



TESTING GUIDANCE FOR PROVIDERS OF ENHANCED FREQUENCY RESPONSE BALANCING SERVICE

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1 **Introduction**

1.1 Purpose

This document aims to provide guidance to Enhanced Frequency Response (EFR) service providers to National Grid regarding the testing requirements for verification of this service. The tests outlined in the document are to verify the requirements of the service description identified in contract documents relating to the provision of an enhanced frequency response service. For any further enquires or questions, contact your Account Manager or:

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1.2 Overview- EFR (Enhanced Frequency Response)

EFR is the change in active power delivered as a proportional response to a change in system frequency. EFR becomes active at a pre-defined frequency. It is available in two variants:

-Service 1 (wide-band)

-Service 2 (narrow-band)

Both services provide a change in active power in reaction to frequency deviations from 50.00Hz greater than $\pm 0.05\text{Hz}$ (service 1) or $\pm 0.015\text{Hz}$ (service 2) respectively. EFR systems must be capable of detecting a change in system frequency within 500ms, and able to provide the contracted change in active power within 1 second. See Figure 1.1, Table 1.1 and Table 1.2

Service providers using an energy source of finite capacity such as a battery can use the envelope of performance identified by regions A and B of Figure 1.2 to maintain an optimum storage level. If doing so, limits on active power levels and rate of change of active power are stated in Tables 1.3 and 1.4.

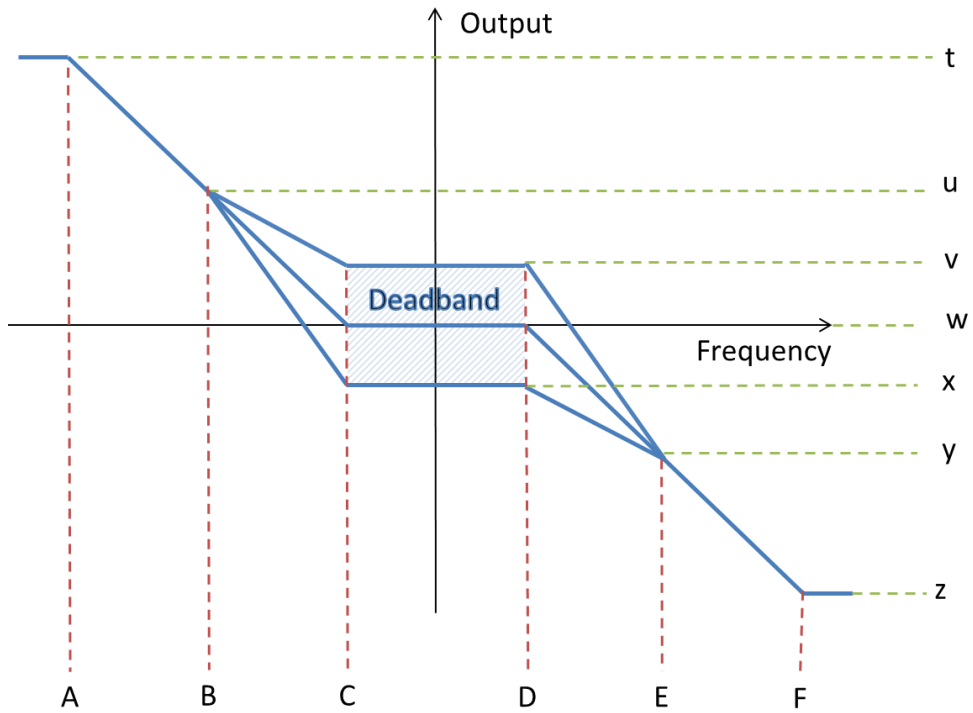


Figure 1.1- Service Envelope

Reference Point	Service 1 (Hz)	Service 2 (Hz)
A	49.5	49.5
B	49.75	49.75
C	49.95	49.985
D	50.05	50.015
E	50.25	50.25
F	50.5	50.5

Table 1.1- Envelope Frequencies

Reference Point	Service 1 (%Capacity)	Service 2 (%Capacity)
t	100%	100%
u	44.44444%	48.45361%
v	9%	9%
w	0%	0%
x	-9%	-9%
y	-44.44444%	-48.45361%
z	-100%	-100%

