Fast Frequency Response (FFR), Primary, Secondary and Tertiary Reserve (POR, SOR, TOR1)

System Services

Test Report

WFPS

Unit Name

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# Document Version History

Revision 3.0 published 12th November 2019

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Version** | **Date** | **Comment** | **Name** | **Company** |
| 0.1 | Insert date | Minor version (v0.1) - First submission for review and approval | Insert name | Insert company |
| 1.0 | Insert Date | Revised to version 1.0 following approval by EirGrid, SONI. | Insert Name | Unit Company Name |

# Introduction

The Unit shall submit the latest version of this test report template as published on the EirGrid or SONI websites[[1]](#footnote-2).

The report shall be developed for technical and non-technical readers and shall follow the agreed test programme. The report is submitted to [generator\_testing@eirgrid.com](mailto:generator_testing@eirgrid.com) or [generator\_testing@soni.ltd.uk](mailto:generation-outages@soni.ltd.uk) as appropriate.

Submission of this document is required if a Unit does not have and existing FFR, POR, SOR or TOR1 contract or is making changes or updates to any of the effected parameters.

To complete the report, the Unit shall have either:

1. Recorded frequency response data as per the test procedure agreed with EirGrid, SONI; or
2. Performance Data showing frequency response capability.

Any issue with meeting any requirements or completing this report, please contact [generator\_testing@eirgrid.com](mailto:generator_testing@eirgrid.com) or [generator\_testing@soni.ltd.uk](mailto:generation-outages@soni.ltd.uk) as appropriate.

# Abbreviations

HV High Voltage

MW Mega Watt

MEC Maximum Export Capacity

kV kilovolt

Hz Hertz – unit of frequency

AAP Available active power

POR Primary Operating Reserve

SOR Secondary Operating Reserve

TOR Tertiary Operating Reserve

FFR Fast Frequency Response

WFCS Wind Farm Control System

DMOL Design minimum operating level

# WFPS Data

|  |  |
| --- | --- |
| WFPS Name | WFPS to Specify |
| WFPS Location | WFPS to Specify |
| WFPS connection point | HV Bushings of T101 in XX 110kV station |
| WFPS connection voltage | WFPS to Specify |
| Installed Turbine type, MW size and quantity | WFPS to Specify |
| Contracted MEC | WFPS to Specify |
| Registered Capacity | WFPS to Specify |
| Limiter applied to Exported MW | WFPS to Specify |
| Limiter applied to AAP | WFPS to Specify |
| DMOL | WFPS to Specify |

# System Services definitions

The definitions referenced in this document are for indicative purposes only. In the event of inconsistency between the definitions in this document and those in the DS3 System Services Agreement, the definitions in the DS3 System Services Agreement shall prevail.

## Fast frequency response (FFR)

FFR is defined as the additional increase in MW output from a unit or a reduction in demand following a frequency event that is available within two seconds of the start of the event and sustainable for at least eight seconds afterwards.

The extra energy provided by the MW increase, in the timeframe from the FFR response time to 10 seconds **shall be greater** than any loss of energy in the ten-to-twenty second timeframe afterwards due to a reduction in MW output. The energy provided and drawn should be compared to the pre-event output.



Figure 1: Example graph showing the additional power provided to, and drawn from, the grid

As shown in the diagram above, in order to be eligible for FFR the amount indicated by the blue hatched area (Power provided) must be greater than the green hatched area (Power drawn).

Please note there are performance monitoring standards that apply for DS3 System Services and specific requirements for FFR. Further detail is available in the DS3 Performance Measurement Device Standards for Fast Acting Services document.

## Operating Reserve (POR, SOR & TOR1)

### Operating Reserve

Operating Reserve is defined as the additional MW output provided from Generation plant, reduction of Active power transfer to an external system or increase of Active power transfer to the Transmission system by interconnectors, or reduction in Customer demand, which must be realisable in real time operation to contain and correct any potential Transmission system deviation to an acceptable level.

### Primary Operating Reserve (POR)

Primary Operating Reserve (POR) is the additional MW output (and/or reduction in Demand) required at the frequency nadir (minimum), compared to the pre-incident output (or Demand) where the nadir occurs between 5 and 15 seconds after an Event.

### Secondary Operating Reserve (SOR)

Secondary Operating Reserve (SOR) is the additional MW output (and/or reduction in Demand) required at the frequency nadir (minimum), compared to the pre-incident output (or Demand) which is fully available and sustainable over the period from 15 to 90 seconds following an event.

