Statnett

Appendix 1:

Technical Product and Interface Specification for Delivery of Automatic Frequency Restoration Reserves (aFRR) to Statnett

Version June 2023

I. Document

This document must be reviewed accordingly if the scope is modified or other significant changes are made that impact the interpretation of the document, e.g. changes in the market conditions.

Version	Revision	Author	Date
0.1	Initial draft SN	DW/EL	10-01-2011
1.0	External version	DW/EL	07-11-2011
2.0	External version for procurement	DW	09-01-2012
3.0	Reworked version	Unknown	10-2021
4.0	Revised version	LPA	01-06-2023

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II. Definitions

aFRR	*Automatic Frequency Restoration Reserves (aFRR)* are automatically activated from the TSOs. The purpose of aFRR is to release primary reserves and bring the frequency in the power grid back to its nominal value of 50.00 Hz.
aFRR providing unit	An aFRR providing unit is a controllable object realised by **one single asset or a group of assets.**
Assets	Power producing/consuming/storing assets such as hydro generators, wind turbines, solar power installations, energy storage, consumption facilities and so on that deliver aFRR to Statnett are referred to as *assets* in this document.
Balancing capacity	A volume of reserve capacity that a BSP has agreed to hold and in respect to which the BSP has agreed to submit bids for a corresponding volume of balancing energy to the TSO for the duration of the contract.
BSP	A Market Participant providing Balancing Services to its Connecting TSO, or in case of the TSO-BSP model, to its Contracting TSO.
BSP's Control System	The BSP's Control System, e.g. automatic generator control, is a control function running in the BSP's SCADA system. It needs to have automatic transmission of set-points to the asset and must be able to take control orders sent by the TSO and execute them. The control system should not have any other closed loop frequency functions other than that of primary reserve. The TSO orders are combined with the BSPs' predefined generation schedule. It is assumed that the system has a control function for executing the schedules.

	The control system does not have to be a closed loop system, but it is preferable. It is used to transfer the control orders from the TSO to the assets. The details of how this is done are up to the BSP and its implementations. Some requirements are mandatory to ensure that the aFRR functions correctly.
Full Activation Time (FAT)	The time it takes from an aFRR activation signal is sent from the TSO's SCADA system until the assets within the aFRR providing unit reach their new power output level according to the new set-point.
Delay time	The period of time between an aFRR activation signal is sent from the TSO's SCADA system until the assets within the aFRR providing unit starts its physical delivery.
Load Frequency Control (LFC)	aFRR has previously been referred to as Load Frequency Control (LFC). With the Nordic harmonization this specific type of reserve is referred to as *automatic Frequency Restoration Reserve.* In European legislation LFC has a different meaning, which include both the frequency containment process and frequency restoration process.
Asset/production mix	An aFRR providing unit can be made up of one or more assets. The TSO provides the set-points which the BSP distributes as they see fit while staying mindful of the performance requirements. It could, for example, be possible to combine a large and slow production unit with a fast, smaller unit. This would provide the capability to provide aFRR from the slow unit without compromising with the performance requirements. To approve this set up, the mix of assets must be documented and used for subsequent deliveries. This is to ensure that the uniform product is delivered.
Station group	A Station group is a set of assets that are co-located and connected to the electrical power grid via several substations. If the TSO approves it, a station group can be treated as one aFRR providing unit. This approval will be part of the pre-qualification process.

1 Introduction

1.1 Brief introduction to aFRR

The automatic Frequency Restoration Reserves (aFRR), previously known as Load Frequency Control (LFC), is a control function running in the TSO's (Statnett's) SCADA system which can control frequency and interchange (flow in or out of the control area) in the power system. This is a secondary control scheme that operates in parallel with the primary regulation but on a slower bandwidth. Primary regulation, now named *Frequency Containment Reserves (FCR)* which is locally implemented in the asset, will match the generation with the load quantum but will not recover system frequency to the nominal level. This task is performed by aFRR using a PI regulator, by automatically regulating the response based on the system frequency.

