to a change larger or equal to the FCR Full Activation Deviation the FCR activated is larger or equal to its corresponding provision of FCR after the Full Activation Time of FCR. The setting of the Droop of all generators in a Synchronous Area shall be compliant with [NC RfG Article 10 (2) (c)]

5.3.3 FCR Provision

FCR provision and activation is crucial for system stability and therefore continuous availability of FCR is very important. Since outages of FCR Providing Unit cannot be excluded and might endanger system security the risk of remarkable reduction of FCR has to be limited by limiting the amount of FCR concentration.

Furthermore FCR should be activated as long as the Frequency Deviation exists. Within SA GB only certain providers are required to meet this requirement. Two aspects have to be considered here.

- Expected activation of FRR and corresponding relief of FCR within Time To Restore Frequency
- Possibly limited storages in FCR Providing Units

The respective requirement in the NC takes both aspects into account by determining the general obligation to activate FCR as long as the Frequency Deviation exists but to also allow for FCR Providing Units with limited storage as long as certain conditions can be fulfilled. In accordance with Article 10 (2) (b) (6) of NC RfG an FCR Providing Unit or FCR Providing Group shall be capable of continuously activating their FCR for a time period no less than 30 minutes. Within SA GB there is not a general requirement to activate FCR as long as the Frequency Deviation exists.

5.4 FREQUENCY RESTORATION RESERVES

Frequency Restoration Reserves are activated within the Frequency Restoration Process of an LFC Area to restore the System Frequency in the Time to Restore Frequency of the Synchronous Area and to relieve system wide activated Frequency Containment Reserves. For the special case of the Synchronous Area of Continental Europe which is consisting of more than one LFC Block and performing a decentralized frequency control, FRR are activated to restore the balance between generation and load for each LFC Block and consequently restore power exchanges between TSOs to their set point.

This chapter of the NC LFCR describes the requirements for TSOs, generating and demand facilities constituting a FRR Providing Unit and FRR Providers with regard to the activation and provision of FRR and gives additional boundary conditions for the operation of the Frequency Restoration Process.

5.4.1 Target and Performance Indicators

5.4.1.1 Target

The TSO's common and individual goal and obligation is to reach a common target. The amounts of FRR and RR needed for this are determined in the TSO's reserve dimensioning process, which shall ensure that the common target can be fulfilled. The fulfilment of requirement for FRR and RR is set at the level of a LFC Blocks. the quality target (jointly or individually) can be measured by global quality reliability indicators.

One general target for the individual FRR dimensioning is the availability of sufficient reserves to cope with the dimensioning incident. FRR shall be sufficient to replace the activated FCR within the time to restore frequency after the dimensioning incident (see below).

In addition a common quality target can be defined for "normal operation". As a recommended quality target for a synchronous area the percentage of time intervals equal to the Time to Restore Frequency (e.g. 15 minutes for Continental Europe, 10 minutes for GB, …) outside a given frequency band is measured. A target value for this is defined in Chapter 2 of the NC LFCR per synchronous area against which this number is evaluated (see below).

This quality target is valid for the control activities of the LFC Block using a combination of FRR and RR.

For FRR and RR an additional target can be defined: the TSO shall not induce systematically an imbalance in the system resulting in a systematic system frequency distortion; the ACE shall be an appropriate measure for this distortion.

The solution to the hour shift ramping problem lies in the market re-design and not in the re-dimensioning of FRR or of RR.

5.4.1.2 Dimensioning Incident

In a synchronous area without any congestion FRR could be theoretically shared by all parties. In reality the FRR dimension and distribution are constrained by congestions inside the synchronous areas.

A TSO shall ensure it has access to sufficient reserves to cope with incidents occurring TSOs within its LFC area according to the rules of the synchronous area. The dimensioning incident is defined as the largest expected N-1 failure of generation, load or HVDC-interconnector within the LFC Block.

The dimensioning incident determines the minimum required volume of FRR to cope with instantaneous failures within the LFC area.

As a global quality reliability indicator a monitoring of the system frequency behaviour after imbalances shall be in place within each synchronous area. After imbalances the system frequency must be restored to the band defined by the tolerance range for FCR activation within the time to restore frequency. The monitoring will be based on a performance indicator measuring the exceeding of certain thresholds. These thresholds are defined on the level of synchronous areas (see Frequency Quality section).

TSOs are allowed to perform cross-border exchange of reserves with other TSOs or to share reserves in order to cope with the dimensioning incident under the conditions defined in Article 29 and Chapter

7 of the NC LFCR. In this case congestions and the respective probability of being short of FRR due to FRR exchange limitations have to be taken into account. This issue has to be addressed within the reserve dimensioning.

In case of reserve sharing the final responsibility to cope with the dimensioning incident remains with the TSO affected by the incident. In case of insufficient operational reserves the TSO has to take appropriate measures to balance its own demand (for example, emergency load or generation reduction according to the type of imbalance).

5.4.1.3 Monitoring the Quality Target

5.4.1.3.1 Frequency as Unique Performance Indicator

As introduced in section above as a general quality target for a synchronous area the number of time units outside a given frequency band is measured. A time frame equal to the Time to Restore Frequency of the Synchronous Area is taken as the relevant time unit since it relates to the reaction time of FRR.

During an observation period, the number of 15-minute time frames, where the average system frequency deviation is outside a given threshold f_{THRS}, is counted. The percentage value (rate) r(f_{THRS}) is calculated by dividing this count by the total number of 15-minute time frames in the observation period. The observation period is typically 1 year.

As an ENTSO-E wide, global quality reliability indicator it is proposed to take a target value for the percentage value (rate) r(f_{THRS}), but different values for the allowed frequency range f_{THRS} per Synchronous Area. The choice of these limit values is performed per synchronous area separately.

5.4.1.3.2 ACE as De-Central Performance Indicator

In large synchronous areas like CE, a de-central load-frequency-control of LFC Blocks is applied. To satisfy the desired overall system frequency quality in this case the ACE of the individual LFC Blocks must to be kept within defined limits on a continuous basis.

The FRR global quality reliability indicator in case of a de-centralised approach is based on the Area Control Error (ACE_i) or Frequency Restoration Control Error of the LFC Block i. The 15 minute time frame is taken as the relevant time unit since it is the Time to Restore Frequency in CE.

The performance of de-centralised load-frequency control is measured by the combination of two indicators:

a) maximum number of time intervals outside the Level 1 Frequency Restoration Control Error Range within a time interval equal to the Time to Restore Frequency, per year shall be equal to 30% of the time intervals in the year;

b) maximum number of time intervals outside the Level 2 Frequency Restoration Control Error Range within a time interval equal to resolution the Time to Restore Frequency, per year shall be equal to 5% or the time intervals in the year..

The observation period is typically 1 year.

Indicator measuring the compliance with the non-intervention.

During the observation period, the number of 15-minute time frames, when the average $\mathrm{ACE_i}$ is outside the given threshold $\mathrm{ACE_{THRS}}$, is counted. The percentage value (rate) $\mathrm{r(ACE_{THRS})}$ is calculated dividing this count by the total number of 15-minute time frames in the observation period. The observation period is typically 1 year.

Using these metrics is in compliance with required control policies and the principle of non-intervention, in which each LFC Block should compensate its ACE (its domestic imbalance) to acceptable limits. It also reflects the fact that the prescribed obligatory PI controller for load- frequency control reacts only to ACE and therefore its performance should be evaluated by appropriate metrics over ACE.

Based on overall system frequency quality requirements, individual ACE thresholds $\mathrm{ACE(f_{THRS})}$ per LFC Blocks can be calculated. Maximum relative time when those limits are exceeded remains constant among all LFC Blocks and equals the value $\mathrm{r(f_{THRS})}$.

The frequency threshold $\mathrm{f_{THRS}}$ for a whole synchronous area with a K-factor KT is translated and decomposed in to the individual $\mathrm{ACE_{THRS}}$ thresholds for one LFC Block with K-factor of $\mathrm{K_i}$ by this formula:

$$\mathrm{ACE_{THRS}} = \mathrm{f_{THRS}}\sqrt{\mathrm{K_T K_i}}$$

5.4.2 FRR Dimensioning

This NC obliges the TSOs to perform a dimensioning of FRR and RR on the level of LFC Blocks. At the same time it sets boundary conditions for the FRR and RR dimensioning with the aim to ensure that the FRR and RR available to the TSOs of LFC Block are sufficient to guarantee a safe operation and to enable the TSOs of any LFC Block to respect its quality target. In effect these boundary conditions aim to achieve the desired frequency quality within the Synchronous Area.

In general the dimensioning of reserves, in particular the dimensioning of FRR and RR in the context of this document is to be seen as a trade-off between the availability of reserves and the costs related to the procurement of these.

The reserve dimensioning of the individual TSO has to take into account the targets defined in section Chapter 2 of the NC LFCR. There is no direct link to calculate the reserve needed from this target, but there are state-of-the-art methodologies that can support the choice of the right level of reserves.

An overview, especially for the well accepted statistical and stimulatory approaches for Reserve Dimensioning, shall be given in the following. The use of the following methodologies by the TSOs is recommended but not mandatory. The suitable dimensioning approach differs from LFC Block to LFC Block due to which the final choice is intentionally left to the TSOs of the LFC Block. The NC LFCR focuses to give guidance and boundary conditions for the performance of the dimensioning process.

In short the boundary conditions set to the TSOs of a LFC Block with regard to the dimensioning of FRR and RR:

- It shall be based on historical records for at least one full year (Article 29.2.a))
- It shall enable the TSOs of a LFC Block to comply with the quality targets (Article 29.2.b))
- It shall be based on a probabilistic approach. This could e.g. be a statistical analysis or a simulatory approach as explained in more detail in the following (Article 29.2.b))
- It shall take all relevant influencing factors into account. (Article 29.2.b))
- It shall include the calculation of the amount of FRR which is required as Automatic FRR and which is required as Manual FRR

- During the dimensioning process the Automatic and Manual FRR Full Activation Times shall set according to the needs of the LFC Block
- Based on the available transmission capacity a certain distribution of FRR and RR within a LFC Block may be required.
- if shall ensure that the FRR capacity is sufficient to outbalance the largest expected instantaneously occurring imbalance within a LFC Block 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.
- It is subject to a minimum requirement for the FRR and RR requirement based on the LFC Block imbalances. The minimum need for positive FRR is defined by the 99% quantile of the LFC Block imbalances. The minimum need for negative FRR is defined by the 1% quantile. These values are to be understood as lower limits for the chosen dimensioning approach and constitute an absolute minimum.
- A LFC Block is allowed to reduce its FRR by sharing of FRR or RR with neighbouring LFC Blocks. To limit the dependency of LFC Blocks due to these sharing rules the reduction is strictly limited according to Article 29.2.j) and k). In effect the sharing of reserves is only permitted for small LFC Blocks for which the covering of the Dimensioning Incident is the largest challenge. In any case the shared amount of FRR is limited to 30 % of the dimensioning incident.

As examples a qualitative description of the statistical and the simulatory approaches for reserve dimensioning are given in the following.

5.4.2.1 Statistical Methodology for Reserve Dimensioning

Within the statistical methodology Probability Density Functions (PDF) of different system characteristics are modelled in order to define the need for FRR and RR for each activation direction. Although in general the determining factors are comparable across synchronous areas and across LFC Blocks, it largely depends on the system itself which characteristic is to be judged as relevant or

irrelevant. Hence each TSO has to choose the relevant characteristics for Reserve Dimensioning in its system.

Due to the fact that RR can be substituted by FRR, but not vice versa the statistical methodology for the dimensioning of FRR and RR can be apportioned into a two-step approach. In the first step the overall need for reserves (full value for the FRR / RR being FRR and RR as a sum) is determined. In the second step from that the need for fast and flexible reserves (i.e. FRR) is determined. The difference, the remaining need for reserves that does not need to be covered by FRR can be covered by RR.

Whereas for the dimensioning of RR in general the long term market forecast error is predominantly relevant, the need for FRR and hence its dimensioning is influenced, amongst others, by the following system characteristics:

- Short term forecast errors
- Unit outages
- Load noise
- Steps of the exchange programs
- Activation delay of RR

Renewable Energy Sources (RES) can affect both the need for FRR and RR, but the above mentioned characteristics can already include their effects.

In order to perform the dimensioning PDF for the relevant system characteristics are needed. Usually the PDF are extracted on the basis of observations from the past (e.g. for the last 12 months). If the characteristic's occurrence is too seldom and not systematic (like for unit outages) the PDF has to be created theoretically.

The overall probability density function of the system (relevant for FRR and RR or only FRR) is calculated by a mathematical combination of each of the single PDFs (convolution). From the resulting total probability density function the probability of having a certain power deficit in the system can be derived for each level of reserve procurement. Reserving this consideration the volume of the reserve needed can be chosen by defining a deficit probability, which is sufficient to fulfil the quality target.

To estimate the market forecast errors (short term and long term as a sum) for reserve dimensioning the open-loop ACE ($\mathrm{ACE}^{\mathrm{OL}}$) is likely to be used[2]. Historical values of open loop ACE can be obtained by summing up the LFC Block's ACE and all activated reserves:

$$\mathrm{ACE}^{\mathrm{OL}} = \mathrm{ACE} + \text{all actvated reserves}$$

Open loop ACE for dimensioning is constructed from several components:

$$\overrightarrow{\mathrm{ACE}_{\mathrm{OL}}} = \overrightarrow{\mathrm{ACE}_{\mathrm{OL1}}} + \overrightarrow{\mathrm{ACE}_{\mathrm{OL2}}} + \overrightarrow{\mathrm{ACE}_{\mathrm{OL3}}} + \ \dots$$

It is each TSO's decision what components are reflecting the LFC Block's behaviour the best and hence have to be taken into account in the dimensioning or have to be removed from the database.

Typical components of the $\mathrm{ACE}^{\mathrm{OL}}$ are:

$\overrightarrow{\mathrm{ACE}_{\mathrm{OL1}}}$ representing fast load noise

$\overrightarrow{\mathrm{ACE}_{\mathrm{OL2}}}$ representing slow load noise and short term market forecast errors

$\overrightarrow{\mathrm{ACE}_{\mathrm{OL3}}}$ representing long term market forecast errors

$\overrightarrow{\mathrm{ACE}_{\mathrm{OL4}}}$ representing unit outages

$\overrightarrow{\mathrm{ACE}_{\mathrm{OL5}}}$ representing fast and slow RES effects in case when RES influence is not included in $\overrightarrow{\mathrm{ACE}_{\mathrm{OL1}}}$, $\overrightarrow{\mathrm{ACE}_{\mathrm{OL2}}}$ components.

For each of these components a time resolution needs to be chosen. For most of the components a quarterly hour time resolution might be sufficient, however e.g. for the fast load noise and the short term market forecast errors a smaller time resolution might be needed in order to reflect the relevant characteristics.

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[2] Please note that in some market arrangements, e.g. centrally dispatched pool based markets, it is not possible to calculate easily open loop ACE as in these markets balancing actions are taken by TSOs in the framework of the same mechanism as redispatching actions and thus they are difficult to differentiate ex post.

After the convolution of all of the relevant PDFs of these data the overall PDF of power imbalances is known. It can be used to calculate the probability of having a certain power deficit in the system for the sum of both kinds of reserves FRR and RR.

The convolution of the PDFs relevant for fast and flexible reserve, the volatile part is only a part of $\mathrm{ACE}^{\mathrm{OL}}$, is used to calculate the need for FRR.

Choosing an ultimate value for the deficit probability in combination with the overall PDF gives the full value for the FRR / RR needed in the system. The need for Reserves should in this case be determined for each activation direction separately, thus the deficit probability needs to be attributed accordingly to the activation directions. According to the market possibilities the TSO decides about the "sourcing", i.e. which part of the maximum value for the FRR / RR is reserved as "firm capacity" and which part can with an acceptable security be delivered by market parties. A TSO with no possibility to activate reserves from the market may have to contract the full value for the FRR / RR as "firm capacity".

5.4.2.2 Simulation Methodology for Reserve Dimensioning

The statistical methodology models each time unit independently (i.e. non-sequential). It does not allow an analysis of the results of a course of events. This limitation can be overcome by the simulation methodology.

With this methodology the dynamic reaction of the whole system can be analysed. The basis is a pre-defined set of events. Typically these events are designed on the basis of experiences from the past. New probable phenomena not observed in the history can be also simulated.

The results of the simulation give the ACE of the system, which can be analysed with regards to the performance indicator. Thus quality target and reference incident reaction can be evaluated from simulation.

Typically during simulation a probable time series of open-loop ACE (or system frequency deviations in smaller system) is generated and activations/deactivations of operational reserves simulated.

Simulation models can be used for simulation of one run throughout investigated period or for a more complex Monte Carlo simulation. The advantage of Monte Carlo simulations is its ability to investigate a broad range of possible situations in a power network.

Ideally at least a whole year period is simulated, however to reduce computation time for Monte Carlo simulation representative shorter periods (typically months) could be used.

If Monte Carlo simulations are performed, it is recommended not only to evaluate system behaviour from by averaging all simulation run but also to choose few representative realisations for evaluation purposes, because averaging leads to some sort of result blurring. A pre-defined worst case is regarded as recommended security approach. Thus simulations results falling around 99 % quintile should be used for dimensioning operational reserves.

5.4.3 FRR Minimum Technical Requirements

The FRR Minimum Technical Requirements may differ depending on the Synchronous Area or LFC Block. In addition the Reserve Connecting TSO, i.e. the TSO to which the Reserve Providing Unit is connected has the possibility to set requirements. The need for different requirements depending on the level arises from the technical conditions that may largely differ from Synchronous Area to Synchronous Area and within these from LFC Block to LFC Block.

The NC LFCR hence differentiates requirements for Reserve Providing Unit, Reserve Providing Groups or Reserve Provider which are:

- Unique across all Synchronous Areas
- Unique for all LFC Block of a Synchronous
- Unique for all Reserve Providing Units within a single LFC Block
- Requirements set by the Reserve Connecting TSO

5.4.4 FRR Operation

In Article 32 in Chapter 5 of the NC LFCR the basic rules for the operation of the Frequency Restoration Process are defined. Whereas the general rules with regard to the design of the Frequency Restoration and Reserves Replacement processes are set in Chapter 2 and Chapter 3 of this NC. The real-time operation of these processes may face additional challenges as unexpected high imbalances of frequency deviations. For the mastering of these this NC sets rules and gives the TSOs additional tools if certain predefined limits are reached. The rules are formalized as common rules for the operation of the FRP on Synchronous Area level and on LFC Block level.

With regard to the operation of the Frequency Restoration Process(es) within a Synchronous Area this NC differentiates three operation states depending on the general risk level measured by the System Frequency Deviation.

- High Synchronous Area State
- Elevated Synchronous Area State
- Normal Synchronous Area State

Whereas the Normal Synchronous Area State is to be seen as a situation with usual Frequency deviations, the Elevated Synchronous Area State and the High Synchronous Area State constitute situations in which the operation of the Synchronous Area faces extraordinary challenges. This NC obliges the TSOs of a Synchronous Area to avert situations with Elevated or High Synchronous Area States and obliges the TSO to collaborate with TSOs of the same but also from different Synchronous

Areas. For this collaboration during times with Elevated or High Synchronous Area States the principle of non-intervention may be disregarded, whereas is stays valid for all other situations.

In addition to the described general operation states within a Synchronous Area, the operation of the Frequency Restoration Processes of the individual LFC Block is categorized into different thresholds.

- Level 2 LFC Block Threshold
- Level 1 LFC Block Threshold
- Normal LFC Block Threshold

Depending on the threshold the NC LFCR gives the TSOS opportunities or obliges the TSOs to take additional measures.

5.4.5 Statistical Analysis of LFC Block Imbalances

In order to assess the adequacy of the amount of operational reserves the behaviour of each LFC Block shall be analysed by the responsible TSO.

In this respect the ACE^{OL} representing the overall sum of imbalances within a LFC Block is of special significance. ACE^{OL} is related to the overall need of reserves (FRR and RR) of a LFC Block. The following rule applies in general: the higher the ACE^{OL} of a LFC Block - the higher is the need for operational reserves.

