TESTING GUIDANCE FOR PROVIDERS OF FIRM FREQUENCY RESPONSE BALANCING SERVICE

Authors	Published	Version	Update Summary
Kevin Smethurst Vicci Walsh	May 2017	D1	
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Kevin Smethurst Honor Hynes Otis Rook-Grignon Vicci Walsh	November 2017	D11	Tolerance values in Tables 3.7 and 3.8 amended to correctly reflect tolerance bands shown in Figures 3.8, 3.9, 3.10 and 3.11.

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1 Introduction

1.1 Purpose

This document aims to provide guidance to Firm Frequency Response (FFR) providers to National Grid. This document covers the testing requirements for pre-qualification assessment and reproving of this service. The tests outlined in the document are to verify that the requirements of the service specified in contract documents can be met. For any further enquires or questions, contact your Account Manager or:

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1.2 Overview- FFR (Firm Frequency Response)

FFR is the change in active power delivered as a response to a change in system frequency. This change in active power could either be from its initial state or a predicted demand level (baseline). It is available in two variants:

Non-Dynamic (also referred to as Static):

Contracted Response	**Delivery timescale**
Primary timescale	10s – 30min
Secondary timescale	30s – 30min
High Frequency timescale	10s – indefinitely [1]

Table 1.1 – Response Timescales for a Non-Dynamic Service

Dynamic:

Contracted Response	**Delivery timescale**
Primary timescale	10s – 30s[2]
Secondary timescale	30s – 30min
High Frequency timescale	10s – indefinitely [1]

Table 1.2 – Response Timescale for a Dynamic Service

[1]High Frequency Response will be tested for a duration of 30 minutes but the service should be capable of being sustained indefinitely.

[2]A dynamic service can't provide primary response only. A dynamic low frequency response requires both a primary and secondary response.

With Non-Dynamic response, the change in active power is a specified value and occurs when the frequency rises through 50.3Hz or falls through 49.7Hz. See Figure 1.1 below.

There are 3 services:

- Low Frequency
    - Primary
    - Secondary

- High frequency

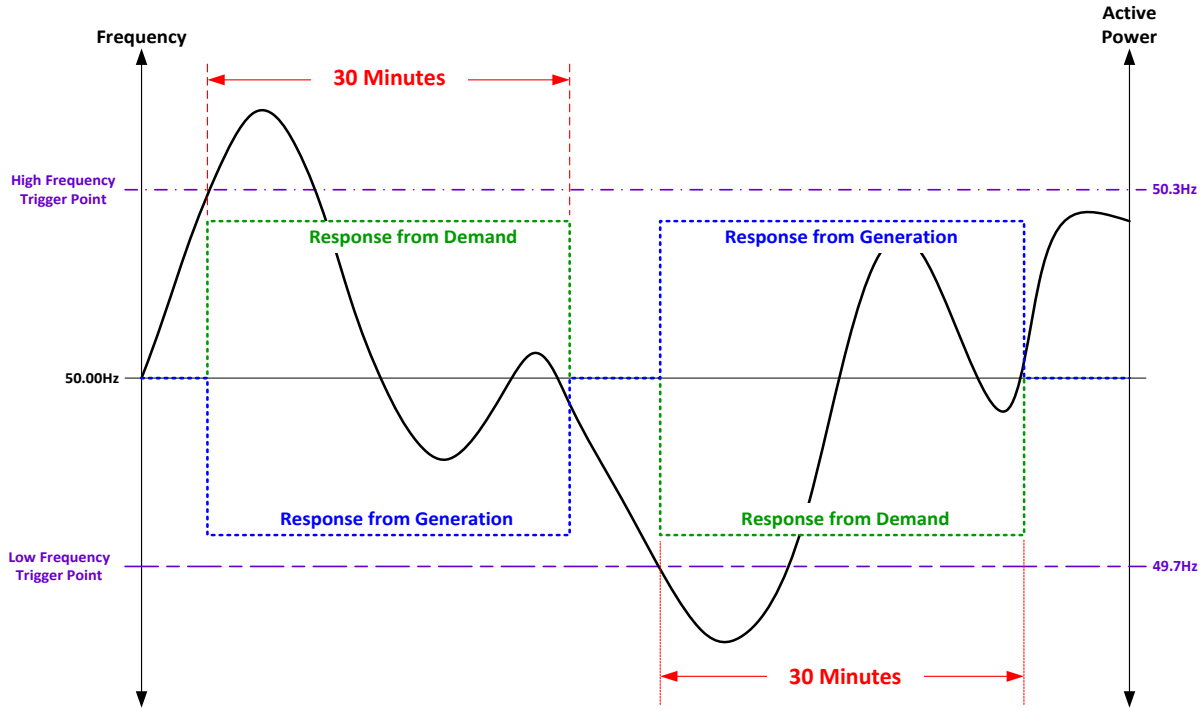

Figure 1.1 – Example of a Non-Dynamic Response to a Varying Frequency

In Dynamic response the change in active power is proportional to the change in frequency as shown in Figure 1.2.

There are 2 services:

- Low Frequency
    - Primary and Secondary Response

- High Frequency Response

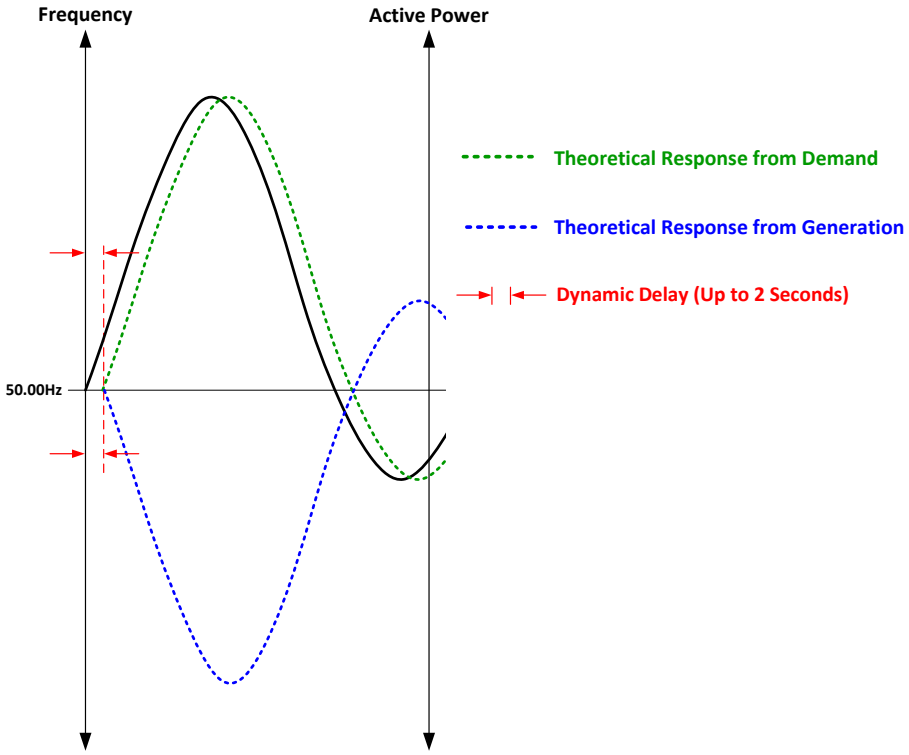

Figure 1.2 – Example of a Dynamic Response to a Varrying Frequency

2 Non-Dynamic Firm Frequency Response Testing

The non-dynamic low and high frequency tests aim to monitor the capability of the provider to deliver the minimum contracted level of response.

Pass criteria for test:

- An acceptable frequency injection profile is used (see Figures 2.1 and 2.2).
- The relay (or equivalent) operating point of the plant/unit(s) occurs at the correct contracted trigger frequency and within the permitted tolerance (±0.01Hz).
- Sustain the response for the 30 minutes.
- The standard deviation of active power error over a 30 minute period must not exceed 2.5% of the contracted active power change.

