TRANSPOWER

Ancillary Service Testing Requirements

GL-EA-1333

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1.0		First edition; migrated ancillary services tests from earlier editions of GL-EA-010 Generator Testing Requirements and interruptible load tests from GL-EA-766 Distribution Asset Test Requirements.

	Position	Date
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IMPORTANT

Disclaimer

This document is developed within the current regulatory framework and is accurate as at the published date. Subsequent changes to the Code or other regulations and policies may result in inaccuracies. Please contact Transpower to discuss current requirements.

This document does not relieve asset owners from identifying and meeting their obligations set out in the Code. Where there is conflict between this document and the Code, the Code takes precedence. Asset owners are strongly advised to seek expert advice to understand their full obligations under the Code. The contents of this document may not be Transpower's final or complete view on any particular subject, and all provisions of it are subject to change. Transpower as the System Operator excludes all representations and warranties relating to the contents of this document, including in relation to any inaccuracies or omissions. Transpower excludes all liability for loss or damage arising from any person's reliance on the contents of this document.

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Introduction

The purpose of this document is to guide you in performing the required testing of your generating asset, battery, or load to demonstrate their capability to provide one or more ancillary services. You can find more information about the ancillary services that the System Operator procures on our *webpage*.

As you prepare for testing, consult the relevant essential documents found on our webpage, including the *Ancillary Services Procurement Plan* and the *Electricity Industry Participation Code 2010* (the Code). Your individual ancillary services procurement contract outlines your specific testing requirements.

If you are commissioning generation, note that testing for ancillary services may be carried out in parallel.

Navigating the Document

The document begins by providing an overview of the testing process and our requirements, then summarises the standard test signals and the applicable signal measurement locations based on the type of technology involved.

We then outline details relevant to each test, including standard injection curves, in the sections connected to each ancillary service:

- Frequency keeping
- Over-frequency reserve
- Instantaneous reserve
- Black start

The test schedules we provide are a guideline and may need to be slightly adjusted to fit your circumstances – contact the System Operator if you intend to deviate from what we have included in this document. . You should also let us know if you intend to use factory or type testing as this may be acceptable in some circumstances.

Note: *You are responsible for meeting all your obligations as stipulated in your contract, the Code, and its amendments. You therefore need to read, understand, and comply with all of these obligations. If there is a conflict between this document and the Code, the Code takes precedence. If you engage a consultant for testing and model validation purposes, it is your responsibility to ensure that they are aware of our requirements and expectations.*

1 Abbreviations and Terms

Abbreviation/Term	Expanded Form/Explanation
ACS	Asset Capability Statement
AOPO	Asset Owner Performance Obligation
ASPP	Ancillary Service Procurement Plan
AVR	Automatic Voltage Regulator
BESS	Battery Energy Storage System
BS	Black start
CACTIS	Connected Asset Commissioning, Testing and Information Standard
CB	Circuit breaker
The Code / EIPC	Electricity Industry Participation Code 2010
FIR	Fast Instantaneous Reserve
IL	Interruptible Load
IR	Instantaneous Reserve
IST	Information Systems Technology
MFK	Multiple Frequency Keeping
NCC	National Co-ordination Centre
OEL	Over-excitation limiter
OFR	Over-frequency reserve
POC or PCC	Point of Connection
PLSR	Partially Loaded Spinning Reserve
PPC	Power Plant Controller
PPO	The System Operator's Principal Performance Obligations
PSS	Power System Stabiliser
SFK	Single Frequency Keeping
SIR	Sustained Instantaneous Reserve
SNL	Speed-no-load
SSES	Small-scale energy system
TWD	Tail-water depressed
UEL	Under-excitation limiter

2 General Requirements

2.1 Test Objectives

The objectives of these tests is to verify that the equipment used by the ancillary service agent can meet the performance requirements defined in the Ancillary Services Procurement Plan (ASPP) and ancillary service contract. These documents are available on our essential documents webpage. All testing must ensure minimal disturbance to the operation of the power system.

