European Network of
Transmission System Operators
for Electricity

Explanation of FCR Energy Requirement for CE and NE as Defined in NC LFCR

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1 INTRODUCTION

This document has been developed by the European Network of Transmission System Operators for Electricity (ENTSO-E) to accompany the consultation of the Network Code on Load-Frequency Control and Reserves (NC LFCR). It should be read in conjunction with the version of NC LFCR published by ENTSO-E on 28.06.2013 as well as the respective Supporting Document.

This document provides further explanation of the general framework of the requirements for Reserve Providing Units and Reserve Providing Groups focusing on provision of FCR and the respective minimum energy availability requirements.

2 RESERVE PROVIDING UNIT AND RESERVE PROVIDING GROUP

This section describes the relationship between

- the Power Generating Module and the Demand Unit introduced by NC RfG and NC DCC as concepts describing technical installations; and
- the Reserve Providing Unite and Reserve Providing Group introduced by NC LFCR.

Although the document focuses on FCR provision, the general definitions and concepts also apply to other reserve types.

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

The NC LFCR defines a Reserve Providing Unit as follows:

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

The definition states that one Reserve Providing Unit may consist of multiple Power Generating Modules and Demand Units with a common Connection Point.

Figure 1 illustrates the implication of this definition: In this example one Reserve Providing Unit consists of *m* Power Generating Modules and *n* Demand Units.

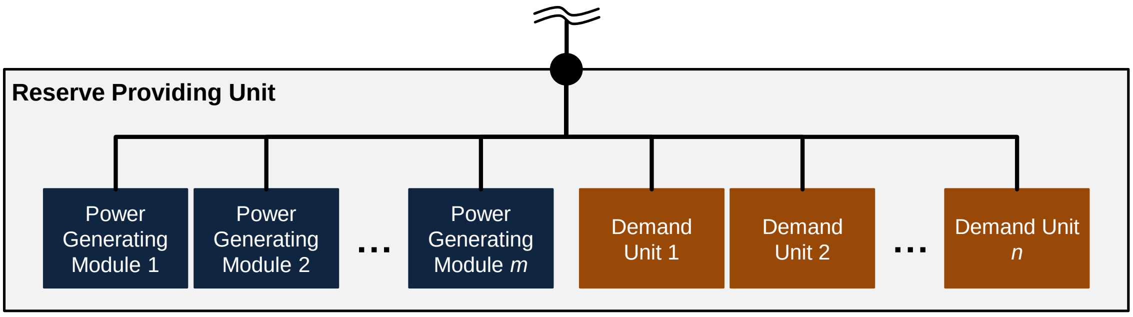


Figure 1: Reserve Providing Unit

The NC LFCR defines a Reserve Providing Group as follows:

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

Figure 2 shows two examples for the implementation of the definition:

- The Reserve Providing Group A consists of *l* Power Generating Modules and *m* Demand Units which are not connected to the same Connection Point. **Each of these Power Generating Modules does not have to fulfil the requirements** for provision of reserves **alone**.
- The Reserve Providing Group B demonstrates that it is **possible but not mandatory to aggregate** Power Generating Modules and/or Demand Units with Reserve Providing Units (which according to the definition fulfil the requirements for reserve provision).

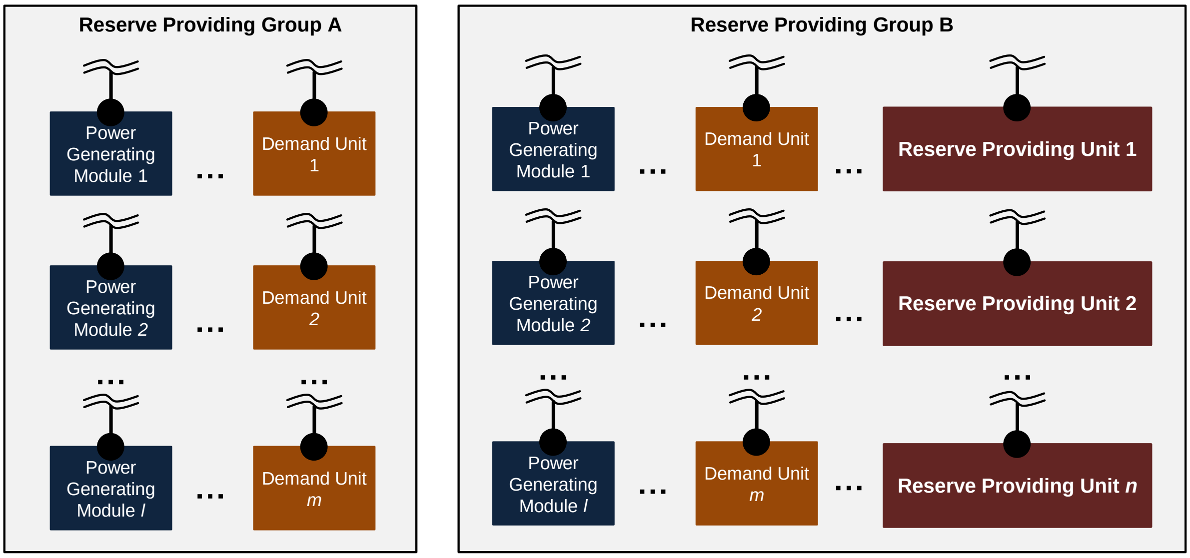


Figure 2: Reserve Providing Group – two examples

In context of stakeholder comments to the NC LFCR it is important to identify the following key implications of the definitions:

- NC LFCR explicitly allows flexible aggregation of Power Generating Modules and Demand Units within a Reserve Proving Group.
- The fulfilment of technical requirements for provision of reserves including the availability of FCR, FRR and RR is not necessary for a single Power Generating Module or Demand Unit within a Reserve Providing Group.
- It is fully up to the potential Reserve Providers to aggregate or not to aggregate Power Generating Modules and Demand Units within Reserve Providing Groups and/or Reserve Providing Units.

3 FCR PROVISION AND THE 30 MIN REQUIREMENT

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

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

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

For CE and NE, a FCR Providing Unit or a FCR Providing Group with a limited energy reservoir shall be able to activate full FCR Capacity for at least 30 minutes and refill the reservoir at latest within 2 hours.

Figure 3 shows an example for a FCR Providing Group with a limited energy reservoir. The illustrated FCR Providing Group consists of two pump-storage units and two batteries. The overall FCR Capacity provided by the FCR Providing Group amounts to 100 MW. Therefore, the FCR Providing Group has to store 50 MWh in order to comply with the 30 min requirement. The required energy is distributed among the single technical units.