The main aim of aFRR is to improve the frequency quality in the Nordic synchronous area. Whenever a frequency deviation is recognized an appropriate volume of balancing capacity is activated automatically such that the system frequency is returned to its nominal value of 50.00 Hz and the activated primary reserves are released. Automatic regulation is the key to achieve a faster response time.

The aFRR regulation should not negatively affect the overall stability of the power system. To ensure this, it is important that the aFRR response does not interfere with the FCR response. Therefore, the aFRR must react slower to changes in the frequency than the FCR). This is achieved by applying a low-pass filter to the frequency measurement that is used to control the aFRR contribution with a sufficiently high time constant.

2 Product specification

2.1 Asset/ production mix

An aFRR providing unit can be made up of one asset or a group of assets. The contribution from each individual asset can vary if the total volume of balancing capacity is kept unchanged.

From the TSOs perspective it is a single unit controlled with a single set-point. How this set-point is distributed among the physical assets within the group is solely decided by the BSP's control system (see **Feil! Fant ikke referansekilden.**). The BSP's bids for supply are given per aFRR providing unit. The bids must comply with the product parameters described in this chapter.

). The BSP's bids for supply are given per aFRR providing unit. The bids must comply with the product parameters described in the aFRR product definition in Chapter 3, Product Specification.

Because of the filtering in the main controller the total power demand will change gradually, one step at a time. The set-point signal from the TSO will always be a multiple of the block size, which at the time of writing is 1 MW.

In the example in **Feil! Fant ikke referansekilden.**, the BSP obligation is to deliver up to 65 MW in a defined time period (e.g. a 6-hour block). The BSP could plan to deliver from their wind power generators e.g. 2 hours and from their hydro power for the remaining 4 hours. This example shows only positive aFRR. A BSP's control system can be used to deliver both positive and/or negative aFRR.

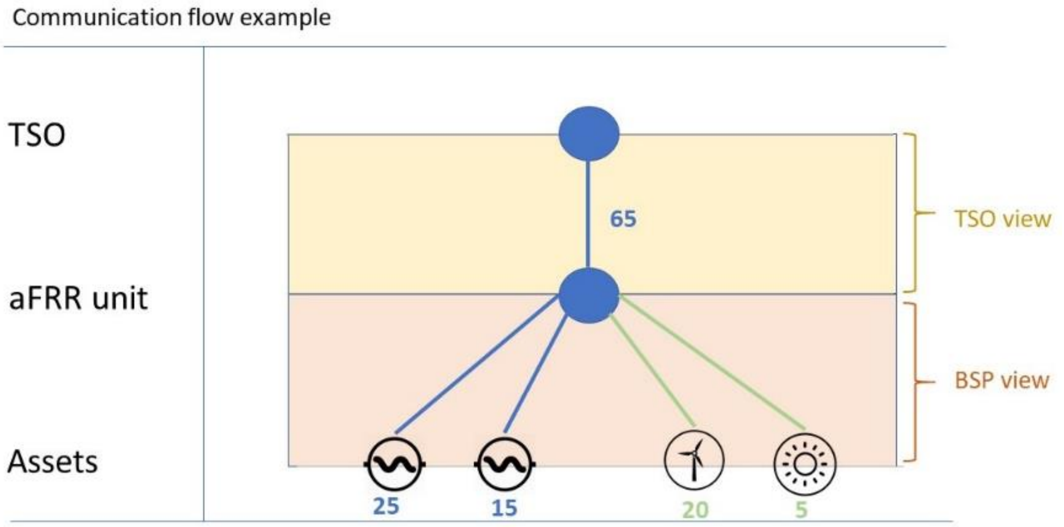

Figure 1: The diagram illustrates the communication flow between the TSO, aFRR providing unit and the power producing assets

2.2 BSP schedules

Each BSP may have a production schedule either executed automatically, using a control system, or manually. However, the units participating in aFRR are required to be automatically controlled by the TSO request known as set-point (SP) or aFRR signal. This alters the resultant production to match the current needs as shown in Figure 2. Planned changes in production according to the BSP schedule are executed independent of TSO control.