### Tertiary Operating Reserve band 1 (TOR1)

Tertiary Operating Reserve (TOR1) is the additional MW output (and/or reduction in Demand) required at the frequency nadir (minimum), compared to the pre-incident output (or Demand) which is fully available and sustainable over the period from 90 seconds to 5 minutes following an event.

## Inertial Emulation

Emulated Inertia means the ability of some Controllable WFPS technologies to provide additional increase in MW Output following a Performance Incident at times.

The response through emulated inertia shall be in addition to the MW provided through frequency response without emulated inertia.

## Hysteresis

FFR Hysteresis Control is defined in the DS3 System Services Agreement and means: the capability of a Providing Unit to deliver a response at a particular Reserve Trigger as the frequency falls and not to withdraw its initial provided response as the frequency recovers through the Reserve Trigger.

For each static step: as the frequency recovers, the provision of the service shall be withdrawn at a frequency specified by the TSO for that step that is greater, i.e. closer to nominal, than the corresponding Reserve Step Trigger.

For each static step: as the frequency recovers, the withdrawal of the provision of the service must be identical in both MW volume and response time to that provided at the corresponding Reserve Step Trigger when providing the service.

# Assessment

The MW amount is based on the absolute lowest sustainable value the unit is capable of in the given timeframe for the service.

## POR, SOR, TOR1 Assessment Examples

The following are a few examples of how the different operating reserve services could be graphed and how they can be assessed:

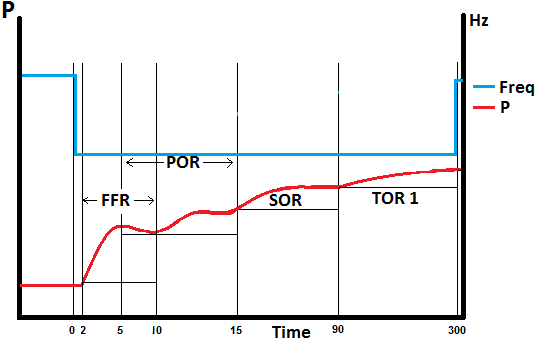


Figure 2: Example of how to measure the lowest MW value for each service

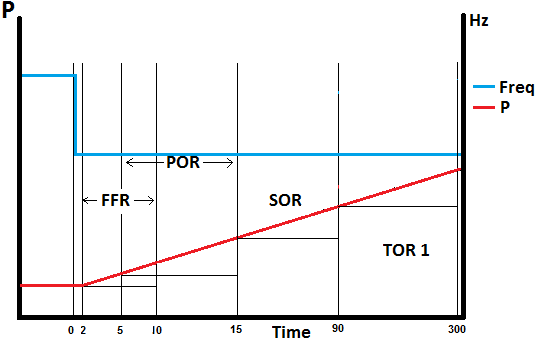


Figure 3: Levels shown with a linear response

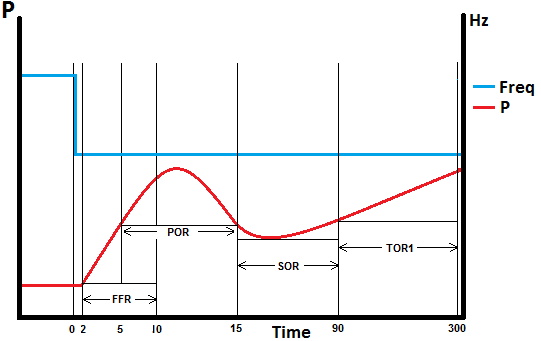


Figure 4: Levels shown with an overshoot response

The lines show where the lowest sustainable values are measured over the timeframe for each service.

## FFR Assessment

The assessment of FFR is the **lowest MW amount** sustained over the 2 –10 second timeframe, compared to the pre-event output.