Parameter	Point																	
	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	D	T
Time (s)	0.0	30.0	40.0	80.0	90.0	120.0	420.0	450.0	750.0	780.0	1080.0	1110.0	1410.0	1440.0	1740.0	1770.0	2070.0	2100.0
Freq (Hz)	50.000	50.000	49.720	49.720	50.000	49.500	49.500	49.800	49.800	49.600	49.600	50.200	50.200	50.400	50.400	50.000	50.000	50.000

Table 2.1 – Injected Frequency against Time for Low Frequency Non-Dynamic Response Testing

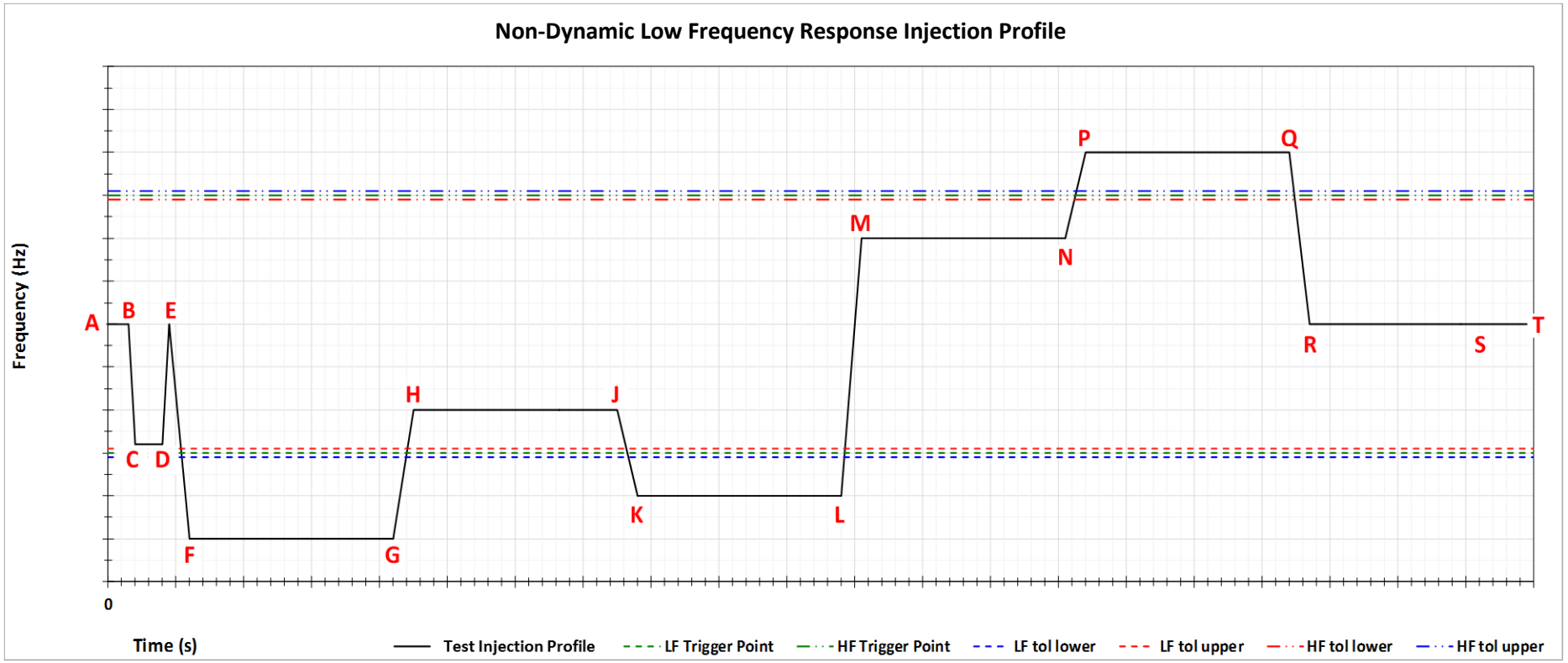

Figure 2.1 – Injection Profile for Low Frequency Non-Dynamic Response Testing

Parameter	Point																	
	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	D	T
Time (s)	0.0	30.0	40.0	80.0	90.0	120.0	420.0	450.0	750.0	780.0	1080.0	1110.0	1410.0	1440.0	1740.0	1770.0	2070.0	2100.0
Freq (Hz)	50.000	50.000	50.280	50.280	50.000	50.500	50.500	50.200	50.200	50.400	50.400	49.800	49.800	49.600	49.600	50.000	50.000	50.000

Table 2.2 - Injected Frequency against Time for High Frequency Non-Dynamic Response Testing

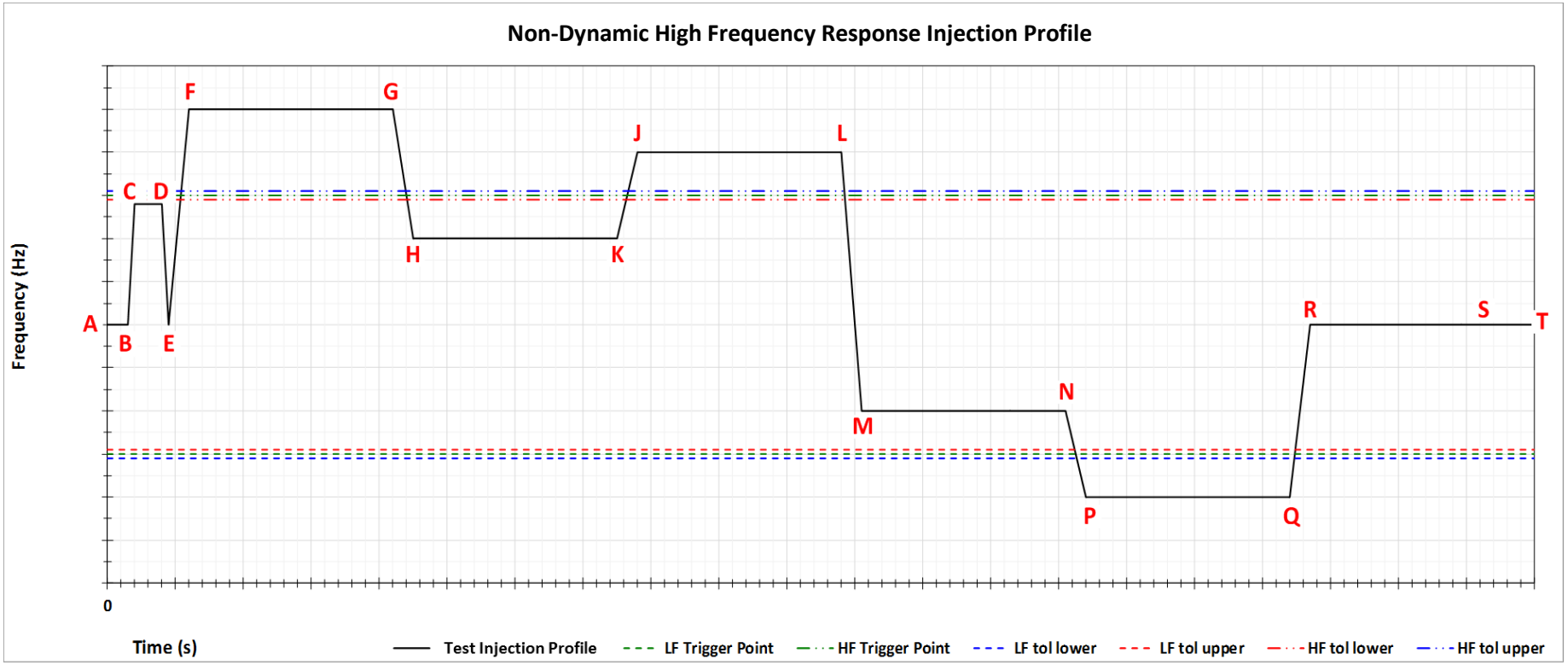

Figure 2.2 - Injection Profile for High Frequency Non-Dynamic Response Testing

a) The injected frequency signals used in testing are shown above (Figures 2.1 and 2.2). These show a trigger frequency of 49.7Hz/50.3Hz.

b) The length of both tests is approximately 2100s in the case where the providers are providing a 1800s response. If the agreed response time is longer or shorter than 1800s, the test may be proportionately increased or decreased as required.

3 Dynamic Firm Frequency Response Testing

The dynamic frequency tests aim to monitor the capability of the service provider to deliver dynamic response.

3.1 Test 1- Step Tests

This test is designed to ensure the system responds when the frequency moves outside of the +/- 0.015Hz deadband.