Table 1.2- Envelope Outputs

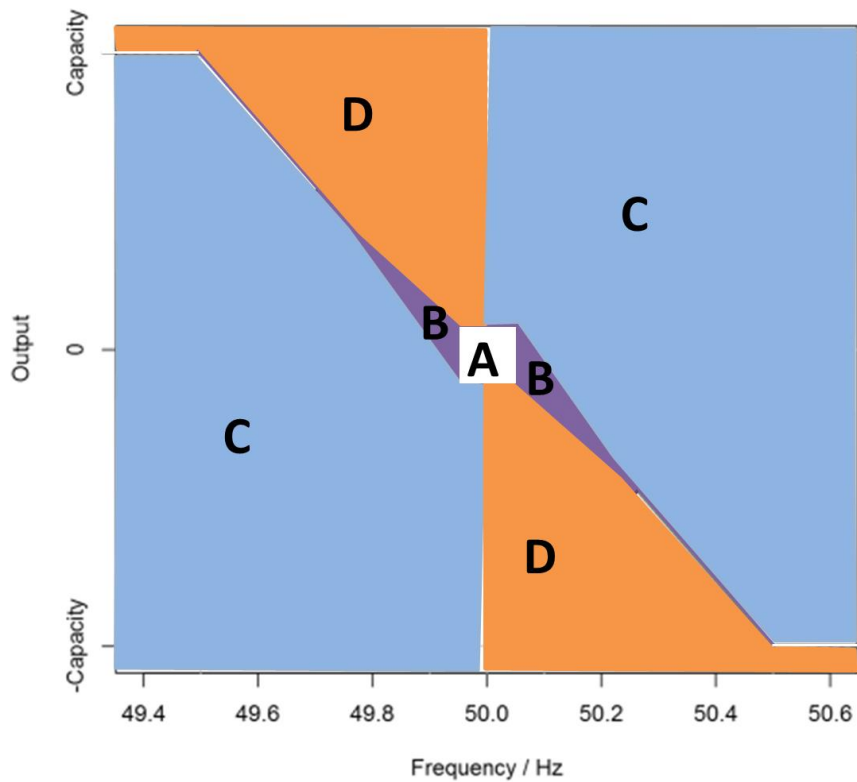


Figure 1.2- Enhanced Frequency Envelope

Area	Maximum Ramp Rate as a percentage of Operational Capacity (MW/s)	Minimum Ramp Rate as a percentage of Operational Capacity (MW/s)
A	1%	0%
C	200%	0%
D	10%	0%

Table 1.3- Ramp rate limits in regions A, C and D

For Ramp Rate Zone B	Maximum Ramp Rate as a percentage of Operational Capacity (MW/s)	Minimum Ramp Rate as a percentage of Operational Capacity (MW/s)
Service 1 (wide)	$\left(-\frac{1}{0.45} \frac{df}{dt} + 0.01\right) * 100$	$\left(-\frac{1}{0.45} \frac{df}{dt} - 0.01\right) * 100$
Service 2 (narrow)	$\left(-\frac{1}{0.485} \frac{df}{dt} + 0.01\right) * 100$	$\left(-\frac{1}{0.485} \frac{df}{dt} - 0.01\right) * 100$

Table 1.4- Ramp rate limits in region B

2 Enhanced Frequency Response Testing

The tests identified in this document are designed to demonstrate that the agreed service provision can be delivered.

2.1 Test 1- Step Tests

This test is designed to ensure the system responds when the frequency falls outside of the deadband. The test will be used to:

- Investigate the time taken for the system to provide a response
- Ascertain the proportionality of the response in the collapsed regions (i.e. Reference point A to B and E to F in Figure 1.1)

The step injections for service 1 and service 2 are shown in Figures 2.1 and 2.2 respectively. Each step is sustained for 30 seconds to verify the stability of the response. The frequency will then be returned to 50Hz for 30 seconds before the next injection is applied. The injections and expected responses for each test are shown in Table 2.1.