Additionally the ACE^{OL} and its derivative $ACE^{OL\prime}$ – defined as the change of the ACE^{OL} from the previous time stamp – can be analysed. In relation to the ACE these two parameters give insight into the intrinsic behaviour of the analysed TSO system.

5.4.5.1 Analysis of Open-Loop ACE

When plotting ACE against ACE^{OL} in its quarterly hour dependency the following distribution is assumed to be typical.

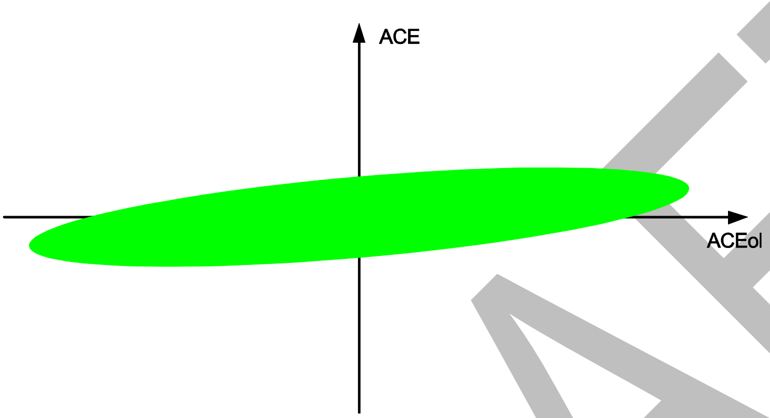


Figure 21: Typical point distribution

One can observe an equal distribution of ACE and ACE^{OL} to positive and negative values. Each of their probabilities abates with size and nearly follows a Gaussian distribution, defined by its variance σ and its mean value μ. The points are concentrated near the x- and the y-axis (μ = 0). While assuming no interrelation between the ACE and ACE^{OL} being independently distributed according to a Gaussian distribution no patterns are recognizable (i.e. no statistical dependency). In this diagram the x–axis

represents the “influence of the market” whereas the y–axis represents the result of the TSO control activities.

If the operational reserves available to the TSO are smaller than the highest observed ACE^{OL} the pattern as depicted in the following diagram is to be expected. It can be seen as a piecewise defined function. The flanks show saturation of reserve capacity.

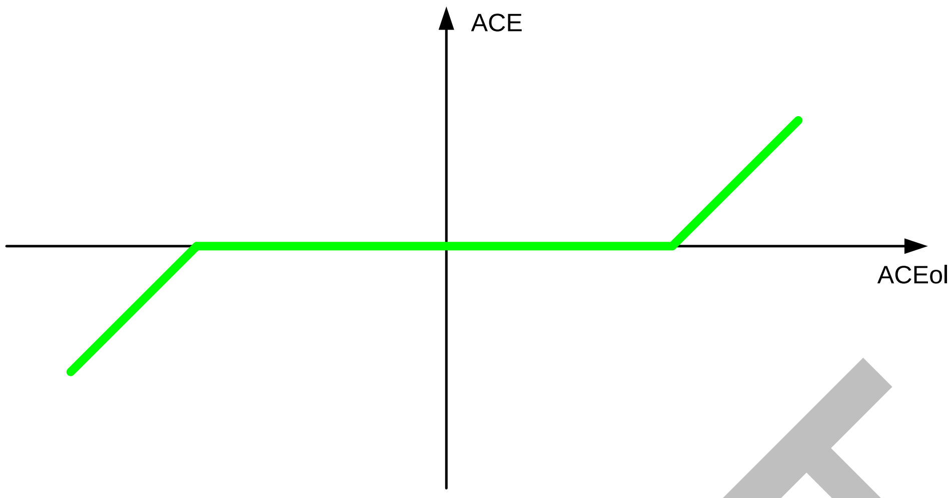


Figure 22: Saturation of reserves with instantaneous control

5.4.5.2 Analysis of the Fast Changing and Unpredictable Part of the Open-Loop ACE

The derivative of the $\mathrm{ACE^{OL}}$ being $\mathrm{ACE^{OL\prime}}$ (defined as ACEol'(t) = ACEol(t) –ACEol(t-1)) can be seen as a proxy for the fast changing and unpredictable part of the $\mathrm{ACE^{OL}}$ and can be used to estimate the need for flexible reserves (e.g. FRR). The assumption is taken that the predictable and slow part of the $\mathrm{ACE^{OL}}$ can be outbalanced by slow reserves (e.g. RR), hence the remaining part has to be outbalanced by FRR.

A realistic point distribution is depicted in the following diagram. A linear relationship between $\mathrm{ACE^{OL\prime}}$ and ACE (ACE ~ k * $\mathrm{ACE^{OL\prime}}$) due to the “reactive” control (i.e. reaction of the control on an ACE different to zero) is recognizable. The steepness k is a measure for the overall control speed of the system.

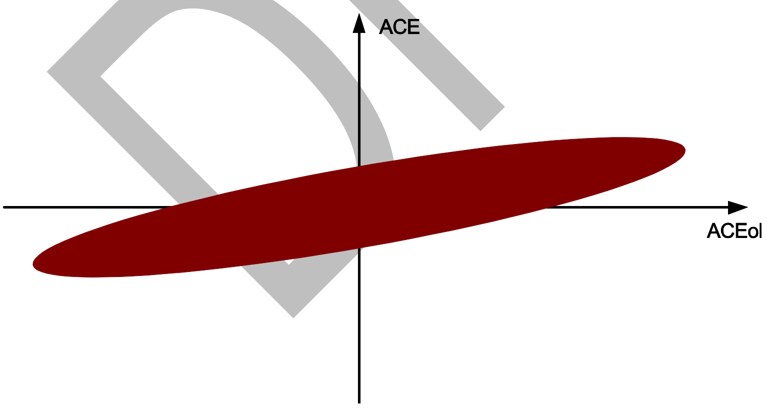


Figure 23: Realistic distribution

If the control speed was extremely fast the following pattern would be observed.

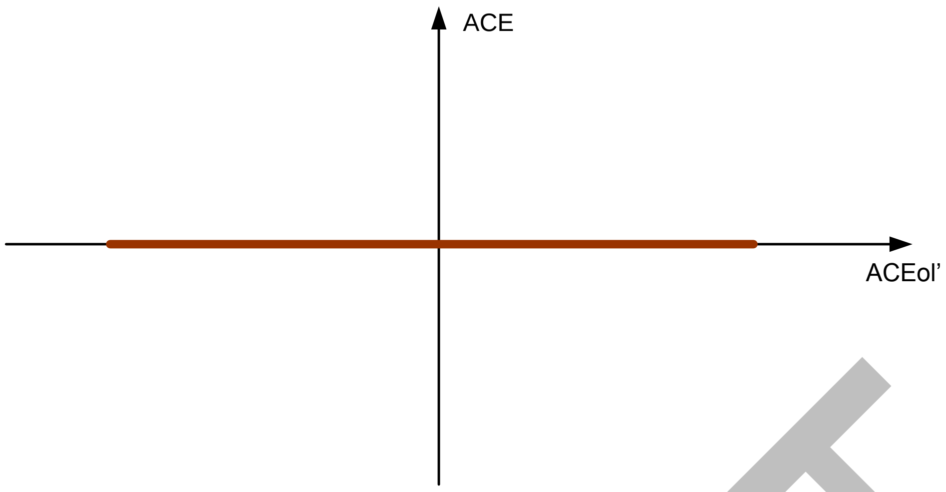


Figure 24: Fast control

If the control speed was limited and lower than the highest observed differentials of the $\mathrm{ACE^{OL}}$ it would be only possible to outbalance the differential $\mathrm{ACE^{OL'}}$ within the same quarter of an hour up to a certain speed. If this speed is reached the remaining change goes directly in the ACE (visible as flanks in Figure 25: Limited speed of control).

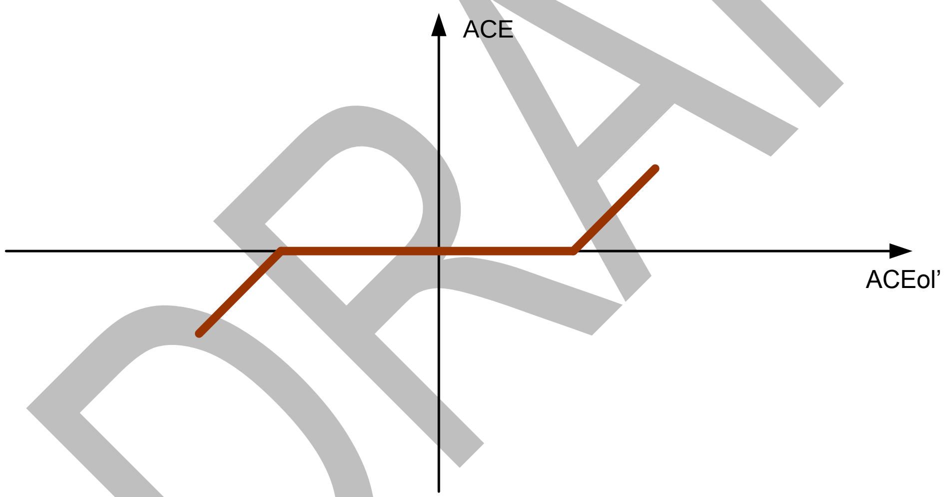


Figure 25: Limited speed of control

In the real world however, due to the reactive nature of the control loop and the limited speed of control a certain part of the ACE always stays imbalanced as depicted in the following diagram.

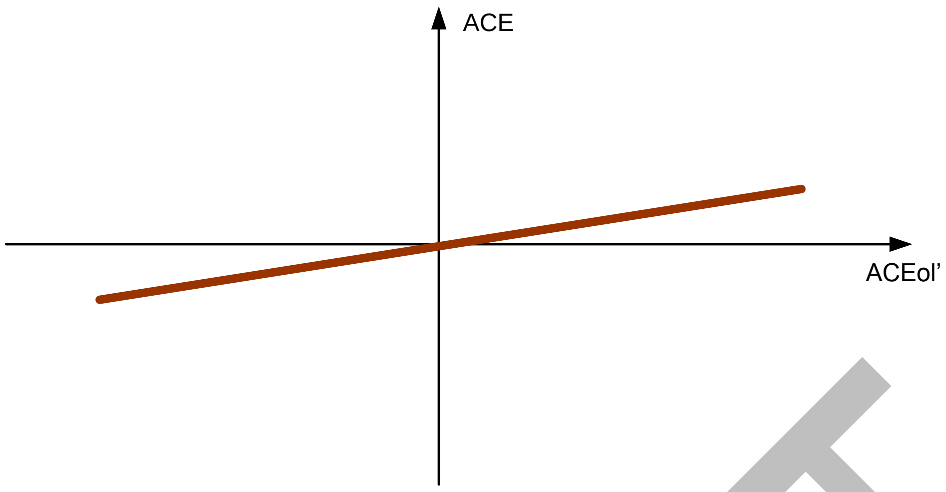


Figure 26: Normal control

5.5 Replacement Reserves

Replacement Reserves are reserves for which activation lead time may be longer than the Time to Restore Frequency, they shall be used to restore activated FRR or anticipate an imbalance and then decrease the use of FRR, to be prepared for further imbalance.

The need for such reserves depends on the market design, and the time during which BRPs may not be able to restore the imbalances. If this neutralization Time is longer than Time to Restore Frequency, a TSO is responsible not only for balancing the system, but also for restoring sufficient level of FRR to be prepared for further imbalances, until BRPs can take actions to do so.

The need for Replacement Reserves may then lead to reduce the need for FRR. So, dimensioning of RR shall take into account at least the following requirements:

- FRR shall at least cover the LFC Block Dimensioning Incident

- the total of FRR + RR shall cover the imbalances of the LFC Block according to the Frequency Restoration Error Quality Target.

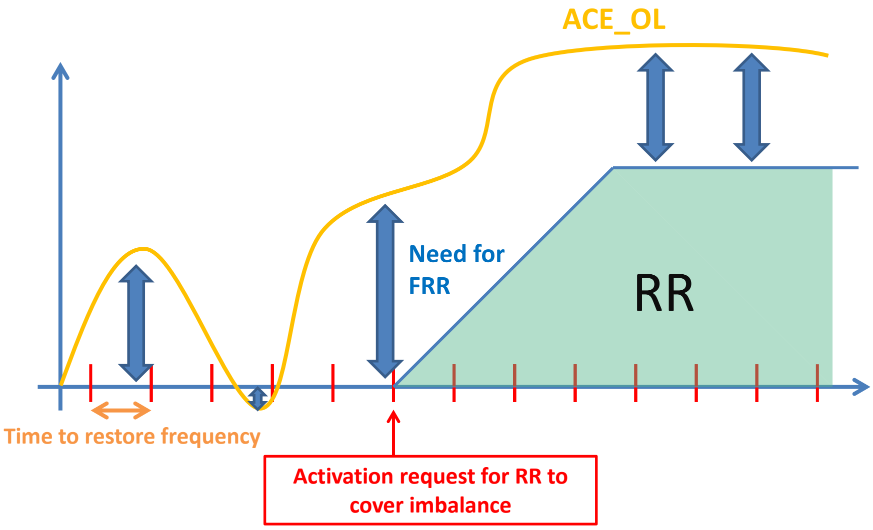


Figure 27: A possible RR activation approach

5.5.1 RR Dimensioning

According to the need for restoration reserves of a LFC Block, each TSO of the LFC Block will define a rule to dimension its RR, and submit it to TSO Decision Process.
The rules for dimensioning will be determined per LFC Block, however, they need to respect at least the mentioned points. If the RR Capacity is taken into account to dimension the FRR Capacity, then RR Capacity will need to ensure that :

- FRR is always available, that is why RR Capacity shall be sufficient to restore the Activated FRR, so that FRR Capacity can always cover at least The Dimensioning incident oft he LFC Block
- RR Capacity along with FRR Capacity shall allow a TSO to respect its Frequency Restoration Error Quality Target.
- for distribution of RR Capacity among TSOs of a LFC Block, it is mandatory to perform a study on the availability of transmission capacity on tie-lines between TSOs at any time.

RR Capacity, along with FRR Capacity shall cover the System Imbalances of a Control Block. However, RR shall be dimensioned so that FRR can cover the Dimensioning Incident of the Control Block. Indeed, FRR reacts faster than RR, and the Imbalances caused by an Incident shall be restored within time to restore Frequency. Whereas RR will have an Activation Time longer than Time to Restore Frequency. It can be used in a proactive manner to prevent activation of FRR, in case an imbalance is forecasted long enough in advance.

5.5.2 RR Minimum Technical Requirements

Since RR are part of the reserves needed to ensure the safety of the system, RR providers shall submit to a prequalification phase, answering minimum technical requirements and other requirements defined by relevant Connecting TSO.
On their side, relevant TSO shall be able to monitor the providers.

As being part of the reserves needed to respect Frequency Restoration Error Quality Target, each RR Providing unit shall be always available, and respect the requirement for availability and information defined by TSOs.

5.6 FCR PROVIDER - FCR PROVIDING UNITS -FCR PROVIDING GROUPS

The concept of terms used in the NC RFG for Generating installations and demand installations can be summarized as follows:

5.6.1 Synchronous Power Generating Module

- indivisible set of installations, either
- a single unit within a PowGen Facility directly connected or
- an ensemble of units within a PowGen Facility directly connected with a common Connection Point, or
- an ensemble of units within a PowGen Facility directly connected that cannot be operated independently from each other, or
- a single synchronous storage device operating in electricity generation mode directly connected, or
- an ensemble of synchronous storage devices operating in electricity generation mode directly connected with a common Connection Point.

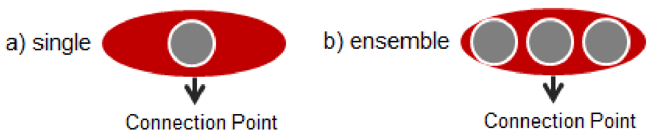
5.6.2 Power Park Module (PPM)

- a unit or ensemble of units
- connected to the Network non-synchronously or through power electronics
- single Connection Point

5.6.3 Power Generating Module

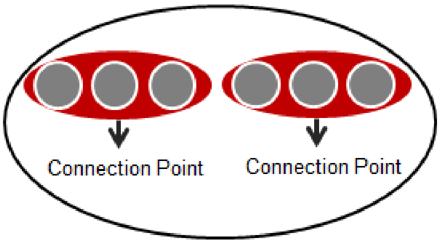
Is either:

- a Synchronous Power Generating Module, or
- a Power Park Module.



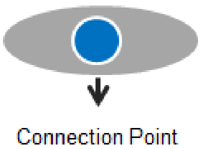
5.6.4 Power Generating Facility

- consists of one or more Power Generating Modules connected to a Network
- at one or more Connection Points.



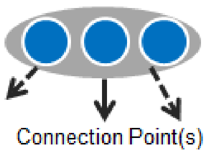
5.6.5 Demand Unit

- indivisible set of installations
- can be actively controlled by a Demand Facility Owner or DNO to moderate its electrical energy demand
- Possible Demand Units:
    - storage device within a Demand Facility or Closed Distribution Network operating in electricity consumption mode
    - A hydro pump-storage unit with both generating and pumping operation .
    - More than one unit within a Demand Facility, that cannot be operated independently from each other or considered in a combined way



5.6.6 Demand Facility

- connected at one or more Connection Points



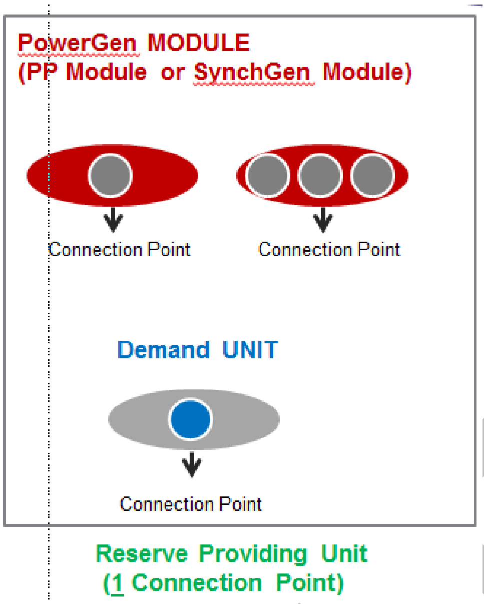
5.6.7 Demand Aggregation

- set of Demand Facilities which can be operated as a single facility for the purposes of offering one or more Demand Side Response services;

The terms of NC LFCR have been defined in accordance with NC RFG

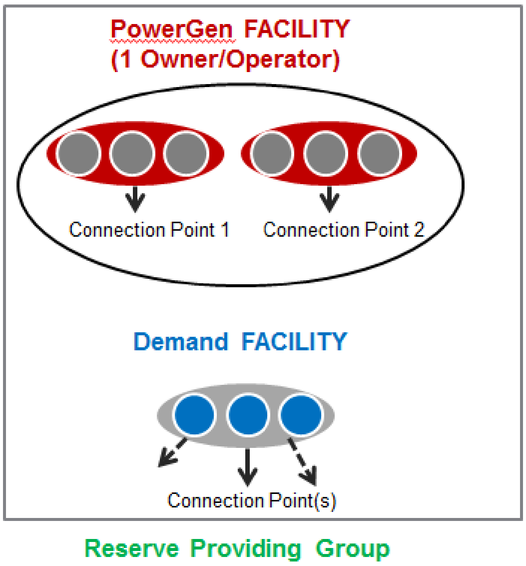
5.6.8 Reserve Providing Unit

A single Generating Unit or Demand Unit or an aggregation of Generating Units or Demand Units connected to a common Connection Point fulfilling the respective requirements for FCR, FRR or RR;

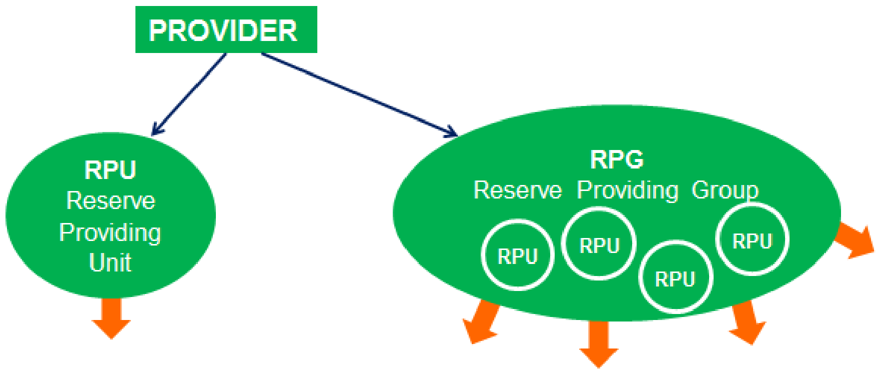


5.6.9 Reserve Providing Group

An aggregation of Reserve Providing Units connected to more than one Connection Point fulfilling the respective requirements for FCR, FRR or RR;

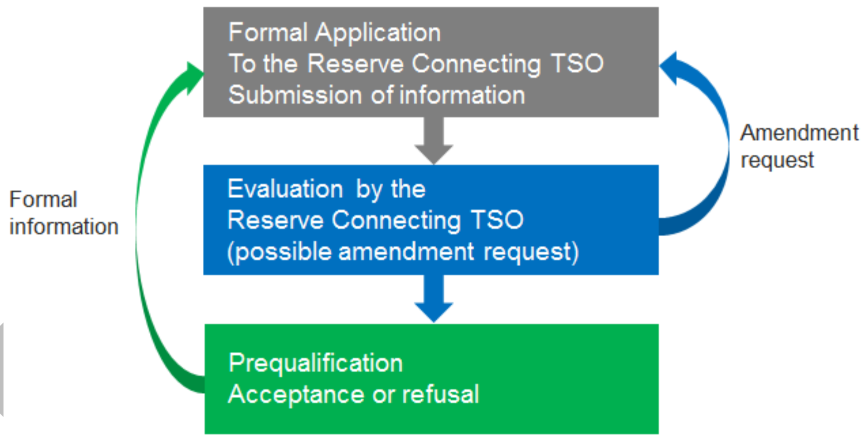


The Reserve Provider is an entity operating a Reserve Providing Unit (RPU) or a Reserve Providing Group (RPG)



A Reserve Providing Unit or a Reserve Providing Group needs to be prequalified to verify compliance with the respective requirements for FCR, FRR or RR. The Reserve Provider has to apply for prequalification at the Connecting TSO.