The step injections are shown in Figure 3.1 with corresponding values in Table 3.1. Each step is sustained for 180 seconds to verify the response. The frequency will then be returned to 50Hz for a minimum of 30 seconds, or until the output is stable, before the next injection is applied. The injections and expected responses for each test are shown in Table 3.2. Tests 1.1 and 1.2 are designed to ensure a change in power when the frequency moves outside the deadband.

Pass criteria for test:

- Delay in response of active power due to a change in frequency is no greater than 2 seconds.
- Minimum of the sampled values of active power within primary, secondary and high frequency timescales are within the allowable tolerances given in Table 3.2 and shown graphically in Figures 3.2 and 3.3.
- The standard deviation of load error at steady state over a 180 second period must not exceed 2.5% of the maximum contracted active power.
- Active power should progressively change to its contracted output.
- For Tests 1.1 and 1.2 a noticeable change in power in the correct direction is observed.

Test	Parameter	Values					
	Time (s)	0	30	30	210	210	240
1.1	Frequency (Hz)	50	50	50.02	50.02	50	50
1.2	Frequency (Hz)	50	50	49.98	49.98	50	50
1.3	Frequency (Hz)	50	50	50.1	50.1	50	50
1.4	Frequency (Hz)	50	50	49.9	49.9	50	50
1.5	Frequency (Hz)	50	50	50.2	50.2	50	50
1.6	Frequency (Hz)	50	50	49.8	49.8	50	50
1.7	Frequency (Hz)	50	50	50.3	50.3	50	50
1.8	Frequency (Hz)	50	50	49.7	49.7	50	50
1.9	Frequency (Hz)	50	50	50.4	50.4	50	50
1.10	Frequency (Hz)	50	50	49.6	49.6	50	50
1.11	Frequency (Hz)	50	50	50.5	50.5	50	50
1.12	Frequency (Hz)	50	50	49.5	49.5	50	50

Table 3.1 – Test 1 Frequency Injection Table Corresponding with Times

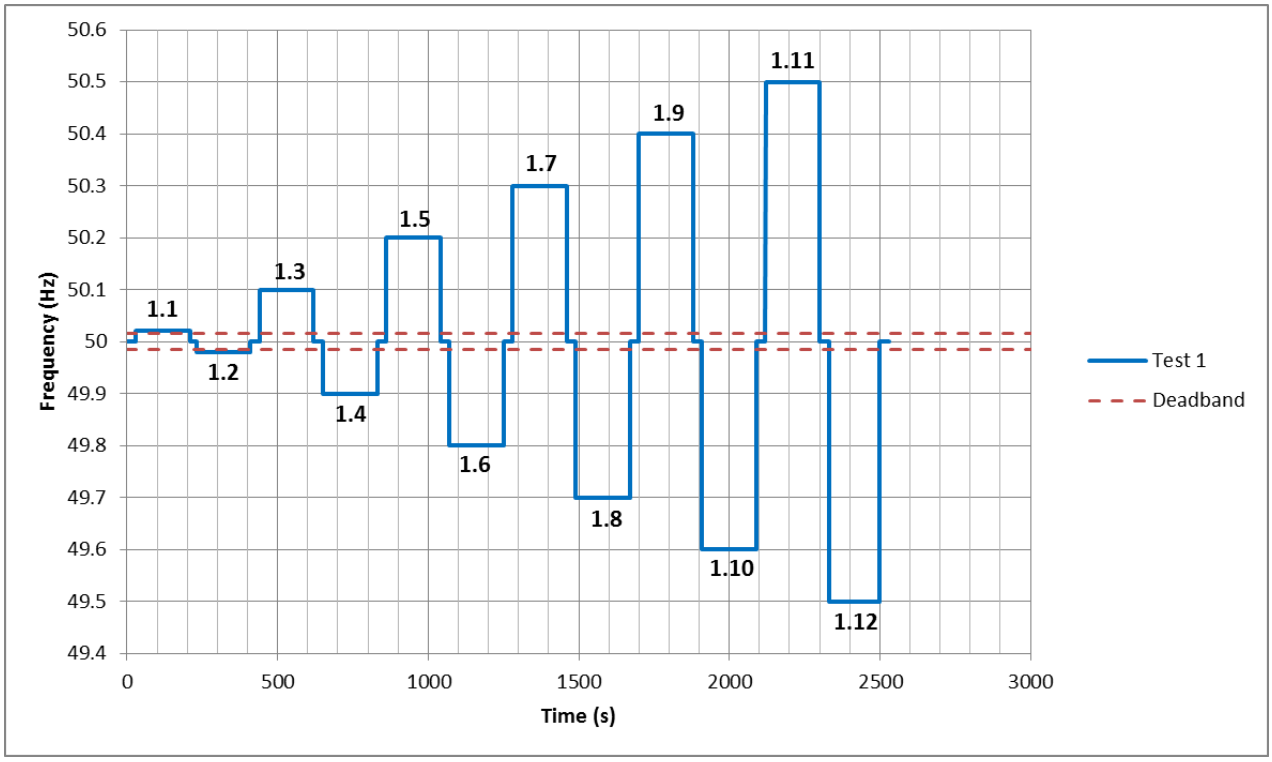

Figure 3.1 – Test 1 Injection Profile

Test Number	Frequency Step (Hz)	Expected Response	Allowable Power Tolerance
1.1	50.02	>0%	n/a
1.2	49.98	>0%	n/a
1.3	50.1	20%	5%/-4%
1.4	49.9	20%	5%/-4%
1.5	50.2	40%	5%/-3%
1.6	49.8	40%	5%/-3%
1.7	50.3	60%	5%/-2%
1.8	49.7	60%	5%/-2%
1.9	50.4	80%	5%/-1%
1.10	49.6	80%	5%/-1%
1.11	50.5	100%	5%/-0%
1.12	49.5	100%	5%/-0%

Table 3.2 - Frequency Injection and Expected Response values

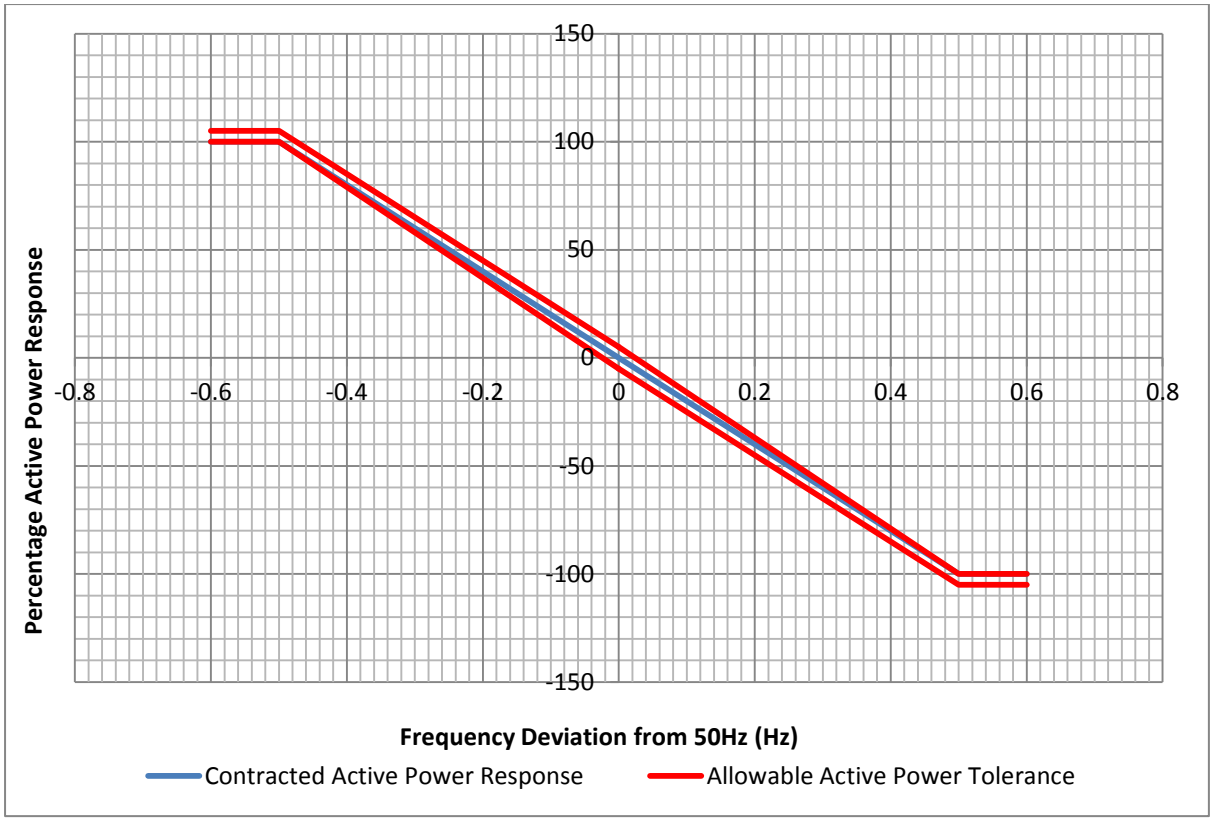

Figure 3.2 - Allowable Power Tolerance for a Negative Gradient Active Power Response