Test Number	Frequency Step (Hz) (Service 1)	Expected Response (Service 1)	Frequency step (Hz) (Service 2)	Expected Response (Service 2)
1.1	50.03	-9% to +9%	50.01	-9% to +9%
1.2	49.97	-9% to +9%	49.99	-9% to +9%
1.3	50.07	-12.54% to +3.66%	50.02	-9.84% to +7.78%
1.4	49.93	-3.66% to +12.54%	49.98	-7.78% to +9.84%
1.5	50.1	-17.86% to -4.36%	50.1	-23.27% to -11.78%
1.6	49.9	+4.36% to +17.86%	49.9	+11.78% to +23.87%
1.7	50.25	-44.44%	50.25	-48.45%
1.8	49.75	44.44%	49.75	48.45%
1.9	50.4	-77.78%	50.4	-79.38%
1.10	49.6	+77.78%	49.6	79.38%
1.11	50.5	-100%	50.5	-100%
1.12	49.5	+100%	49.5	+100%
1.13	50.7	-100%	50.7	-100%
1.14	49.3	+100%	49.3	+100%

Table 2.1- Frequency Injection and Expected Response values

Pass criteria for test:

- Provide an active power response within the contracted performance envelope within 1 second of a frequency step outside of the deadband.
- Provide an output of no more than $\pm 9\%$ of operational capacity whilst in the deadband.
- Sustain the response until the frequency is returned to 50Hz.

