Appendix 1: Technical Product Specification
For delivery of Frequency Restoration Reserves to Statnett

<table>
<thead>
<tr>
<th>Project</th>
<th>Norwegian FRR Implementation</th>
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<tbody>
<tr>
<td>Authors</td>
<td>Lindeberg/Whitley</td>
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Abstract

The purpose of this document is to specify the uniform product that is required by Statnett in the delivery of Frequency Restoration Reserves (FRR) from Providers.

This document is a reference document for potential Provider and the National project team implementing FRR in the Norway.

Furthermore it is and information document for other Nordic TSO who with Statnett are collectively committed to implement FRR in the Nordic Synchronous system.
Document
The management control document shall be reviewed if the scope is modified or if other significant changes which impact the completion of the project

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<th>Version</th>
<th>Revision</th>
<th>Author</th>
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Contents

PREFACE .............................................................................................................................. 1
PURPOSE .............................................................................................................................. 1
STRUCTURE OF THE DOCUMENT .................................................................................... 1
1. INTRODUCTION .............................................................................................................. 1
   1.1 OVERALL CONTROL PHILOSOPHY .................................................................... 1
   1.2 UNIFORM NORDIC PRODUCT .............................................................................. 1
2. PRODUCT SPECIFICATION ............................................................................................ 2
   2.1 PARAMETERS AND VALUES .................................................................................. 2
   2.2 CAPACITY/REGULATING VOLUME ....................................................................... 3
   2.3 SET-POINT-DEFINITION ...................................................................................... 3
   2.4 DELIVERY TIME .................................................................................................... 4
   2.5 DELAY .................................................................................................................. 4
   2.6 TURN TIME LIMIT ................................................................................................. 4
   2.7 BLOCK .................................................................................................................... 5
   2.8 STATION/GENERATOR MIX ................................................................................ 5
   2.9 INTERPLAY BETWEEN FCR AND FRR ............................................................... 5

ANNEX A: STEP DYNAMICS FROM OPEN LOOP TESTS .................................................... 7
(N.B. FOR INFORMATION PURPOSES ONLY) ..................................................................... 7

DESCRIPTION OF OPEN-LOOP OPERATION ....................................................................... 7
KEY RESULTS ....................................................................................................................... 8

TABLES AND FIGURES

TABLE 1 - TECHNICAL PRODUCT PARAMETERS FOR DELIVERY OF SECONDARY RESERVES.......................................................... 2
FIGURE 1 - EXAMPLE OF A REGULATION SCHEDULE ................................................... 4
FIGURE 2 - EXAMPLE OF TURN TIME LIMIT ................................................................. 5
TABLE 2 – REGULATING MARGIN OF TEST UNITS ......................................................... 7
FIGURE 3- SECONDARY RESERVE SET-POINTS TO 3 TEST UNITS FOR AN HOUR WITH LARGE IMBALANCES ....................... 8
TABLE 3- KEY STATISTICS FROM 24 HOURS OF OPERATION IN CLOSED LOOP ................. 8
Preface

Purpose
This document describes the uniform product in terms of the technical parameters required by the Providers' response when a set-point signal from the Statnett is received in their Automatic Frequency Restoration Regulation scheme. The response can be from a generator or other solution, but must meet these criteria.

Structure of the document
Chapter 1 – Introduction
Chapter 2 – Product specification
Annex A – Step dynamics (information document only)
1. Introduction

This document will describe the uniform product response which has been identified in analysis conducted by the Nordic TSO in their Review of Automatic Reserves (RAR). In this work the time constant of the Nordic synchronous system was studied and this is the basis for the response requirements. Furthermore FRR need to operate in a way that does not cause instability with primary reserves and this has also been evaluated in the RAR project.

1.1 Overall control philosophy

The Frequency Restoration Regulation control system works by measuring the system frequency error that is used to calculate the required power to balance the system.

The aim of Nordic FRR is to ensure system stability is maintained. The risk of a major incident or outage occurring whilst the system frequency outside the 49,9 to 50,1 frequency band is increasing and improvements are necessary.

The Automatic Frequency Restoration regulation should not affect the overall stability of the Power Control system. To do this it is important to make sure that the FRR control loop does not interfere with the Frequency Containment Reserves control system dynamics. Therefore the FRR must react slower to changes in the frequency than the FRR (primary). This is achieved by applying a low-pass filter to the frequency measurement in FCR with a sufficiently high time constant.