2.2 Timing and Regularity of Tests

Ancillary service testing is required when an ancillary service agent wants to offer a new ancillary service product. Because the requirements for testing a new product (which may occur during a 'new build' commissioning project or when connecting new loads to the power system) may differ from regular/ongoing testing, agents must contact the System Operator in advance to confirm the applicable testing requirements before undertaking any tests.

The ancillary service agent must also conduct and pass a test following any change to the equipment used to deliver an ancillary service where that change could impact performance. This includes, but is not limited to, changes to governor settings. The System Operator retains the right to determine whether a test is required following any change.

During the contracted period for an ancillary service, further testing may be required at different times. Refer to your ancillary service procurement contract and the ASPP for the testing requirements applicable to your specific product.

In instances where compliant operational performance has been fully demonstrated, extra testing will not be required. For this exemption to apply, the ancillary service agent must have provided the System Operator with the corresponding operational data for verification of compliant operational performance.

You must notify the System Operator that you intend to undergo any testing if you are connected to the power system. If you are undergoing the generation commissioning process and intend to test ancillary services in parallel, you must note this in the Code commissioning plan, as well as provide details in the engineering methodology and operational test plans. The time frames associated with these are mandated in the *Connected Asset Commissioning, Testing and Information Standard* (CACTIS).

The following sections describe the minimum requirements before, during, and after testing.

2.3 Before Testing

2.3.1 Engineering Methodology

If you are intending to provide an ancillary service for the first time, or if you have modified your equipment in a way , you must provide an engineering methodology to describe the relevant testing. Chapter 1 of *CACTIS* outlines the time by which a final copy of an engineering methodology must be submitted to the System Operator for review. We recommend that you submit a draft 2 months earlier to give sufficient time for feedback.

If you are undergoing routine testing instead, an operational test plan is sufficient – see the section below.

The rest of this document (GL-EA-1333) will help you organise the contents of an engineering methodology, for which you should use our DT-EA-1337 Engineering Methodology Template (for generation assets or BESS) or the appropriate section of DT-EA-1346 Interruptible Load Proposal Template (for IL). Submit your draft and final versions to compliance@transpower.co.nz (unless advised otherwise). The System Operator will review and provide feedback.

Note: *If you deviate from any of the requirements in this testing document, ensure that you record this in your engineering methodology.*

2.3.2 Operational Test Plan

If you have obligations under clauses 2(6) 2(8) and 2(9) of Schedule 8.3, Technical Code A of the Code to submit an operational test plan, you must submit it at least 15 business days before testing. The test plan must summarise the testing to be completed each day. This will allow us to assess any potential risks related to:

- the asset owner's ability to meet their asset owner performance obligations (AOPOs) and obligations under their service contract and,
- the System Operator's ability to meet the Principal Performance Obligations (PPOs).

After assessing your operational test plan, the System Operator may impose certain conditions. Testing can only go ahead if you agree with those conditions.

Further details are available on our *Asset Testing webpage*, including the test forms to use. For most ancillary service testing, use the main *operational test plan form*. There is a separate form for *backup single frequency keeping*.

Send the completed form to *operationaltestplans@transpower.co.nz*.

2.3.3 Load Reduction During Testing

The System Operator requires ancillary service agents that intend to carry out testing via a load reduction of more than 30 MW notifies the System Operator via email at XXXX

2.3.4 Demand Change Limits

Under the the System Operator's *policy statement*, each purchaser within each island is subject to the following limits:

- the maximum instantaneous demand change and the net rates of change in electricity offtake must not exceed 40 MW per minute, and
- the total change must be no more than a 75 MW change within any 5-minute period.

2.4 During Testing

You must follow all terms and conditions noted on the agreed operational test plan at all times, as well as the obligations in the Code and your own ancillary services contract. If you need to test the performance of multiple pieces of equipment of the same design (i.e. a group of identical assets, built by the same manufacturer), you must:

- first complete a full set of tests on the asset that is to be representative of the group; then
- complete sufficient testing on the remainder of the assets to demonstrate the performance is fully consistent with the representative asset; and,
- certify to the System Operator the performance of assets is fully consistent with the representative asset as detailed in the Code.