Thus, the Prequalification process has to be started by the potential Reserve Provider



The Reserve connecting TSO can request an amendment of the provided information in case the provided information was not complete or to get more detailed information in case it is needed for the evaluation.

5.6.10 Provider and Providing unit(s) in NC LFCR

For the readability and convenience of all parties that are interested in or can be considered as 'providers' as defined in the NC LFC&R, we compiled one list which contain all article numbers where the terms 'provider', 'providing unit' or 'providing group' appears.

Chapter 1 General Provisions

Article 1(1)

Definitions

Article 2

Confidentiality obligations

Article 6(1)

Chapter 6 Frequency Containment Reserves

Article 36(1)

Article 36(2)

Article 36(3)

Article 36(4)

Article 36(5)

Article 36(6)

Article 36(8)

FCR Provision

Article 37(4)

Article 37(5)

Article 37(6)

Chapter 7 Frequency Restoration Reserves

Article 39(1)

Article 39(2)

Article 39(3)

Article 39(4)

Article 39(5)

Article 39(6)

Article 39(7)

Article 39(8)

Chapter 8 Replacement Reserves

Article 41(1)

Article 41(2)

Article 41(3)

Article 41(4)

Article 41(5)

Article 41(6)

Article 41(7)

Article 41(8)

Chapter 9 Exchange and sharing of reserves

Article 42(8)

Article 45(1)

Article 45(2)

Article 45(3)

Article 45(4)

Article 45(5)

Article 45(6)

Article 45(7)

Article 50(2)

Article 50(3)

Article 50(7)

Article 53(1)

Article 53(2)

Article 53(3)

Article 54(4)

Article 55(4)

Article 56(4)

Article 57(4)

Chapter 11 Co-operation with DNOs

Article 60(2)

Article 60(3)

Article 60(4)

Article 60(5)

Chapter 12 Transparancy of Information

Article 66(3)

Chapter 13 Final Provisions

Article 70

Article 71

5.7 Exchange and Sharing of Reserves

5.7.1 Scope

The chapter on the exchange and sharing of reserves sets the technical framework allowing the development of a sustainable and efficient cooperation between TSOs of the same and/or different Synchronous Areas in performing Load-Frequency Control and ensuring the provision of reserves. The aim 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.

The NC LFCR identifies four main types of cooperation, being:

- Exchange of reserves
- Sharing of reserves
- Cross-border activation process of FRR and RR for optimization purposes
- Imbalance Netting Process

The paragraphs below explain the different kinds of cross-border co-operations:

<u>Exchange and sharing of reserves:</u>

The exchange and sharing of reserves aim to optimize the provision of the required amount of reserves capacity (in [MW]) resulting from the reserves dimensioning processes.

- The exchange of reserves allows the TSO(s) of Area A to place part of their reserves (FCR, FRR or RR) within the Area B of other TSO(s) in order to ensure the provision of the required amount of reserves resulting from the reserve dimensioning process. The exchange of reserves changes the geographical distribution of reserves without changing the total amount of reserves in the system.

Figure 28 illustrates the exchange of 100 MW of FRR from Area B to Area A. Suppose that the FRR Dimensioning rules for Area A and Area B result in the need of 500 MW FRR for Area A and 600 MW for Area B. Without the exchange of reserves the TSOs of Area A and Area B have to ensure the provision of 500 MW and 600 MW of FRR within their respective Areas.

As a result of the exchange of 100 MW of FRR from Area B to Area A, 100 MW of FRR of Area B is now located within Area A, whereas Area A still ensures in addition the provision of its full FRR in Area A. Although the geographical distribution of the FRR changed, the total amount of FRR within Area A and B is still 1100 MW, which is the same as before the exchange.

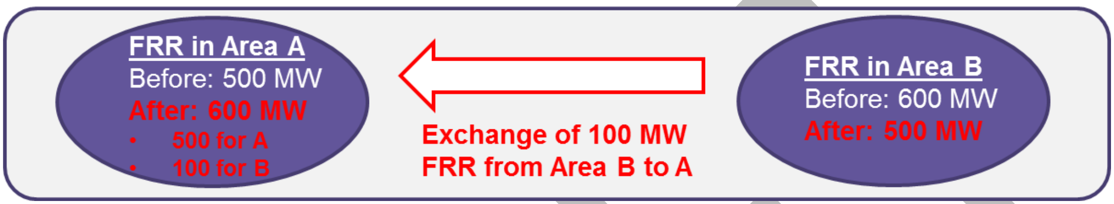


Figure 28: Exchange of 100 MW of FRR from Area A to Area B.

- The sharing of reserves allows the TSO(s) of an Area A and the TSOs of an Area B to rely on the same reserves (FCR, FRR and RR) in order to ensure the provision of the required amount of reserves resulting from the reserve dimensioning process. The sharing of reserves changes the total amount of reserves in the system, thereby also impacting the geographical distribution.

Figure 29 illustrates the sharing of 100 MW of FRR between the TSOs of Area A and the TSOs of Area B. Suppose that the FRR Dimensioning rules for Area A and Area B result in the need of 500 MW FRR for Area A and 600 MW for Area B. Without the exchange of reserves the TSOs of Area A and Area B have to ensure the provision of 500 MW and 600 MW of FRR within their respective Areas.

However, as in some cases it might be very unlikely that both TSOs need to activate the full amount of FRR at the same time, the TSOs of Area A and Area B can 'share' part of their FRR. In practice this means that the TSOs of Area B can make use of e.g. 100 MW of FRR of the TSOs in Area A and vice versa. As a result the TSOs of Area A and Area B now need to ensure the provision of 400 MW and 500 MW of FRR in their respective Areas. The TSOs of both Areas now make 100 MW of their own FRR also available to the TSOs of Area B. The total amount of FRR within the system is now 900 MW, whereas it was 1100 MW without the sharing agreement.

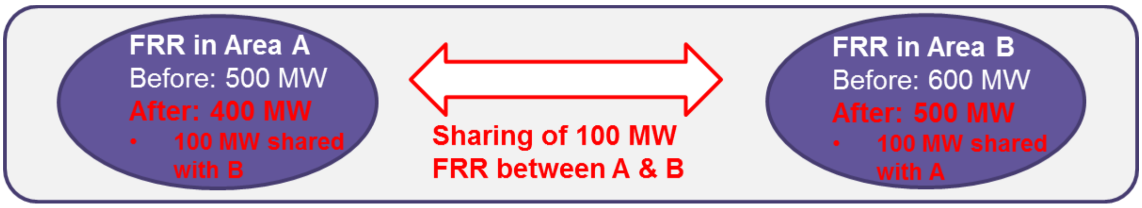


Figure 29: Sharing of 100 MW of FRR between Area A and Area B

A geographically even distribution of reserves and a sufficient amount of reserve capacity ([MW]) in the system are key requisites for ensuring Operational Security. As the exchange of reserves impacts the geographical distribution of the reserves 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 secure Operational Security. These are treated further on in this supporting document.

Imbalance Netting Process and Cross-Border Activation Process of FRR and RR for Optimization purposes:

The cross-border activation process of FRR and RR for optimization purposes and the imbalance netting process aim to optimize the activation of reserves (energy in [MWh]) without impacting the provision of reserves (capacity in [MW])[3].

- The Imbalance Netting Process aims to avoid the counteracting activation of FRR within different LFC Areas thereby reducing the activated control energy (in MWh). As the Imbalance Netting Process is already discussed in the chapter on the Load-Frequency Control Structure and is not considered in this chapter.

- The Cross-Border Activation Process of FRR and RR For Optimization Purposes is introduced in order to allow the TSOs to activate the most efficient reserve resources in the system, regardless of their geographical location and subject to available transmission capacity to accommodate the resulting fluxes. This process is also referred to as a Common Merit Order list for the activation of reserves. As this process deals with the activation of reserves [MWh] only, it is not related to the exchange or sharing of reserves which are related to reserve capacity [MW].

  Figure 30 gives an example of the cross-border activation of FRR for optimization purposes. Suppose that the FRR Dimensioning rules for Area A and Area B result in the need of 500 MW FRR for Area A and 600 MW for Area B. Area A and Area B therefore have to ensure the provision of 500 MW and 600 MW of FRR within their respective Areas. The TSOs of Area B now have to activate 100 MW of FRR in response to an imbalance of 100 MW within their Area. The cost for activating 100 MW of FRR within Area B is 90 €/MWh, whereas the cost of activating 100 MW of FRR in Area A would be only 60 €/MWh. Using the common merit order Area B will then activate the cheaper 100 MW in Area A instead of the more expensive 100 MW located in Area B.

[3] As the dimensioning of FRR and RR are based on historical imbalances of the LFC Block, the imbalance netting between different LFC Areas of the LFC Blocks is taken implicitly into account in the FRR and RR Dimensioning Process and therefore impacts the required amount of FRR and RR. The imbalance netting between different LFC Blocks however does not impact the required amount of reserves within the involved LFC Blocks.

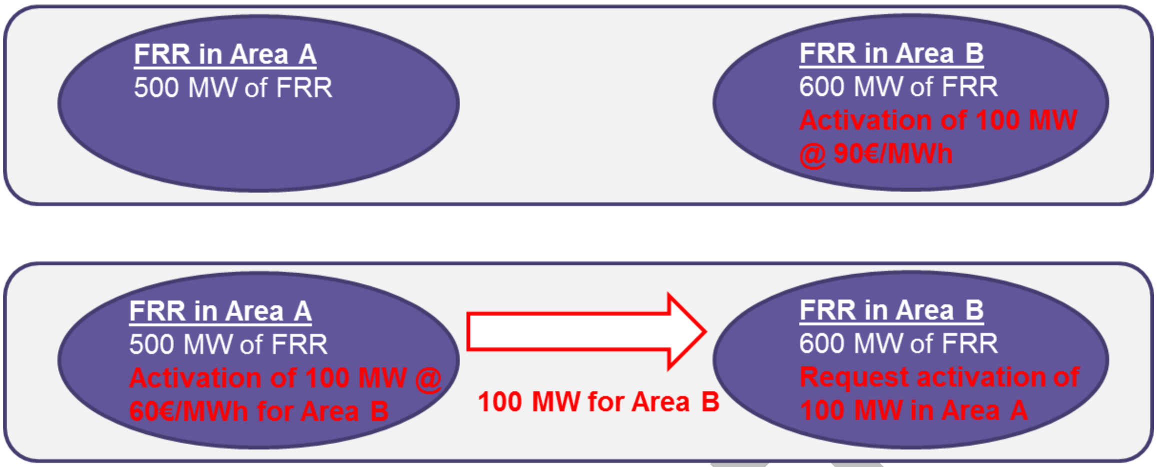


Figure 30: Cross-border activation of 100 MW of FRR for optimization purposes

The NC LFCR sets technical limits for the Imbalance Netting Process and the Cross-Border Activation Process of FRR and RR for Optimization Purposes as to ensure Operational Security. It is however in the scope of the Network Code on Electricity Balancing to define the market arrangements to develop these processes within the technical limits set by the NC LFCR.

Cross-border transmission capacity:

It is important to note that sufficient cross-border transmission capacity must be available to accommodate the cross-border flows resulting from the activation of reserves in case of a cross-border cooperation (exchange and sharing of reserves, imbalance netting, …). The NC LFCR sets forth the technical requirements for cross-border transmission capacity (e.g. amount of capacity required, its availability etc.), whereas the Network Code on Electricity Balancing shall deal with the market aspects (e.g. reservation of capacity, …).

The next paragraphs give further details on the requirements and limits for the exchange and sharing of reserves and on the cross-border activation process of FRR and RR for optimization purposes.

5.7.2 Exchange of reserves

The Network Code 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 ensure the provision of this required amount of reserves, TSOs can also rely on reserve providers located within the Area of another TSO. This is called the exchange of reserves. The reason for this can be either

- technical, e.g. in case of insufficient reserves within the Area of a TSO ;
- economical, e.g. in case that the provision of reserves within the Area of another TSO is economically more efficient.

An even distribution of 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 this Network Code. The even distribution of reserves ensures that reserves are more or less located near the location where imbalances originate 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;
- minimizes the risk in case that transmission capacity is unavailable, e.g. due to congestions.

The NC LFCR sets forth 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, as well as the technical requirements for the exchange of reserves are covered in the NC LFCR.

<u>Exchange of FCR within a Synchronous Area:</u>

The Initial FCR Distribution ensures the even distribution of FCR within the Synchronous Area. Furthermore the FCR chapter provides limits for the maximum amount of FCR located on a single unit or electrical node, thereby ensuring an even distribution of FCR within the area of the TSO.

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

- the flows arising from the activation of exchanged FCR can be managed;
- that sufficient FCR is available in the different grid areas in case of network splitting;
- issues of rotor angle stability shall not occur upon activation of the FCR.

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 re-distribution of FCR are set on different types of areas, constituting the Synchronous Area:

- For the Synchronous Area of Continental Europe: the limits are set on the level of LFC Areas and LFC Blocks; and
- For the Synchronous Areas of Northern Europes: limits for the internal distribution are fixed in a multi-party agreement

As the other Synchronous Areas only consist of a single TSO, there is no exchange of FCR Obligation within the Synchronous Area. The requirements and limits for the exchange of FCR Obligation between Synchronous Areas are explained further in this document.

The exchange of FCR Obligation is limited to adjacent LFC Blocks (SA CE) and subject to a multi-party agreement in the Northern Europes in order to ensure that the exchanged FCR remains locally available and to avoid the large scale shift of FCR from one side of the Synchronous Area to the other side which can cause issues of rotor angle stability or issues in case of network splitting.

The amount of FCR Obligation that the TSOs of an LFC Block (SA CE) can fulfil for neighbouring LFC Blocks is limited to 30% of the Initial FCR Obligation of the LFC Block. This avoids local concentration of FCR in a single LFC Block, which would be problematic in case of network splitting and might cause issues of rotor angle stability. As to enable small LFC Blocks to participate in the exchange of FCR, each LFC Block is allowed to fulfil at least 100 MW of FCR Obligation for its neighbouring LFC Blocks.

Each LFC Block (SA CE) must keep 30% of its Initial FCR Obligation located within its own Area as to ensure the availability of a minimum amount of FCR within the LFC Block in case of network splitting. This rule is only applicable for the SA CE due to its large size.

Figure 31 gives an example for the application of the limits for the exchange of FCR within the Synchronous Area. Simulations show that these limits for the exchange of FCR obligation ensure the even distribution of FCR throughout the Synchronous Area.

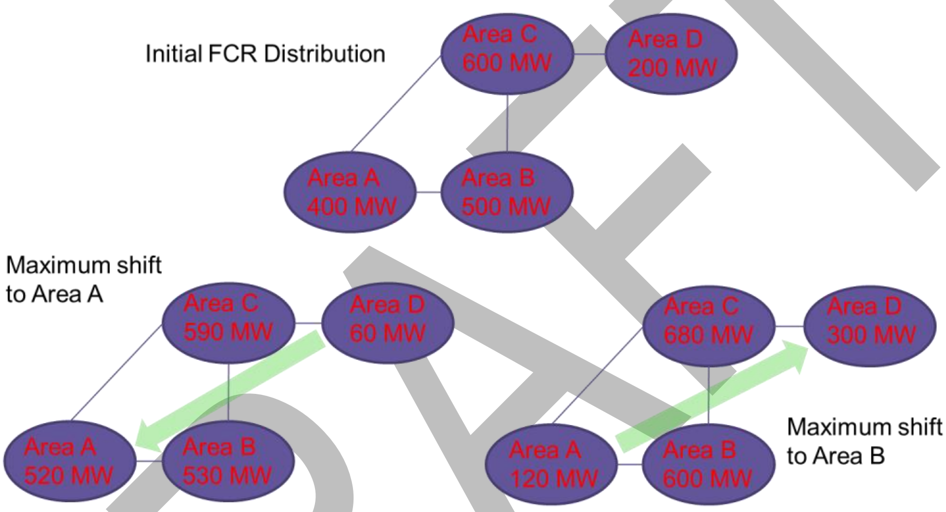


Figure 31: Exchange of FCR within the Synchronous Area (Continental Europe)

The Real-Time 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 re-distribution of FCR therefore changes the flows resulting from its activation throughout the entire Synchronous Area and therefore impacts the Real-Time Reliability Margin. Depending on the new distribution of the FCR, the Real-Time Reliability Margin of some Areas can increase or decrease. The NC LFCR sets requirements for the TSOs to adjust the RT RM, if required, in case of the exchange of FCR Obligation.

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 the exchange of the 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 activation and the monitoring of the exchanged FCR. Therefore the exchange of FCR is always performed according to the technical TSO – TSO model.

The market arrangement can be either TSO – BSP or TSO – TSO as this depends on whether:

- the Reserve Receiving TSO has an arrangement with the Reserve Connecting TSO for the exchanged FCR Obligation and the Reserve Connecting TSO ensures the provision of the exchanged FCR Obligation; or

- the Reserve Receiving TSO has an arrangement with the Reserve Connecting TSO for the exchange of FCR Obligation but ensures the provision of the exchanged FCR Obligation within the area of the Reserve Connecting TSO by itself.

In both cases the Reserve Connecting TSO becomes however technically responsible for the exchanged FCR (technical TSO-TSO model). A TSO is therefore technically responsible for all the FCR Providing Units and FCR Providing Groups physically located within its area. Furthermore an FCR Providing Unit or FCR Providing Groups can only have a responsibility for the activation of FCR with the TSO responsible for the area where it is located.

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 case the Reserve Connecting TSO(s) of the other Synchronous

Area are then responsible for the provision of this exchanged FCR Obligation, in addition to their own FCR Obligation within their Synchronous Area. An example of such an exchange is shown in Figure 32.