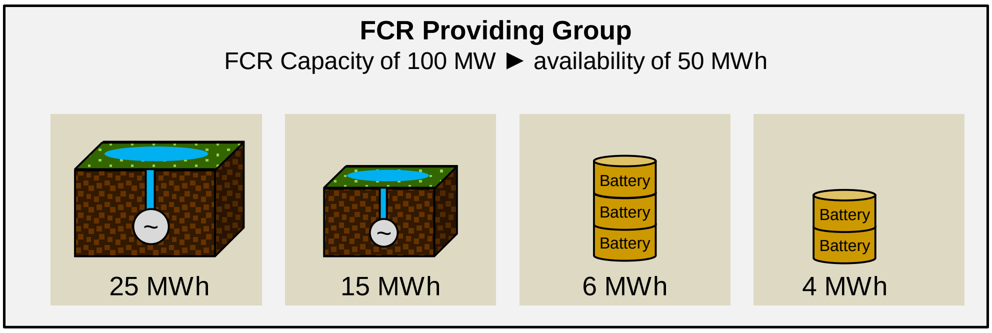


Figure 3: Reserve Providing Group with a limited energy reservoir

In context of stakeholder comments to the NC LFCR it is important to stress the following:

- It is fully up to the FCR Provider to aggregate single Power Generating Modules and/or Demand Units with limited energy reservoirs within a Reserve Providing Group.
- In this case the 30 min requirement shall apply in accordance with the definition to the whole Reserve Providing Group (not to a single Power Generating Module or Demand Unit).
- Obviously, the same requirement applies to single FCR Providing Units which are not to be confused with technical units that are part of an FCR Providing Group.

4 Analysis of the 30 min Requirement

The main argument related to the 30 min requirement raised by the stakeholders during the public consultation can be summarised as follows:

> *Since the Frequency Restoration Process is designed to regulate the Frequency Deviation to zero within Time To Restore Frequency which is equal to 15 min, it should be sufficient to require 15 min of FCR delivery.*

This section demonstrates the relationship between the disturbance, the FRR activation, the Frequency Deviation and the respective requirement.

4.1 Energy Requirement and Time To Restore Frequency

Figure 4 shows a simplified example for a possible series of disturbances and the respective FRR activation within 15 min.

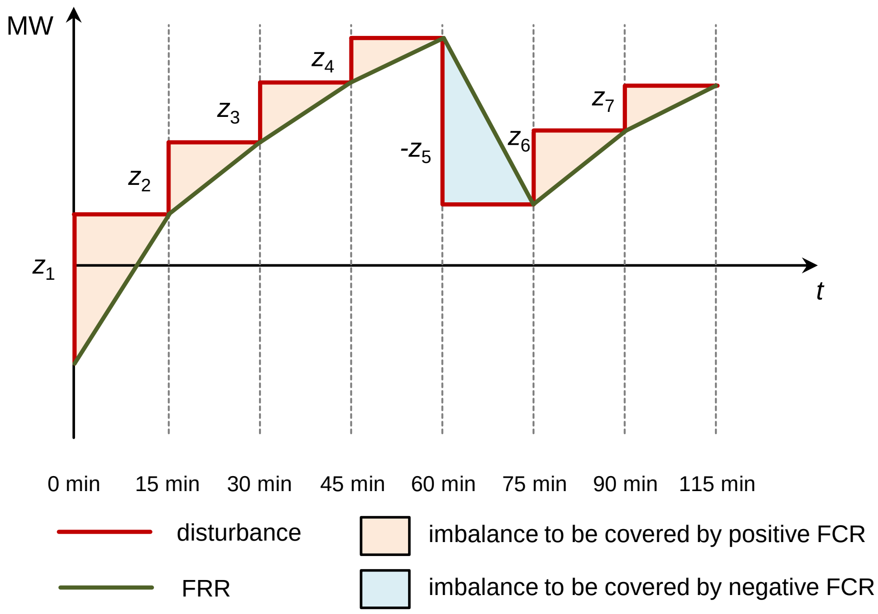


Figure 4: Example for a series of step-shaped disturbances and FRR activation

In this example the required FCR energy delivery in one 15 min interval E^i is equal to the area between the disturbance and FRR activation:

$$E^i = 0.5 \cdot z_i \text{ MW} \cdot 0.25 \text{ h} = z_i \cdot 0.125 \text{ MWh}$$

The overall FCR energy in this example is therefore equal to:

$$E = 0.125 \cdot (z_1 + z_2 + z_3 + z_4 + z_5 - z_6 + z_7) \text{ MWh}$$

It is obvious that the FCR energy required to offset the disturbance does not only depend on the correct functioning of FRR and its activation within Time To Restore Frequency but also on the overall pattern of disturbances.

Moreover, the dimensioning methodologies for reserves inherently include a probability of insufficient reserves or major disturbances which are not covered by the methodology. In these cases additional measures must be taken in order to limit the Frequency Deviations. These measures are often implemented by operational procedures which require a certain additional time to become effective.

Regarding the relationship between the Time To Restore Frequency and the FCR energy requirement the following conclusions can be made:

> Although there is a direct relationship between FRR activation and the required FCR activation as well as the respective energy, the overall FCR energy delivery depends on the overall behaviour, i.e. disturbance patterns, duration, gradients etc.

4.2 Analysis based on Real Frequency Data

Since the energy to be delivered by FCR depends highly on the disturbance and Frequency Deviation patterns, a respective investigation based on real frequency measurements was performed. This section summarizes the results of the analysis.

4.2.1 Methodology

In order to estimate the amount of energy required for ensuring FCR availability real Frequency measurements (for Synchronous Area CE) are taken as input for a simple model which simulates an FCR response of a FCR Providing Unit (or FCR Providing Group) with a FCR Capacity of 100 MW (figure 5):

- In the first step the Frequency data of one day is taken as an input to calculate the according Frequency Deviation which is then passed through a 10 mHz dead-band.
- The FCR activation is simulated by a constant proportional term.
- The resulting FCR energy is calculated by the integral of the FCR activation.
- It is assumed that the simulated FCR Providing Unit or FCR Providing Group uses the time frames with negative FCR activation to store energy and the time frames with positive FCR activation to release energy.
- The dynamics of FCR activation are neglected which is justified due to the fact that the FCR response is fast and the dynamic effects offset each other in the energy calculation.

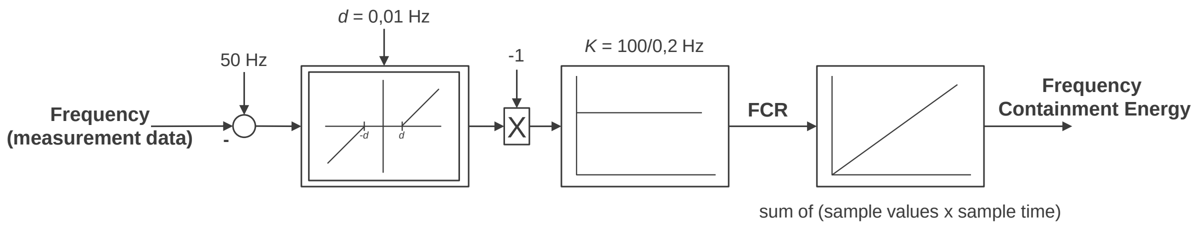


Figure 5: Model for simulation of FCR activation and energy with real frequency measurements

4.2.2 Evaluation Results

Figure 6 shows the result of the evaluation for one day (17.04.2012). The Frequency signal filtered by the 10 mHz dead-band is shown in blue, the resulting FCR energy in red. It can be seen that for this day an energy reservoir of less than 20 MWh is sufficient to supply FCR (20 MWh correspond to 12 min of full capacity activation).