2.5 After Testing

2.5.1 Results and Model Validation

The final test results must be submitted to the System Operator at the end of testing in accordance with the time frames set out in the individual procurement contracts, unless requested earlier. The results should clearly identify the equipment and test they refer to.

After testing, no change to settings, including governor or control settings, must be made without approval from the System Operator.

If you are testing instantaneous reserve, use your final test results to validate your model (including for routine testing) and submit it to the System Operator. Advise us if asset performance differs from your model. Refer to *GL-EA-716* (for synchronous assets) and GL-EA-1311 (for inverter-based resources) for more information on modelling requirements.

If a test report is required in addition to the above, it is specified in the applicable test methodologies.

2.5.2 File Names

We have provided the file name format in Table 1 below to help you correctly associate test result files to specific tests. Your files names should follow this pattern:

AssetName_EquipmentID_TestID_TestNumber_DateTime

Table 1: Expected File Name Pattern Explanations

Part	Explanation
AssetName	The asset name under test; for example, the name of a station.
EquipmentID	The ID of the equipment under test; for example, G1 to represent the ID of generating unit 1.
TestID	The ID assigned to each test; for example AS_GEN_OFT refers to the Synchronous Over-Frequency Reserve Test (AS_GEN_OFT).
Test Number	The number to identify the test from another test of the same type; for example 01 represents the first test of that type.
DateTime	The timing formatted as follows: DDMMYYYYhhmmss

2.5.3 Time Stamping

You must GPS-time stamp all data to ensure that data obtained from different sources aligns accurately.

3 Signal Measurement Locations

You should measure signals according to the specifications below, depending on the type of asset you are using to provide the relevant ancillary service.

3.1 Synchronous Generation

You must record signals:

- at the point of connection (POC/PCC);
- at the input and output of control components such as exciter; governor etc.; and
- at any physical points on the equipment where data is required for model validation.

The table below captures the signals the System Operator would typically expect.

Table 2: Synchronous Generation Signal ID, Signal Name and Signal Description List (see Figure 1)

Signal ID	Signal Name	Signal Description
1	Ppcc, Qpcc, fpcc, Vpcc (HV)	PCC at HV of the generator unit transformer
2	Ppcc, Qpcc, fpcc, Vpcc (LV)	PCC at LV of the generator unit transformer
3	Vt, It, Pt, Qt, ft, SPt	Generator terminal parameters required if PCC is on LV only If SP_t cannot be obtained or is too noisy, this should be documented, and a clean frequency signal used
4	V_{fd},I_{fd}	Excitation system parameters. For brushless excitation systems the field-voltage and field-current of the exciter should be recorded as the V_{fd} and I_{fd} will not be accessible.
5	AVRcom	AVR output command
6	UELcom, OELcom	Limiters output command
7	PSScom	PSS output command
8	GOVcom, Pos	Governor output command, Gate/Valve position
9	fref, Pref	Frequency reference, Power reference
10	Vref, Qref	Voltage reference, Reactive power reference

Figure 1 below plots the measurement points on a typical synchonous asset's topology.