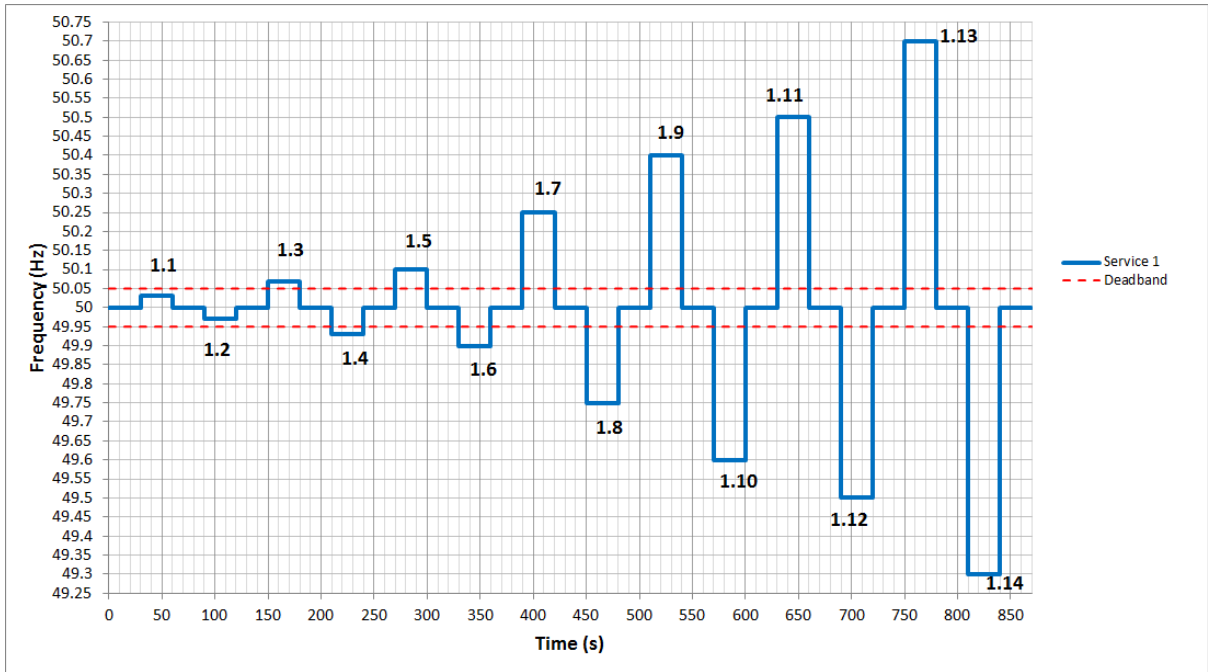


Figure 2.1- Test 1 for Service 1

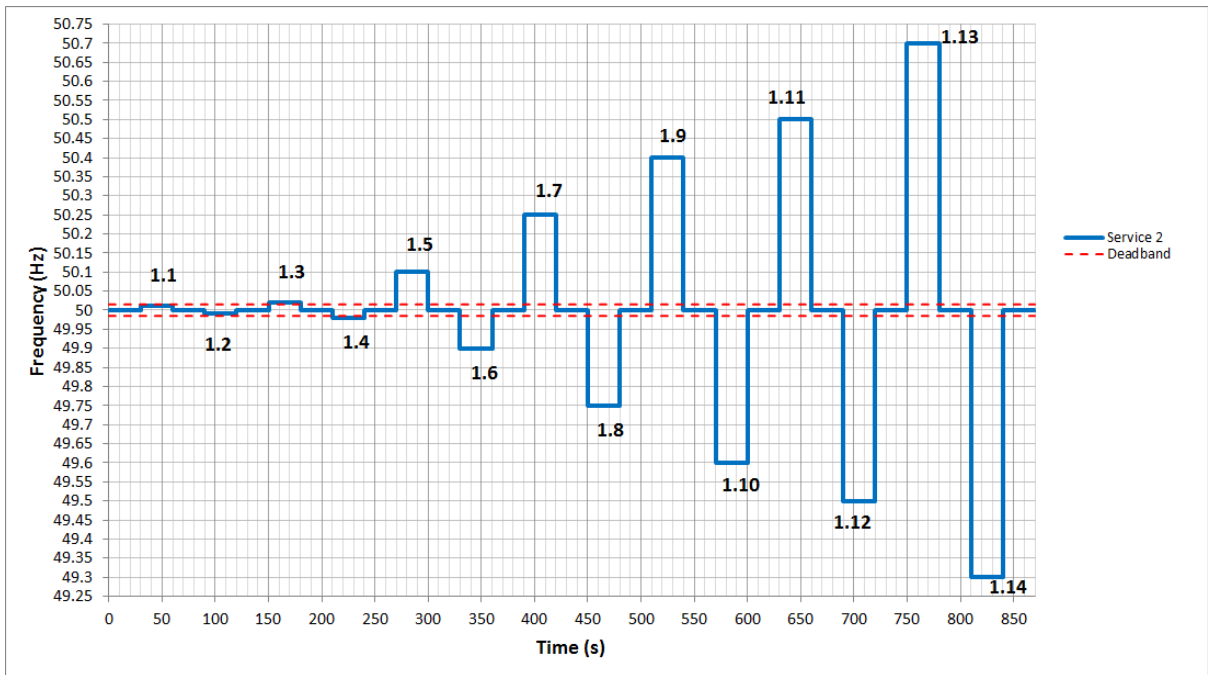


Figure 2.2- Test 1 for Service 2

2.2 Test 2- Frequency Sweep Tests

These tests will comprise of a frequency ramp from 49.4Hz to 50.6Hz and a ramp from 50.6Hz to 49.4Hz, in order to examine the systems entire performance envelope. Both of the ramps will be injected over 30 seconds. The same injection will be used for both service 1 and service 2. The test will verify:

- Proportionality in the collapsed envelope regions (i.e. Reference point A to B and E to F in Figure 1.1)
- Performance within the contracted envelope
- Key data points, i.e. 100% import/export at 50.5/49.5Hz and $\pm 44.44\%$ (Service 1)/ $\pm 48.45\%$ (Service 2) at 50.25/49.75Hz

Pass criteria for test:

- Provide an active power response within the contracted performance envelope, within 1 second of a frequency deviation outside of the deadband.
- Provide an output of no more than $\pm 9\%$ of operational capacity whilst in the deadband.
- The maximum ramp rate as a percentage of operational capacity must not exceed 1% inside region A.
- The max/min ramp rates as a percentage of operational capacity must not exceed the limits defined in Table 1.4 inside region B.