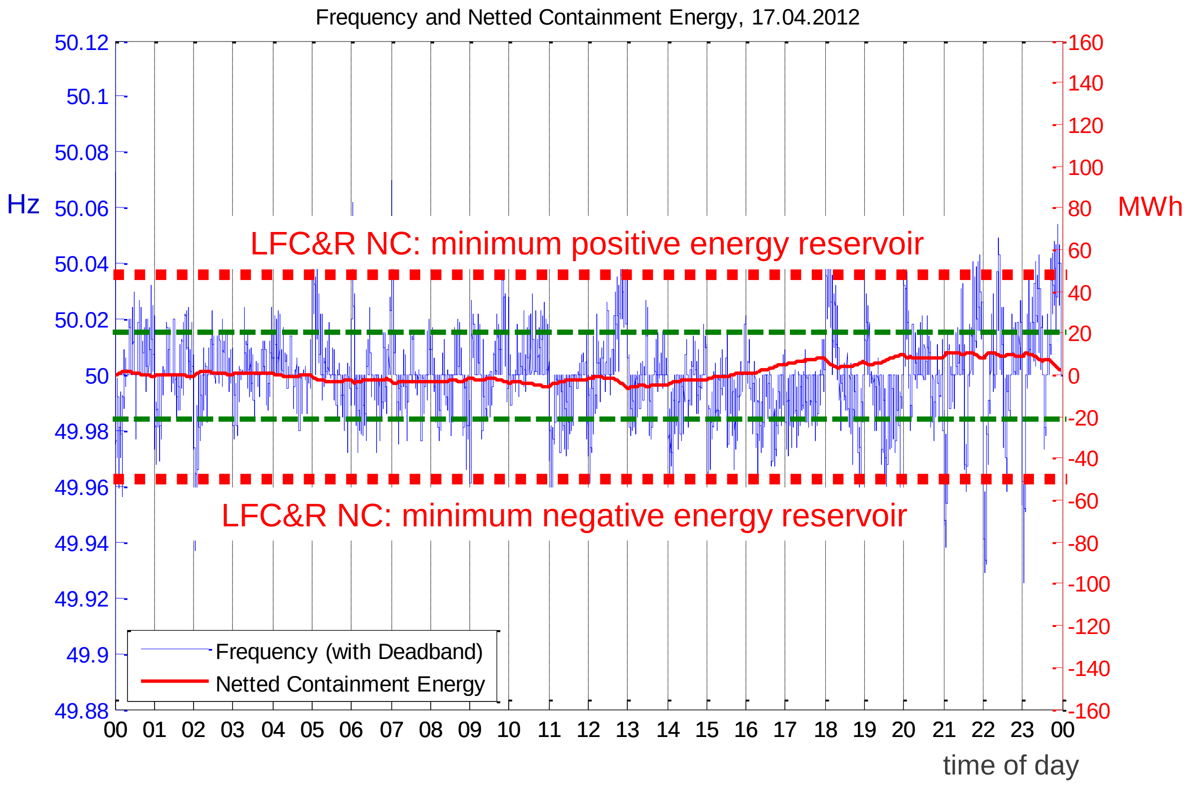


Figure 6: Example 1 – 17.04.2012

Figure 7 and

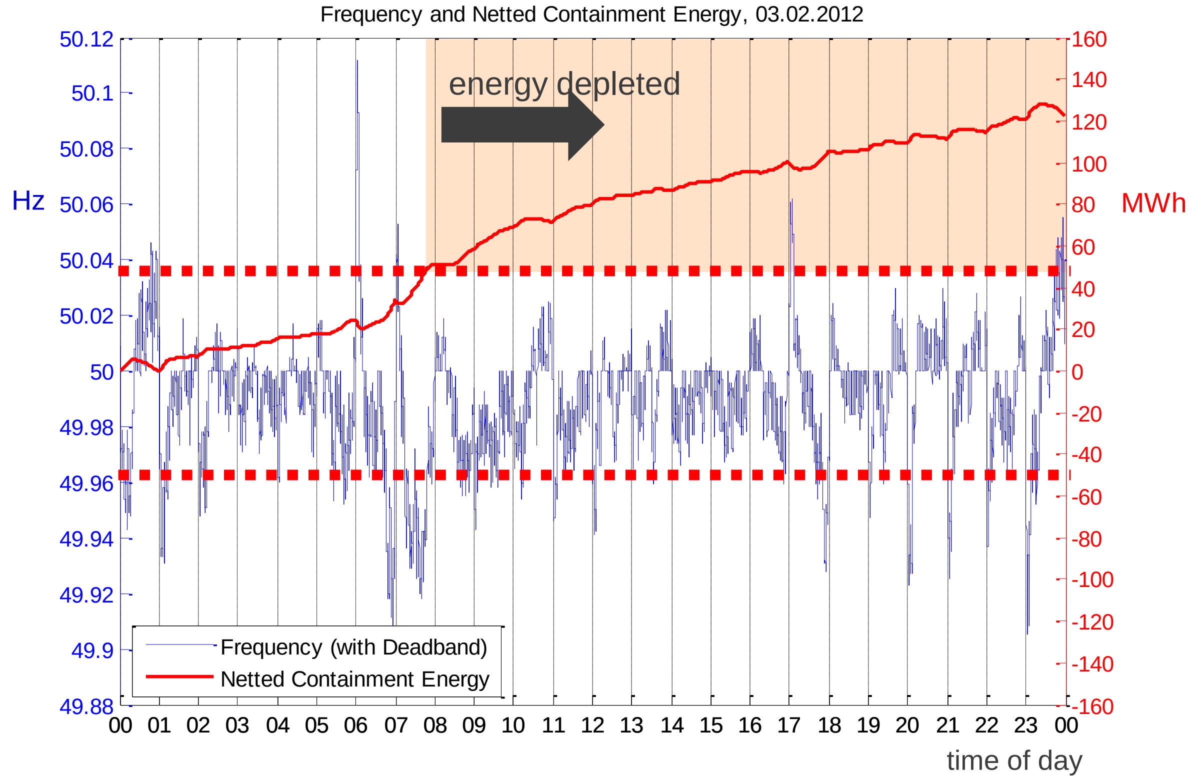


figure 8 show two examples for different days (18.10.2011 and 03.02.2012). In both cases following effects can be observed:

- The overall energy reservoir needed to deliver FCR during the whole day amounts to over 120 MWh (1 h and 20 min of full capacity activation).
- The 30 min requirement would lead to exhaustion of the energy reservoir at approximately 8:00.
- The primary drivers for the FCR energy demand are mean Frequency Deviations in one direction (in contrast to single events like the Frequency Deviations around the hour shift).