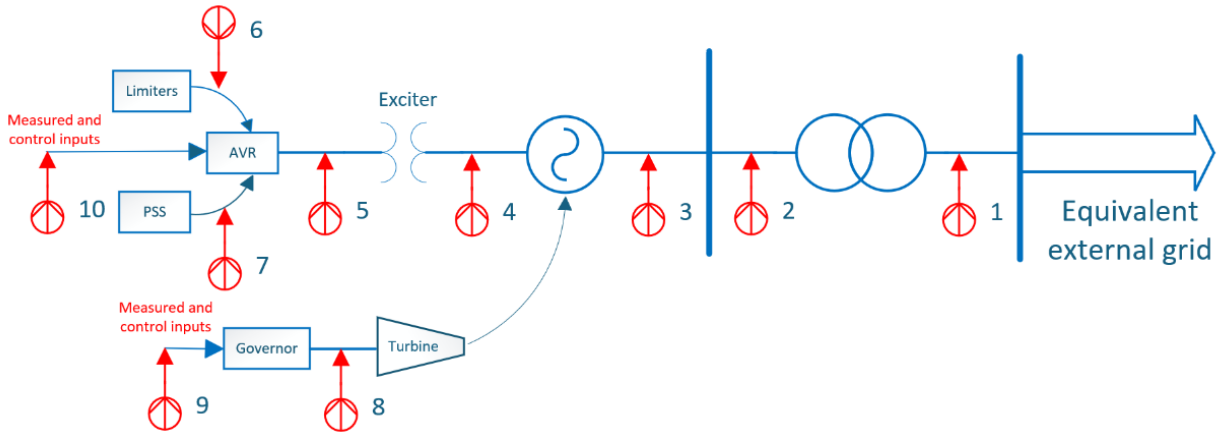

Figure 1: Typical Synchronous Generator Configuration and Measurement Points

3.2 Inverter-based Generation

You must record signals:

- at the individual Inverter connected module for both:
  - inputs and outputs for validating individual module model; and
  - internal signals such as converter DC voltage and Phase-Locked Loop input and output if accessible; and

- at the Power Plant Controller level:
  - inputs to the controller and active power at the point of connection (POC/PCC) (if applicable); and
  - outputs to modules.

Note: If you are testing a battery energy storage system (BESS), ensure that you test all modes of operation: charging, standby, and discharging.

The table below captures the signals the system operator would typically expect of this generator type.

Table 3: Inverter Generation Signal ID, Signal Name and Signal Description List (see)

Signal ID	Signal Name	Signal Description
1	Ppcc, Qpcc, fpcc, Vpcc (HV)	PCC at HV of the step-up transformer
2	Ppcc, Qpcc, fpcc, Vpcc (LV)	Required if PCC at LV of the generator unit transformer only
3	Pcom, Qcom, Vcom	Plant controller request command to inverter string
4	INVcom	Inverter command, signal type to be discussed with the system operator
5	INVdc	Inverter DC voltage
6	Pinv, Qinv, Vinv	Inverter string parameters to be recorded for a few indicative inverters at each end of a string for each type of device installed as agreed between the asset owner and System Operator