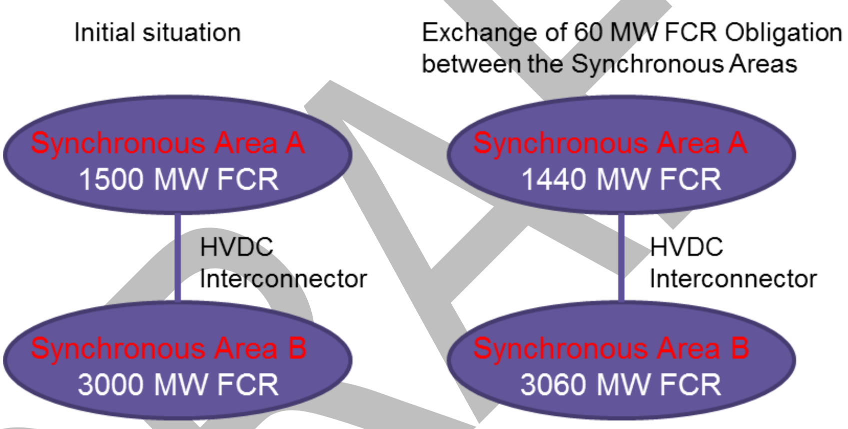


Figure 32: example of the exchange of 60 MW of FCR Obligation between Synchronous Areas A and B

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 Obligation between Synchronous Area as the exchanged FCR Obligation 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 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 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 multi-party agreement on a set of rules and minimum requirements for the exchange of FCR Obligation between Synchronous Areas.

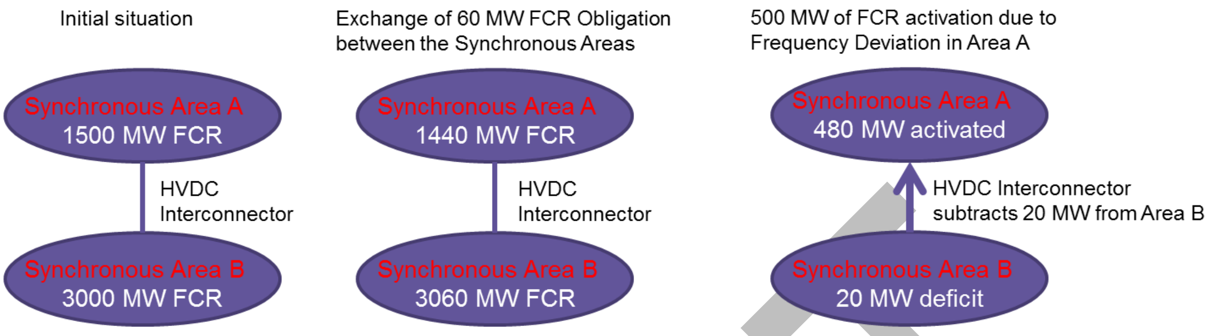


Figure 33: FCR activation in case of the exchange of FCR Obligation between Synchronous Areas

Figure 33 gives an example for the exchange of 60 MW of FCR Obligation between Synchronous Area A and B as indicated in Figure 32. Suppose that there occurs a sudden Frequency Deviation of -50 mHz in the Synchronous Area A requiring the activation of 500 MW of FCR (1/3 of the total FCR of Synchronous Area A) and no Frequency Deviation in Synchronous Area B. Due to the exchange of 60 MW of FCR Obligation, 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.

Furthermore such an exchange 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 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 TSOs shall furthermore verify that the amount of exchanged FCR Obligation delivered per HVDC Bi-pole shall not exceed the maximum amount of FCR delivered by a single FCR Providing Unit or electrical node as agreed within the Synchronous Area.

Exchange of FRR and/or 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 the provision of this amount of FRR and RR and to perform the FRP and Replacement Process for their LFC Block.

An even distribution of FRR/RR in the Synchronous Area is crucial to ensure Operational Security as it ensures that:

- A sufficient amount of FRR/RR to be available to all TSOs in case of Network Splitting; and
- Allows the LFC Blocks of the Synchronous Area to operate more or less in an independent way (in case of communication or IT-issues,…); and
- Reduces the risk of having insufficient FRR/RR available in case of sudden issues of congestions in the network.

The initial dimensioning of FRR/RR on the level of the LFC Blocks ensures 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 allows a further optimization 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 and must therefore be limited.

The exchange of FRR/RR within a Synchronous Area only applies to the Synchronous Area of Continental Europe as it is the only Synchronous Area consisting of more than one LFC Block. The dimensioning rules for FRR/RR ensure the even distribution of FRR/RR within the LFC Blocks.

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. This amount of FRR/RR would allow 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 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 e.g. internal congestions in the LFC Block.

As for the exchange of FCR, the exchange of FRR/RR is also subject to a notification procedure and approval by the Affected TSOs.

Both a technical TSO – TSO as a TSO – BSP model are allowed for the exchange of FRR/RR between LFC Blocks of the Synchronous Area. This means that either the Reserve Connecting or Reserve Receiving TSO can be responsible for the activation (imperfections) and monitoring of the exchanged FRR.

In case of a common merit order list for FRR and/or RR, the technical TSO – TSO model is considered to be superior to the technical TSO – BSP model. In anticipation of the implementation of such a single common merit order list and in order not to forbid currently implemented technical TSO – BSP arrangements throughout Europe, the technical TSO – BSP model is also allowed. Furthermore the TSO – BSP model facilitates the cross-border cooperation between TSOs with a different market design or reserve products.

The FRR/RR Providing Units or Groups can only have obligations for the activation of FRR/RR with one and only one TSO. This is required to allow the unambiguous monitoring of the performance of the FRR/RR Providers.

The exchange of FRR requires that transmission capacity is available to transport the energy resulting from activation of the exchanged FRR to the area of the Reserve Receiving TSO. The Reserve Connecting and Reserve Receiving TSO have to agree on who is responsible for securing and ensuring before real-time that sufficient transmission capacity is available for the exchange of FRR/RR.

Exchange of FRR and/or RR between Synchronous Areas:

The rules and limits for the exchange of FRR and/or RR between LFC Blocks of different Synchronous Areas are identical to the rules of exchange of FRR and/or RR between LFC Blocks of the same Synchronous Area.

The operators of the HVDC Interconnectors shall operate the HVDC Interconnector in such a way that the activated FRR and/or RR are transported from the Reserve Connecting TSO to the Reserve Receiving TSO.

5.7.3 Sharing of reserves

The dimensioning procedures for FCR/FRR/RR result in a certain amount of FCR/FRR/RR capacity to be provided by each TSO. However, as demonstrated in paragraph 5.7.1, in some cases it is very

unlikely that a couple of TSOs would need to activate their full amount of either FCR/FRR/RR at the same time, which results in a potential to reduce the amount of FCR/FRR/RR to be provided by these TSOs and to make common use of part of the reserves. This is called the '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. Sharing therefore introduces a risk in the system in case the involved TSOs would need to have access at the reserves made available for common use. Limits for the sharing of reserves are therefore required to ensure Operational Security.

In case of sharing of reserves it is always the Reserve Connecting TSO that has priority access to the reserves made available for common use. This is because the Reserve Connecting TSO ensured the provision of this amount of reserves. In case the Reserve Receiving TSO wouldn't have access to the reserves made available for common use, he shall have to take other measures in order to fulfil its responsibilities in terms of the FCP/FRP/RP towards the other TSOs of the Synchronous Areas.

The sharing of reserves is always according to a technical and economical TSO – TSO model as TSOs make available part of their own reserves to other TSOs.

This chapter focuses further on the roles and responsibilities of the TSOs involved in the sharing of FRR and lays down the technical requirements for the sharing of FRR.

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 shared -implicitly- amongst the TSOs of the Synchronous Area. Therefore no further sharing of FCR within the Synchronous Area can be considered, as this would lead to a total amount of FCR being less than the required amount of FCR for the Synchronous Area.

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.

The sharing of FCR between TSOs of different Synchronous Areas, and the resulting reduction of FCR within the total system, is not allowed since it would introduce a dependency between the Synchronous Areas in terms of Frequency Containment.

The sharing of FCR between Synchronous Areas is only allowed between the Synchronous Areas of Great Britain and Ireland due to the specific situation of a nearby small and relatively large Synchronous Area.

The sharing of FCR between different Synchronous Areas might however be further considered in the future, but will be linked most likely with a common FCR Dimensioning.

Sharing of FRR within a Synchronous Area:

The sharing of FRR within a Synchronous Area allows small LFC Blocks, needing a relatively high amount of FRR to cover their Dimensioning Incident compared to the FRR required to cover other imbalances, to reduce their FRR capacity by cooperation 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 more than one TSO would need to access the reserves 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 provision of 99% of their required FRR resulting from the FRR Dimensioning Process. This ensures that in 99% of the time the TSOs of the LFC Block have sufficient FRR available without having to access the FRR made available for common use; and
- Only TSOs of an LFC Block for which the FRR required to cover the Dimensioning Incident (positive and negative) exceeds the amount of FRR required to cover 99% of the historical (positive and negative) imbalances are allowed to reduce their FRR capacity. 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 wouldn't work out.

Figure 34 and Figure 35 give an example of the application of the sharing rules for two different LFC Blocks.

- In Figure 34 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 Process with 200 MW by concluding sharing agreements with other LFC Blocks.
- In Figure 35 the LFC Block cannot reduce its FRR by concluding sharing agreements with other TSOs. This is due to the fact that the TSOs of this LFC Block need an amount of FRR, 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.

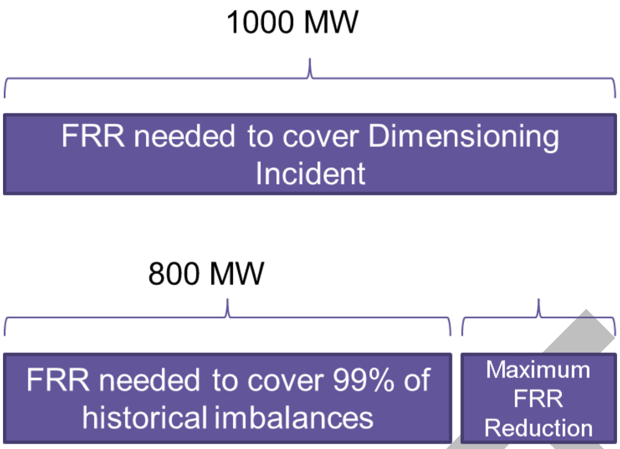


Figure 34: Calculation of maximum FRR reduction by the sharing of FRR within a Synchronous Area

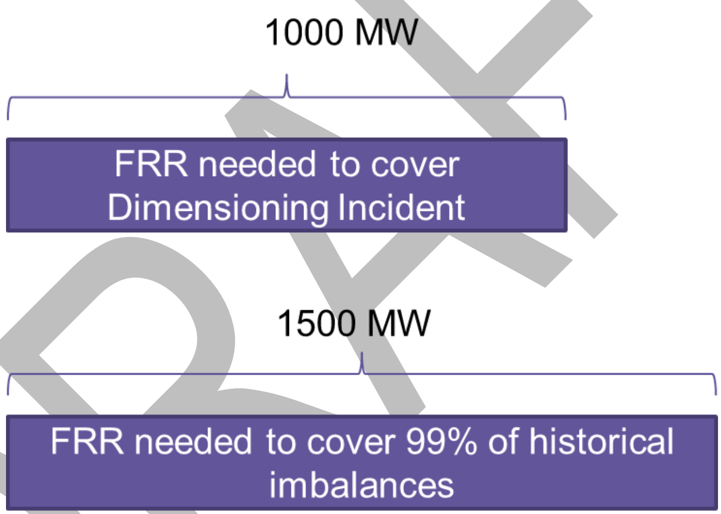


Figure 35: Calculation of maximum FRR reduction by the sharing of FRR within a Synchronous Area

The Reserve Receiving TSO shall only activate the 'shared' FRR in other LFC Blocks in case sufficient transmission capacity is available.

In case two LFC Areas of a Synchronous Area would like to further optimize their total amount of FRR they can perform a common FRR Dimensioning by forming a LFC Block. The common dimensioning of FRR ensures that there is no risk to have insufficient FRR, which cannot be guaranteed in case of simple sharing of FRR without common dimensioning.

Sharing of FRR between Synchronous Areas:

The limits and requirements set for the sharing of FRR between LFC Blocks of different Synchronous Areas are identical to the limits and requirements for the sharing of FRR between LFC Blocks within a Synchronous Area.

Sharing of RR within a Synchronous Area:

The limits for the sharing of RR are less strict that those for the sharing of FRR as the longer activation delay of RR compared to FRR gives more reaction time to the TSOs to elaborate alternative solutions in case the sharing wouldn't work out.

The TSOs of different LFC Blocks of the same Synchronous Area are allowed to share part of their RR in case they are able to verify that the risk of needing simultaneous access to the common RR is very unlikely.

Sharing of RR between Synchronous Areas:

The limits and requirements set for the sharing of FRR between LFC Blocks of different Synchronous Areas are identical to the limits and requirements for the sharing of FRR between LFC Blocks within a Synchronous Area.

5.7.4 Cross-border activation of reserves for optimization purposes

In addition to the provision of reserves, TSOs are allowed to cooperate in order to optimize the efficiency of the activation of FRR and RR (cost for activated energy [€/MWh]). This chapter lays down the technical limits and requirements for this process in order to ensure operational security and to enable the TSOs to perform their tasks according to the requirements within this Network Code. The market arrangements shall be further elaborated by the Network Code on Electricity Balancing (principles for the development of a common merit order list for the activation of FRR/RR).

5.8 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 the time etalon. 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 50Hz, the voltage time period represents 1 / 50 = 0.02s = 20ms.

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. The TSO members of same Synchronous Area shall use best endeavours to maintain this difference between the agreed limits.

5.8.1 Causes for electrical time deviations

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 cascaded integral processes (FRR). Even in normal operation, the total process of Active Power has an integral character which requires be controlled and adjusted for long time periods. Causes of frequency deviations are: tripping of units /consumers , electricity market rules using step schedules and larger time frame schedules (usually hourly frame), load behaviour (load is a continuous process and generation has a step scheduling), real time load – frequency control based on different units ramp rates.

Due to these causes, the instantaneous system frequency has to be modified appropriately, to bring the average system frequency and thus the electrical time, back to its corresponding UTC value.

5.8.2 Need for time control

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.

However, this service is often called into question. Costs and advantages are still being estimated in many electrical systems.

5.8.3 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 set-point 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 50Hz as nominal frequency = 0,01Hz (Continental Europe)
- ±0.033% for system with 60Hz as nominal frequency = 0,02Hz (NERC)

- Correction duration:
  - 1 day - Continental Europe
  - 1/4h – GB, NERC
- Allowed range:
  - [-30s;+30s] - Continental Europe, NE
  - [-10s;+10s] – GB, East NA
  - [-2s;+2s] - West NA
  - [-3s;+3s] - West NA
- Range of started correction actions:
  - [-20s;+20s] - Continental Europe
  - [-15s;+15s] – NE

In the synchronous area of Continental Europe, the deviation between electrical time and UTC (based on International Atomic Time) is calculated at 08:00 each day in a 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 sec × 60 min × 24 hours = 4,320,000 voltage cycles per day.

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

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

That justifies the adopted range of 20 seconds as the range to start the corrective actions inside the Continental Europe 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 0.02Hz during 1/2 hour is:

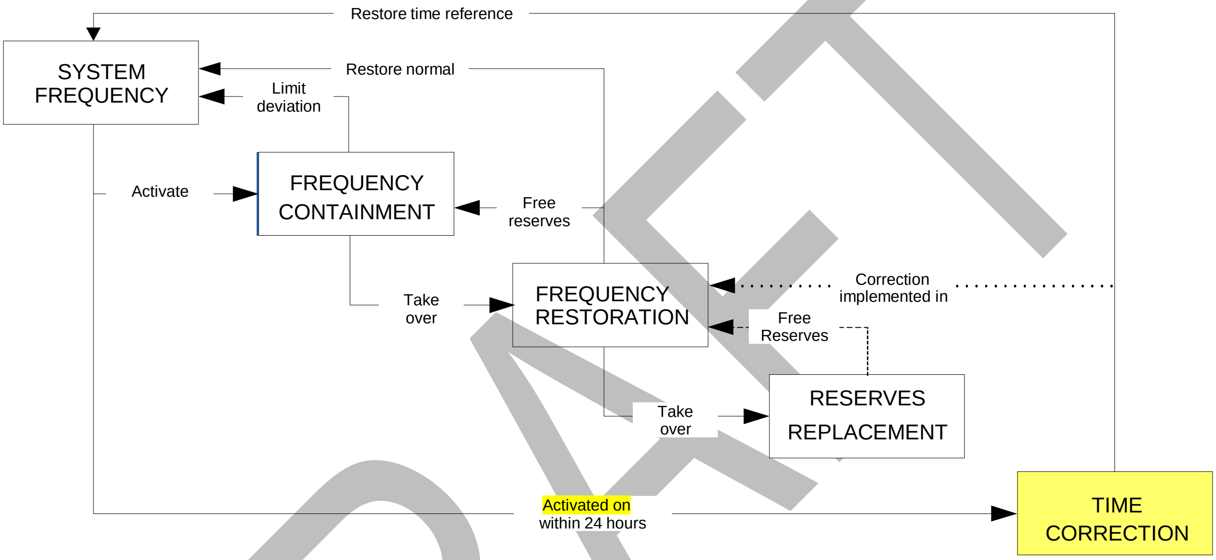
0.02 Hz / 60 Hz *30*60s = 0.6 seconds

5.8.4 Current approach in Continental Europe

The Active Power control in the interconnected networks is progressively controlled in four steps, the FCR control, the FRR control, the RR control and the electrical time control. The objective of the last one is to monitor and to limit discrepancies observed between the synchronous time and the Universal Coordinated Time (UTC) within the synchronous area of the Continental Europe.

The hierarchy of frequency control structure, including electrical time control is present in following figure:

Figure 36: Control Processes from the UCTE Operation Handbook



The Operational Handbook defines three levels of electrical time deviation from UTC (Discrepancy):

Tolerated Range of Discrepancy: a range of ±20 seconds in which there is no need for time control actions.

Target Range of Discrepancy: a range of ±30 seconds under normal conditions in case of normal operation of the interconnected network.

Exceptional Range of Discrepancy defined under exceptional conditions: In case of normal operation of the interconnected network the discrepancy between electrical time and UTC is within a range of ±60 seconds.

The electrical time control in Continental Europe consists on the adjustment the set-point frequency for automatic FRR controllers. The Synchronous Area Monitor must ensure that the mean value of the system frequency is close to the nominal frequency value of 50 Hz and the electrical time deviation within the target range.

The time deviation between synchronous time and UCT is calculated for 8 a.m. each day by the Synchronous Area Monitor – a central instance that monitors continuously the deviation. If the time deviation is within tolerated range, the frequency offset for time correction has to be set to zero. If the deviation is out of tolerated range and electrical time is behind UTC, the frequency offset has to be set to +10 mHz. If the deviation is out of tolerated range and electrical time is ahead of UTC, the frequency offset has to be set to –10 mHz. This offset is determined by the time monitor.

The frequency offset will be added to the nominal frequency 50 Hz in all FRR controllers of the Synchronous Area (Continental Europe) and the time correction is valid for all hours of the next day, starting at 0 a.m.

The information for the time correction has to be forwarded towards all LFC areas / Blocks of the Synchronous Area every day at 10 a.m. by the time monitor. The LFC areas / Blocks themselves forward this information towards their underlying LFC areas without delay.

The quality of system frequency can be evaluated as deviation of electrical time from UTC during a time interval. In Continental Europe the Operational Handbook specifies that the frequency control is satisfactory over a one month period where the number of days' operation at a set point frequency of 49.99 Hz or 50.01 Hz does not exceed eight days per month respectively.

5.8.5 Current approach in Grid Codes of NE, GB, Ireland

The Northern Europe Grid Code specifies that the time deviation is used as a tool for ensuring that the average value of the frequency is 50.00 Hz.

The time deviation shall be held within the time range of - 30 to + 30 seconds. At ΔT = 15 seconds, Statnett and Svenska Kraftnat shall contact each other in order to plan further action.

The frequency target has a higher priority than the time deviation and the costs of frequency regulation. The time deviation shall be corrected during quiet periods with high frequency response and with a moderate frequency deviation.

5.9 Co-operation with DNO

The basic concept for the co-operation with DNO is the "Reserve Connecting DNO", which is defined as "the DNO responsible for the grid to which a Reserve Providing Unit or Reserve Providing Group is connected to providing reserves to a TSO".