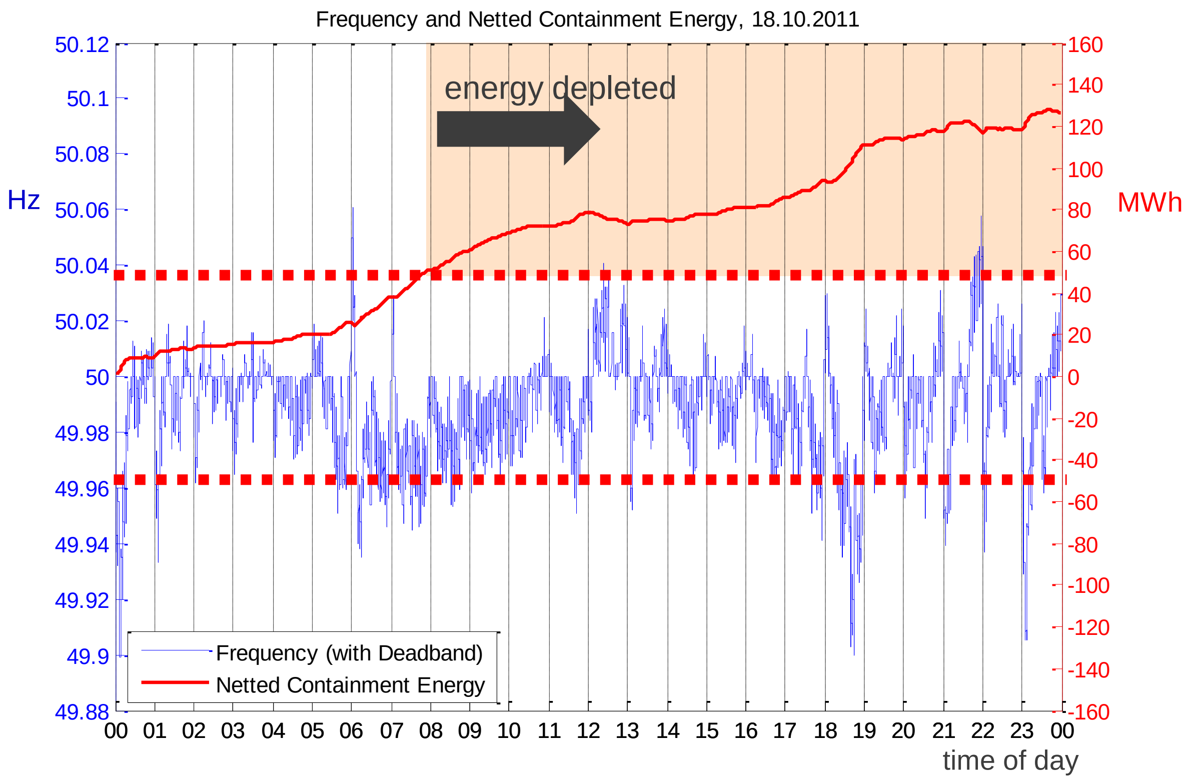


Figure 7: Example 2 – 03.02.2012

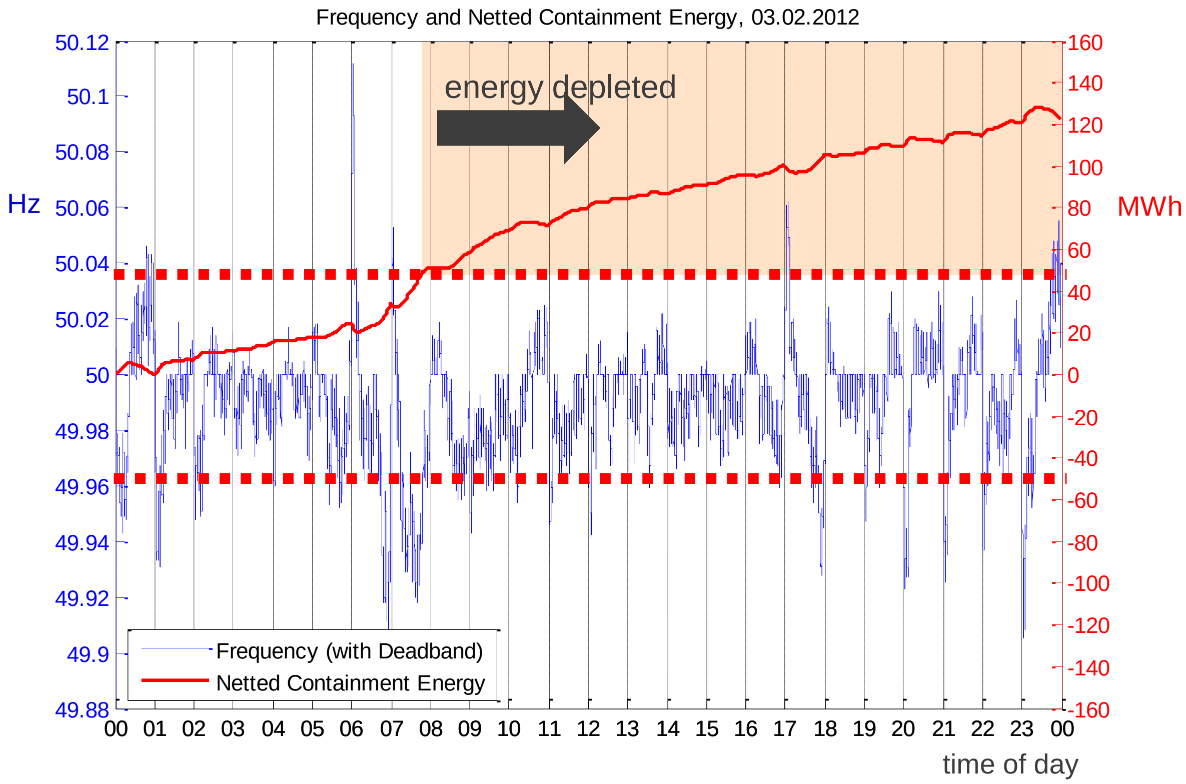
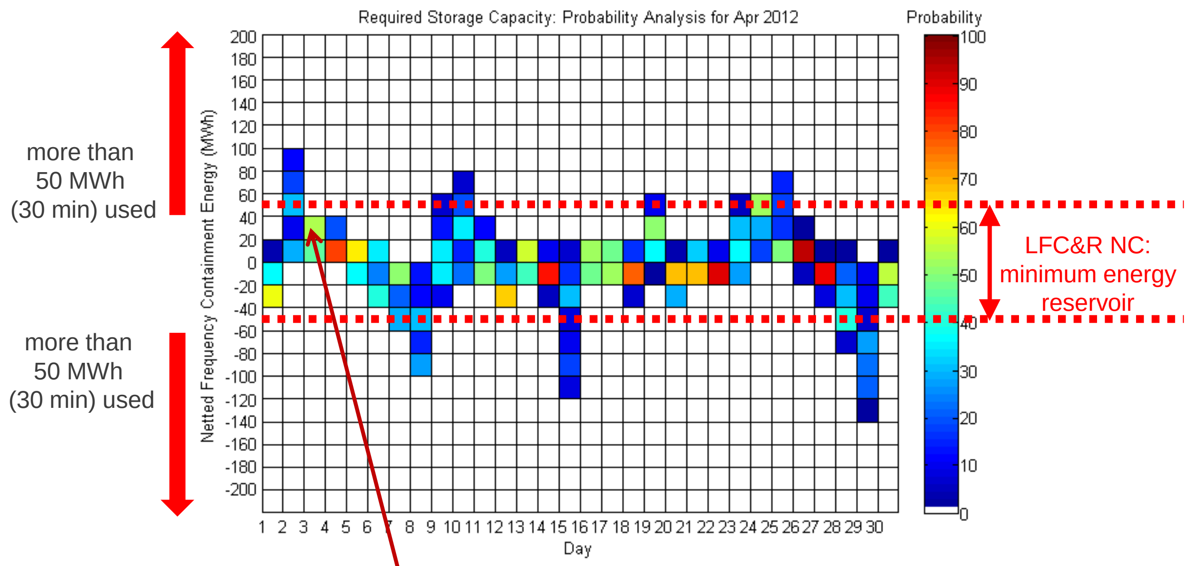


Figure 8: Example 3 – 18.10.2012

Figure 9 shows the results of the statistical evaluation of FCR energy for April 2012. Each vertical column represents a histogram for one day (20 MW classes). The colour of the rectangle represents the occurrence of the energy demand during the day as a percentage value. The evaluation shows that there were 7 days in April when an energy reservoir with a capacity higher than 60 MWh was required in order to ensure a continuous availability of FCR (3 days in positive and 4 days in negative direction).