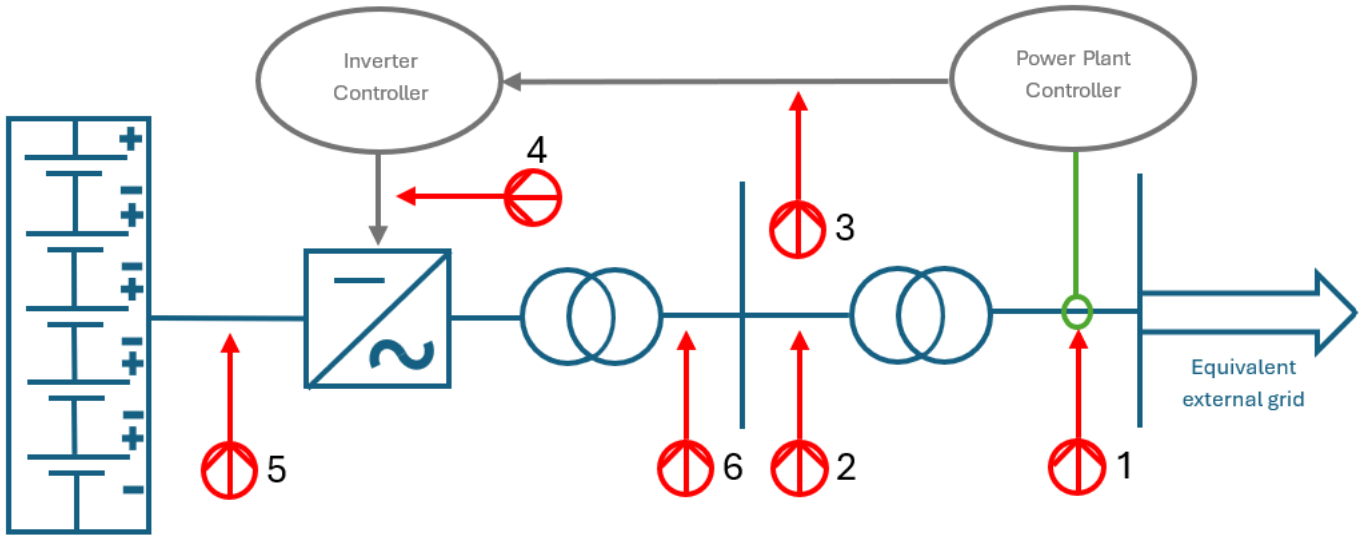

Figure 2: Typical IBR Generator (BESS) Configuration and Measurement Points

3.3 Interruptible Load

You must record signals:

- at the Grid Exit Point (GXP), and/or
- at the feeder level, and/or
- at the Installation Control Point (ICP).

The table below captures the signals the System Operator would typically expect.

Table 4: Interruptible Load Signal ID, Signal Name and Signal Description List (see Figure 3)

Signal ID	Signal Name	Signal Description
1	P_{GXP}, F_{GXP}, t_{GXP}	GXP level data
2	P_i, F_i, t_i	Feeder level data (i – 1, 2, 3, etc)
3	P_j, F_j, t_j	ICP level data (j – 1, 2, 3, etc)