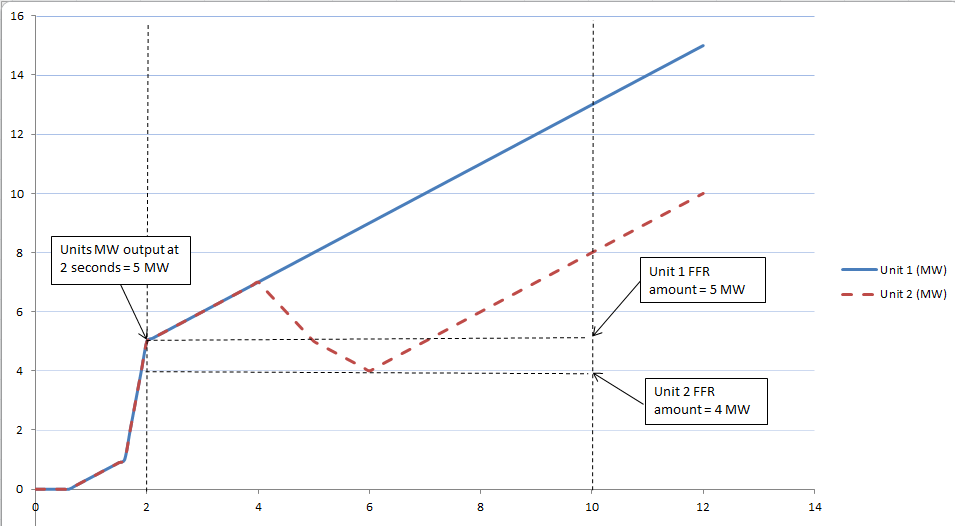


Figure 5: Example graph showing two units frequency response in the FFR timeframe

In figure 5, above, Unit 1 reaches 5 MW by the two second mark and continues ramping upwards over the course of the FFR timeframe. 5 MW is therefore the **lowest sustainable MW amount provided** over the timeframe by Unit 1.

Unit 2 also gets to 5 MW by two seconds, like Unit 1. Unlike Unit 1, it drops to 4 MW in the time frame. 4 MW is therefore the **lowest sustainable MW amount provided** over the timeframe by Unit 2.

The Pre-Event output is defined as the mean of the providing unit’s output between T-1.5 seconds and T-0.5 seconds from the time of the frequency passing through the reserve trigger for the providing unit (T=0). In the example above the pre-event output is 0MW.

## FFR Response Time

A Providing Unit’s contracted FFR Response Time is the time from when the frequency falls through its contracted Reserve Trigger (T=0) to the time at which the Providing Unit must have achieved its contracted FFR volume, as dictated by its contracted FFR response curve.

The FFR response time provided in Section 7.4 shall be based on test data.

Please note that the FFR Response Time, as recorded on the Providing Unit’s installed performance measurement equipment, will be evaluated as part of the FFR performance monitoring process.

The product scalar for faster response of FFR will be based on the FFR response time of the Providing Unit.

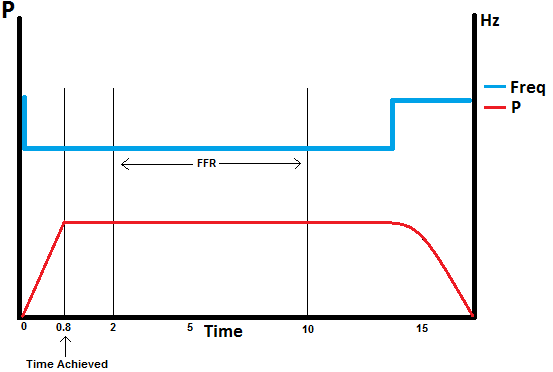


Figure 6: FFR volume achieved before the FFR time period

## FFR Eligibility

Measure the energy provided (in MW seconds) in the timeframe from FFR response time to 10 seconds following an event, compared to the pre-event output. Measure the energy drawn (in MW seconds) during the 10-20 second timeframe following an event, compared to the pre-event output.

If a unit draws more energy from the grid in the 10 – 20 second period after this then it will **not qualify** for an FFR contract.



Figure 5 FFR Energy provided in blue and FFR Energy withdrawn in green

## Emulated Inertia Measurement

The measurement of the amount of emulated inertia is calculated as the difference between the power output of the unit with emulated inertia switched on and the units output with emulated inertia switched off.

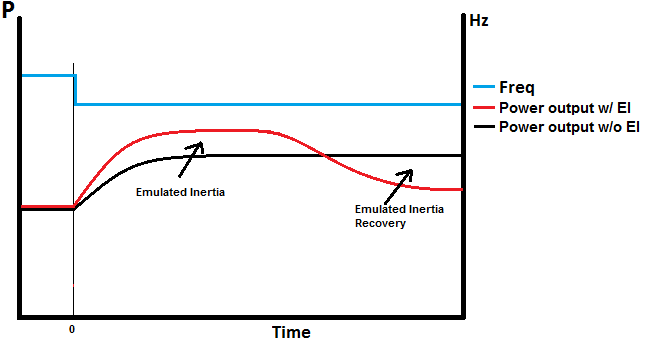


Figure 7: Emulated Inertia response

As shown in the graph above, the difference between the red line (Output with EI switched on) and the black line (Output with EI switched off) is the amount of extra energy delivered by the emulated inertia response.