Explanation: An energy reservoir of 20 MWh to 40 MWh is required for FCR delivery during approx. 50 % of this day (lower reservoir would mean that no FCR is available during approx. 50 % of this day)

Figure 9: Statistical evaluation of FCR energy requirement for April 2012

4.3 Conclusion of the Analysis

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

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

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

- the ability to activate full FCR Capacity for at least 30 minutes; and
- the ability to refill the reservoir at latest within 2 hours.

In this context the evaluations show:

- The ability to activate full FCR Capacity not longer than for 30 min leads regularly to energy exhaustion of the respective FCR Providing Units or FCR Providing Groups.
- Nonetheless, 30 min can be considered as a good compromise between ensuring the availability of FCR and enabling technical units with limited energy storage to participate in FCR Provision.

5 SUMMARY

The present document explains in detail the technical background of the FCR energy availability requirements for CE and NE in the context of the concepts Reserve Providing Unit and Reserve Providing Group.

- **The requirement to activate 30 min of full FCR Capacity** is derived from statistical analysis of Frequency Deviation patterns and is **a compromise** between continuous FCR availability and enabling technical units with limited energy reservoir to provide FCR.
- The requirement to activate 30 min of full FCR Capacity (like other requirements for reserve provision) **does not apply to each Power Generating Module or Demand Unit which is part of a FCR Providing Unit or a FCR Providing Group.**
- The **NC LFCR leaves the flexibility** to potential FCR Providers **to aggregate single Power Generating Modules or Demand Units in an FCR Providing Group** in order to fulfil the respective requirements as a group.
- Consequently, **the energy required** to fulfil the 30 min requirement **can be distributed among all energy reservoirs** which are part **of the same FCR Providing Group** without any further constraints.
- The **operation of Power Generating Modules and Demand Units within the FCR Providing Group** including the energy management **is fully up to the FCR Provider** and is not covered by NC LFCR.

In conclusion it can be stated:

Taking into account

- the implications of Frequency Deviation patterns for FCR activation; and
- full flexibility to aggregate any type of Power Generating Modules and Demand Units within a FCR Providing Group in order to fulfil the requirements for FCR provision,

the energy availability requirement can be considered as justified.