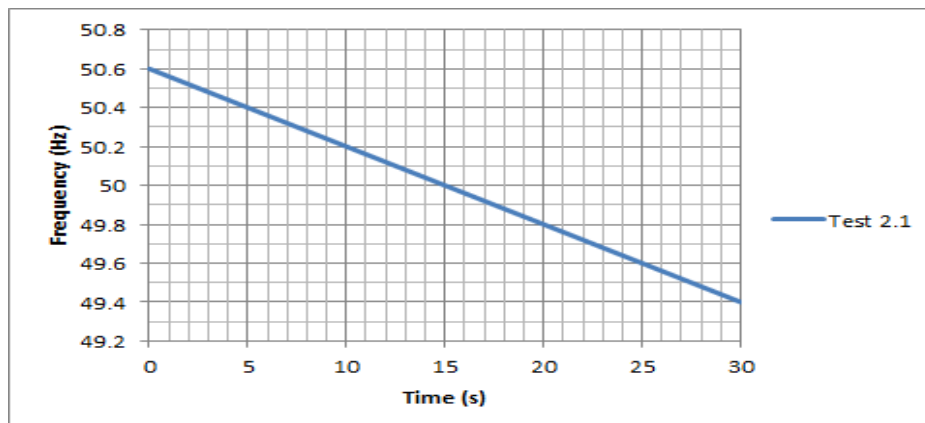


Figure 2.3- Test 2.1

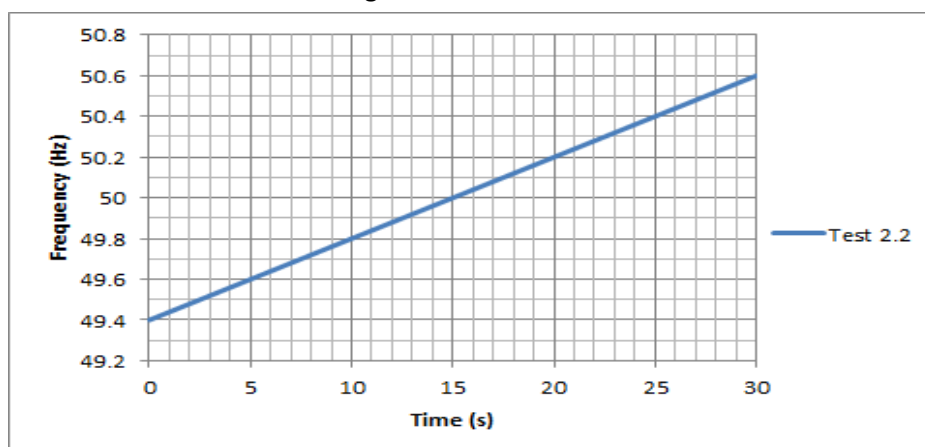


Figure 2.4- Test 2.2

2.3 Test 3- Duration Tests

EFR requires the system to be able to respond at full output for 15 minutes should a major frequency event occur. Operation will be tested at $\pm 100\%$ of capability to ensure the system is compliant. This is carried out by a frequency step of $\pm 0.6\text{Hz}$ onto the system for 15 minutes. The frequency will then be stepped back to 50Hz . The sample rate for the Duration tests should be reduced to 10 Hz .

Pass criteria for test:

- Provide an active power response within the contracted performance envelope, within 1 second of a frequency step outside of the deadband.
- Provide an output of no more than $\pm 9\%$ of operational capacity whilst in the deadband (region A).
- Sustain response for 15 minutes.
- The maximum ramp rate as a percentage of operational capacity must not exceed 1% inside the deadband.
-