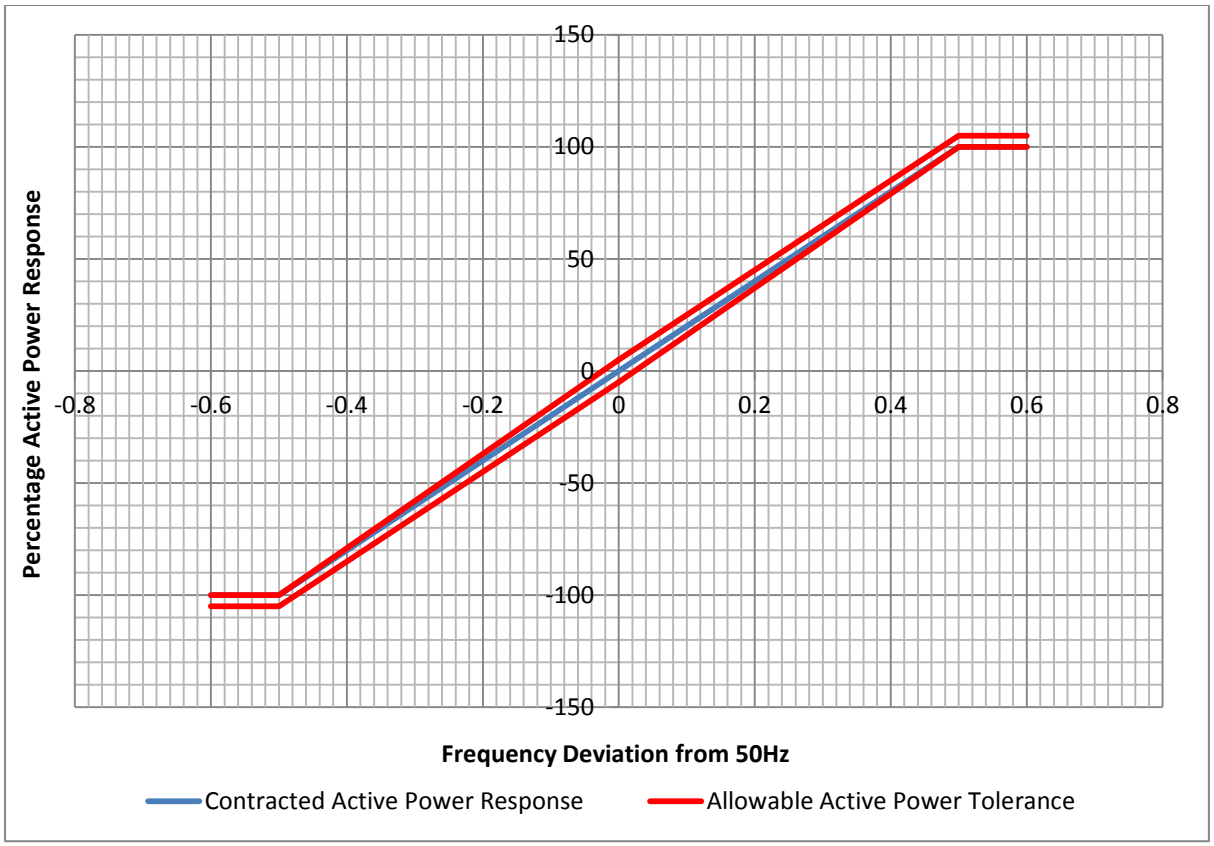

Figure 3.3 - Allowable Power Tolerance for a Positive Gradient Active Power Response

3.2 Test 2- Frequency Sweep Tests

These tests will comprise of frequency ramps from 50.6Hz to 49.4Hz and from 49.4Hz to 50.6Hz, in order to examine the system's entire performance envelope. The ramps will be injected over 30 seconds (Test 2.1, 2.2) and 90 seconds (Tests 2.3, 2.4). The injection profiles are shown in Tables 3.3 to 3.6 and Figures 3.4 to 3.7. The test will verify:

- At key data points the ability of the service to provide the correct active power response in accordance with the injected frequency.
- The active power as the frequency passes through the dead band.
- The 2 frequency ramp rates used enable assessment where primary and secondary contract values are different.

Pass criteria for test:

- Delay in response of active power due to a change in frequency is no greater than 2 seconds.
- Active power is consistent with the contracted values within the tolerances given in Tables 3.7 and 3.8 which are shown graphically in Figures 3.8, 3.9, 3.10 and 3.11.

	Test 2.1 Frequency Injection Table							
Time (s)	0	30	30	80	110	160	160	190
Frequency (Hz)	50	50	50.6	50.6	49.4	49.4	50	50

Table 3.3 – Test 2.1 Frequency Injection Table Corresponding with Times

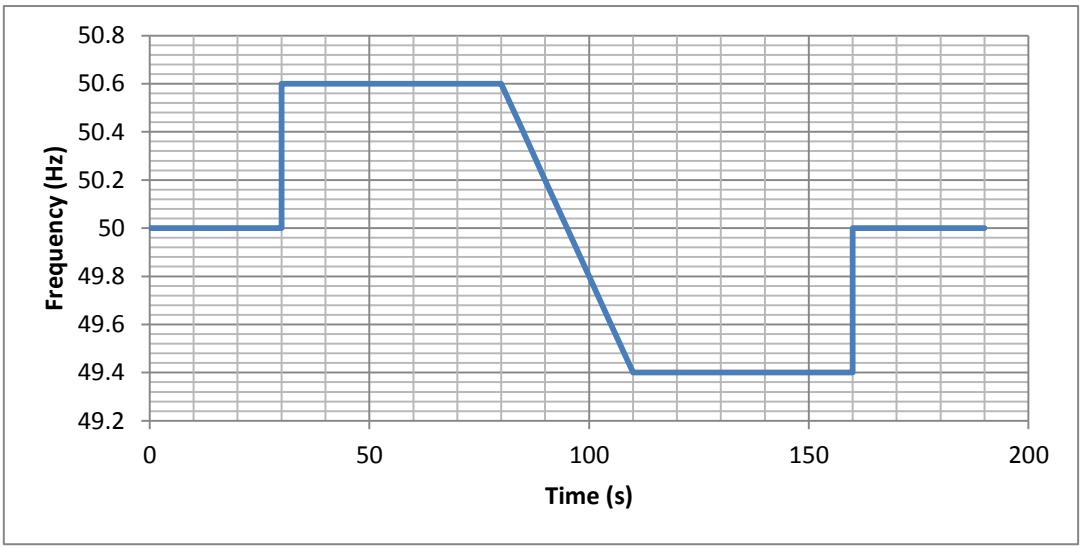

Figure 3.4 - Test 2.1 Injection Profile

	Test 2.2 Frequency Injection Table							
Time (s)	0	30	30	80	110	160	160	190
Frequency (Hz)	50	50	49.4	49.4	50.6	50.6	50	50