# Results

## Summary

Testing was completed on [DATE].

*[Insert comment on the results, highlighting any issues encountered in performing the test or in analysing the results.]*

*[Insert Report summary]*

*[Include any relevant test notes here, relating to how the test was carried out or to any specific conditions encountered during the test.]*

*[Any abnormal behaviour during the test (spikes, dips, unusual vibrations, etc.) shall be noted and documented. The reasons behind these shall be detailed along with any corrective actions taken and what its effects are on the unit and/or the result. If possible a clear graph of the issue shall also be presented.]*

*[WFPS does (not) have the ability to provide Inertial Emulation.]*

## FFR, POR, SOR, TOR1 Results

The following table shows the minimum sustained FFR, POR, SOR and TOR values achieved for each load range during testing.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **No.** | **Test Condition** | **(a) FFR Energy Provided (2 – 10 Sec)** | **(b) FFR Energy drawn (10 – 20 Sec)** | **FFR Eligibility: is (a) MW > (b) MW?** | **FFR** | **POR**  **(5 -15 Sec)** | **SOR**  **(15 – 90 Sec)** | **TOR1**  **(90 – 300 Sec)** |
| **Provided by WFPS Controller** | | | | | | | | |
| 1 | APC ON (40% Registered Capacity)  Frequency Response Mode ON, Emulated inertia OFF | \_\_\_\_\_\_MWs | \_\_\_\_\_\_MWs | Yes/No | \_\_\_\_\_\_MW | \_\_\_\_\_\_MW | \_\_\_\_\_\_MW | \_\_\_\_\_\_MW |
| **Provided by WFPS Controller and Emulated Inertia** | | | | | | | | |
| 2 | APC On (40% Registered Capacity)  Frequency Response Mode ON, Emulated inertia ON | \_\_\_\_\_\_MWs | \_\_\_\_\_\_MWs | Yes/No | \_\_\_\_\_\_MW | \_\_\_\_\_MW | \_\_\_\_\_\_MW | \_\_\_\_\_\_MW |
| **Provided by Emulated Inertia** | | | | | | | | |
| 3 | APC OFF Frequency Response Mode OFF, Emulated inertia ON | \_\_\_\_\_\_MWs | \_\_\_\_\_\_MWs | Yes/No | \_\_\_\_\_\_MW | \_\_\_\_\_MW | \_\_\_\_\_\_MW | \_\_\_\_\_\_MW |
| 4 | APC OFF  Frequency Response ON, Emulated inertia ON | \_\_\_\_\_\_MWs | \_\_\_\_\_\_MWs | Yes/No | \_\_\_\_\_\_MW | \_\_\_\_\_MW | \_\_\_\_\_\_MW | \_\_\_\_\_\_MW |
| 5 | Additional test  APC ON, Frequency Response OFF, Emulated Inertia ON | \_\_\_\_\_\_MWs | \_\_\_\_\_\_MWs | Yes/No | \_\_\_\_\_\_MW | \_\_\_\_\_MW | \_\_\_\_\_\_MW | \_\_\_\_\_\_MW |

## Graph of results

*[Insert full plots of the results demonstrating the frequency response of the unit. Graphs should be clear and highlight all relevant values and time periods, including levels. All Graphs should be clearly labelled and easy to read.]*

*Graphs should clearly show the MW value prior to frequency event, and the minimum sustained MW value for each time period. Available Active Power should be included in all graphs*

*[Graph should be a time series plot with Power and Frequency on the y axis and time on the x axis.]*

*[Include any relevant test notes here, relating to how the test was carried out or any specific conditions encountered during this test]*

## FFR Response Characteristics

|  |  |  |  |
| --- | --- | --- | --- |
| **No** | **Details** | **Value** | **Comment** |
| **1** | **FFR Response Time** | **\_\_\_\_\_ms** |  |
| **2** | **Is the response Static or Dynamic?** |  | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  *WFPS to fill in sections below as applicable* |
|  | **Dynamic Response Characteristics** | | |
| **3** | **Reserve Trigger** | **\_\_\_\_Hz** |  |
| **4** | **Trajectory Capability** | **\_\_\_\_Hz** |  |
|  | **Static Response Characteristics** | | |
| **5** | **Reserve trigger** | **\_\_\_\_Hz** |  |
| **7** | **Number of discrete steps** |  |  |
| **8** | **Max discrete step value for static provision** | **MW** |  |
| **9** | **Hysteresis capability** |  | Y/N |
| **10** | **Hysteresis recovery trigger** | **Hz** |  |