The Reserve Connecting DNO has the right to check, if the provision of reserves is admissible from the point of view of system security in the DNO grid. For this purpose the Reserve Provider has to ask the Reserve Connecting DNO for permission before offering reserves to the TSO. The Reserve Connecting DNO has the right to object or to limit the reserve provision if necessary from a system security point of view. The idea is that the DNO gives a general permission for the reserve provision. Thus the DNO shall check different operational scenarios for the permission. Since this general permission can obviously not be given for an unlimited period of time the DNO has the right to reassess the permission on an annual basis. This is an important opportunity to take into account grid developments.

The TSO is by purpose not involved in the relationship between the DNO and the Reserve Provider. The idea is that the Reserve Provider receives a kind of permission document from the Reserve Connecting DNO and sends it to the TSO as a prerequisite to provide Reserves. It is the full DNO responsibility to give the permission for the reserve provision. In case a DNO objects or limits the reserve provision the NRAs may be involved for the sake of dispute resolution between the Reserve Provider and the Reserve Connecting DNO.

For the activation of reserves there will be no interference between the TSO and the Reserve Connecting DNO; the reserves are activated directly by the TSO. For this reason it is very important for the Reserve Connecting DNO to perform the security checks mentioned above carefully before the permission of reserve provision. Additionally the Reserve Connecting DNO has the right to request information from the Reserve Provider needed to perform a proper system operation planning and system operation of the DNO grid.

In critical situations the Reserve Connection DNO may – as any System Operator – apply remedial actions and eventually stop reserve provision if needed. Such cases will be taken into account in the reserve provision contracts and are not part of the NC.

6 Explanation of different approaches in Synchronous Areas

6.1 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 50Hz. 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 andthe “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.

6.1.1 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 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.

6.1.2 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, 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 +/- 200mHz. 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.

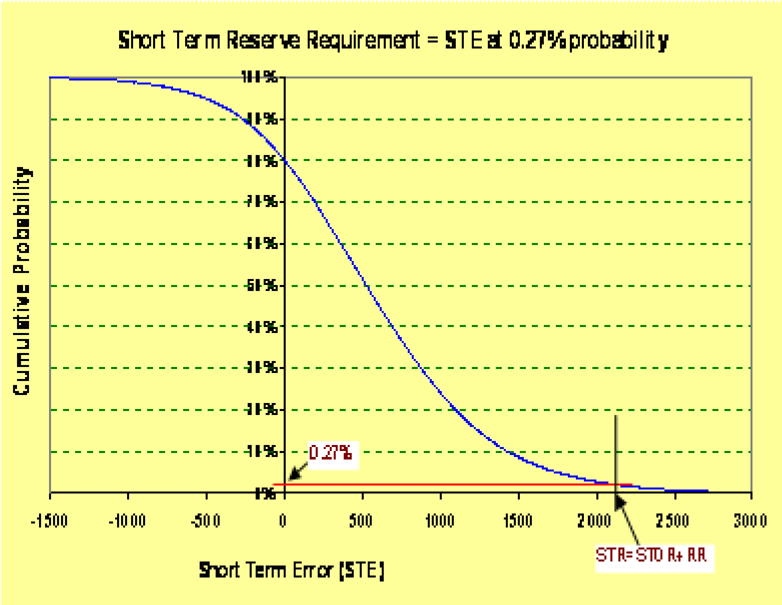


Figure 37:Short term reserve requirement probability for GB

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

6.1.3 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.

6.1.4 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

6.1.5 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.

6.1.6 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.

6.2 IRELAND SYNCHRONOUS AREA

From the perspective of load – frequency control and reserves the island of Ireland constitutes a single Synchronous Area, a single Load Frequency Control Block and a single Load Frequency Control Area. 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 10MW (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.

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 make 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 consideration should be given to resetting the target frequency as appropriate.

6.3 NORTHERN EUROPE SYNCHRONOUS AREA.

6.3.1 Introduction

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.

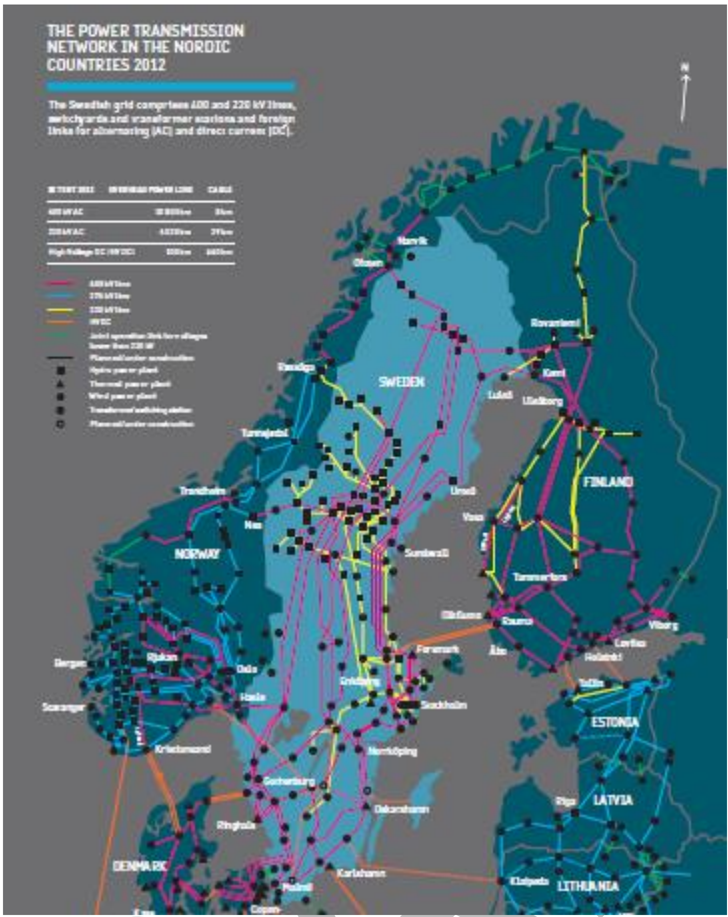


Figure 38: Northern Europe Transmission System

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 50Hz. 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) 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.

6.3.2 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 exceed. In the code this is referred to as the maximum steady state frequency deviation.

6.3.3 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, 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 10MW 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 +/- 100mHz 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.

6.3.4 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.

6.3.5 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.

6.4 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 Control Areas and Control Blocks. The goal is to keep the frequency as close as possible to the nominal value, which is 50Hz and to keep the Control Areas and Control Blocks balanced by keeping the power exchange values between them to their scheduled values.

The Synchronous Area of CE consists of multiple interconnected Control Blocks, each of them with centralised control. Each Control Block may divide up into sub-control 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:

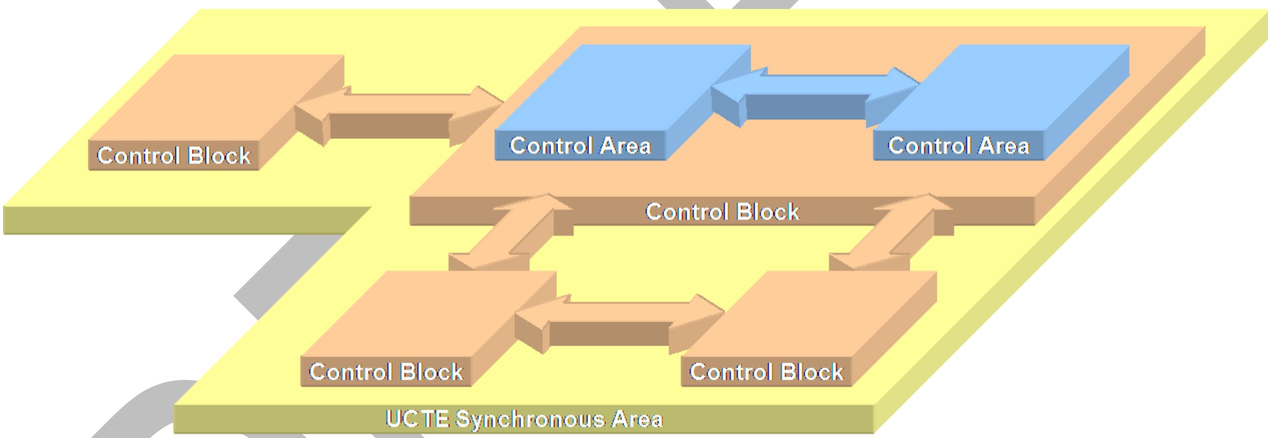


Figure 39: Hierarchy of the decentralized control in CE

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 Control Area or Control 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 Control Area or Control 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.

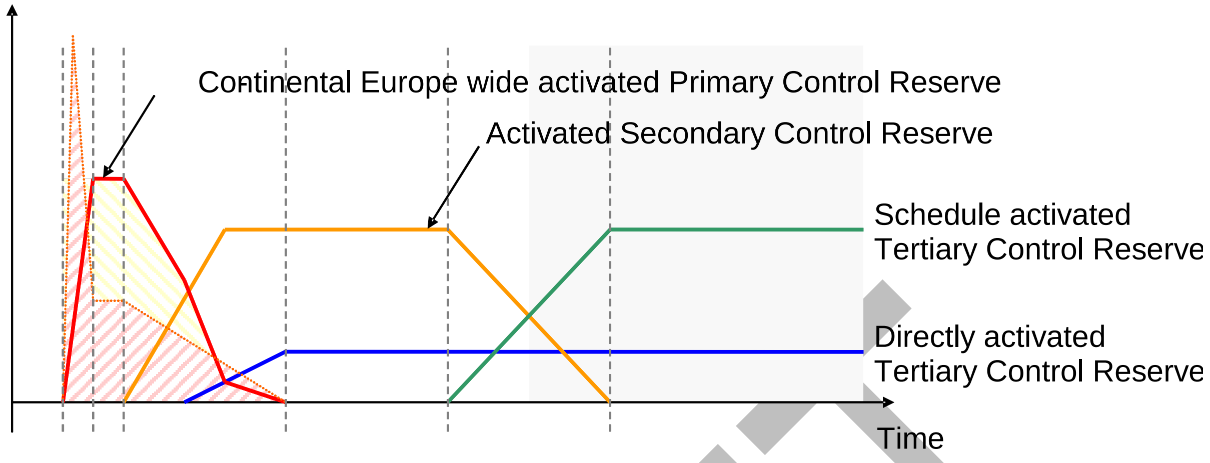


Figure 40: Principle frequency deviation and subsequent activation of reserves in CE

6.4.1 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 Control Block must contribute to the correction of an imbalance with the providers of this service with obligations to the Control Block. The overall primary reserve of the whole Synchronous Area is shared between Control Blocks in accordance with their respective contribution coefficient to primary control. These contribution coefficients are calculated on a yearly basis for each Control Block taking into account the electricity generated in the Control 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 Control Blocks are defined by multiplying the determined total primary control reserve for CE and the contribution coefficients of the Control Block.

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

The primary control reserve of each Control 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 s. 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.

6.4.2 Frequency Restoration Reserves: 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 Control Block and, consequently, to keep or to restore the System

Frequency to its set-point value of 50 Hz and the power interchanges with adjacent control 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 Control Blocks provide mutual support by the supply of primary control power during the primary control process, only the Control Block affected by a power unbalance is required to undertake secondary control action for its correction. Consequently, only the controller of the Control Block in which the imbalance between generation and consumption has occurred will activate the corresponding secondary control power within its Control Block. Parameters for the secondary controllers of all Control 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 Control Block, in order to maintain this balance, generation 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 Control Block. A secondary controller computes power set-point values of selected Providing Units for control and the transmission of these set-point 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 Control Block. If a Control Block has more than one internal Control Areas, the Control Block organises the internal secondary control.

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

6.4.3 Frequency Restoration Reserves and Replacement Reserves: Tertiary Control

Tertiary control is any automatic or manual change in the working points of generations or loads participating, in order to guarantee the provision of an adequate secondary control reserve at the right time and distribute the secondary control power to the various generations in the best possible way, in terms of economic considerations.

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.

6.4.4 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 set-point frequency for secondary control in each Control Block and Control 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).

6.4.5 Hourly ramps of scheduled programs

The algebraic sum of the agreed hourly exchange programs of cross-border exchange transfers between Control Blocks and Control Areas and the adjacent Control Blocks or Control 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).

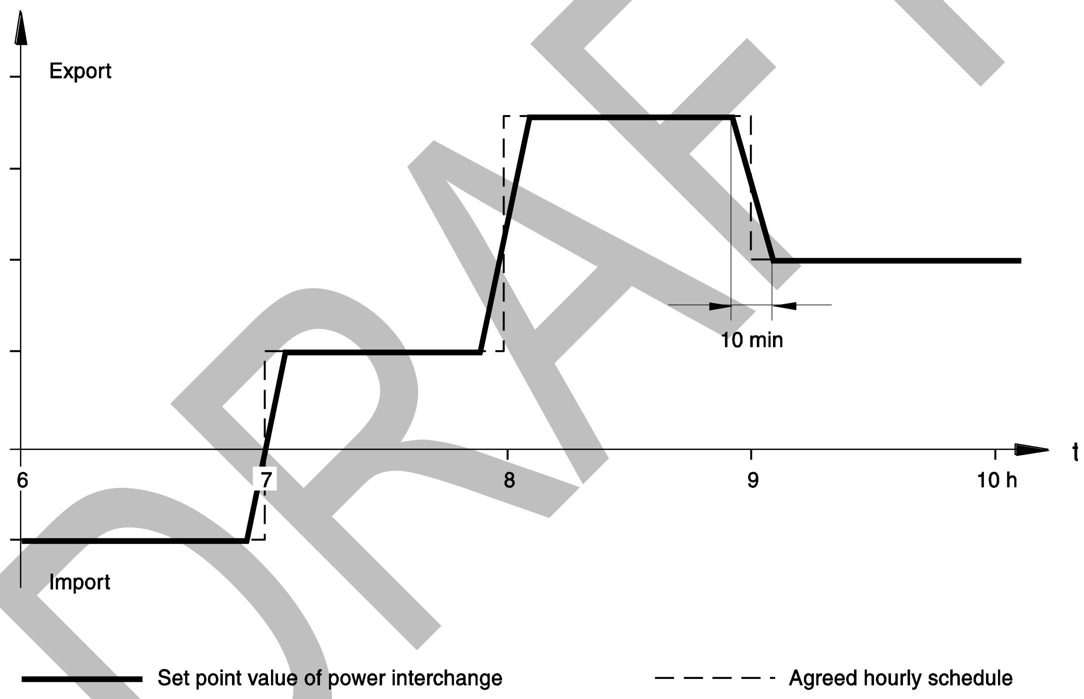


Figure 41: Example of ramping between Control Blocks in CE

6.4.6 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.

7 ADDED VALUE OF THE NC LFCR

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 [1] has been carried out. The analytic approach taken for drafting the NC LFCR resulted in the current code structure. Reaching this point and by recognising 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 Load, Frequency Control and Reserves Network Code 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. The improved and common reporting methods drive greater transparency of actions at LFC Block as well as Synchronous Area level, making it easier to identify frequency quality problems at all scales.

Harmonisation and use of common language in 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.

The LFCR structure 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 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.

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 they serve, 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 be 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, with limiting the risks of failure and capacity constraints which become 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, shared or exchanged 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 Balancing Network Code 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 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, which prevent brittle solutions being developed 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 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.

CONCLUSIONS

A key goal of the NC LFCR is to achieve as much as possible 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.

8 Responses and Next Steps

8.1 Overview

This chapter provides information on how to respond to the consultation on the NC LFCR and provides an overview of the processes which ENTSO-E intends to follow in developing a final version of the NC LFCR for submission to ACER.

8.2 Public Consultation

A public consultation period was completed on 2nd April 2013. There were 1382 responses received.

8.3 Responding to Comments

ENTSO-E will endeavour to respond to comments raised by stakeholders, indicating how a comment has been taken into account or indicating the reasons for not doing so in the supporting document at a later stage. This document will seek to answer some of the questions which we have been repeatedly asked during the process of developing the code up to date.

8.4 Next Steps

As a consequence of the 12 month timescale, this is the only formal consultation by ENTSO-E on the NC LFCR. Following the closure of the consultation ENTSO-E has considered the comments and the NC LFCR drafting team, which contributed to the development of this code has processed comments, will provide feedback and has made changes as necessary. An updated code will be subject to internal approval and will be sent to ACER ahead of the deadline.

As mentioned in section 2.3. of this document, another public workshop for the NC LFCR will be held on 7th May 2013. As a result of the public consultation, the major comments received and therefore amendments made in the Code will be presented.

9 MAPPING OF BASELINE HARMONISATION AND NEW AREAS INTRODUCED BY THE NC LFCR

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	RECOVERY OF COSTS	■		
	6	CONFIDENTIALITY OBLIGATIONS	■		
	7	AGREEMENT WITH TSOS NOT BOUND BY THIS NETWORK CODE			■
	8	TSO CO-OPERATION			■
Chapter 2		OPERATIONAL AGREEMENTS	■	■	■
	9	SYNCHRONOUS AREA OPERATIONAL AGREEMENT	■	■	
	10	LFC BLOCK OPERATIONAL AGREEMENT	■	■	
Chapter 3		**FREQUENCY QUALITY**			
	11	FREQUENCY QUALITY DEFINING AND TARGET PARAMETERS	■		
	12	FREQUENCY RESTORATION CONTROL ERROR TARGET PARAMETERS			■
	13	CRITERIA APPLICATION PROCESS and FREQUENCY QUALITY	■	■	
	14	DATA COLLECTION AND DELIVERY PROCESS	■	■	
	15	SYNCHRONOUS AREA MONITOR	■		
	16	LFC BLOCK MONITOR		■	■
	17	INFORMATION ON LOAD AND GENERATION BEHAVIOUR	■		
	18	RAMPING PERIOD FOR SA	■		
	19	RAMPING RESTRICTIONSFOR POWER LEVEL ON SA LEVEL	■		
	20	RAMPING RESTRICTIONS ON BLOCK LEVEL	■		
	21	MITIGATION	■		
Chapter 4		**LOAD-FREQUENCY CONTROL STRUCTURE**			
	22	BASIC STRUCTURE			■
	23	PROCESS ACTIVATION STRUCTURE	■	■	
	24	PROCESS RESPONSIBILITY STRUCTURE			■
	25	FREQUENCY CONTAINMENT PROCESS (FCP)	■		
	26	FREQUENCY RESTORATION PROCESS (FRP)	■	■	
	27	RESERVE REPLACEMENT PROCESS (RRP)	■		
	28	IMBALANCE NETTING PROCESS	■		■
	29	CROSS-BORDER FRR ACTIVATION PROCESS	■		
	30	CROSS-BORDER RR ACTIVATION PROCESS	■		
	31	GENERAL REQUIREMENT FOR CROSS BORDER CONTROL PROCESSES			■
	32	TSO NOTIFICATION	■	■	
	33	INFRASTRUCTURE	■		
Chapter 5		OPERATION OF LOAD FREQUENCY CONTROL	■		
	34	SYSTEM STATES RELATED TO SYSTEM FREQUENCY			■
Chapter 6		**FREQUENCY CONTAINMENT RESERVES (FCR)**			
	35	FCR Dimensioning	■	■	
	36	FCR TECHNICAL MINIMUM REQUIREMENTS	■		
	37	FCR PROVISION	■	■	
Chapter 7		**FREQUENCY RESTORATION RESERVES (FRR)**			
	38	FRR DIMENSIONING	■	■	
	39	FRR TECHNICAL MINIMUM REQUIREMENTS	■		
Chapter 8		**REPLACEMENT RESERVES (RR)**			
	40	RR DIMENSIONING	■		
	41	RR TECHNICAL MINIMUM REQUIREMENTS	■		

Chapter 9		**EXCHANGE AND SHARING OF RESERVES**			
	Section 1	**Exchange and Sharing of Reserves within a Synchronous Area**			
	42	EXCHANGE OF FCR WITHIN A SYNCHRONOUS AREA	■		■
		Table 4: Limits and requirements for the Exchange of FCR Obligation			■
	43	SHARING OF FCR WITHIN A SYNCHRONOUS AREA	■		
	44	GENERAL REQUIREMENTS FOR THE EXCHANGE OF FRR AND RR	■	■	
	45	GENERAL REQUIREMENTS FOR THE SHARING OF FRR AND RR			■
	46	EXCHANGE OF FRR WITHIN A SYNCHRONOUS AREA	■		
	47	SHARING OF FRR WITHIN A SYNCHRONOUS AREA			■
	48	EXCHANGE OF RR WITHIN A SYNCHRONOUS AREA	■	■	
	49	SHARING OF RR WITHIN A SYNCHRONOUS AREA	■		
	Section 2	**Exchange and Sharing of Reserves between Synchronous Areas**			
	50	GENERAL REQUIREMNTS			
	51	EXCHANGE OF FCR BETWEEN SYNCHRONOUS AREAS			■
	52	SHARING OF FCR BETWEEN SYNCHRONOUS AREAS			■
	53	GENERAL REQUIREMENT FOR SHARING AND EXCHANGE BETWEEN SA			■
	54	EXCHANGE OF FRR BETWEEN SYNCHRONOUS AREAS			■
	55	SHARING OF FRR BETWEEN SYNCHRONOUS AREAS			■
	56	EXCHANGE OF RR BETWEEN SYNCHRONOUS AREAS.			■
	57	SHARING OF RR BETWEEN SYNCHRONOUS AREAS			■
	Section 3	**Cross-Border Activation Process of FRR and RR for Optimisation Purposes**			
	58	CROSS-BORDER ACTIVATION PROCESS OF FRR AND RR FOR OPTIMIZATION PURPOSES			■
Chapter 10		**TIME CONTROL PROCESS**			
	59	TIME CONTROL PROCESS	■		
Chapter 11		**CO-OPERATION WITH DNO**			
	60	RESERVE PROVIDING UNITS CONNECTED TO THE DNO GRID	■		
Chapter 12		**Transparency of Information**			
	61	General Requirements			■
	62	INFORMATION ON OPERATIONAL AGREEMENTS			
	63	Information on Frequency Quality		■	■
	64	ANNUAL REPORT	■		■
	65	Information on Load-Frequency-Control Structure			■
	66	Information on FCR		■	■
	67	Information on FRR			■
	68	Information on RR		■	■
	69	Information on Sharing and Exchange			■
Chapter 13		**FINAL PROVISIONS**			
	70	AMENDMENT OF CONTRACTS AND GENERAL TERMS AND CONDITIONS			■
	71	ENTRY INTO FORCE			■

10 LITERATURE & LINKS

[1] "Framework Guidelines on System Operation" (FG SO), ACER, 2 December 2011. (http://acernet.acer.europa.eu/)

[2] "Initial Impact Assessment", ACER, June 2011.