The RAR project has defined the necessary changes to Frequency Containment Reserves (FCR) and the requirements for FRR such that the system time constant could be reduced to optimize the total automatic reserve response.

1.2 Uniform Nordic Product

A successful Nordic implementation of a FRR market will depend on that Providers in all countries are delivering a comparable product. It is Statnett’s opinion that this is best achieved by having one uniform product, this will assist ease of monitoring and be an efficient tool for regulation. It is also a prerequisite to achieve a common market.
2. Product specification

2.1 Parameters and values.

The response required from providers is illustrated in the figure below and defined in the table which defines the parameters that form the FRR Unit response.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block Size</td>
<td>5 MW</td>
<td>Minimum value; every set-point is a multiple of this. N:B Statnett have changed this from 10MW according to Nordic harmonisation-</td>
</tr>
<tr>
<td>Delivery time</td>
<td>120 s</td>
<td>Maximum value, N.B Statnett may request a longer time period up to 210 s should Nordic harmonisation require it.</td>
</tr>
<tr>
<td>Delay</td>
<td>30 s</td>
<td>Maximum value</td>
</tr>
<tr>
<td>Duration</td>
<td>30 Min</td>
<td>The maximum duration of a single set-point[^1]</td>
</tr>
<tr>
<td>Maximum step</td>
<td>20 MW</td>
<td>This is the maximum step required from a provider in single set-point change</td>
</tr>
<tr>
<td>Ramp rate</td>
<td>N/A</td>
<td>Not specified dependent on Block size and Delivery time, note the Block is Provider defined.</td>
</tr>
<tr>
<td>Set-point signal rate</td>
<td>10s</td>
<td>Cycle time of Statnett EMS</td>
</tr>
<tr>
<td>Turn time limit</td>
<td>60 s</td>
<td></td>
</tr>
<tr>
<td>Minimum change per Unit</td>
<td>5 MW</td>
<td>A set-point change from the AGC to a single generator should not be less than this value. [to ensure accuracy in activation]</td>
</tr>
</tbody>
</table>

[^1]: There are at this moment no limitations to the length continuous activation in one direction; neither for time nor for energy. Nordic harmonisation may require duration of capacity bids to be limited in time as some types of Providers may have limited energy. This may be defined by the time periods of the blocks to be bid, see Appendix 4 in the framework agreement; "Vilkår for anmelding og håndtering av tilbud" for more information on the current requirements.

Table 1 - Technical product parameters for delivery of Secondary Reserves
2.2 Capacity/Regulating volume

The regulating volume defines the maximum and minimum change that Statnett can request from an FRR Unit.

The available regulating volume for each FRR Unit is the result of the Secondary Reserves Market. Statnett can only regulate within the purchased regulating margins; unless Statnetts’ control centre agrees an increase to regulation limits in operation (for example with failure of delivery from another Provider).

2.3 Set-point-definition

The signal from Statnett is a delta set-point and tells how much the Provider should differ from the planned production, or the production without FRR.

Planned changes in production due to tertiary regulation or spot trade shall go ahead, and shall not affect the contribution to FRR.
Frequency Containment Reserves can still be delivered (see Appendix 2 of the framework agreement).

Figure 3 - Example of a regulation schedule (N.B. GENCO means Provider)

2.4 Delivery time
The delivery time is the time from the signal is sent from the TSO to the generators reach their new set-point.

The minimum delivery time should be met for individual changes of up to the max step size (see table 1 currently 20MW).

2.5 Delay
The delay time denotes the time from the signal is sent from the TSO until the generators start to change their generation. This delay time should be as short as possible, maximum equal to the time set in table 1.

The delay time shall be the same when responding to changes in both directions.

2.6 Turn time limit
The Turn time limit is a minimum time the set-point should be unchanged before the TSO could send a set-point in the opposite direction.

The turn time limit should only be set if it exists unstable dynamics in the waterways in the system with slower dynamics than the main filter dynamics in the central FRR controller.

The turn time parameter will be evaluated in the approval process, see Appendix 3.
2.7 Block
The set-point signal from the TSO will always be multiples of the MW block size. I.E. if the MW block size is 5 MW the set-point signal will always be multiples of 5 (E.G: 0, 5, 80, -40).

Because of the filtering in the main controller the total power demand will change gradually. This in turn means that most changes sent to the FRR Unit are one step only. Refer to Annex A for more information.