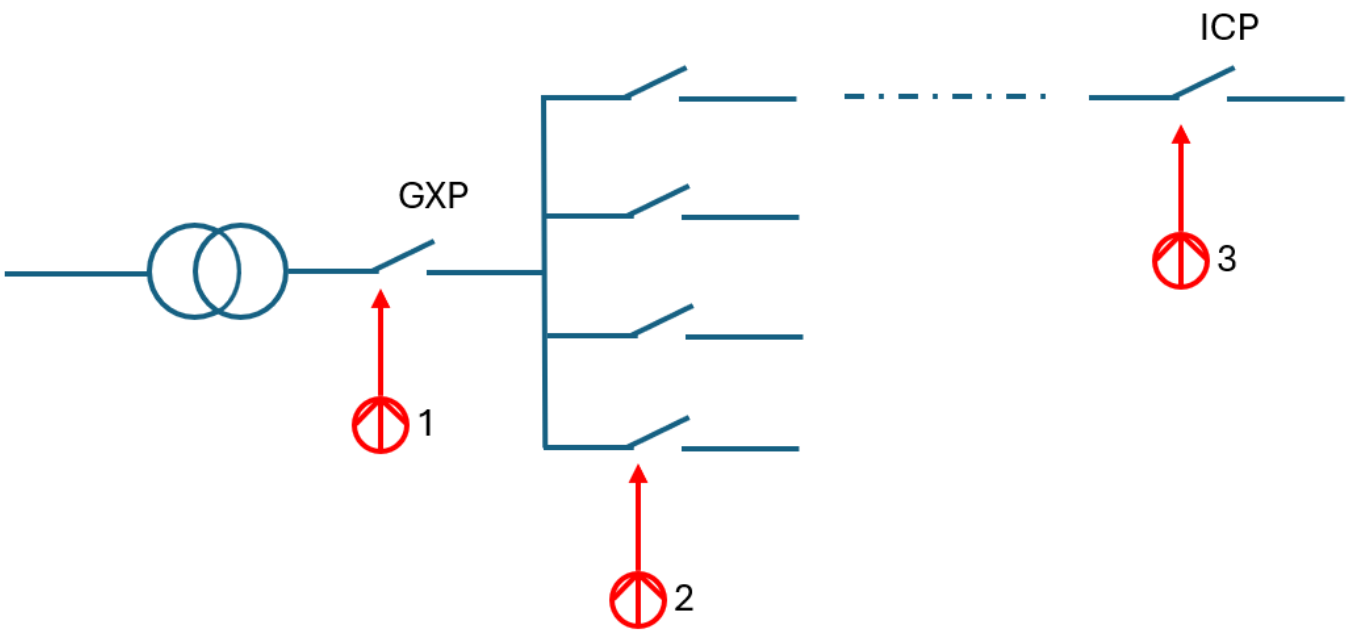

Figure 3: Interruptible Load Single Line Diagram

4 Frequency Keeping

There are two frequency keeping products procured by the System Operator: Multiple Provider Frequency Keeping (MFK) and Back-up Single Provider Frequency Keeping (SFK).

Only sites that are contracted to provide frequency keeping services can be dispatched to provide this service. Providers may not offer frequency keeping without a valid and enforceable ancillary service procurement contract.

4.1 Multiple Frequency Keeping

Applicability: generating units and BESS offering MFK services.

Testing Outcomes: demonstration of:

- appropriate response rates and response times while responding to regulating instructions,
- stability of the control changes when first enabling the frequency keeping mode,
- stability of the control changes when responding to small positive and negative deviations in frequency ,
- frequency keeping performance.

Test Objectives: perform testing to…	**Test Outcomes:** demonstrate…
▪ demonstrate ability to respond to regulating instructions	▪

4.1.1 MFK Injection Curves

Purpose: Measures an asset's capability to maintain stability across different frequency bands. Figure 4 shows an injected signal (blue) and the response expected (red) to demonstrate MFK.

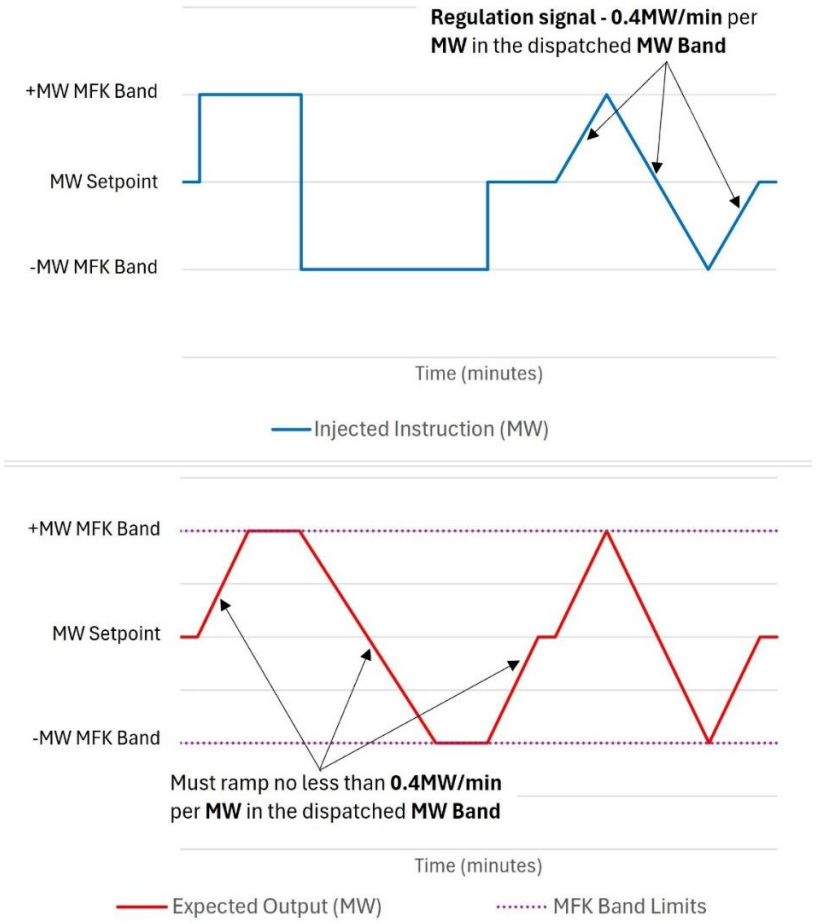

Figure 4: MFK Injected Frequency Curves

4.1.2 Multiple Frequency Keeping Test (AS_MFK)

Purpose: This test aims to demonstrate…

- that the unit follows regulating control signals,
- the response rate in the dispatched MW band,
- the response time of the unit to the regulating control signal,
- the SCADA performance for MFK operation.