[3] ENTSO-E Ad-hoc Team Operational Reserves Report (https://www.entsoe.eu/fileadmin/user_upload/_library/resources/LCFR/2012-06-14_SOC-AhT-OR_Report_final_V9-3.pdf)

[4] ENTSO-E CE Operation Handbook Policy 1 Annex 1 (https://www.entsoe.eu/publications/system-operations-reports/operation-handbook/)

11 APPENDICES

11.1 APPENDIX I: GLOSSARY

(N-1)-Criterion means the rule according to which elements remaining in operation within TSO's Responsibility Area after a Contingency from the Contingency List must be capable of accommodating the new operational situation without violating Operational Security Limits; (from [NC OS])

(N-1)-Situation means the situation in the Transmission System in which a Contingency from the Contingency List has happened; (from [NC OS])

1 pu grid Voltage - for the 400 kV grid Voltage level (or alternatively commonly referred to as 380 kV level) the reference 1 pu value is 400 kV, for other grid Voltage levels the reference 1 pu Voltage may differ for each TSO in the same synchronous area i.e. the Voltage range in kV for all TSOs within a synchronous area may not be the same. (from [NC RfG])

1-minute Average Frequency Data means the set of data consisting of the average values of the recorded Instantaneous Frequency Data over a period of 1 minute each (from [NC LFCR])

1-minute Average Frequency Deviation Data means the set of data consisting of the average values of the difference between the Nominal Frequency and the recorded Instantaneous Frequency Data over a period of 1 minute each (from [NC LFCR])

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 Frequency Response - is an automatic response of Active Power output from a Power Generating Module, in response to a change in system Frequency from the nominal system Frequency. (from [NC RfG])

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

Adequacy means the ability of Generation connected to an area to meet the demand in this area (from [NC OPS])

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

Affected TSO means the TSO for which the impact in case of a cross-border exchange and/or sharing agreement of reserves and/or Imbalance Netting Process and/or cross-border activation processes in terms of electricity flows within its LFC Area exceeds a certain threshold (from [NC LFCR])

Agency – The Agency for the Cooperation of Energy Regulators (ACER) as established by Regulation (EC) No 713/2009 (from [NC RfG])

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

Aggregated Netted External Schedule means a Schedule representing the netted aggregation of all External TSO Schedules and External Commercial Trade Schedules between two Scheduling Areas or between a Scheduling Area and a group of other Scheduling Areas (from [NC OPS])

Aggregator means a legal entity which is responsible for the operation of a number of Demand Facilities by means of Demand Aggregation (from [NC DCC])

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])

Allocation Constraints means the constraints specified by the System Operator that are respected during Capacity Allocation. Allocation Constraints may include: operational security constraints, ramping constraints and/or transmission losses (from [NC CACM])

Allocation/Capacity Allocation means the attribution of Cross Zonal Capacity (from [NC CACM])

Alternator – is a device that converts mechanical energy into electrical energy by means of a rotating magnetic field. (from [NC RfG])

Apparent Power - is the product of Voltage and Current at fundamental Frequency. It is usually expressed in kilovolt-amperes (kVA) or megavolt-amperes (MVA) and consists of a real component (Active Power) and an imaginary component (Reactive Power). (from [NC RfG])

Area Control Error (ACE) means the he sum of the instantaneous difference between the actual and the set-point value (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 LFCR])

Area Control Error (ACE) means the sum of the instantaneous difference between the actual and the set-point 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])

Authorised Certifier - is an entity to issue Equipment Certificates. The accreditation of the Authorised Certifier shall be given from the national affiliation of the European co-operation for Accreditation (EA), established according to Regulation (EC) 765/2008. (from [NC RfG])

Automatic FRR Activation Delay means the period of time between the set point change and the commencement of Automatic FRR delivery (from [NC LFCR])

Automatic FRR Full Activation Time means the time period between the set point change and the corresponding full activation of Automatic FRR (from [NC LFCR])

Automatic FRR means FRR that can be activated by an automatic control device (from [NC LFCR])

Automatic Voltage Control means the automatic control actions at the generation node, at the end nodes of the AC lines or High-Voltage DC lines, on transformers, or other means, designed to maintain the set voltage level or the set value of Reactive Power; (from [NC OS])

Automatic Voltage Regulator (AVR) - is the continuously acting automatic equipment controlling the terminal Voltage of a Synchronous Power Generating Module by comparing the actual terminal Voltage with a reference value and controlling by appropriate means the output of an Excitation System, depending on the deviations. (from [NC RfG])

Availability Plan means the combination of all planned Availability Statuses for a Relevant Asset for a given time period (from [NC OPS])

Availability Status means the capability for a given time period of a Power Generating Module, grid element, Demand Facility, non-TSO owned Interconnector or another facility to provide service, whether or not it is in operation (from [NC OPS])

Available Transmission Capacity (ATC) means the transmission capacity which can be used for Imbalance Netting Power, Frequency Restoration Power and Replacement Power interchange without endangering the Operational Security (from [NC LFCR])

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

Bidding Zone Border means a set of physical transmission lines linking adjacent Bidding Zones (from [NC CACM])

Bidding Zone means the largest geographical area within which Market Participants are able to exchange energy without Capacity Allocation (from [NC CACM])

Black Start Capability - is the capability of recovery of a Power Generating Module from a total shutdown through a dedicated auxiliary power source without any energy supply which is external to the Power Generating Facility. (from [NC RfG])

Blackout State means the System State where the operation of part or all of the Transmission System is terminated; (from [NC OS])

Block Loading means the maximum step Active Power loading of reconnected demand during system restoration after black-out (is the state where the operation of part or all Transmission System is terminated) (from [NC DCC])

Business Continuity Plan means the plan detailing TSO’s responses to a loss of critical tools and facilities; (from [NC OS])

Capacity Calculation Approach means either a Flow Based Approach or a Coordinated Net Transmission Capacity approach (from [NC CACM])

Capacity Calculation Methodology means the description of the way in which Capacity Calculation is performed (from [NC CACM])

Capacity Calculation Process means a process in which the capability of the Transmission System to accommodate market transactions is assessed, it consists of calculation of the Cross Zonal Capacity. This assessment must be in line with operational security and optimisation of Cross Zonal Capacity made available to market participants (from [NC CACM])

Capacity Calculation Region means the regions in which regional coordinated capacity calculation shall be applied. A System Operator belongs to a Capacity Calculation Region if a part of its Control Area belongs to a Bidding Zone having its Bidding Zone Border within the Capacity Calculation Region (from [NC CACM])

Capacity Management Module means a module containing up to date available Cross Zonal Capacity in real time for allocating Cross Zonal Capacity in a continuous manner (from [NC CACM])

Central Counter Party means the role of entering into contracts with Market Participants, by novation of the contracts resulting from the Matching process and of organizing the transfer of Net Positions resulting from Capacity Allocation with other Central Counter Parties or Shipping Agents (from [NC CACM])

Clearing Price means the price determined from the highest accepted selling Order and the lowest accepted buying Order (from [NC CACM])

Close to Real-Time means the time delay between last intraday gate closure and real time, no later than 15 min before real time (from [NC OPS])

Closed Distribution Network means in the context of this Network Code a Network classified as closed distribution network pursuant to Article 28(1) of Directive 2009/72/EC at national level. Article 28 of Directive 2009/72/EC defines such a Network as a system which distributes electricity within a geographically confined industrial, commercial or shared services site and does not (without prejudice to a small number of households located within the area served by the system and with employment or similar associations with the owner of the system) supply household customers. This Closed Distribution Network will either have its operations or the production process of the users of the system integrated for specific or technical reasons or distribute electricity primarily to the owner or operator of the Closed Distribution Network or their related undertakings (from [NC DCC])

Closed Distribution System Operator (CDSO) - is a natural or legal person operating, ensuring the maintenance of and, if necessary, developing a closed distribution Network according to Article 28 of Directive 2009/72/CE. (from [NC RfG])

Common Grid Model means European-wide or multiple-System Operator-wide data set, created by the European Merging Function, through the merging of relevant data (from [NC CACM])

Compliance Monitoring - is the process to verify that the (technical) capabilities of Power Generating Modules are maintained compliant by the Power Generating Facility Owner with the specifications and requirements of this Network Code. (from [NC RfG])

Compliance Simulation - is the process to verify that Power Generating Modules are compliant with the specifications and requirements of this Network Code, for example before starting their operation. The verification should include, inter alia, the revision of documentation, the verification of the requested capabilities of the Power Generating Module by simulation studies and the revision against actual measurements. (from [NC RfG])

Compliance Testing - is the process to verify that Power Generating Modules are compliant with the specifications and requirements of this Network Code, for example before starting their operation. The verification includes, inter alia, the revision of documentation, the verification of the requested capabilities of the Power Generating Module by practical tests. (from [NC RfG])

Congestion Income Distributor(s) means the role of distributing Congestion Income (from [NC CACM])

Congestion Income means the revenues received as a result of Capacity Allocation (from [NC CACM])

Connecting CDSO means the CDSO to whose Network a Power Generating Module, Demand Facility, non-TSO owned Interconnector, or grid element is connected (from [NC OPS])

Connecting DNO means the DNO to whose Network a Power Generating Module, Demand Facility, non-TSO owned Interconnector, or grid element is connected (from [NC OPS])

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 Agreement - is a contract between the Relevant Network Operator and the Power Generating Facility Owner which includes the relevant site and technical specific requirements for the Power Generating Facility. (from [NC RfG])

Connection Point - is the interface at which the Power Generating Module is connected to a transmission, distribution or closed distribution Network according to Article 28 of Directive 2009/72/CE as identified in the Connection Agreement. (from [NC RfG])

Constraint means a situation in which there is a need to implement Remedial Action in order to respect Operational Security Limits (from [NC OPS])

Consumption Schedule means a Schedule representing the consumption of a Demand Facility or a group of Demand Facilities (from [NC OPS])

Contingency Analysis means computer based simulation of Contingencies from the Contingency List; (from [NC OS])

Contingency Influence Threshold means a numerical limit value against which the Influence Factors must be checked. The outage of an external Transmission System element with an Influence Factor higher than the Contingency Influence Threshold is considered having a (from [NC OS])

Contingency List means the list of Contingencies to be simulated in the Contingency Analysis in order to test the compliance with the Operational Security Limits before or after a Contingency took place; (from [NC OS])

Contingency means the identified and possible or already occurred Fault of an element within or outside a TSO's Responsibility Area, including not only the Transmission System elements, but also Significant Grid Users and Distribution Network elements if relevant for the Transmission System Operational Security. Internal Contingency is a Contingency within the TSO's Responsibility Area. External Contingency is a Contingency outside the TSO's Responsibility Area, with an Influence Factor higher than the Contingency Influence Threshold; (from [NC OS])

Continuous Trading Matching Algorithm means the algorithm used in the Intraday Market for Matching (from [NC CACM])

Control Area - is a part of the interconnected electricity transmission system controlled by a single TSO. (from [NC RfG])

Control Program means the set-point value (schedule) for the netted power interchange of a LFC Area over Tie-Lines (from [NC LFCR])

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

Control Room means a Relevant Network Operator's centralised operation centre (from [NC DCC])

Coordinated Capacity Calculator(s) means the role of calculating Cross Zonal Capacity, at least at a regional level and managing the validation process (from [NC CACM])

Coordinated Net Transmission Capacity means either a Cross Zonal Capacity or a capacity calculation method based on the principle of assessing and defining ex-ante a maximum energy exchange between adjacent Bidding Zones (from [NC CACM])

Cost-Benefit Analysis – is a process by which the Relevant Network Operator weighs the expected costs of alternative actions aiming at the same objective against the expected benefits in order to determine the alternative with the highest net socio-economic benefit. If applicable, the alternatives include network-based and market-based actions. (from [NC RfG])

Costly Remedial Action means a Remedial Action with direct payments made to procure the service (this may include but shall not be limited to, Countertrading and Redispatching) (from [NC CACM])

Countertrading means a Cross Zonal energy exchange initiated by System Operators between two Bidding Zones to relieve a Physical Congestion (from [NC CACM])

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])

Critical Fault Clearing Time means the maximum Fault duration for which the Transmission System remains stable; (from [NC OS])

Critical Network Element means a network element either within a Bidding Zone or between Bidding Zones taken into account in the Capacity Calculation Process, limiting the amount of power that be exchanged in order to maintain the System Security (from [NC CACM])

Cross Border means across a border between two or more Member States or a Member State and one or more jurisdictions in which this Network Code applies (from [NC CACM])

Cross Control Area Remedial Action means a Remedial Action that requires an action to be undertaken by at least one System Operator different than the System Operator in charge of the Control Area where the Physical Congestion to be relieved is located (from [NC CACM])

Cross Zonal Capacity means the capability of the Interconnected System to accommodate energy transfer between Bidding Zones. It can be expressed either as a Coordinated Net Transmission Capacity value or Flow Based Parameters, and takes into account Operational Security Constraints (from [NC CACM])

Cross-border Flow means a physical flow of electricity on a transmission network of a Member State that results from the impact of the activity of producers and/or consumers outside that Member State on its transmission network (from Regulation EC N° 714/2009)

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])

Current - unless stated otherwise, Current refers to the root-mean-square value of the positive sequence of the phase Current at fundamental Frequency. (from [NC RfG])

D-1 means the day prior to the day on which the energy is delivered (from [NC CACM])

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])

Day Ahead Firmness Deadline means the point in time after which Cross Zonal Capacity becomes firm (from [NC CACM])

Day Ahead Market Gate Closure means the point in time until which Orders are accepted in the Day Ahead Market (from [NC CACM])

Day Ahead Market means the market timeframe where commercial electricity transactions are executed the day prior to the day of delivery of traded products (from [NC CACM])

Declared Availability means declaration and notice prepared in respect of a Significant Grid User, submitted to the TSO setting out the values and times applicable to those values of availability and Ancillary Services capability; (from [NC OS])

Demand Aggregation means a set of Demand Facilities which can be operated as a single facility for the purposes of offering one or more Demand Side Response services (from [NC DCC])

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 Facility Operator means the natural or legal person who is the operator of a Demand Facility (from [NC OPS])

Demand Facility Owner means the owner of the Demand Facility (from [NC DCC])

Demand Side Response (DSR) means demand offered for the purposes of, but not restricted to, providing Active or Reactive Power management, Voltage and Frequency regulation and System Reserve (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 Low Frequency Demand Disconnection (DSR LFDD) means demand within a Demand Facility or Closed Distribution Network that can be disconnected in case of low Frequency (from [NC DCC])

Demand Side Response Low Voltage Demand Disconnection (DSR LVDD) means demand within a Demand Facility or Closed Distribution Network that can be disconnected in case of low Voltage (from [NC DCC])

Demand Side Response Reactive Power Control (DSR RPC) means Reactive Power or Reactive Power devices (Mvar's) in a Demand Facility or Closed Distribution Network that are accessible for modulation by the Relevant Network Operator (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 Transmission Constraint Management (DSR TCM) means demand that is accessible for modulation by the Relevant Network Operator to manage transmission constraints within the Network (from [NC DCC])

Demand Side Response Unit Document (DSRUD) means a document issued either by the Demand Facility Owner or Distribution Network Operator to the Relevant Network Operator or Relevant TSO pursuant to Article 9(3) for demand connections with DSR above 1000V. The DSRUD is intended to contain information confirming that the Demand Unit with DSR has demonstrated compliance with the technical criteria as referred to in this Network Code and provided the necessary data and statements including a Statement of Compliance (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])

Derogation - is a time limited or indefinite (as specified) acceptance in writing of a non-compliance of a Power Generating Module with regard to identified requirements of this Network Code. (from [NC RfG])

Designated Nominated Electricity Market Operator means a party which has fulfilled the designation criteria specified in the draft Comitology Guideline on Governance (from [NC CACM])

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

Direct Current Line means a transmission link between two Bidding Zones using direct current technology (from [NC CACM])

Distribution means the transport of electricity on high-voltage, medium-voltage and low-voltage distribution systems with a view to its delivery to customers, but does not include suppl (from Directive 2009/72/EC)

Distribution Network Connection means the electrical plant and equipment present at the Connection Point, typically a substation, of either a new or existing Distribution Network to the Transmission Network (from [NC DCC])

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])

Distribution Network Operator (DNO) means either a Distribution System Operator or an operator of a Closed Distribution Network (from [NC DCC])

Disturbance means an unplanned event that may cause the Transmission System to divert from Normal State; (from [NC OS])

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])

Dynamic Stability Assessment (DSA) means the Operational Security Assessment in terms of Dynamic Stability; (from [NC OS])

Dynamic Stability is a common term including the Rotor Angle Stability, Frequency Stability and Voltage Stability; (from [NC OS])

Economic Surplus means the sum over all Bidding Zones, of seller surplus, being the aggregated difference between the sellers' willingness to sell and the Clearing Price and of buyer surplus, being the aggregated difference between buyers' willingness to pay and the Clearing Price, Congestion Income, and other costs and benefits, where appropriate (from [NC CACM])

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

Elevated Synchronous Area State means the Synchronous Area alert state; active if High Synchronous Area State is not active and the 1 Minute Moving Average of the Frequency Deviation is outside 75 % of the Maximum Steady State Frequency Deviation for at least the Time to Restore Frequency (from [NC LFCR])

Emergency Situation means a situation where the System Operator must act in an expeditious manner and Redispatching or Countertrading is not possible as defined by Article 16 of Regulation (EC) No 714/2009 (from [NC CACM])

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])

Energisation Operational Notification (EON) - is a notification issued by the Relevant Network Operator to a Power Generating Facility Owner prior to energisation of its internal Network. An EON entitles the Power Generating Facility Owner to energise its internal Network by using the grid connection. (from [NC RfG])