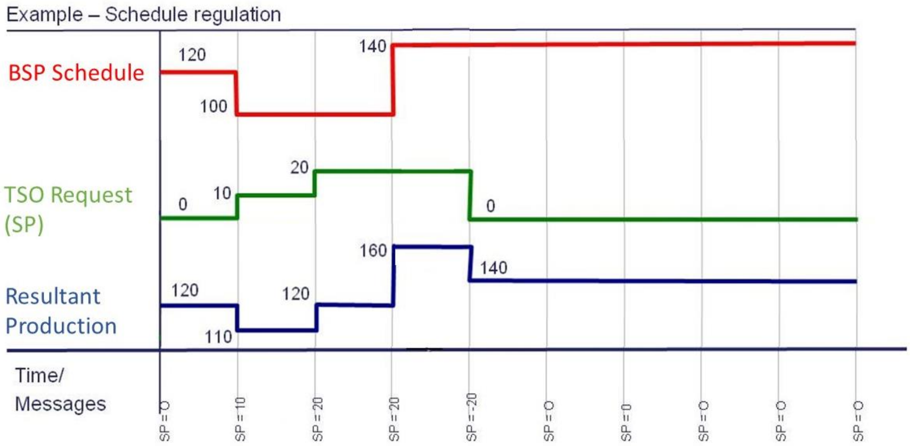

Figure 2 shows an example of when a BSP schedule (red) is modified by a TSO request (green). The BSP's resultant production is then the sum of the original schedule and the TSO request (blue).

2.3 Parameters and Values

The aFRR response required from the BSP is illustrated in Figure 3, Figure 4, and the utilized parameters are defined in Table 1.

Table 1 Definition of parameters that form the aFRR providing unit response

Parameter	Value	Comment
Step Size	1 MW	Minimum value: every set-point is a multiple of this. *NB. Statnett has changed this from 10MW according to Nordic harmonisation.*
Full activation time (FAT)	120 s 300 s	Preferred value Maximum value
Delay time	30 s	Maximum value
Accuracy of delivery at FAT	1 MW or 10% of set-point delta	When a set-point changes the observed change in aFRR, delivery should be within these values. *See examples in 2.7*
	5 MW	Total sustained error from setpoint shall not exceed 5 MW.