## Emulated Inertia Characteristics

|  |  |  |  |
| --- | --- | --- | --- |
| **No** | **Details** | **Value** | **Comment** |
| **1** | Highest under-frequency trigger at which the WFPS can provide FFR through emulated inertia | **\_\_\_\_Hz** |  |
| **2** | Highest under-frequency trigger at which the WFPS can provide POR through emulated inertia | **\_\_\_\_Hz** |  |
| **3** | Number of discrete steps that a Providing Unit is capable of providing FFR/POR through Emulated Inertia in response to a Reserve Trigger. | **\_\_\_\_\_** |  |
| **4** | MW output below which a WFPS unit is not available to provide FFR through Emulated Inertia | **\_\_\_\_MW** |  |
| **5** | MW output below which a WFPS unit is not available to provide POR through Emulated Inertia | **\_\_\_\_MW** |  |

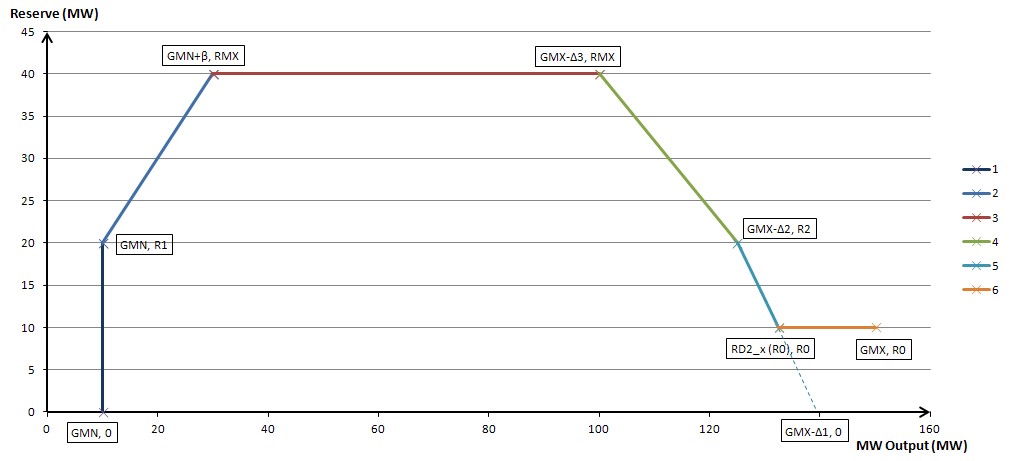
## Proposed Volumes

Please provide the proposed contract values for each service as per test results.

|  |  |  |  |
| --- | --- | --- | --- |
| **1** | Proposed Maximum FFR Available Volume via Emulated Inertia | **\_\_\_\_MW** | Delete if not providing FFR through emulated inertia |
| **2** | Proposed Maximum FFR Available Volume | **\_\_\_\_MW** | (If not provided through Emulated inertia) |
| **3** | Proposed Maximum POR Available Volume via Emulated Inertia | **\_\_\_\_MW** | Delete if not providing POR through emulated inertia |
| **4** | Proposed Maximum POR Available Volume | **\_\_\_\_MW** | (If not provided through Emulated inertia) |
| **5** | Proposed Maximum SOR Available Volume | **\_\_\_\_MW** |  |
| **6** | Proposed Maximum TOR1 Available Volume | **\_\_\_\_MW** |  |

## Reserve Curve Characteristics

The Unit shall provide a proposed reserve curve for each service based on test data showing the levels of Operating Reserve at varying MW outputs.



|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **FFR** | **POR** | **SOR** | **TOR1** |
| **RMX (Max reserve volume)** |  |  |  |  |
| **GMN (Min Load / Min Gen)** |  |  |  |  |
| **R0** |  |  |  |  |
| **R1** |  |  |  |  |
| **R2** |  |  |  |  |
| **DELTA1** |  |  |  |  |
| **DELTA2** |  |  |  |  |
| **DELTA3** |  |  |  |  |
| **BETA** |  |  |  |  |

1. <http://www.eirgridgroup.com/> or <http://www.soni.ltd.uk/> [↑](#footnote-ref-2)