ENTSO-E Network Area means the geographic area covered by the Network of the members of ENTSO-E (from [NC DCC])

ENTSO-E Operational Planning Data Environment means the set of application programs and equipment developed in order to allow the storage, the exchange and the management of the data used within operational planning processes between TSOs (from [NC OPS])

Equipment Certificate - is a document issued by an Authorised Certifier for equipment used in Power Generating Modules confirming performance in respect of the requirements of this Network Code. In relation to those parameters, for which this Network Code defines ranges rather than definite values, the Equipment Certificate shall define the extent of its validity. This will identify its validity at a national or other level at which a specific value is selected from the range allowed at a European level. The Equipment Certificate can additionally include models confirmed against test results for the purpose of replacing specific parts of the compliance process for Type B, C and D Power Generating Modules. The Equipment Certificate will have a unique number allowing simple reference to it in the Installation Document or the Power Generating Module Document. (from [NC RfG])

European Merging Function means the role of creating unique Common Grid Models, through the merging of all Individual Grid Models (from [NC CACM])

Exceptional Contingency means the loss of a busbar or more than one element such as, but not limited to: a common mode Fault with the loss of more than one Power Generating Module, a common mode Fault with the loss of more than one AC or DC line, a common mode Fault with the loss of more than one transformer; (from [NC OS])

Exchange of Reserves means a concept for reserves connected in one LFC Area, LFC Block, or Synchronous Area but exclusively taken into account in the Dimensioning Process by to a single TSO responsible for another LFC Area, LFC Block or Synchronous Area (from [NC LFCR])

Excitation System - is the equipment providing the field Current of a synchronous electrical machine, including all regulating and control elements, as well as field discharge or suppression equipment and protective devices. (from [NC RfG])

Existing Demand Facility means a Demand Facility which is not a New Demand Facility. (from [NC DCC])

Existing Distribution Network Connection means a Distribution Network Connection which is not a New Distribution Network Connection (from [NC DCC])

Existing Power Generating Module - is a Power Generating Module which is not a New Power Generating Module or which is a new Power Generating Module whose classification as an emerging technology according to Article 60 of this Network Code has been revoked according to Article 61 of this Network Code. (from [NC RfG])

Explicit (Capacity) Allocation means the allocation of Cross Zonal Capacity only, without the energy transfer (from [NC CACM])

External Commercial Trade Schedule means a Schedule representing the commercial exchange of electricity between Market Participants in different Scheduling Areas (from [NC OPS])

External TSO Schedule means a Schedule representing the exchange of electricity of TSO between different Scheduling Areas (from [NC OPS])

Fault means all types of short-circuits: single-, double- and triple-phase, with and without earth contact. It means further a broken conductor, interrupted circuit, or an intermittent connection, resulting in a permanent non-availability of the affected Transmission System element; (from [NC OS])

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])

Final Operational Notification (FON) - is a notification issued by the Relevant Network Operator to a Power Generating Facility Owner confirming that the Power Generating Facility Owner is entitled to operate the Power Generating Module by using the grid connection because compliance with the technical design and operational criteria has been demonstrated as referred to in this Network Code. (from [NC RfG])

Firm/Firmness means arrangements to guarantee that capacity rights remain unchanged or are compensated (from [NC CACM])

Flow Based or Flow Based Approach means a capacity calculation method limiting the exchanges between Bidding Zones directly with the maximum flows on the Critical Network Elements and Power Transfer Distribution Factors (from [NC CACM])

Flow Based Parameters mean the available margins on Critical Network Elements with associated Power Transfer Distribution Factors (from [NC CACM])

Force Majeure means, for the purpose of application in respect of capacity allocation mechanisms as foreseen in Article 16 of Regulation (EC) No 714/2009, any unforeseeable and/ or unusual event or situation beyond the reasonable control of a System Operator, and not due to a fault of such System Operator, which cannot be avoided or overcome with reasonable foresight and diligence, which cannot be solved by measures which are from a technical, financial and/or economic point of view, reasonably possible for the System Operator, which has actually happened and is objectively verifiable, and which makes it impossible for such System Operator to fulfil temporarily or definitively, its obligations in accordance with this Network Code (from [NC CACM])

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])

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 LFCR])

Frequency Containment Reserves (FCR) means the Operational Reserves activated to contain System Frequency after the occurrence of an imbalance; (from [NC OS])

Frequency Control - is the capability of a Power Generating Module to control speed by adjusting the Active Power Output in order to maintain stable system Frequency (also acceptable as speed control for Synchronous Power Generating Modules). (from [NC RfG])

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 LFCR])

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. These parameters reflect the system behaviour in normal operation by design (from [NC LFCR])

Frequency Quality Evaluation Criteria means the criteria set determined in order to evaluate the Frequency Quality with reference to the Frequency Quality Target Parameters (from [NC LFCR])

Frequency Quality Evaluation Data means the set of data used to evaluate 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 the FRR and RR of the LFC Block is evaluated in Normal State (from [NC LFCR])

Frequency Range within Time to Recover Frequency means 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 Frequenc (from [NC LFCR])

Frequency Range within Time to Restore Frequency means 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 Restore 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 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 Are (from [NC LFCR])

Frequency Restoration Control Error 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 Control Error Target Parameters means the main LFC Block variables on basis of which the state and 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 Restoration Controller means an automatic control device that aims at reducing the Frequency Restoration Control Error to zero (from [NC LFCR])

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

Frequency Restoration Process (FRP) means 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 LFCR])

Frequency Restoration Process (FRP) means 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 Operational 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 Sensitive Mode (FSM) - is a Power Generating Module operating mode which will result in Active Power output changing, in response to a change in System Frequency, in a direction which assists in the recovery to Target Frequency, by operating so as to provide Frequency Response. (from [NC RfG])

Frequency Stability means the ability of the Transmission System to maintain stable frequency in N-Situation and after being subjected to a disturbance; (from [NC OS])

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])

FRR Prequalification Process means the process in which the Reserve Connecting TSO qualifies a single generating or demand facility or a conglomeration of these as a FRR Providing Unit (from [NC LFCR])

Generation means the production of electricity (from Directive 2009/72/EC)

Generation Schedule means a Schedule representing the Generation of electricity of a Power Generating Module or a group of Power Generating Modules (from [NC OPS])

Generation Shift Key(s) mean a method of translating a Net Position change of a given Bidding Zone into estimated specific injection increases or decreases in the Common Grid Model (from [NC CACM])

High Synchronous Area State means the Synchronous Area alert state; active if the 1 Minute Moving Average of the Frequency Deviation is above 90 % of the Maximum Steady State Frequency Deviation for at least one third of the Time to Restore Frequency (from [NC LFCR])

Houseload Operation - in case of Network failures resulting in disconnection of Power Generating Modules from the Network and being tripped onto their auxiliary supplies, house-load operation ensures that Power Generating Facilities are able to continue to supply their in-house loads. (from [NC RfG])

Imbalance Netting Power Interchange means the power which is interchanged between one or more 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 Frequency Restoration Control Errors as well as activated FRR and correcting the input of the involved FRPs accordingly (from [NC LFCR])

Individual Grid Model means a data set prepared by the responsible System Operator(s), to be merged with other Individual Grid Model components through the European Merging Function in order to create the Common Grid Model (from [NC CACM])

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])

Influence Factor means a numerical value used to quantify the highest effect of the outage of an external Transmission System element on any Transmission System branch. The worse the effect, the higher the influence factor value is; (from [NC OS])

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

Installation Document - is a simple structured document (data/tick sheet) containing information about a Type A Power Generating Module and confirming compliance with the relevant requirements of this Network Code. The blank Installation Document shall be available from the Relevant Network Operator for the Type A Power Generating Facility Owner or alternatively the site installer on the owner's behalf to fill in and submit to the Relevant Network Operator. (from [NC RfG])

Instantaneous Frequency Data means a set of data measurements of the overall System Frequency for the Synchronous Area with a very small measurement period used for System Frequency quality evaluation purposes (from [NC LFCR])

Instantaneous Frequency Restoration Control Error Data means a set of data of the Frequency Restoration Control Error for a LFC Block with a with a very small measurement period used for System Frequency quality evaluation purposes (from [NC LFCR])

Instruction - is a command given orally, manually or by automatic remote control facilities, e. g. a Setpoint, from a Network Operator to a Power Generating Facility Owner in order to perform an action. (from [NC RfG])

Interconnected System means a number of transmission and distribution systems linked together by means of one or more interconnectors (from Directive 2009/72/EC)

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

Interim Compliance Statement means an itemized statement of compliance provided by the Demand Facility Owner or, Distribution Network Operator, to the Relevant Network Operator as established in this Network Code and as additionally required by national legislation including the national codes (from [NC DCC])

Interim Operational Notification (ION) - is a notification issued by the Relevant Network Operator to a Power Generating Facility Owner confirming that the Power Generating Facility Owner is entitled to operate the Power Generating Module by using the grid connection for a limited period of time and to undertake compliance tests to meet the technical design and operational criteria of this Network Code. (from [NC RfG])

Internal Commercial Trade Schedule means a Schedule representing the commercial exchange of electricity within a Scheduling Area between different Market Participants or between Nominated Electricity Market Operators and Market Coupling Operators (from [NC OPS])

Intraday Cross Zonal Gate Closure Time means the point in time where Cross Zonal Capacity Allocation is no longer permitted for a given Market Time Period. There is one Intraday Cross Zonal Gate Closure Time for each Market Time Period for a given Bidding Zone Border (from [NC CACM])

Intraday Cross Zonal Gate Opening Time means the point in time when Cross Zonal capacity between Bidding Zones is released for a given Market Time Period and a given Bidding Zone Border (from [NC CACM])

Intraday Energy Gate Closure Time means the point in time when energy trading for a Bidding Zone is no longer permitted for a given Market Time Period within the Intraday Market. There is one Intraday Energy Gate Closure Time for each Market Time Period per Bidding Zone. The Intraday Energy Gate Closure Times shall be after or at the same time as the Cross Zonal Intraday Gate Closure Time (from [NC CACM])

Intraday Energy Gate Opening Time means the point in time when energy trading for a Bidding Zone is permitted for a given Market Time Period. There is one Intraday Energy Gate Opening Time for each day of delivery per Bidding Zone. The Intraday Energy Gate Opening Times of at least the Bidding Zones adjacent to a Bidding Zone Border shall be prior or equal to the Intraday Cross Zonal Gate Opening Time of this Bidding Zone Border (from [NC CACM])

Intraday Market means the electricity market which operates for the period of time between Intraday Cross Zonal Gate Opening Time and Intraday Cross Zonal Gate Closure, where commercial electricity transactions are executed prior to the delivery of traded products (from [NC CACM])

Island Operation - is the independent operation of a whole or a part of the Network that is isolated after its disconnection from the interconnected system, having at least one Power Generating Module supplying power to this Network and controlling the Frequency and Voltage. (from [NC RfG])

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 LFCR])

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 Frequency Restoration Control Error Range means a Frequency Restoration Control Error Defining Parameter used for System Frequency quality evaluation purposes (from [NC LFCR])

Level 2 Frequency Restoration Control Error Range means a Frequency Restoration Control Error Defining Parameter used for System Frequency quality evaluation purposes (from [NC LFCR])

LFC Block Imbalances means the sum of the Frequency Restoration Control Error, FRR Activation and RR Activation of a LFC Block (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])

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])

Limited Operational Notification (LON) - is a notification issued by the Relevant Network Operator to a Power Generating Facility Owner which has previously reached FON status, but is temporarily subject to either a significant modification or loss of capability which has resulted in non-compliance to the Network Code. (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 Area (LFC Area) means a part of a Synchronous Area or an entire Synchronous Area, physically demarcated by points of measurement of Tie-Lines to other LFC Areas, operated by one or more TSOs fulfilling the obligations of a LFC Area (from [NC LFCR])

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 Block (LFC Block) means a part of a Synchronous Area or an entire Synchronous Area, physically demarcated by points of measurement of Tie-Lines 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 LFCR])

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 Operational Reserves (Process Activation Structure) (from [NC LFCR])

Local means the qualification of an Alert, Emergency or Blackout State when there is no risk of extension of the consequences outside of the Responsibility Area of a single TSO; (from [NC OS])

Low Frequency Demand Disconnection (LFDD) means an action where demand is disconnected during a low Frequency event in order to recover the balance between demand and generation to restore system Frequency to acceptable limits (from [NC DCC])

Low Voltage Demand Disconnection (LVDD) means a restoration action where demand is disconnected during a low voltage event in order to recover Voltage to a sustainable level within acceptable limits (from [NC DCC])

Main Plant means at least one of the following equipment: motors, transformers, high voltage equipment at the Connection Point and process production plant (from [NC DCC])

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

Market Congestion means a situation in which the Economic Surplus has been limited by the Cross Zonal Capacity or other active Allocation Constraints (from [NC CACM])

Market Coupling Operator(s) means the role of Matching Orders for all Bidding Zones, taking into account Allocation Constraints and Cross Zonal Capacity and thereby implicitly allocating capacity for the Day Ahead and Intraday timeframes (from [NC CACM])

Market Information Aggregator means the role of aggregating and publishing market information (from [NC CACM])

Market Participant means market participant within the meaning of the Regulation (EU) No 1227/2011 of the European Parliament and of the Council of 25 October 2011 on wholesale energy market integrity and transparency (from [NC CACM])

Market Time means Central European Summer Time or Central European Time, whichever is in effect (from [NC CACM])

Market Time Period means the time resolution for the delivery of energy (from [NC CACM])

Matched Orders means all matched, buy and sell, Orders within a Trade performed by the Matching Algorithm (from [NC CACM])

Matching Algorithm means either the Price Coupling Algorithm or Continuous Trading Matching Algorithm (from [NC CACM])

Matching means the trading mode through which sell Orders are assigned to appropriate buy Orders to ensure the maximization of Economic Surplus (from [NC CACM])

Maximum Capacity - is the maximum continuous Active Power which a Power Generating Module can feed into the Network as defined in the Connection Agreement or as agreed between the Relevant Network Operator and the Power Generating Facility Owner. It is also referred to in this Network Code as Pmax. (from [NC RfG])

Maximum Export Capability (MEC) means the maximum continuous Active Power which a Demand Facility, or Distribution Network, can feed into the Network at the Connection Point as defined in the Connection Agreement or as agreed between the Relevant Network Operator and the Demand Facility Owner or Distribution Network Operator respectively (from [NC DCC])

Maximum Import Capability (MIC) means the maximum continuous Active Power which a Demand Facility or a Distribution Network, can consume from the Network at the Connection Point as defined in the Connection Agreement or as agreed between the Relevant Network Operator and the Demand Facility Owner or Distribution Network Operator respectively (from [NC DCC])

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 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])

Minimum Regulating Level - is the minimum Active Power as defined in the Connection Agreement or as agreed between the Relevant Network Operator and the Power Generating Facility Owner, that the Power Generating Module can regulate down to and can provide Active Power control. (from [NC RfG])

Minimum Stable Operating Level - is the minimum Active Power as defined in the Connection Agreement or as agreed between the Relevant Network Operator and the Power Generating Facility Owner, at which the Power Generating Module can be operated stably for unlimited time. (from [NC RfG])

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 LFC Areas, operated by one or more TSOs fulfilling the obligations of a Monitoring Area (from [NC LFCR])

Net Position means the netted sum of electricity exports and imports for each Market Time Period for a given geographical area. In the context of this Network Code, geographical area is a Bidding Zone (from [NC CACM])

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

Network - is plant and apparatus connected together in order to transmit or distribute electrical power. (from [NC RfG])

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

New Demand Facility means a Demand Facility for which: a) with regard to the provisions of the initial version of this Network Code, a final and binding contract of purchase of the Main Plant has been signed after the date, which is two years after the date of the entry into force of this Network Code, or, b) with regard to the provisions of the initial version of this Network Code, no confirmation is provided by the Demand Facility Owner, with a delay not exceeding thirty months as from the date of entry into force of this Network Code, that a final and binding contract of purchase of the Main Plant exists prior to the date, which is two years after the date of the entry into force of this Network Code, or, c) with regard to the provisions of any subsequent amendment to this Network Code and/or after any change of thresholds pursuant to the re-assessment procedure of Article 6, a final and binding contract of purchase of the main plant has been signed after the date, which is two years after the entry into force of any subsequent amendment to this Network Code and/or after the entry into force of any change of thresholds pursuant to the re-assessment procedure of Article 6 (from [NC DCC])

New Distribution Network Connection means a Distribution Network Connection of either a new or existing Distribution Network, which is or will be connected to the Transmission Network for which a) with regard to the provisions of the initial version of this Network Code, a final and binding contract of purchase of the Main Plant has been signed after the date, which is two years after the date of the entry into force of this Network Code, or, b) with regard to the provisions of the initial version of this Network Code, no confirmation is provided by the Distribution Network Operator, with a delay not exceeding thirty months as from the date of entry into force of this Network Code, that a final and binding contract of purchase of the Main Plant exists prior to the date, which is two years after the date of the entry into force of this Network Code, or, c) with regard to the provisions of any subsequent amendment to this Network Code and/or after any change of thresholds pursuant to the re-assessment procedure of Article 6, a final and binding contract of purchase of the main plant has been signed after the date, which is two years after the entry into force of any subsequent amendment to this Network Code and/or after the entry into force of any change of thresholds pursuant to the re-assessment procedure of Article 6 (from [NC DCC])

New Power Generating Module - is a Power Generating Module for which □ with regard to the provisions of the initial version of this Network code, a final and binding contract of purchase of the main plant has been signed after the day, which is two years after the day of the entry into force of this Network Code, or, □ with regard to the provisions of the initial version of this Network code, no confirmation is provided by the Power Generating Facility Owner, with a delay not exceeding thirty months as from the day of entry into force of this Network Code, that a final and binding contract of purchase of the main plant exists prior to the day, which is two years after the day of the entry into force of this Network Code, or, □ with regard to the provisions of any subsequent amendment to this Network Code and/or after any change of thresholds pursuant to the re-assessment procedure of Article 3(6), a final and binding contract of purchase of the main plant has been signed after the day, which is two years after the entry into force of any subsequent amendment to this Network Code and/or after the entry into force of any change of thresholds pursuant to the re-assessment procedure of Article 3(6). (from [NC RfG])

Nominal Frequency means the rated value of the System Frequency in a power system, namely 50 Hz (from [NC LFCR])

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

Nominated Electricity Market Operator means the role of interfacing between local markets and the Market Coupling Operator(s), including collecting and delivering Orders, consistent with the draft (from [NC CACM])

Non Costly Remedial Action means a Remedial Action without direct payments (from [NC CACM])

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])

Normal Synchronous Area State means the Synchronous Area alert state ; active if neither Elevated Synchronous Area State nor High Synchronous Area State are active (from [NC LFCR])

Notification Process means the process in which a TSO notifies an exchange and/or sharing agreement with another TSO to the other TSOs (from [NC LFCR])

N-Situation means the situation where no element of the Transmission System is unavailable due to a Fault; (from [NC OS])

Observability Area means the own Transmission System and the relevant parts Distribution Networks and neighbouring TSOs' Transmission Systems, on which TSO implements real-time monitoring and modelling to ensure Operational Security in its Responsibility Area; (from [NC OS])

Offshore Connection Point - is a Connection Point located offshore. (from [NC RfG])

Offshore Grid Connection System - is the complete interconnection between the Offshore Connection Point and the connection to the interconnected onshore system at the Onshore Grid Interconnection Point. (from [NC RfG])

Offshore Power Park Module - is a Power Park Module located offshore with an Offshore Connection Point. (from [NC RfG])

On Load Tap Changer Blocking means an action that blocks the On Load Tap Changer[s] during a low Voltage event in order to stop transformers from further tapping and suppressing Voltages in an area. This should be employed in association with LVDD (from [NC DCC])

On Load Tap Changer means a device for changing the tap of a winding, suitable for operation while the transformer is energized or on load (from [NC DCC])

Onshore Grid Interconnection Point - is the point at which the Offshore Grid Connection System is connected to the onshore Network of the Relevant Network Operator. (from [NC RfG])

Operational Reserves means the spinning and non-spinning reserves that are accessible to at least one TSO (from [NC LFCR])