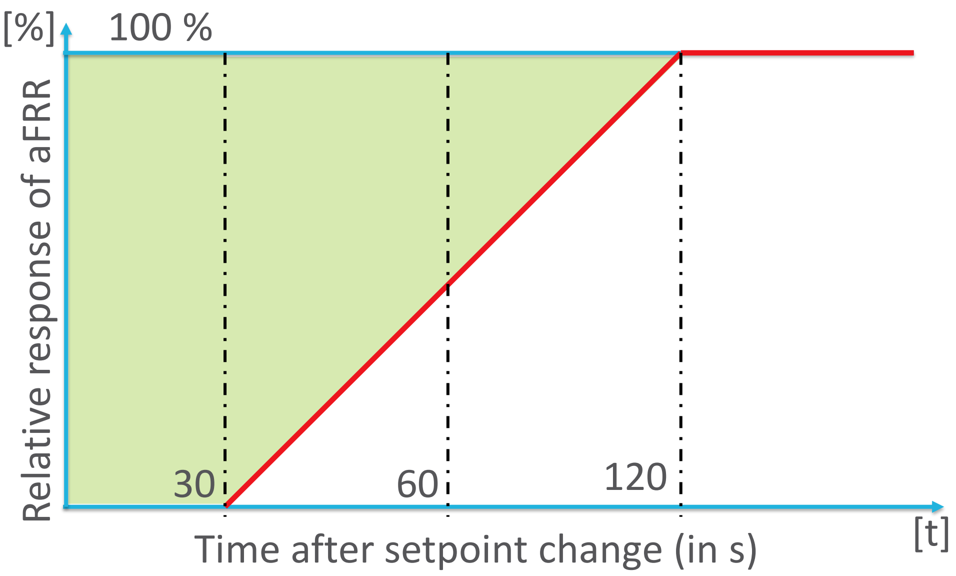

Figure 3: Shows the relative response of aFRR as a function of time after set point change.

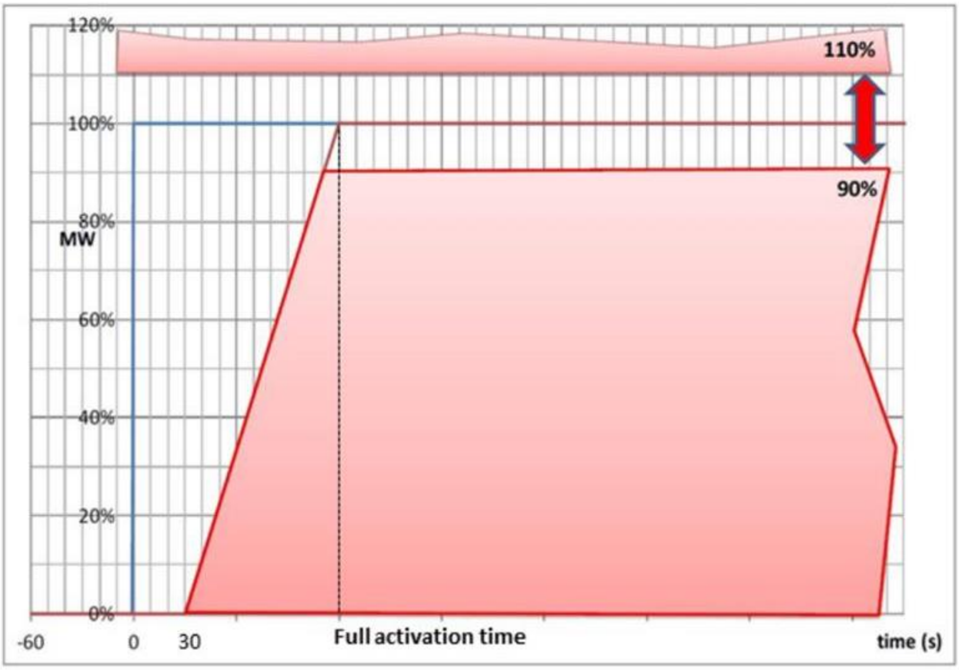

Figure 4: Accepted response to a change in set-point.

2.4 Full Activation Time (FAT)

FAT is the time it takes from an aFRR activation signal is sent from the TSO's SCADA system until the assets reach their new power output level according to the new set-point.

All individual changes should be fulfilled within the FAT.

Maximum allowed FAT is 5 minutes. Statnett preferers a 2 min FAT or faster.

Deactivation time should not be longer than FAT.

2.5 Delay time

The delay time denotes the time from the signal is sent from the TSO until the assets start to change their power output level. This delay time should be as short as possible, maximum equal to the time set in table 1 above.

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

2.6 Set-point definition

The signal from Statnett's SCADA system is a delta set-point and tells how much the BSP should differ from the planned production.

Available aFRR capacity shall not affect or be affected by other obligations such as FCR, mFRR, day-ahead or XBID.

2.7 Accuracy

The accuracy of an aFRR providing unit is defined by how precisely it responds to a change of the set-point. At FAT, the change of generated power output should be no more than 10 % different from the change in Statnett set-point OR within 1 MW of the change in the set-point sent from Statnett. Further, the total sustained error should be no more than 5 MW.