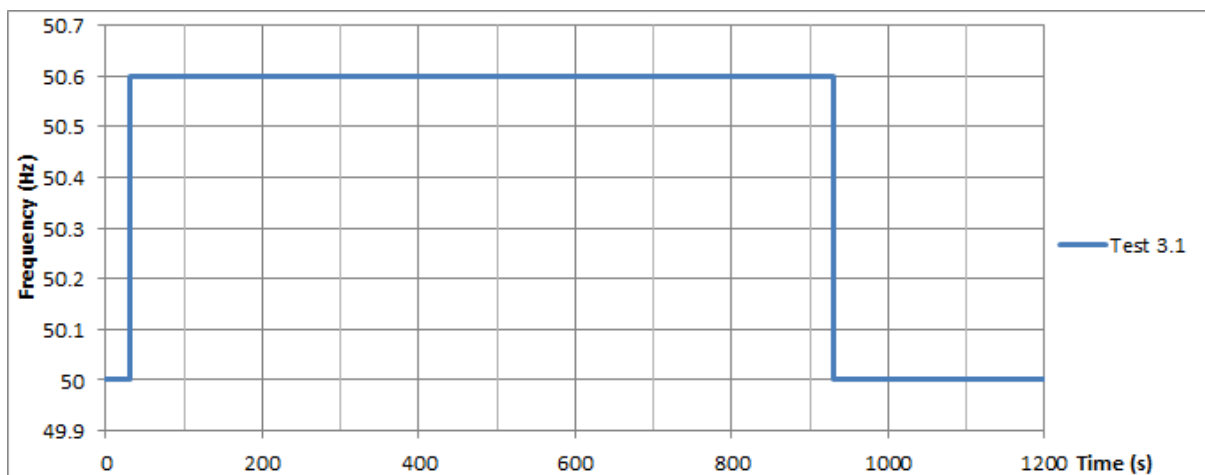


Figure 2.5- Test 4.1

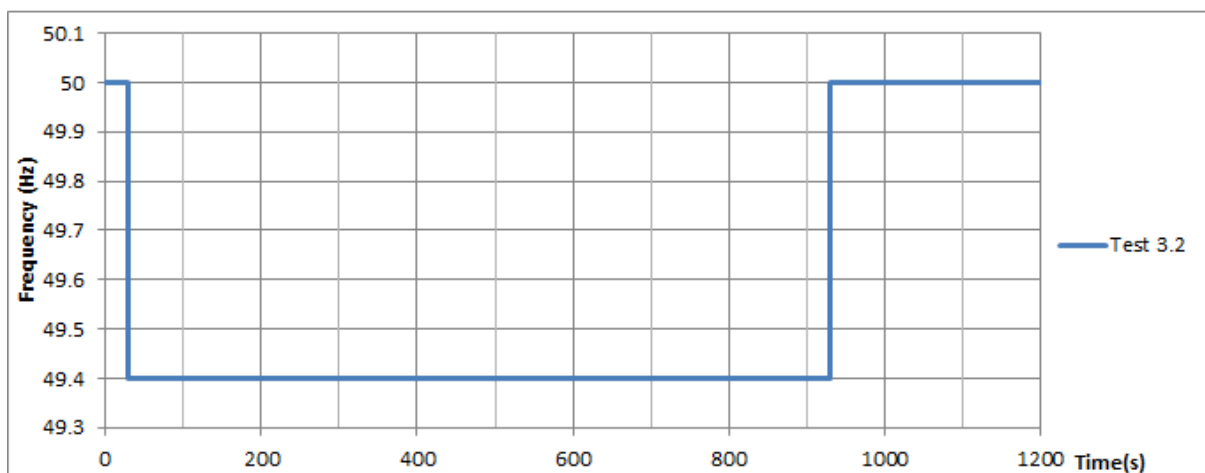


Figure 2.6- Test 4.2

2.4 Test 4- Connection to the Grid Test

This test investigates the system's ability to respond to the system frequency. The active power response of the system and the system frequency will be recorded for 6 hours. The sample rate should be reduced to 10Hz for this test.

Pass criteria for test:

- Provide an active power response within the contracted performance envelope, within 1 second of a frequency step outside of the deadband.
- Provide an output of no more than +/-9% of operational capacity whilst in the deadband.
- Observe ramp rate limits where applicable.