Operational Reserves means the spinning and non-spinning reserves that are accessible to at least one TSO; (from [NC OS])

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 Constraints means a limit that guarantees the secure and reliable operation of the Transmission System (from [NC CACM])

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

Operational Security means keeping the Transmission System within agreed security limits (from [NC CACM])

Operational Security Performance Indicators are used for monitoring of the Operational Security in terms of Faults, incidents, disturbances and other events which influence Operational Security, as specified in the ENTSO-E incidents classification scale developed pursuant to the Article 8(3)(a) of the Regulation (EC) 714/2009; (from [NC OS])

Operational Security Ranking is used for monitoring of the Operational Security on the basis of the Operational Security Performance Indicators, according to the ENTSO-E incidents classification scale developed pursuant to the Article 8(3)(a) of the Regulation (EC) 714/2009; (from [NC OS])

Order means an intention to purchase or sell energy and/or capacity expressed by a Market Participant subject to a certain number of execution conditions (from [NC CACM])

Ordinary Contingency means the loss of a Transmission System element such as, but not limited to: a single line, a single transformer, a single phase-shifting transformer, a voltage compensation installation connected directly to the Transmission System; it means further also the loss of a single Power Generating Module connected directly to the Transmission System, the loss of a single Demand Facility connected directly to the Transmission System, or the loss of a single DC line; (from [NC OS])

Outage Coordination Process means the process of coordinating the Availability Plans of all Relevant Assets (from [NC OPS])

Outage Coordination Region means a combination of Responsibility Areas in which procedures are defined to monitor and where necessary coordinate Availability Statuses of Relevant Assets on all planning timescales (from [NC OPS])

Outage Incompatibility means the state in which a combination of the Availability Status of one or more Relevant Grid Elements, Relevant Power Generating Modules, Relevant Demand Facilities and/or non-TSO owned Interconnectors and the best estimate of the forecasted electricity grid situation leads to violation of Operational Security Limits taking into account non-costly Remedial Actions at the TSO's disposal (from [NC OPS])

Outage Planning Agent means the role of planning the Availability Status of Relevant Power Generating Modules, Demand Facilities or Relevant Non-TSO Owned Interconnectors (from [NC OPS])

Out-of-Range Contingency means the simultaneous loss, without a common mode Fault, of several Transmission System elements such as, but not limited to: two independent lines, a substation with more than one busbar, a tower with more than two circuits, one or more Power Generating Facilities with a total lost capacity exceeding the Reference Incident; (from [NC OS])

Overexcitation Limiter - is a control device within the AVR which prevents the rotor of an Alternator from overload by limiting the excitation Current. (from [NC RfG])

Physical Congestion means any network situation, either described in a Common Grid Model, or occurring in real time, where power flows has to be modified to respect Operational Security (from [NC CACM])

Power Factor - is the ratio of Active Power to Apparent Power. (from [NC RfG])

Power Generating Facility - is a facility to convert primary energy to electrical energy which consists of one or more Power Generating Modules connected to a Network at one or more Connection Points. (from [NC RfG])

Power Generating Facility Operator means the natural or legal person who is the operator of a Power Generating Facility (from [NC OPS])

Power Generating Facility Owner - is a natural or legal entity owning a Power Generating Facility. (from [NC RfG])

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

Power Generating Module Document (PGMD) - is a document issued by the Power Generating Facility Owner to the Relevant Network Operator for a Type B or C Power Generating Module. The PGMD is intended to contain information confirming that the Power Generating Module has demonstrated compliance with the technical criteria as referred to in this Network Code and provided the necessary data and statements including a Statement of Compliance. (from [NC RfG])

Power Park Module (PPM) - is a unit or ensemble of units generating electricity, which is connected to the Network non-synchronously or through power electronics, and has a single Connection Point to a transmission, distribution or closed distribution Network. (from [NC RfG])

Power System Stabilizer (PSS) - is an additional functionality of the AVR of a Synchronous Power Generating Module with the purpose of damping power oscillations. (from [NC RfG])

Power Transfer Distribution Factor means a representation of the physical flow on a Critical Network Element induced by the variation of the Net Position of a Bidding Zone (from [NC CACM])

P-Q-Capability Diagram - describes the Reactive Power capability of a Power Generating Module in context of varying Active Power at the Connection Point. (from [NC RfG])

Prequalification means the Process to verify the compliance of a Reserve Providing Unit of kind FCR, FRR or RR with the requirements set by the TSO (from [NC LFCR])

Price Coupling Algorithm means the algorithm used in the Day Ahead market for Matching (from [NC CACM])

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

Process Responsibility Structure means the structure to determine responsibilities and obligations with respect to Operational Reserves based on Area Types (from [NC LFCR])

Provider means an entity operating a Reserve Providing Unit or a Reserve Providing Group (from [NC LFCR])

Pump-Storage - is a hydro unit in which water can be raised by means of pumps and stored to be used later for the generation of electrical energy. (from [NC RfG])

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

Reactive Power - is the imaginary component of the Apparent Power at fundamental Frequency, usually expressed in kilovar (kvar) or megavar (Mvar). (from [NC RfG])

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

Redispatching Aggregator means a legal entity which is responsible for the operation of a number of Power Generating Modules by means of generation aggregation for the purpose of offering Redispatching; (from [NC OS])

Redispatching means a measure activated by one or several System Operators by altering the generation and/or load pattern, in order to change physical flows in the Transmission System and relieve a Physical Congestion (from [NC CACM])

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 LFCR])

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])

Regulatory Authorities means the regulatory authorities referred to in Article 35(1) of Directive 2009/72/EC (from Regulation EC N° 714/2009)

Relevant Asset means any Relevant Demand Facility, Relevant Power Generating Module, Relevant Non-TSO Owned Interconnector, or Relevant Grid Element partaking in the Outage Coordination Process (from [NC OPS])

Relevant CDSO - is the CDSO to whose Network a Power Generating Module is or will be connected. (from [NC RfG])

Relevant Demand Facility means a Demand Facility which participates in the Outage Coordination Process as its Availability Status influences cross-border Operational Security (from [NC OPS])

Relevant DNO - is the DNO to whose Network a Power Generating Module is or will be connected. (from [NC RfG])

Relevant Grid Element means a grid element located in a Transmission Network, in a Distribution Network, or in a Closed Distribution Network which participates in the Outage Coordination Process as its Availability Status influences cross-border Operational Security (from [NC OPS])

Relevant National Regulatory Authority - is the regulatory authority as referred to in Article 35(1) of Directive 2009/72/EC. (from [NC RfG])

Relevant Network Operator - is the operator of the Network to which a Power Generating Module is or will be connected. (from [NC RfG])

Relevant Non-TSO Owned Interconnector means a non-TSO owned Interconnector which participates in the Outage Coordination Process as its Availability Status influences cross-border Operational Security (from [NC OPS])

Relevant Power Generating Module means a Power Generating Module which participates in the Outage Coordination Process as its Availability Status influences cross-border Operational Security (from [NC OPS])

Relevant TSO - is the TSO in whose Control Area a Power Generating Module is or will be connected to the Network at any Voltage level. (from [NC RfG])

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])

Remedial Action means a measure activated by one or several System Operators, manually or automatically, that relieves or contributes to relieving Physical Congestions. They can be applied pre-fault or post-fault and may involve costs (from [NC CACM])

Replacement Power Interchange means the power which is interchanged between one or more 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 further 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 DNO means the DNO responsible for the Grid to which a Reserve Providing Unit or Reserve Providing Group is connected to providing Reserves to a TSO (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 Providing Group: A conglomeration of generating and/or demand facilities that are located in the area of one single Reserve Connecting TSO together providing reserves of kind FCR, FRR or RR to a TSO and which together fulfil the requirements of the Reserve Connecting TSO (from [NC LFCR])

Reserve Providing Unit means a single generating or demand facility providing reserves of kind FCR, FRR or RR to a TSO and fulfilling the requirements of the Reserve Connecting TSO (from [NC LFCR])

Reserve Receiving TSO means the TSO involved in an exchange or sharing agreement with a TSO and/or Reserve Providing Unit from another LFC Area (from [NC LFCR])

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

Responsibility Area means a coherent part of the interconnected Transmission System including Interconnectors, operated by a single TSO with connected Demand Facilities, or Power Generating Modules , if any; (from [NC OS])

Restoration means the System State in which the objective of all activities in Transmission System is to re-establish the system operation and maintain Operational Security after a Blackout; (from [NC OS])

Rotor Angle Stability means the ability of synchronous machines to remain in synchronism under N-Situation and after being subjected to a disturbance; (from [NC OS])

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

Schedule means a reference set of values representing the Generation, consumption or exchange of electricity between actors for a given time period (from [NC OPS])

Scheduled Exchange Calculator(s) means the role of calculating Scheduled Exchanges (from [NC CACM])

Scheduled Exchange means the transfer scheduled between geographic areas, for each Market Time Period and for a given direction (from [NC CACM])

Scheduling Agent means the role of providing Schedules (from [NC OPS])

Scheduling Area means Responsibility Area except if there are several Bidding Zones within this Responsibility Area. In the latter case, the Scheduling Area equals Bidding Zone (from [NC OPS])

Secured Fault - is defined as a fault, which is successfully cleared by Network protection according to the Network Operator's planning criteria. (from [NC RfG])

Security Plan means the plan containing a risk assessment of critical TSO's assets to major physical- and cyber-threat scenarios with an assessment of the potential impacts; (from [NC OS])

Set Point Frequency means the Frequency target value for FRR. In general the sum of the Nominal System Frequency and an offset value needed to reduce an Electrical Time Deviation (from [NC LFCR])

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

Shared Order Book means a module collecting all matchable Orders from the participating Nominated Electricity Market Operators and performing continuous Matching of those Orders (from [NC CACM])

Shipping Agent means the role of transferring Net Position(s) between different Central Counter Parties (from [NC CACM])

Significant Demand Facility means a Demand Facility which is deemed significant, either singularly or when considered aggregated, on the basis of its impact on the cross-border system performance via influence on the control area's security of supply, RES integration or market integration, which is identified according to the criteria set forth in this Network Code in Article 3 to 8 (from [NC DCC])

Significant Distribution Network Connection means a Distribution Network Connection which is deemed significant on the basis of its impact on the cross-border system performance via influence on the control area's security of supply, RES integration or market integration, which is identified according to the criteria set forth in this Network Code in Article 3 to 8 (from [NC DCC])

Significant Distribution Network means a Distribution Network which is deemed significant on the basis of its impact on the cross-border system performance via influence on the control area's security of supply, RES integration or market integration, which is identified according to the criteria set forth in this Network Code in Article 3 to 8 (from [NC DCC])

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])

significant impact on the TSO's Responsibility Area. The value of the Contingency Influence Threshold is based on the risk assessment of each TSO; (from [NC OS])

Significant Power Generating Module - is a Power Generating Module which is deemed significant on the basis of its impact on the cross-border system performance via influence on the control area's security of supply, which is identified according to the criteria set forth in this Network Code and falls within one of the categories provided in Article 3(6). (from [NC RfG])

Significant Temperature Controlled Device means a Temperature Controlled Device which is deemed significant on the basis of its impact on the cross-border system performance via influence on the control area's security of supply, RES integration or market integration, which is identified according to the criteria set forth in this Network Code in Article 21 (from [NC DCC])

Slope - is the ratio of the change in Voltage, based on nominal Voltage, to a change in Reactive Power infeed from zero to maximum Reactive Power, based on maximum Reactive Power. (from [NC RfG])

Small Isolated System means any system with consumptionof less than 3 000 GWh in the year 1996, where less than5 % of annual consumption is obtained through interconnection with other systems (from Directive 2009/72/EC)

Social Welfare means a quantification to assess the potential implications of alternative policy options. The assessment of social welfare shall include a consideration of the additional economic benefit or cost, defined as the sum of the additional individual benefits and costs which are expected to be accrued due to the implementation of the respective policy options compared to the status quo. These benefits and costs shall be analysed independently for tariff customers (as a whole and separated based on their ability to afford the cost of electricity), Market Participants and System Operators. In undertaking this assessment, in all cases, the undertaking party shall clearly specify: assumptions about the redistributive effects of an increase of one of the above components for the surpluses of the other groups stated above; assumptions about preconditions for market functioning such as market power and liquidity; and assumptions about implications stemming from external effects used to undertake the analysis (from [NC CACM])

Sophisticated Product means a product with specific characteristics designed to reflect system operation practices or market needs, examples may include but shall not be limited to, Orders covering multiple Market Time periods and products reflecting start up costs (from [NC CACM])

Stability Limits means the permitted operating boundaries of the Transmission System in terms of respecting the constraints of Voltage Stability, Rotor Angle Stability and Frequency Stability; (from [NC OS])

Stakeholder Committee means a group of appointed representatives forming an advisory group consistent with the draft Comitology Guideline on Governance (from [NC CACM])

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])

State Estimation means the methodology and algorithms used to calculate a reliable set of measurements defining the state of the Transmission System out of the redundant set of measurements; (from [NC OS])

Statement of Compliance - is a document provided by the Power Generating Facility Owner to the Network Operator stating the current status with respect to compliance itemised for each relevant element of this Network Code. (from [NC RfG])

Steady-State Stability - if the Network or a Synchronous Power Generating Module previously in the steady-state reverts to this state again following a sufficiently minor disturbance, it has Steady-State Stability. (from [NC RfG])

Structural Congestion means congestion in the Transmission System that: can be unambiguously defined; is predictable; is geographically stable over time; and is frequently reoccurring under common circumstances (from [NC CACM])

Synchronous Area - means an area covered by interconnected TSOs with a common System Frequency in a steady state such as the Synchronous Areas Continental Europe (CE), Cyprus (CY), Great Britain (GB), Ireland (IRE), Northern Europe (NE) and the power systems of Lithuania, Latvia and Estonia (Baltic) as a part of a Synchronous Area. (from [NC RfG])

Synchronous Area Agreement means a multi-party agreement between all TSO of a Synchronous Area if the Synchronous Area consists of not only one TSO; if a Synchronous Area consists only of one TSO it means a formal declaration of the obligations defined in this NC (from [NC LFCR])

Synchronous Area Agreement means a multi-party agreement between all TSOs of a Synchronous Area if the Synchronous Area consists of more than one TSO. If a Synchronous Area consists of only one TSO, the Synchronous Area Agreement means a formal declaration of the obligations defined in this Network Code; (from [NC OS])

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), Cyprus (CY), Great Britain (GB), Ireland (IRE) and Northern Europe (NE) and the power systems of Lithuania, Latvia and Estonia (Baltic) as a part of a synchronous area (from [NC LFCR])

Synchronous Area means an area covered by interconnected TSOs with a common System Frequency in a steady state such as the Synchronous Areas Continental Europe (CE), Cyprus (CY), Great Britain (GB), Ireland (IRE), Northern Europe (NE) and the power systems of Lithuania, Latvia and Estonia (Baltic) as a part of a Synchronous Area; (from [NC OS])

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])

Synchronous Compensation Operation - is the operation of an Alternator without prime mover to regulate Voltage dynamically by production or absorption of Reactive Power (from [NC RfG])

Synchronous Power Generating Module - is an indivisible set of installations which can generate electrical energy. It is either a a single synchronous unit generating power within a Power Generating Facility directly connected to a transmission, distribution or closed distribution Network, or an ensemble of synchronous units generating power within a Power Generating Facility directly connected to a transmission, distribution or closed distribution Network with a common Connection Point, or an ensemble of synchronous units generating power within a Power Generating Facility directly connected to a transmission, distribution or closed distribution Network that cannot be operated independently from each other (e. g. units generating in a combined-cycle gas turbine facility), or a single synchronous storage device operating in electricity generation mode directly connected to a transmission, distribution or closed distribution Network, or an ensemble of synchronous storage devices operating in electricity generation mode directly connected to a transmission, distribution or closed distribution Network with a common Connection Point. (from [NC RfG])

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 Defence Plan means the summary of all technical and organisational measures to be undertaken to prevent the propagation or deterioration of an incident in the Transmission System, in order to avoid a widespread disturbance and Blackout State; (from [NC OS])

System Frequency is the electric frequency of the 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) (from [NC LFCR])

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 Operator Employee means the person who is a TSO employee in charge of system operation and control of the Transmission System in real-time, or the person who is a TSO employee in charge of operational planning; (from [NC OS])

System Operator means a the role covering various tasks and operational responsibilities assumed by Transmission System Operators pursuant to this Network Code, including the physical transmission of electricity resulting from wholesale electricity market transactions and from all interconnectors which have an impact on the trading of electricity between Bidding Zones, without prejudice to the exemptions granted under Regulation (EC) No 1228/2003 and Regulation (EC) No 714/2009 which shall continue to apply until the scheduled expiry date as decided in the granted exemption decision (from [NC CACM])

System Protection Scheme (SyPS) means the set of coordinated and automatic measures designed to ensure fast reaction to Disturbances and to avoid the propagation of Disturbances in the Transmission System; (from [NC OS])

System Reserve means Active or Reactive Power reserves to actively manage the Network predominantly to respond to Frequency and Voltage fluctuations (from [NC DCC])

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])

Temperature Controlled Device means a device which heats and cools, and therefore whose electrical usage is proportional to the temperature regulated. Examples include but are not restricted to fridges, freezers, heat pumps, water heating (from [NC DCC])

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

Time Control Process: 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 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 Range Within Time To Restore Frequency 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 OS])

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 Range Within Time To Restore Frequency for Synchronous Areas with only one LFC Area or for Synchronous Areas with more than one LFC Area the maximum expected time after the occurrence of an imbalance of an LFC Area within which the imbalance is compensated (from [NC LFCR])

Topology means necessary data about the connectivity of the different Transmission System or Distribution Network elements in a substation. It includes the electrical configuration and the position of circuit breakers and isolators; (from [NC OS])

Trade means one or more Matched Orders; an (from [NC CACM])

Transitory Admissible Overloads means the temporary overloads of Transmission System elements which are allowed for a limited period and which do not cause physical damage to the Transmission System elements and equipment as long as the defined duration and thresholds are respected; (from [NC OS])

Transmission Connected Closed Distribution Network means a Closed Distribution Network which has a Connection Point to a Transmission Network (from [NC DCC])

Transmission Connected Demand Facility means a Demand Facility which has a Connection Point to a Transmission Network (from [NC DCC])

Transmission Connected Demand Facility Owner means the owner of a Transmission Connected Demand Facility (from [NC DCC])

Transmission Connected Distribution Network means a Distribution Network which has a Connection Point to a Transmission Network (from [NC DCC])

Transmission Connected Distribution Network Operator means the operator of a Transmission Connected Distribution Network (from [NC DCC])

Transmission means the transport of electricity on the extra high-voltage and high-voltage interconnected system with a view to its delivery to final customers or to distributors, but does not include supply (from Directive 2009/72/EC)

Transmission Network means an electrical Network for the transmission of electrical power from and to third party[s] connected to it, including Demand Facilities, Distribution Networks or other Transmission Networks. The extent of this Network is defined at a national level (from [NC DCC])

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 (TSO) - is 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 [NC RfG])

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)

Underexcitation Limiter - is a control device within the AVR, the purpose of which is to prevent the Alternator from losing synchronism due to lack of excitation. (from [NC RfG])

U-Q/Pmax-profile - is a profile representing the Reactive Power capability of a Power Generating Module in context of varying Voltage at the Connection Point. (from [NC RfG])

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])

Virtual Tie-Line means a telemetered reading or value that is updated in real-time and represented as a “virtual” tie-line flow, but for which no physical Interconnector or energy metering actually exists. The integrated value is used as a metered energy value for accounting purposes; (from [NC OS])

Voltage - unless stated otherwise, Voltage refers to the root-mean-square value of the positive sequence of the phase-to-phase Voltages at fundamental Frequency. (from [NC RfG])

Voltage Stability means the ability of a Transmission System to maintain acceptable voltages at all buses in the Transmission System under N-Situation and after being subjected to a Disturbance; (from [NC OS])

Week-Ahead means the week before the calendar week of operation (from [NC OPS])

Wide Area means the qualification of an Alert, Emergency or Blackout State when there is a risk of propagation to the interconnected Transmission Systems. (from [NC OS])

Year-Ahead means the year before the calendar year of operation (from [NC OPS])