Examples:

- If the set-point changes from -10 to -15, the decrease in total generation should be between 4 and 6 MW (within 1 MW of change in setpoint).
- If the set-point changes from 20 to 35 (an increase of 15 MW) the increase of total generation should be between 13,5 and 16,5 (15 MW ± 10 %) (Within the 10 % limit).
- If the set-point is 80 MW the generation on the assets should be between 75 to 85 MW higher than the scheduled production (also after adjusting for primary regulation). (Within 5 MW)

Statnett may still approve aFRR providing units with larger deviations than listed above. In such cases, it may be required that the BSP work on improving the accuracy to be within the limits within a reasonable time frame.

2.8 Balancing Capacity

The aFRR Balancing Capacity defines the maximum and minimum change that Statnett can request from an aFRR providing unit.

The available aFRR Balancing Capacity for each aFRR providing unit is the result of the aFRR capacity market. Statnett can only regulate within the purchased regulating margins, unless otherwise agreed with Statnett's National Control Centre, i.e. some BSP have agreed to transfer the aFRR capacity obligation.

2.9 aFRR ACE calculation mode

aFRR ACE (Area Control Error) calculation mode can be set in three different modes by the TSO:

- Constant frequency (CF) when only frequency is considered,
- Constant net interchange (CNI) where only interchange in and out of the control block is considered
- Tie-Line Bias (TLB) where both frequency and interchange are used.

Regulation mode in the aFRR control function in Statnett SCADA-system is currently set to Constant frequency (CF) but will in the future be changed to TLB mode.

2.10 Actual aFRR contribution

The actual aFRR contribution from an aFRR providing unit is a calculated measurement. Under normal circumstances this should coincide with the control set-point. This signal is sent from the BSP to Statnett.

This signal should be a continuous measurement, reflecting how much the aFRR providing unit is contributing to the aFRR. If the contribution is spread over multiple assets their individual contribution should be summed in this measurement.

$$ActualFRR = SP_{FRR} + e = P_{gen} - P_{plan} - FB \cdot \Delta f$$

where SP_{FRR} is the set-point from Statnett, e is errors due to oscillations, inaccuracy in the turbine regulator etc., P_{gen} is the MW measurement from the asset(s), P_{plan} is planned production (including mFRR, period shift, and other intended regulations) before aFRR and the last term $FB \cdot \Delta f$[1] is an adjustment for delivery of FCR.

2.11 Interplay between FCR and aFRR

The BSP may deliver both aFRR and FCR from the same asset at the same time.

When the BSP defines the capacity of aFRR to which it will be obligated through a bidding process it must calculate the FCR maximum capacity[2] based on a frequency deviation of 0.5 Hz [49.5 – 50.5 Hz], also considering the current droop settings.

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[1] As defined in [Vedlegg til retningslinjer for fos § 14 - nvf (statnett.no)]
[2] As defined in [Vedlegg til retningslinjer for fos § 8a (statnett.no)]

2.12 Bidding Limitations

The BSPs control system must check that an asset does not belong to more than one active aFRR providing unit.

The aFRR providing unit should normally only include assets co-located and connected to the electrical power grid via one substation, however inclusion of co-located assets that are connected to the electrical power grid via several substations defined as a Station group can be accepted following acceptance by the TSO.

3 Interface Specification

3.1 Using the Set-Point

The BSP's control systems must be able to read the set-point transferred via ICCP from Statnett and divide this change in set-point among the assets currently at disposal. The actual division is up to the BSP. One suggestion is to use participation factors which are dynamically normalised. This correction is added to the scheduled generation level (base point) for the individual assets. The BSP's control systems will send out set-points to the individual assets according to the system's implementation.

3.2 Setting the Remote Control Permitted Status

The TSO will only regulate an aFRR providing unit if the signal *Remote Control Permitted* is set. This should be set when the aFRR providing unit is ready to receive and execute set-points.