Table 3.4 – Test 2.2 Frequency Injection Table Corresponding with Times

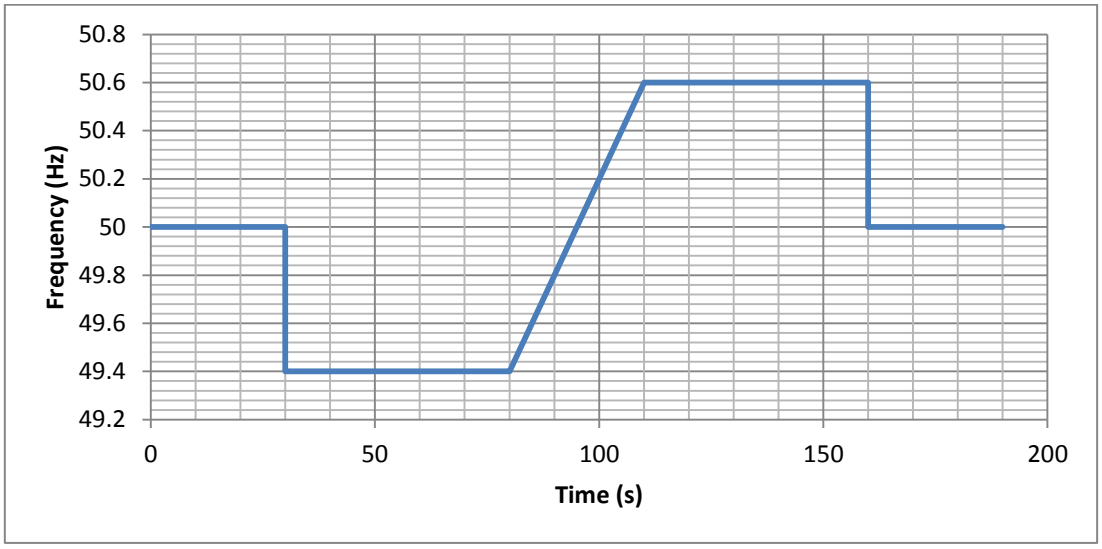

Figure 3.5 – Test 2.2 Injection Profile

	Test 2.3 Frequency Injection Table							
Time (s)	0	30	30	80	170	220	220	250
Frequency (Hz)	50	50	50.6	50.6	49.4	49.4	50	50

Table 3.5 – Test 2.3 Frequency Injection Table Corresponding with Times

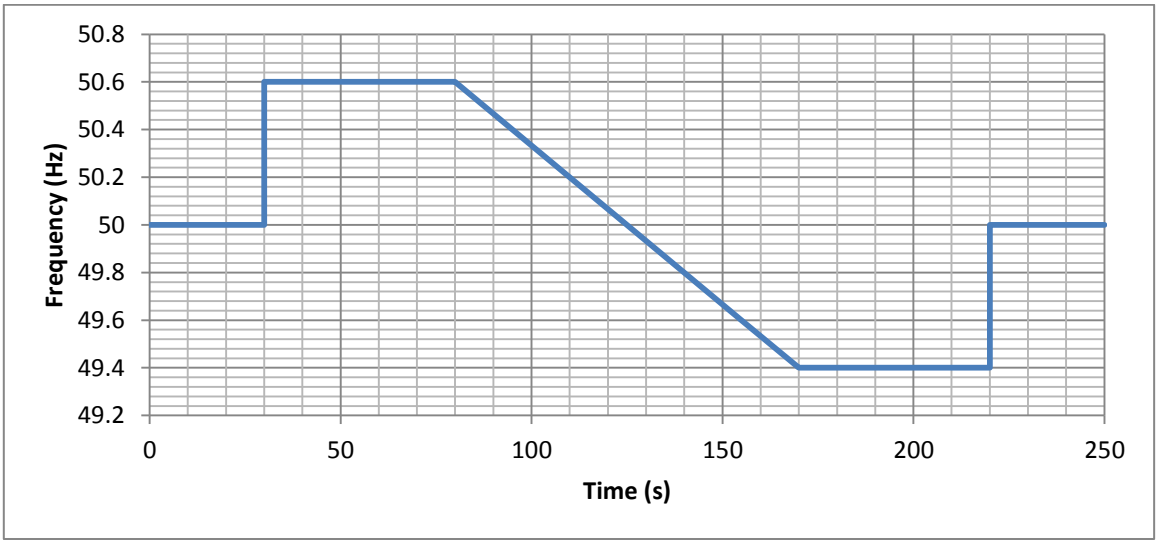

Figure 3.6 – Test 2.3 Injection Profile

	Test 2.4 Frequency Injection Table							
Time (s)	0	30	30	80	170	220	220	250
Frequency (Hz)	50	50	49.4	49.4	50.6	50.6	50	50

Table 3.6 – Test 2.4 Frequency Injection Table Corresponding with Times

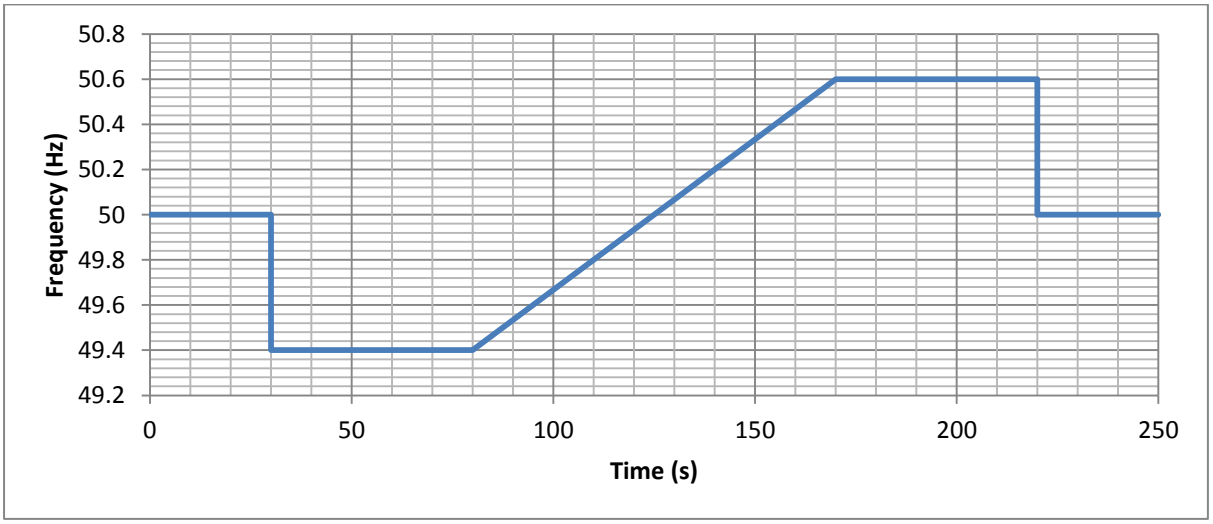

Figure 3.7 – Test 2.4 Injection Profile

Test 2.1 and 2.2				
	Negative Active Power Gradient		**Positive Active Power Gradient**	
Time	Expected Percentage Active Power Response	Tolerance	Expected Percentage Active Power Response	Tolerance
82.5	100	-0%/+5%	-100	-5%/+0%
84.5	84	-0.8%/+21%	-84	-21%/+0.7%
85	80	-1%/+21%	-80	-21%/+1%
87.5	60	-2%/+21%	-60	-21%/+2%
90	40	-3%/+21%	-40	-21%/+3%
92.5	20	-4%/+21%	-20	-21%/+4%
95	0	-5%/+21%	0	-21%/+5%
97.5	-20	-5%/+20.2%	20	-20.2%/+5%
100	-40	-5%/+19.3%	40	-19.3%/+5%
102.5	-60	-5%/+18.4%	60	-18.5%/+5%
105	-80	-5%/+17.6%	80	-17.6%/+5%
107.5	-100	-5%/+16.7%	100	-16.7%/+5%
109.5	-100	-5%/+0%	100	-0%/+5%

Table 3.7 - 30 Second Sweep Test Tolerances

Test 2.3 and 2.4				
	Negative Active Power Gradient		**Positive Active Power Gradient**	
Time	Expected Percentage Active Power Response	Tolerance	Expected Percentage Active Power Response	Tolerance
87.5	100	-0%/+5%	-100	-5%/+0%
89.5	94.67	-0.3%/+10.4%	-94.67	-10.4%/+0.3%
95	80	-1%/+10.4%	-80	-10.4%/+1%
102.5	60	-2%/+10.4%	-60	-10.4%/+2%
110	40	-3%/+10.4%	-40	-10.4%/+3%
117.5	20	-4%/+10.4%	-20	-10.4%/+4%
125	0	-5%/+10.4%	0	-10.4%/+5%
132.5	-20	-5%/+9.4%	20	-9.4%/+5%
140	-40	-5%/+8.5%	40	-8.5%/+5%
147.5	-60	-5%/+7.5%	60	-7.5%/+5%
155	-80	-5%/+6.6%	80	-6.6%/+5%
162.5	-100	-5%/+5.6%	100	-5.6%/+5%
164.5	-100	-5%/+0%	100	-0%/+5%