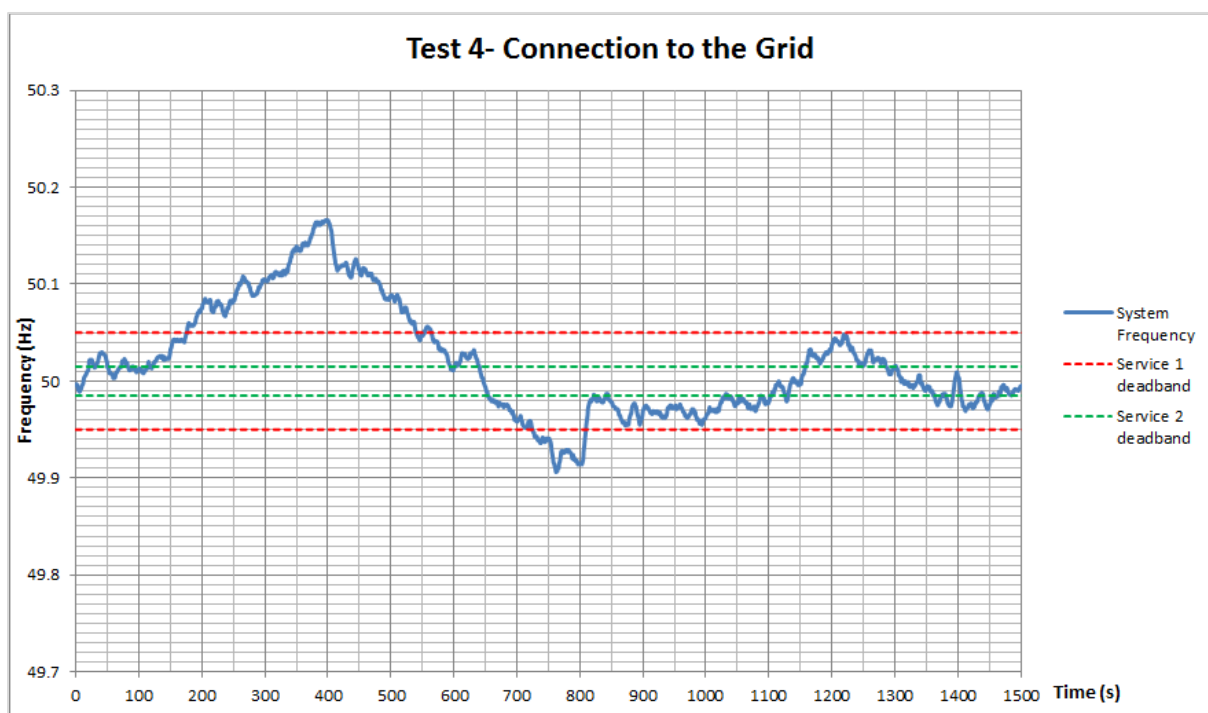


Figure 2.7- Test 4 (Note this is an example: the real test will follow actual Grid frequency)

Appendix A – Test Data and Test Signals

The test data shall be submitted in a format compatible with Microsoft Excel as shown in Appendix B.

The limits of error and minimum sample rates for testing are shown below in Table A.1. All success criteria are subject to the stated limit of error/accuracy threshold.

	Limit of error/ Accuracy threshold	Minimum Sample rate
Frequency (Hz)	± 0.01 Hz	100Hz ** Apart from Test 4 which is 10Hz
Active Power (MW)	$\pm 1\%$ contracted capacity	100Hz ** Apart from Test 4 which is 10Hz

Table A.1- Limits of error and minimum sample rates

Simulations / simulated tests are not permitted. Each test submitted must record real time data from the plant and sites under test: The test data submitted must come from the specific site to be contracted; substituted data will not be accepted.

Test Signals

In ALL cases, the data should record ALL required signals for at least 30 seconds BEFORE the application of the frequency injection signal and for at least 30 seconds AFTER the completion of the test.

For ALL services, the data for the following signals will need to be provided

- a) Time
- b) Active Power
- c) System Frequency or Injected frequency as appropriate
- d) Any other relevant signals that may affect the success criteria. Examples of such signals include State of Charge, Control signals and Relay Logics.

Appendix B – Format of Test Results

As identified in Appendix A, test data needs to be in a format compatible with Microsoft Excel. The data should be clear and concise with no ambiguities for the recipient of the data.