The BSP's control systems must have a monitoring function that checks the conditions for setting this signal, sets it and transmits this signal to the TSO.

3.3 Monitoring Validity of Set-points

The BSP's control system must have a monitoring function that checks that the set-point sent from Statnett are within the available capacity and in compliance with other parameters. If set point is outside capacity, only available capacity should be activated

3.4 Other Information

The BSP's control system shall provide Statnett with the currently available balancing capacity (up and down) and how much they are currently contributing to the aFRR.

3.5 Communication Timeout

In case of a communication breakdown, the aFRR providing unit should maintain its current aFRR contribution level for some time. This timeout should be for a pre-defined period from the last change of the set-point. The timeout period is set by the TSO and should be possible to configure.

This function is added to allow for smooth recovery after a short communication breakdown. With a loss of communication between the aFRR providing unit and TSO's SCADA system, or if the set-point signal received is invalid, the current aFRR contribution will be maintained for e.g. 900 seconds from the last received change from the TSO as shown in Figure 5.

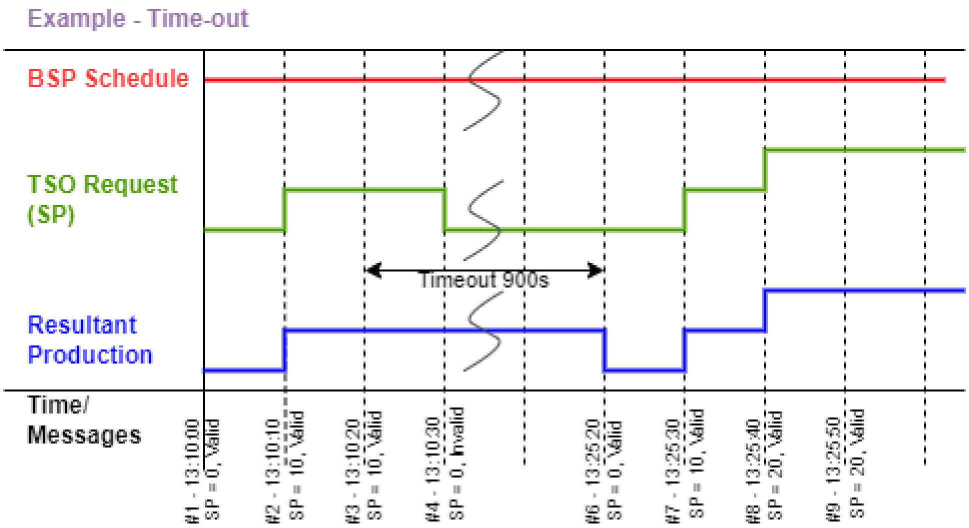

Figure 5: Illustration of the timeout functionality. The resultant production does not change in the timeout period.

This regime ensures that the BSPs do not set their aFRR contribution to zero at the same time, should the TSO communication be lost, keeping the last received change for some time.

3.6 Communication Failure

The BSP should monitor the communication band and ensure that an alarm will be generated with loss of the connection. This alarm will then be used to initiate the timeout condition above.

4 System Design

This section describes requirements regarding system design, protocol, and availability for the connection between the TSO SCADA servers and BSP SCADA servers, as illustrated in Figure 5.