Table 3.8 - 90 Second Sweep Test Tolerances

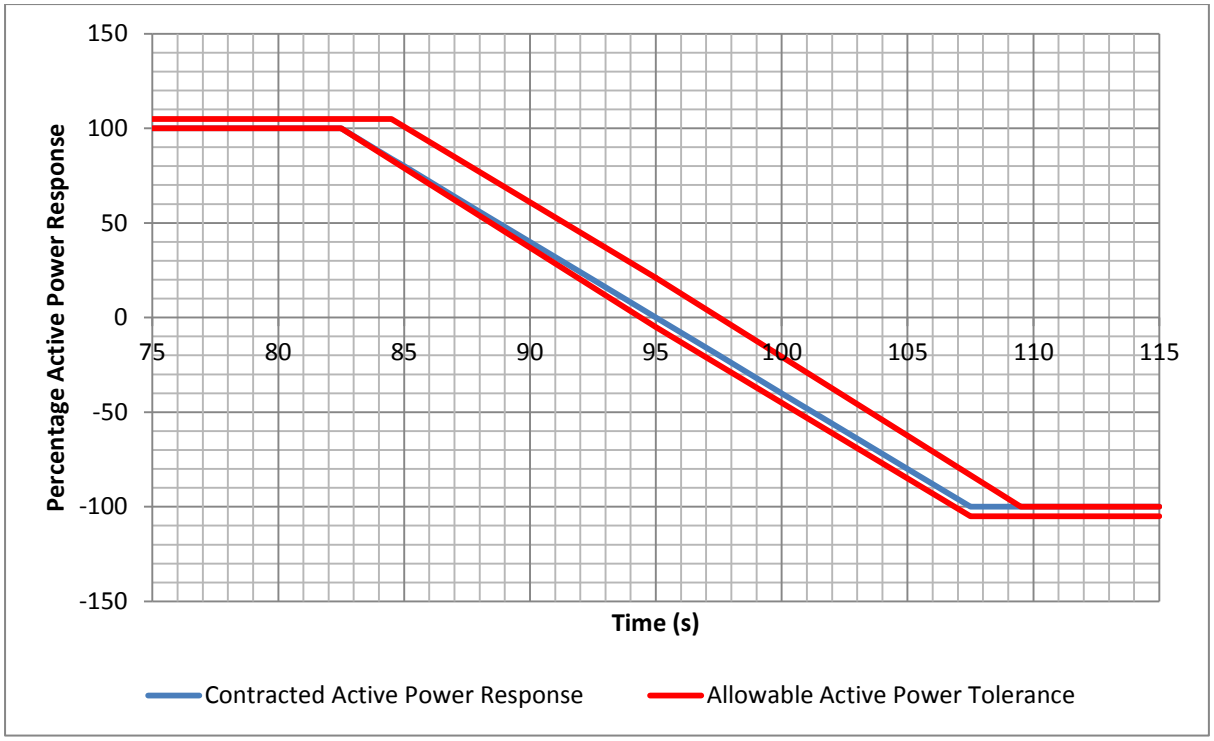

Figure 3.8 - Negative Active Power Gradient Tolerance Band

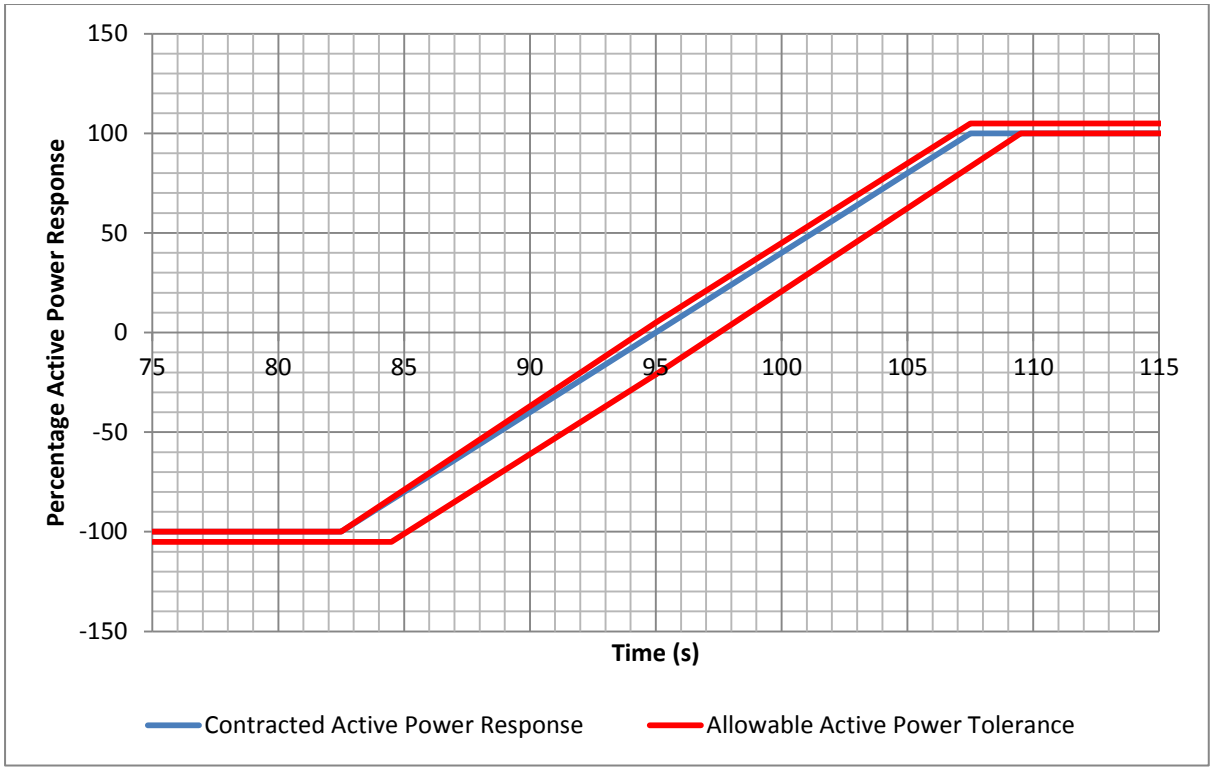

Figure 3.9 - Positive Active Power Gradient Tolerance Band

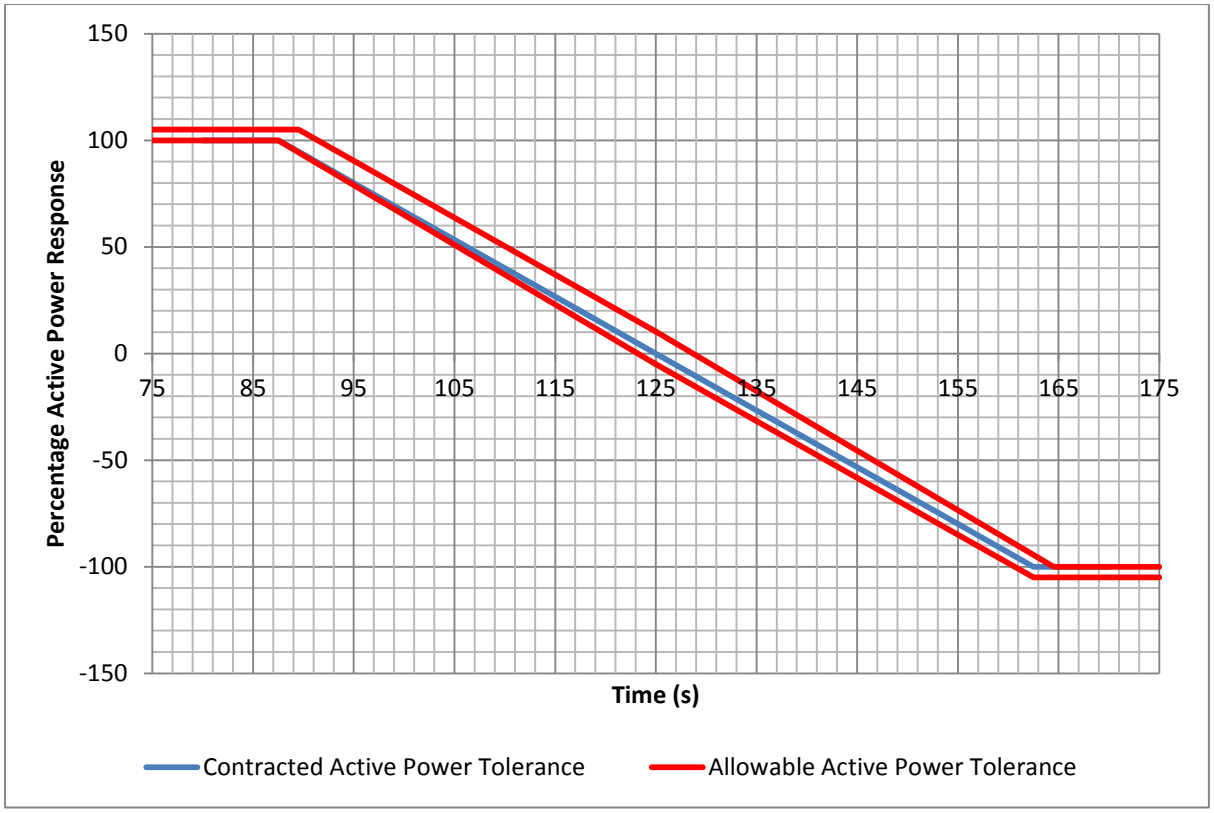

Figure 3.10 - Negative Active Power Gradient Tolerance Band

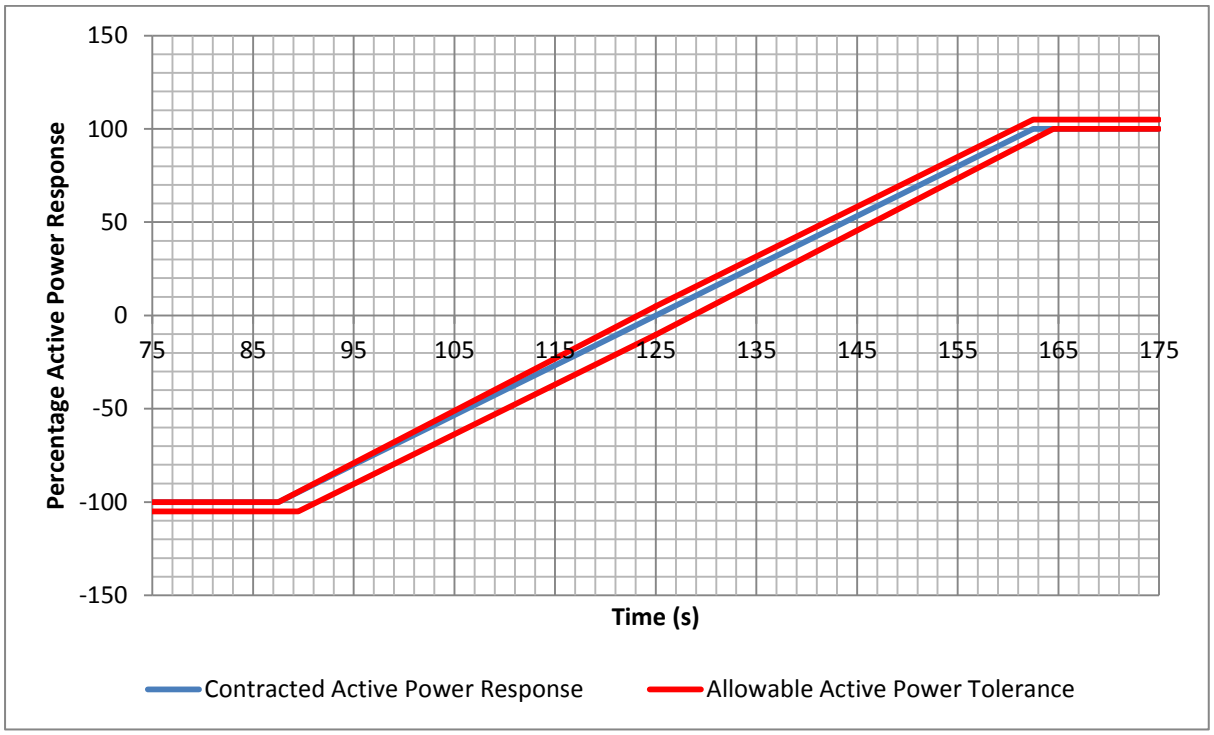

Figure 3.11 - Positive Active Power Gradient Tolerance Band

3.3 Test 3- Duration Tests

FFR duration tests require the service provider to be able to respond at full output for 30 minutes. Operation will be tested at ±100% of capability to ensure the system is compliant. This is carried out by a frequency step of ±0.6Hz onto the system for 30 minutes. The frequency will then be stepped back to 50Hz. The frequency injection profiles are shown in Tables 3.9 and 3.10 and Figures 3.12 and 3.13.