2.8 Station/generator mix
The FRR Unit can be made up of one or more generators, and the set-points coming from the TSO could be distributed among these as the Provider sees fit, as long as the FRR Unit can comply with all the performance requirements described above.

It could, for example, be possible to combine a large and slow production unit with a fast smaller unit in order to deliver secondary reserves also from the slow unit without compromising with the performance requirements. The approval requires that the mix of generators is documented and used for subsequent deliveries to ensure that the uniform product is actually delivered.

2.9 Interplay between FCR and FRR
The Provider may deliver both FRR and FCR from the same station/generator at the same time.
When the Provider defines the capacity of FRR to which it will be obligated through a bidding process it must calculate the FCR maximum capacity based on a frequency deviation of 0.5 Hz [49.5 – 50.5 Hz], taking into account the current droop settings.
Annex A: Step dynamics from open loop tests  
(N.B. for information purposes only)

This appendix provides the provider with an insight into how the Secondary reserves may vary with the Nordic frequency as an input. It is provided for information purposes only and is not guaranteed by Statnett, it is meant to give the Provider some insight to assist their evaluations only.

Description of open-loop operation

The FRR functionality has been implemented in the Statnett EMS system and is running in open-loop operation with real input values.

The FRR has been implemented with 3 SR Units and a total regulating margin of +/- 300 MW, and integral action limited to +/- 100 MW.²

<table>
<thead>
<tr>
<th>Unit</th>
<th>Regulating margin UP [MW]</th>
<th>Regulating margin DOWN [MW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Unit 1</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Test Unit 2</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Test Unit 3</td>
<td>150</td>
<td>150</td>
</tr>
</tbody>
</table>

Table 2 – Regulating margin of test units

The main insight that can be drawn from the test operation is in the allocation algorithm. How often and with how large steps the set-point signals will change, and how often will the changes change direction. It could also be interesting to compare the large and the small units and see where they differ and where they are similar.

The data presented here is from one 24-hour period. 10 MW step-size is used.

² Integral action in a PI(D) controller does not really make sense in open-loop operation, and is therefore limited. It is not excluded to give some insight in how the complete dynamics will be.
Figure 5 - Secondary reserve set-points to 3 test units for an hour with large imbalances

Key results

<table>
<thead>
<tr>
<th></th>
<th>Test Unit 1</th>
<th>Test Unit 2</th>
<th>Test Unit 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total no. of changes (24 hrs)</td>
<td>682</td>
<td>688</td>
<td>1077</td>
</tr>
<tr>
<td>Avg. time between changes [min]</td>
<td>2,1114</td>
<td>2,093</td>
<td>1,337</td>
</tr>
<tr>
<td>Avg. size of changes [MW]</td>
<td>10,66</td>
<td>10,727</td>
<td>11,058</td>
</tr>
<tr>
<td>No. of direction changes</td>
<td>216</td>
<td>216</td>
<td>224</td>
</tr>
<tr>
<td>Avg time between direction changes [min]</td>
<td>6,6667</td>
<td>6,6667</td>
<td>6,4286</td>
</tr>
<tr>
<td>Average size sustained changes [MW]</td>
<td>24,17</td>
<td>23,63</td>
<td>43,36</td>
</tr>
<tr>
<td>Average set-point value [MW]</td>
<td>-8,5</td>
<td>24,7</td>
<td>16,0</td>
</tr>
<tr>
<td>Average absolute set-point value [MW]</td>
<td>45,3</td>
<td>50,3</td>
<td>93,4</td>
</tr>
<tr>
<td>Accumulated energy over 24 hrs. [MWh]</td>
<td>-203</td>
<td>593,74</td>
<td>384,04</td>
</tr>
</tbody>
</table>

Table 3 - Key statistics from 24 hours of operation in closed loop
The key findings from this test are as follows:

i. **Small changes** – The average size of changes sent to the FRR Units is just over 10 MW. Since this is also the minimum step in these simulations that means that almost all changes are 10MW.

ii. **In the same direction**: Most changes are in the same direction as the last one, and the average time between direction changes is higher than the time between changes in the same direction. Nearly half of the direction changes is for 1 step, 10 MW only.

iii. **Large unit get more but still the same.** The large units will receive more changes than the small units, but the number of direction changes is stable.

iv. **Not necessarily energy neutral.** For this 24 Hour period the frequency has been slightly lower than 50 on average, and hence the SR demand has been more positive than negative.