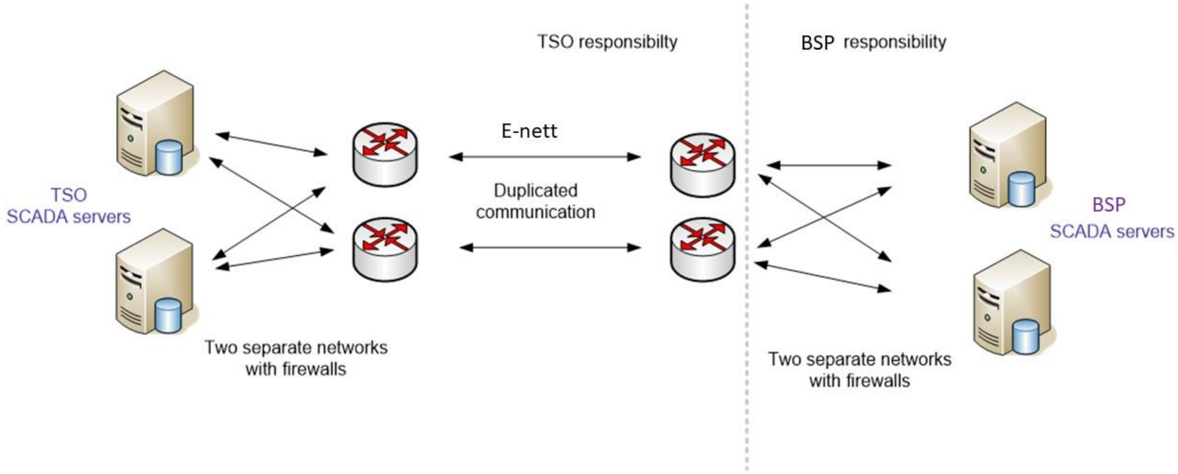

Figure 5: System design

4.1 System design

The following requirements are valid for BSPs to partake in the aFRR capacity market:

- The BSP must have two separate physical connections to the network called E-NETT.
- The BSP must have a Control Centre with two separate redundant SCADA servers.
- The BSP should have two separate networks with two firewalls connecting their SCADA servers to the E-NETT network.

4.2 Protocol

aFRR should have a dedicated ICCP connection. Other SCADA signals should go on another ICCP connection.

To ensure lowest possible down-time, the TSO will install duplicate routers at the BSP site, each of them connected to a separate BSP firewall. This configuration will ensure redundancy in the complete chain from the TSO SCADA servers to the BSP SCADA servers. BSP will be responsible for the duplication of firewalls and network at the BSP site.

All signals between the TSO and the BSP shall be based on ICCP protocol. The communication will be encrypted using ICCP.

All indications and set-point values are transferred spontaneously, while all measurements are sent cyclically.

4.3 Availability

A dedicated ICCP connection will be established between Statnett's National Control Centre and the BSP SCADA. The availability requirement for this connection and subsequent connection from the BSP SCADA to the Station will be 99 %. Availability is measured on a weekly basis starting Monday 00:00 and approximates to 10 min/week. ICCP server restarts should not be included in this metric.

When calculating the availability of the system, down-time caused by the TSO is subtracted.

4.4 Signal descriptions

Remote control permitted status signal BSP → TSO	When set, this signal means that the TSO is permitted to control the aFRR providing unit. This does not imply that the TSO has taken control of the aFRR providing unit but it is a pre-requirement for the TSO to use it in regulation.
Limitation status signals BSP → TSO	When this signal is sent, it means that the aFRR providing unit has reached its available reserves limits either up or down. There is one upper and one lower limitation signal. This signal is used by the BSP to no longer increase or alternatively no longer decrease regulation as long as the corresponding signal is sent. This signal is sent by the BSP when the first signal equal to the max or min available reserves is received NB! This signal will no longer be in active use by Statnett. Please use the "*Available reserves*" to cover the functionality.
Available reserves BSP → TSO	Available reserves up and down. This is a confirmation that there is available sufficient regulation with reference to the contractual obligations of the BSP. Example: sold capacity =100, activated = 10 -> available reserves =100)
Control Set-point TSO → BSP	The set-point is sent as a set-point value over ICCP. Whenever the TSO is controlling the aFRR providing unit this value will be updated; it will not be updated if the TSO is not controlling it. If this value is not valid the BSP control system should not use this signal. A time out should be applied before considering this signal invalid in order to handle temporary loss of communication. The control signal will be increments of the step size 1 MW, and its signal rate will be no more than every 4 seconds. A configurable delay after set-point transmission can be added. To verify that the BSP control system has received the set-point value, a measurement containing the last received set-point value is returned to the TSO.