ANNEX – RESULTS OF STATISTICAL EVALUATIONS

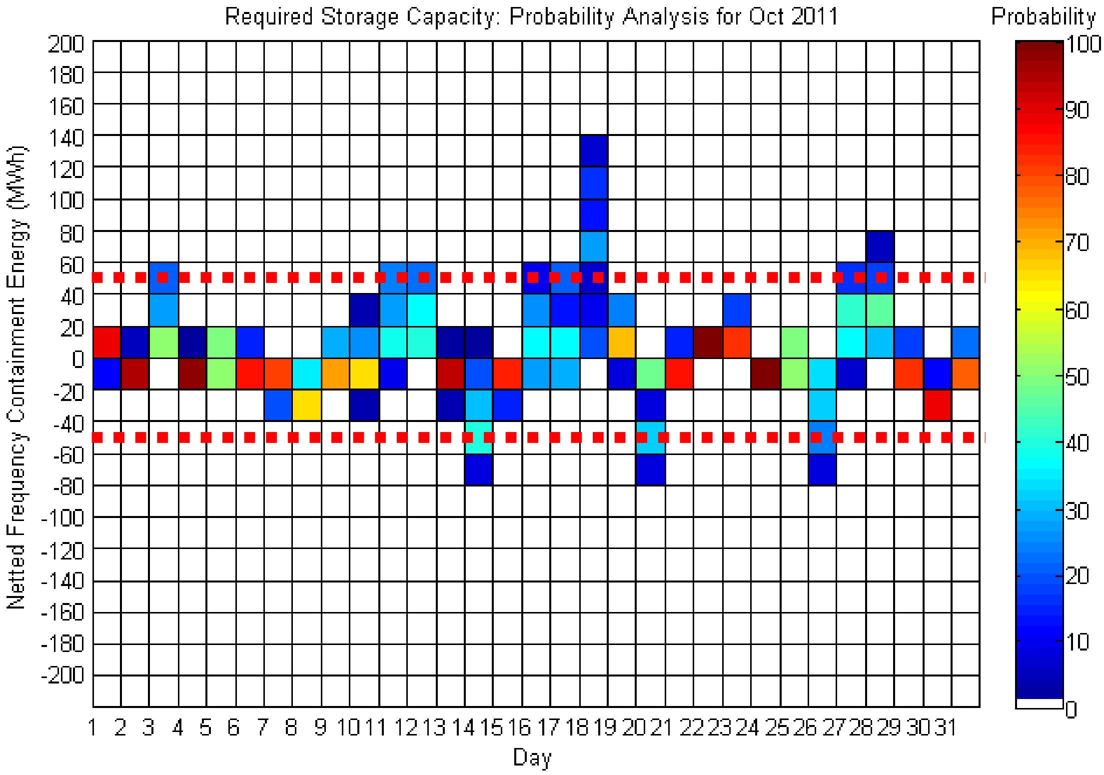


Figure 10: Statistical evaluation of FCR energy requirement for October 2011

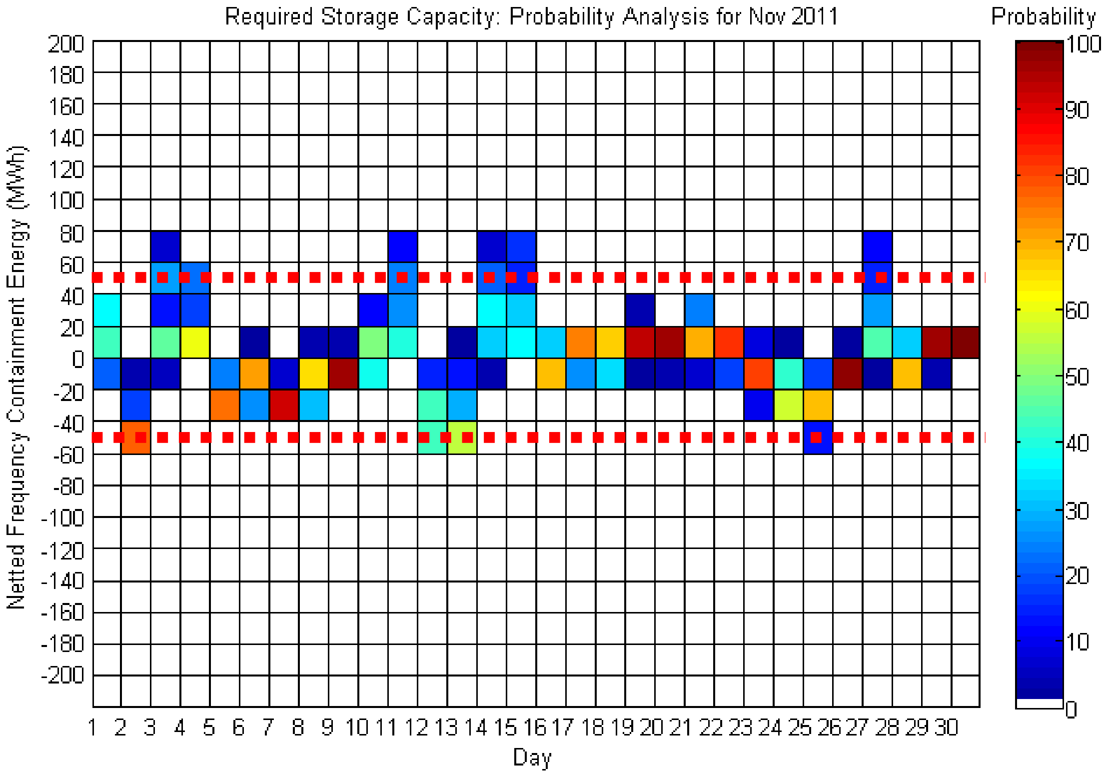


Figure 11: Statistical evaluation of FCR energy requirement for November 2011

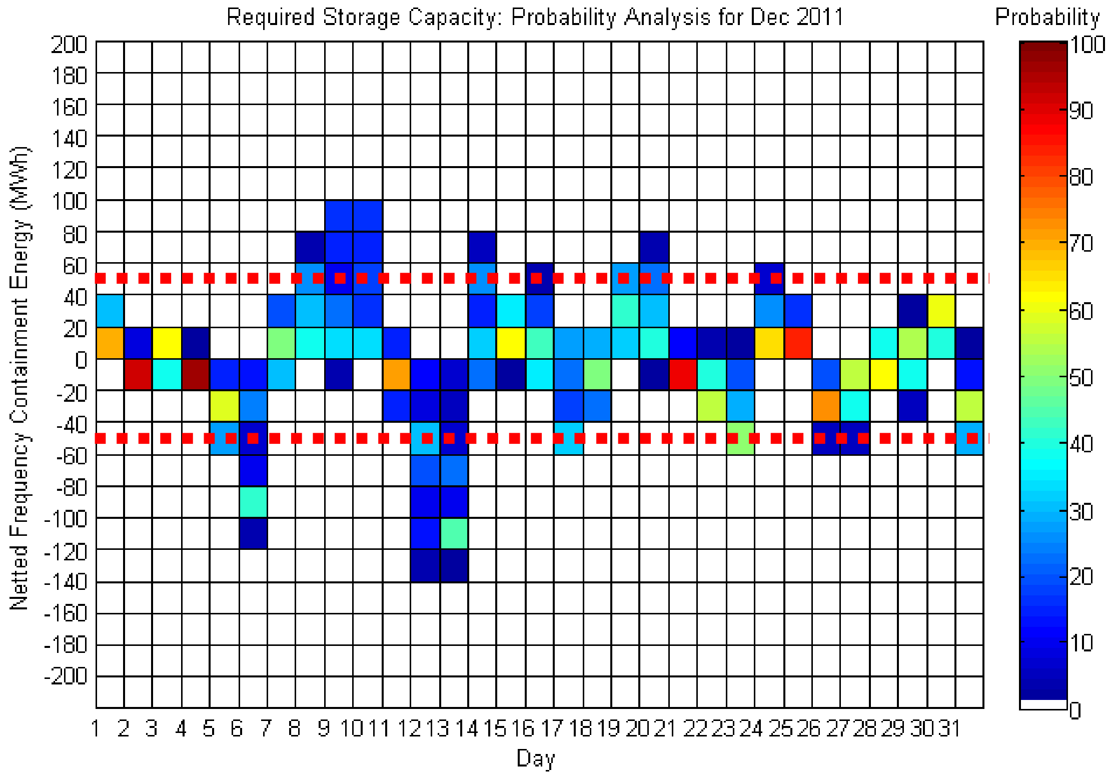


Figure 12: Statistical evaluation of FCR energy requirement for December 2011