Each test will need to be recorded on an individual worksheet and include:

- Identification of the asset
- The location
- Provider’s company name
- Date of the test
- Associated test number
- Service being provided (EFR service 1 or EFR service 2)

Example Test Results

	A	B	C	D	E
1	Provider	Company Name			
2	Date	xx-xx-xxxx			
3	Test	4			
4	Location	AA			
5	Service	Enhanced Frequency Response			
6	Site / Group / Plant	A			
7	Time	Injected Frequency (Hz)	System Frequency (Hz)	Power (MW)	Other Required Control Signals
8	0.01	50	50	15.251	x
9	0.02	50	49.987	15.254	x
10	0.03	50	49.985	15.249	x
11	0.04	50	49.99	15.248	x
12	0.05	50	49.992	15.254	x
13	0.06	50	49.991	15.251	x
14	0.07	50	49.987	15.252	x
15	0.08	50	49.976	15.249	x
16	0.09	50	49.977	15.254	x
17	0.1	50	49.975	15.252	x
18	0.11	50	49.981	15.249	x
19	0.12	50	49.985	15.249	x
20	0.13	50	49.986	15.498	x
21	0.14	50	49.992	15.249	x
22	0.15	50	49.981	15.498	x
23	0.16	50	49.985	15.247	x
24	0.17	50	49.987	15.248	x
25	0.18	50	49.989	15.249	x
26	0.19	50	49.984	15.245	x
27	0.2	50	49.986	15.248	x
28	0.21	50	49.981	15.244	x
29	0.22	50	49.982	15.248	x
30	0.23	50	49.989	15.249	x
31	0.24	50	49.992	15.247	x
32	0.25	50	49.991	15.241	x

Figure B.1- One Site

	A	B	C	D	E	F	G	H	I	J	
1	Provider	Company Name									
2	Date	xx-xx-xxxx									
3	Test	4									
4	Location	AA				AB					
5	Service	Enhanced Frequency Response									
6	Site / Group / Plant	A				B					
7	Time	Injected Frequency (Hz)	System Frequency (Hz)	Power (MW)	Other Required Control Signals	Time	Injected Frequency (Hz)	System Frequency (Hz)	Power (MW)	Other Required Control Signals	
8	0.01	50	50	15.251	x	0.01	50	50	10.411	x	
9	0.02	50	49.987	15.254	x	0.02	50	49.987	10.413	x	
10	0.03	50	49.985	15.249	x	0.03	50	49.985	10.412	x	
11	0.04	50	49.99	15.248	x	0.04	50	49.99	10.415	x	
12	0.05	50	49.992	15.254	x	0.05	50	49.992	10.412	x	
13	0.06	50	49.991	15.251	x	0.06	50	49.991	10.421	x	
14	0.07	50	49.987	15.252	x	0.07	50	49.987	10.416	x	
15	0.08	50	49.976	15.249	x	0.08	50	49.976	10.421	x	
16	0.09	50	49.977	15.254	x	0.09	50	49.977	10.425	x	
17	0.1	50	49.975	15.252	x	0.1	50	49.975	10.427	x	
18	0.11	50	49.981	15.249	x	0.11	50	49.981	10.431	x	
19	0.12	50	49.985	15.249	x	0.12	50	49.985	10.432	x	
20	0.13	50	49.986	15.498	x	0.13	50	49.986	10.428	x	
21	0.14	50	49.992	15.249	x	0.14	50	49.992	10.425	x	
22	0.15	50	49.981	15.498	x	0.15	50	49.981	10.426	x	
23	0.16	50	49.985	15.247	x	0.16	50	49.985	10.431	x	
24	0.17	50	49.987	15.248	x	0.17	50	49.987	10.435	x	
25	0.18	50	49.989	15.249	x	0.18	50	49.989	10.442	x	
26	0.19	50	49.984	15.245	x	0.19	50	49.984	10.441	x	
27	0.2	50	49.986	15.248	x	0.2	50	49.986	10.444	x	
28	0.21	50	49.981	15.244	x	0.21	50	49.981	10.438	x	
29	0.22	50	49.982	15.248	x	0.22	50	49.982	10.434	x	
30	0.23	50	49.989	15.249	x	0.23	50	49.989	10.435	x	
31	0.24	50	49.992	15.247	x	0.24	50	49.992	10.429	x	
32	0.25	50	49.991	15.241	x	0.25	50	49.991	10.425	x	

Figure B.2- Multiple Sites