	For each aFRR providing unit there will be defined a control set-point that is updated through ICCP. This set-point shall be interpreted as a deviation from the current scheduled generation level. The control set-point signal is an accumulated value and therefore a new signal replaces the old one. The value is defined in MW.

4.5 Regulation Validation

Regulation validation aims to ensure that activated regulation is in-line with the balancing capacity bids submitted by the BSP and within the product specification set for the assets.

The validation happens due to the functionality of limiting the set-point regulation signal to blocks of 1 MW and a signal rate of 4 seconds.

In addition to the validation by Statnett, the BSP can have its own validation of performance. This is however not a requirement from Statnett.

Appendix:

Signal list

*Table 2 shows the mapping between SCADA and the correct telemetry. * aFRR_PROVIDING UNIT_NAME in column ICCP GLOBAL ID should be exchanged with the aFRR providing unit name in question.*

Discrete Name	Telemetry Template	GEN description	ICCP GLOBAL ID
LFGD - AGC in limit down	CZMBR_INPUT CZMBR_ATMN_P_I	AT LIMIT DOWN STATUS	***aFRR_PROVIDING_UNIT**** _AGC_LIM_DOWN
LFGD - AGC in limit UP	CZMBR_INPUT CZMBR_ATMX_P_I	AT LIMIT UP STATUS	***aFRR_PROVIDING_UNIT**** _AGC_LIM_UP
LFSE - enabled	CZMBR_OUTPUT CZMBR_LFC_P_O	LFC ENABLED	***aFRR_PROVIDING_UNIT**** _FRR_ENABLED
LFSF – Remote Control Permit	CZMBR_INPUT CZMBR_AUT_P_I	REMOTE CONTROL PERMITTED	***aFRR_PROVIDING_UNIT*** ***_AGC_RCP
Analog name			
LFAC – Actual LFC Contributi	CZMBR_INPUT CZMBR_AREG_A_I	ACTUAL LFC CONTRIBUTION	***aFRR_PROVIDING_UNIT**** _AGC_ACTUAL_MW

RDOW – Current LFC res. down	CZMBR_INPUT CZMBR_RVDN_A_I	CURRENT LFC RESERVE DOWN	***aFRR_PROVIDING_UNIT **** _AGC_RES_DOWN
RUP – Current LFC res. up	CZMBR_INPUT CZMBR_RVUP_A_I	CURRENT LFC RESERVE UP	***aFRR_PROVIDING_UNIT **** _AGC_RES_UP

Table 3 – Signals between BSP and Statnett

Direction	Signal name	Signal type	Unit	Short Name*
SN -> BSP	aFRR set-point	Set-Point	MW	FRR_Set_Point
SN -> BSP	aFRR Enabled	Indication		FRR_enabled
BSP-> SN	Remote control permitted	Indication		AGC_RCP
BSP-> SN	Received set-point	Measurement	MW	AGC_recv_SP
BSP-> SN	Actual aFRR contribution	Measurement	MW	AGC_actual_MW
BSP-> SN	Current aFRR reserves Up	Measurement	MW	AGC_res_up
BSP-> SN	Current aFRR reserves Down	Measurement	MW	AGC_res_down
BSP-> SN	Unit in limitation Up	Indication		AGC_lim_up
BSP-> SN	Unit in limitation Down	Indication		AGC_lim_down
BSP -> SN	Generator Participation Flag	Indication(s)		Gen_FRR_ON

Table 4 – Other relevant signals, which are not distributed between the parties

Signal Name	Comment	Signal Type
Frequency		Measurand
BSP_MW	Sum of production of the participating BSP generators	Measurand
Int_Dev	Interchange deviation	Measurand
ACE	Area control error	Measurand
FACE	Filtered ACE	Measurand
IACE	Integrated ACE	Measurand