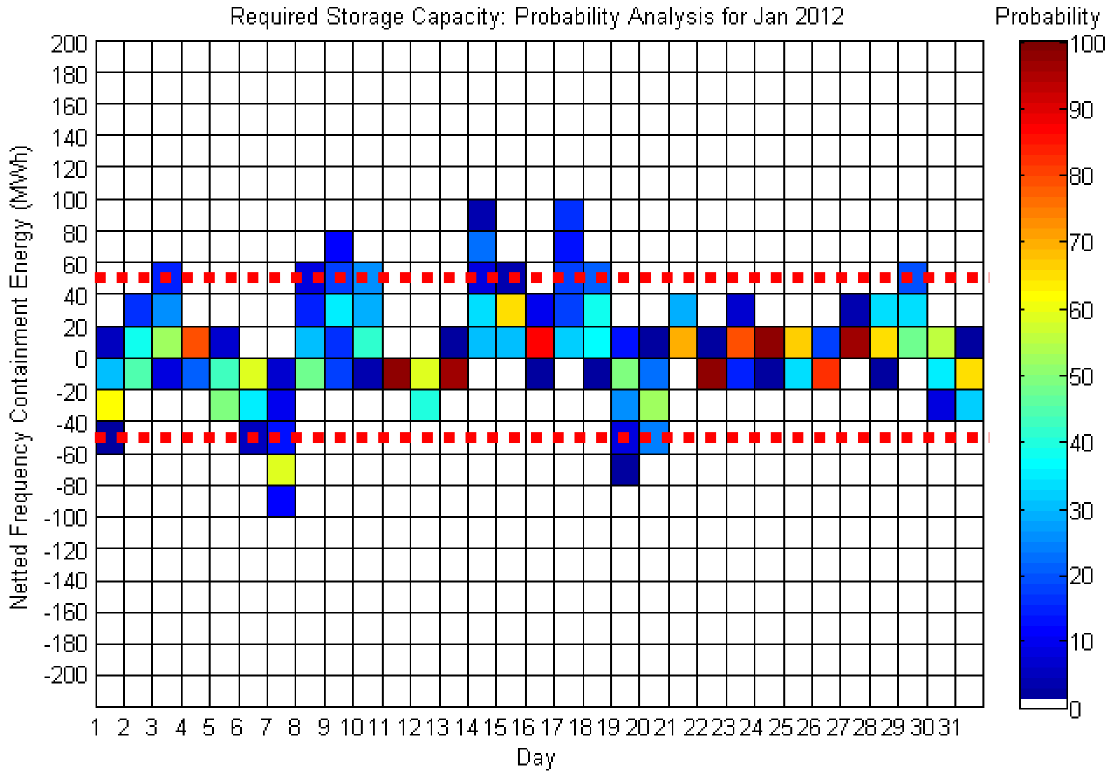


Figure 13: Statistical evaluation of FCR energy requirement for January 2012

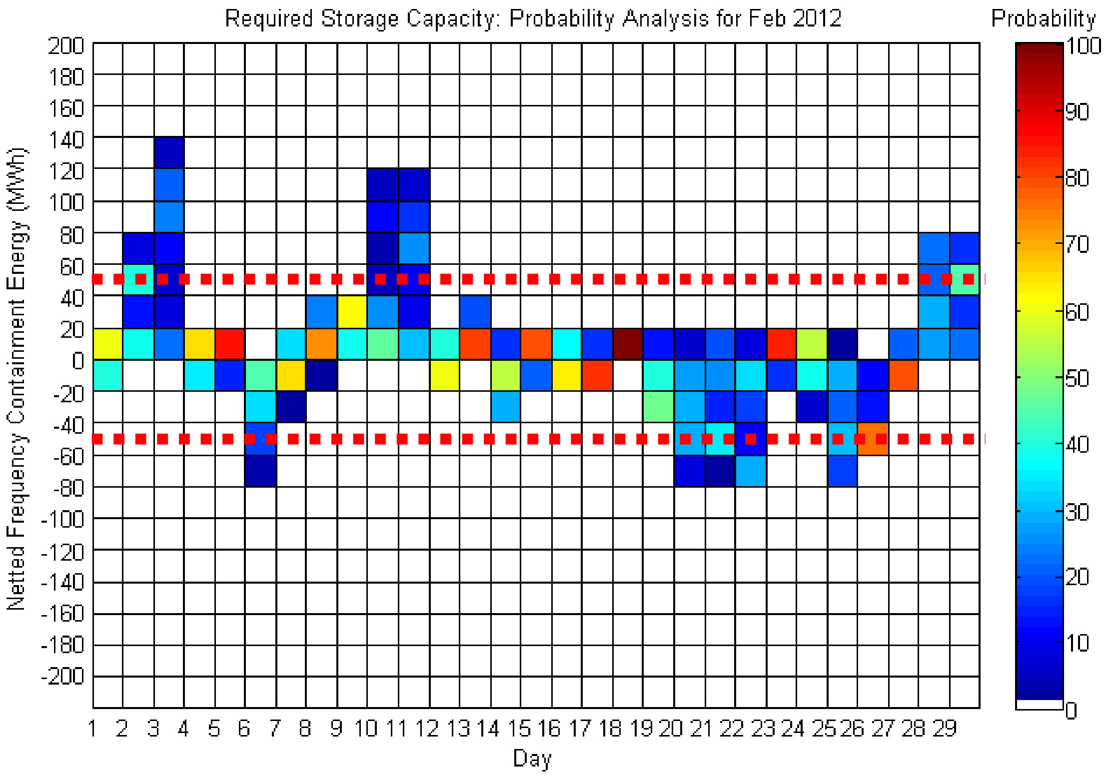


Figure 14: Statistical evaluation of FCR energy requirement for February 2012

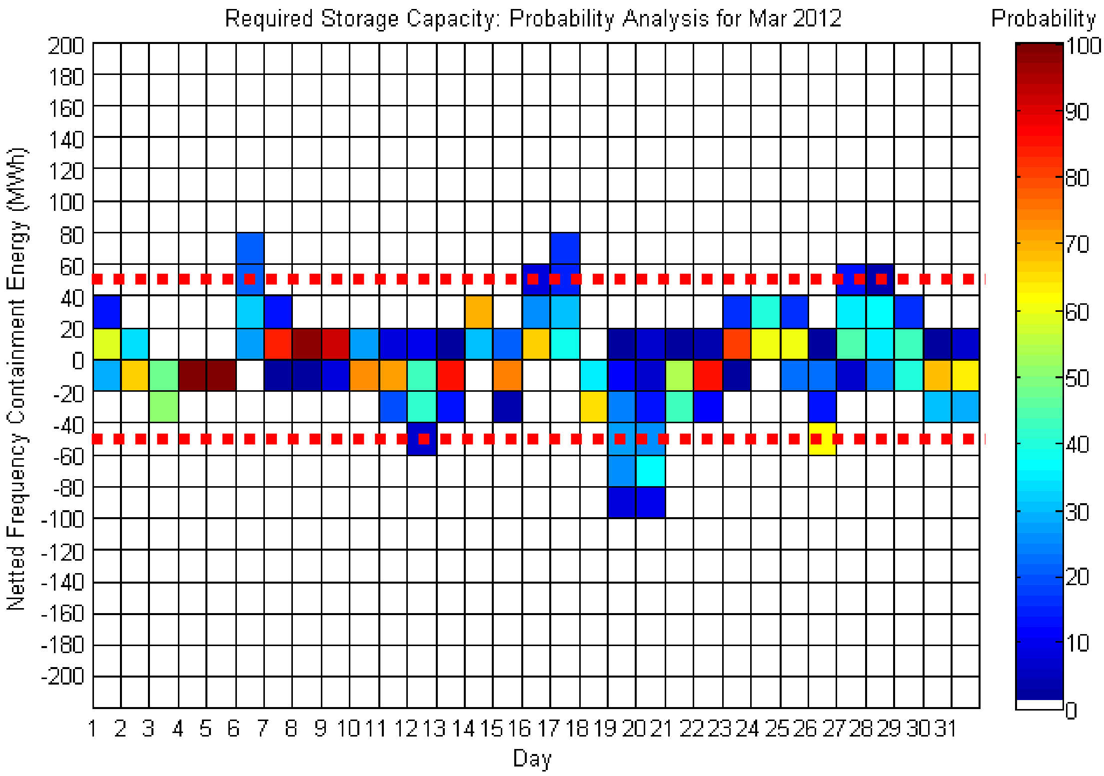


Figure 15: Statistical evaluation of FCR energy requirement for March 2012