Pass criteria for test:

- The standard deviation of load error at steady state over an 1800 second period must not exceed 2.5% of the maximum contracted active power.
- Sustain response for 30 minutes.

•	**Test 3.1 Frequency Injection Table**					
Time (s)	0	30	30	1830	1830	1860
Frequency (Hz)	50	50	50.6	50.6	50	50

Table 3.9 – Test 3.1 Frequency Injection Table Corresponding with Times

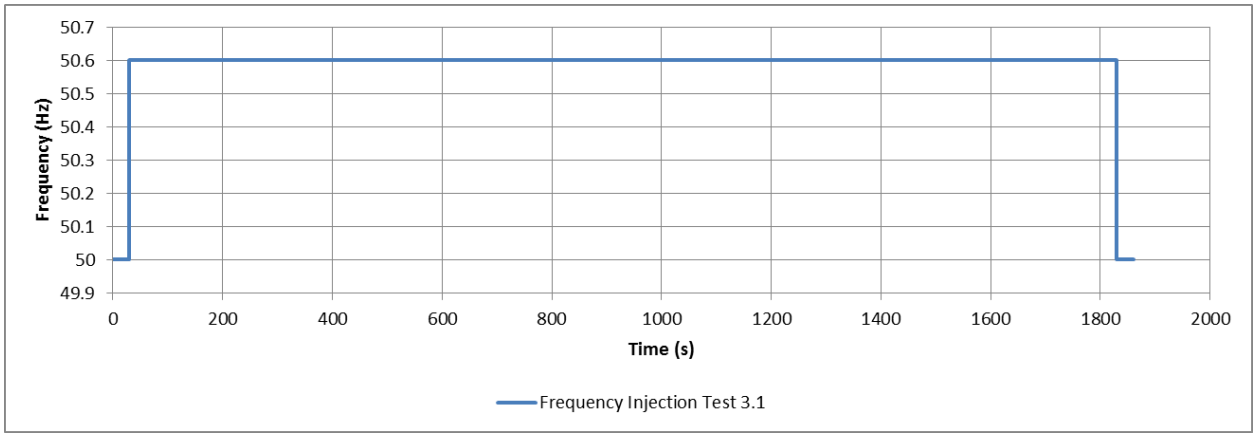

Figure 3.12 - Test 3.1 Injection Profile

	Test 3.2 Frequency Injection Table					
Time (s)	0	30	30	1830	1830	1860
Frequency (Hz)	50	50	49.4	49.4	50	50

Table 3.10 – Test 3.2 Frequency Injection Table Corresponding with Times

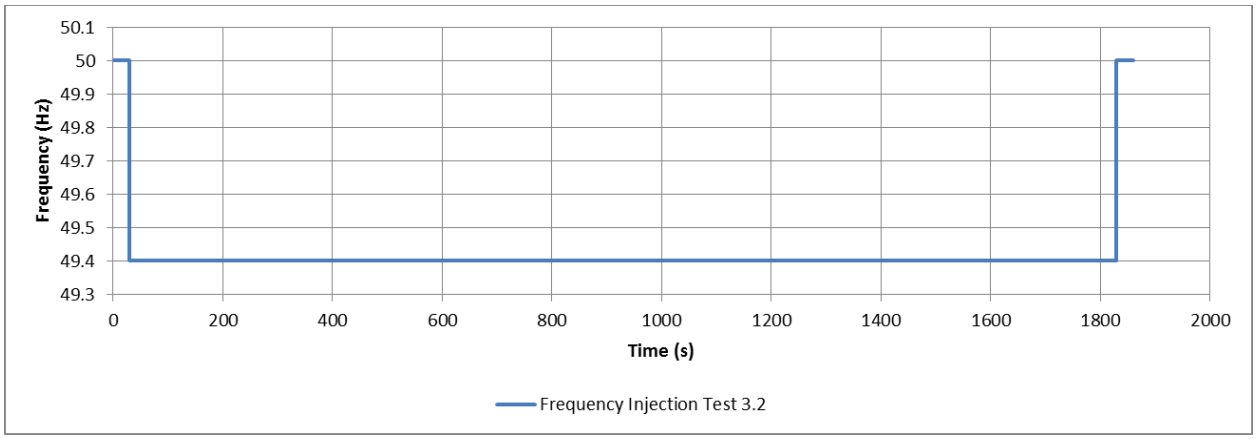

Figure 3.13 - Test 3.2 Injection Profile

3.4 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 1 hour. The sample rate should be 10Hz for this test. An example is shown in Figure 3.14.