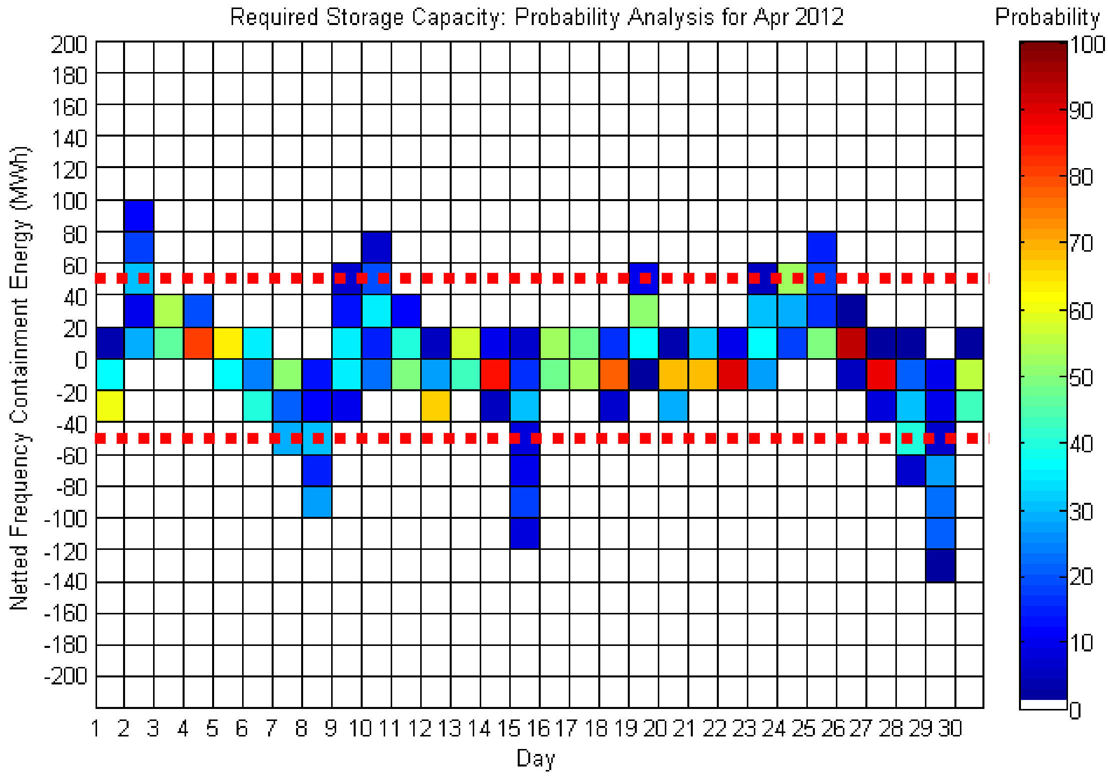


Figure 16: Statistical evaluation of FCR energy requirement for April 2012

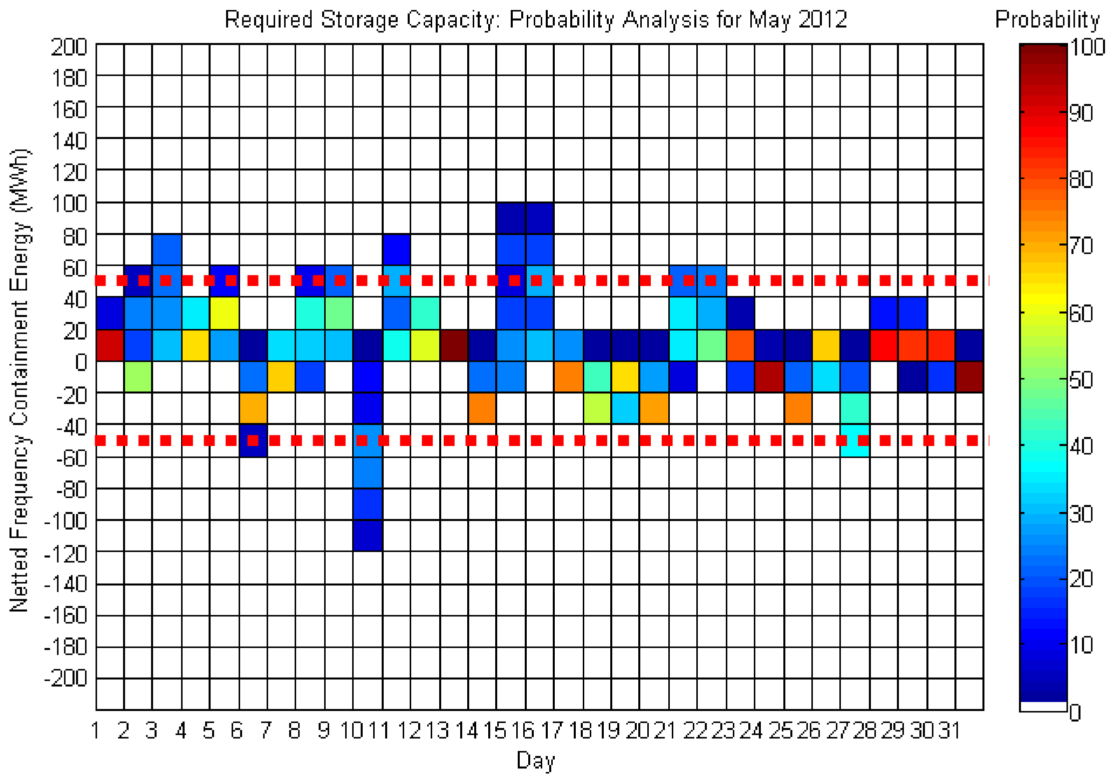


Figure 17: Statistical evaluation of FCR energy requirement for May 2012

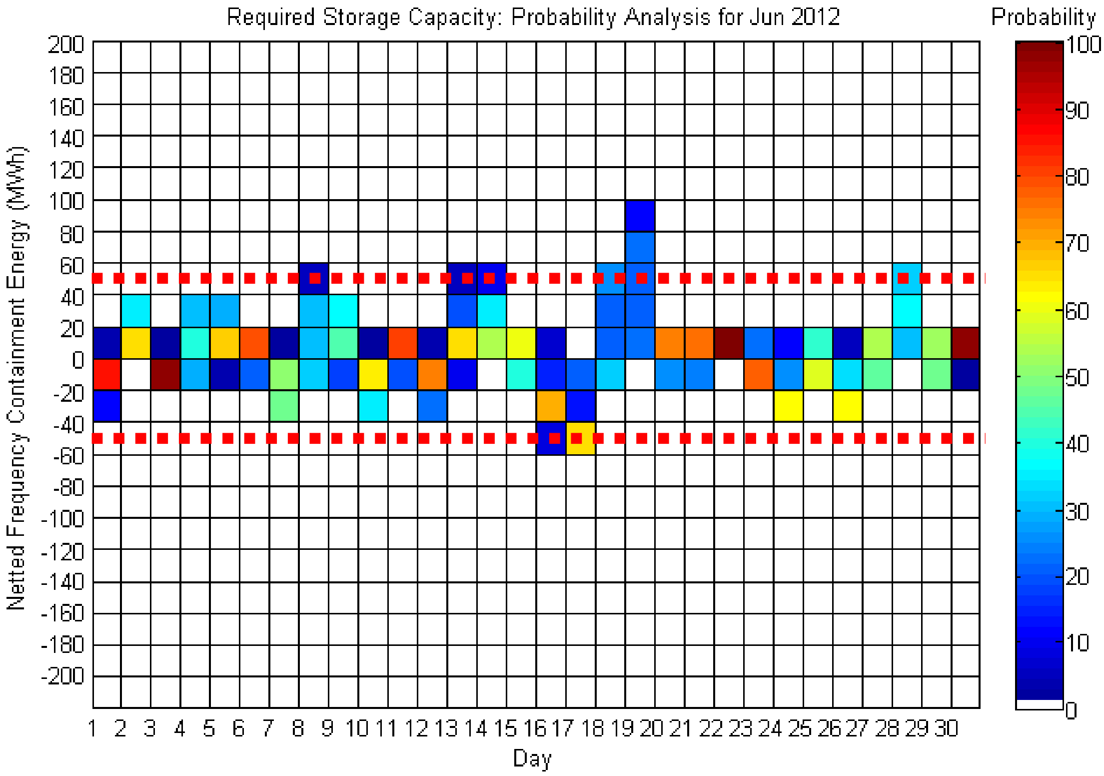


Figure 18: Statistical evaluation of FCR energy requirement for June 2012