Pass criteria for test:

- Provide an active power response consistent with the contracted performance within Primary, Secondary and/or High frequency response timescales.

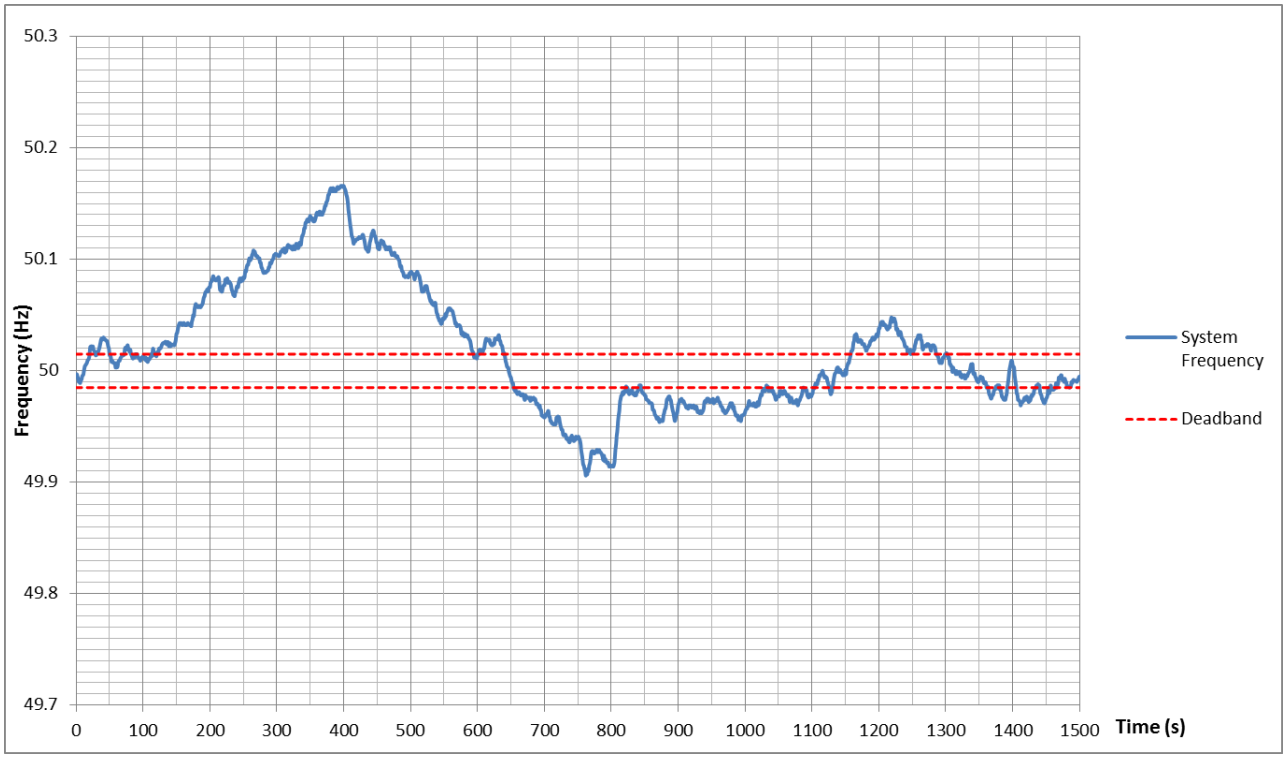

Figure 3.14 - Test 4 *(Note this is an example frequency of 1500 seconds: the real test will follow actual Grid frequency for 1 hour)*

Appendix A – Test Data and Test Signals

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	10Hz
Active Power (MW)	Please see pass criteria	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

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 (High Frequency Non Dynamic, Low Frequency Dynamic, etc.)

Example Test Results

Figure B.1- One Site

	A	B	C	D	E
1	**Provider**	Company Name			
2	**Date**	xx-xx-xxxx			
3	**Test**	1			
4	**Service**	Low Frequency Non-Dynamic Secondary Response			
5	**Location**	AA			
6	**Site/Group/Plant**	A			
7					
8	**Time**	**Injected Frequency (Hz)**	**Baseline Power (MW)**	**Measured Power (MW)**	**Relay**
9	0	50.000	0.000	0.000	0
10	0.1	50.000	0.000	0.000	0
11	0.2	50.000	0.000	0.000	0
12	0.3	50.000	0.000	0.000	0
13	0.4	50.000	0.000	0.000	0
14	0.5	50.000	0.000	0.000	0
15	0.6	50.000	0.000	0.000	0
16	0.7	50.000	0.000	0.000	0
17	0.8	50.000	0.000	0.000	0
18	0.9	50.000	0.000	0.000	0
19	1	50.000	0.000	0.000	0
20	1.1	50.000	0.000	0.000	0
21	1.2	50.000	0.000	0.000	0
22	1.3	50.000	0.000	0.000	0
23	1.4	50.000	0.000	0.000	0
24	1.5	50.000	0.000	0.000	0
25	1.6	50.000	0.000	0.000	0

Figure B.2- Multiple Sites

	A	B	C	D	E	F	G	H	I	J	K
1	**Provider**	Company Name									
2	**Date**	xx-xx-xxxx									
3	**Test**	1									
4	**Service**	Low Frequency Non-Dynamic Secondary Response									
5	**Location**	AA				AB					
6	**Site/Group/Plant**	A				B					
7											
8	**Time**	**Injected Frequency (Hz)**	**Baseline Power (MW)**	**Measured Power (MW)**	**Relay**	**Time**	**Injected Frequency (Hz)**	**Baseline Power (MW)**	**Measured Power (MW)**	**Relay**	
9	0	50.000	0.000	0.000	0	0	50.000	0.000	0.000	0	
10	0.1	50.000	0.000	0.000	0	0.1	50.000	0.000	0.000	0	
11	0.2	50.000	0.000	0.000	0	0.2	50.000	0.000	0.000	0	
12	0.3	50.000	0.000	0.000	0	0.3	50.000	0.000	0.000	0	
13	0.4	50.000	0.000	0.000	0	0.4	50.000	0.000	0.000	0	
14	0.5	50.000	0.000	0.000	0	0.5	50.000	0.000	0.000	0	
15	0.6	50.000	0.000	0.000	0	0.6	50.000	0.000	0.000	0	
16	0.7	50.000	0.000	0.000	0	0.7	50.000	0.000	0.000	0	
17	0.8	50.000	0.000	0.000	0	0.8	50.000	0.000	0.000	0	
18	0.9	50.000	0.000	0.000	0	0.9	50.000	0.000	0.000	0	
19	1	50.000	0.000	0.000	0	1	50.000	0.000	0.000	0	
20	1.1	50.000	0.000	0.000	0	1.1	50.000	0.000	0.000	0	
21	1.2	50.000	0.000	0.000	0	1.2	50.000	0.000	0.000	0	
22	1.3	50.000	0.000	0.000	0	1.3	50.000	0.000	0.000	0	
23	1.4	50.000	0.000	0.000	0	1.4	50.000	0.000	0.000	0	
24	1.5	50.000	0.000	0.000	0	1.5	50.000	0.000	0.000	0	
25	1.6	50.000	0.000	0.000	0	1.6	50.000	0.000	0.000	0	