Regularity: This test must be performed…

Pre-testing:

- Agree with the System Operator the MFK band values that will define the test signal to be used.
- Check that *a test plan* has been submitted to and accepted by the System Operator (these are reviewed on a case-by-case basis).
- test plan has been submitted to and accepted by the System Operator (these are reviewed on a case-by-case basis)
- Coordinate with the System Operator (via *market.operations@transpower.co.nz*) or the ancillary services lead to arrange MFK regulation signals with Transpower IST at least 15 business days before testing. Include your operational test plan when you reach out.
- Ensure that the monitoring equipment is available, measures and records in a time-tagged manner:
  - FK output at each FK site at least once every 1 second, each measurement accurate to within ±2% of the total expected FK output range of the FK site; and
  - the regulating instructions received for the FK site.

Monitoring Signals: Record the following:

- Electrical frequency – ft (Hz)
- Mechanical speed – SPt (rpm)
- Generator terminal voltage – Vt (kV)
- Generator terminal active power – Pt (MW) (measured at least once a second)

Additional requirements for this test:

- Active power dispatch signal
- MFK regulation signal (measured at least once a second)

(see section 3 for signal measurement locations)

Methodology:

ICCP end-to-end tests

1. Run the generating unit online with MFK mode enabled.
2. Record the monitoring signals.
3. Confirm that the signal being sent by the System Operator can be received on-site.
4. Receive a positive MFK test signal from the System Operator.
5. Wait for at least 60 seconds.
6. Receive a negative MFK test signal from the System Operator.
7. Wait for at least 60 seconds.

Response rate, response time, turn-around time and MFK band test

1. Run the generating unit online with MFK mode enabled.
2. Record the monitoring signals.
3. Send the agreed test signal to the generator to ramp up or down on the proposed MFK band (refer to 4.1.1).
4. Repeat the tests with different test signals to achieve the test objectives.

Notes:

Each unit that is part of a block dispatch group, station dispatch group or group of load sources must be tested.

The unit is not required to operate outside the limits of the MW band contained in the relevant dispatch instruction or above the relevant control maximum or below the relevant control minimum.

Acceptance Criteria: Demonstration of:

- the MFK signal having been successfully received with a time delay of less than 5 seconds and compliant with all regulating instructions,
- active power measurements' accuracy within ±2% of total expected output (band),
- the response rate of 0.4 MW per minute per MW in the dispatched MW band,
- a response time of less than 10 seconds to dispatched value,
- upon turn-around, a response time of less than 10 seconds.

After Testing:

Within 15 business days of completion of a test, you must contact the System Operator (via the market.operations@transpower.co.nz mailbox) and provide the corresponding test data and verification of meeting the relevant performance requirements. Test results should also be uploaded to ACS.

When submitting test results, include any calculations or charts to demonstrate the response of the unit.

4.2 Single Frequency Keeping

Applicability: generating units and BESS offering SFK services.

Testing Outcomes: demonstration of:

- appropriate response rates and response times both from within, and from outside, the frequency keeping band,
- stability of the control changes when first enabling the frequency keeping mode,
- stability of the control changes when responding to small positive and negative deviations in frequency,
- frequency keeping performance.

4.2.1 SFK Injection Curves

Purpose: Measures the extent to which an asset's frequency remains within acceptable limits. Figure 5 shows an injected signal (blue) and the response expected (red) to demonstrate SFK.

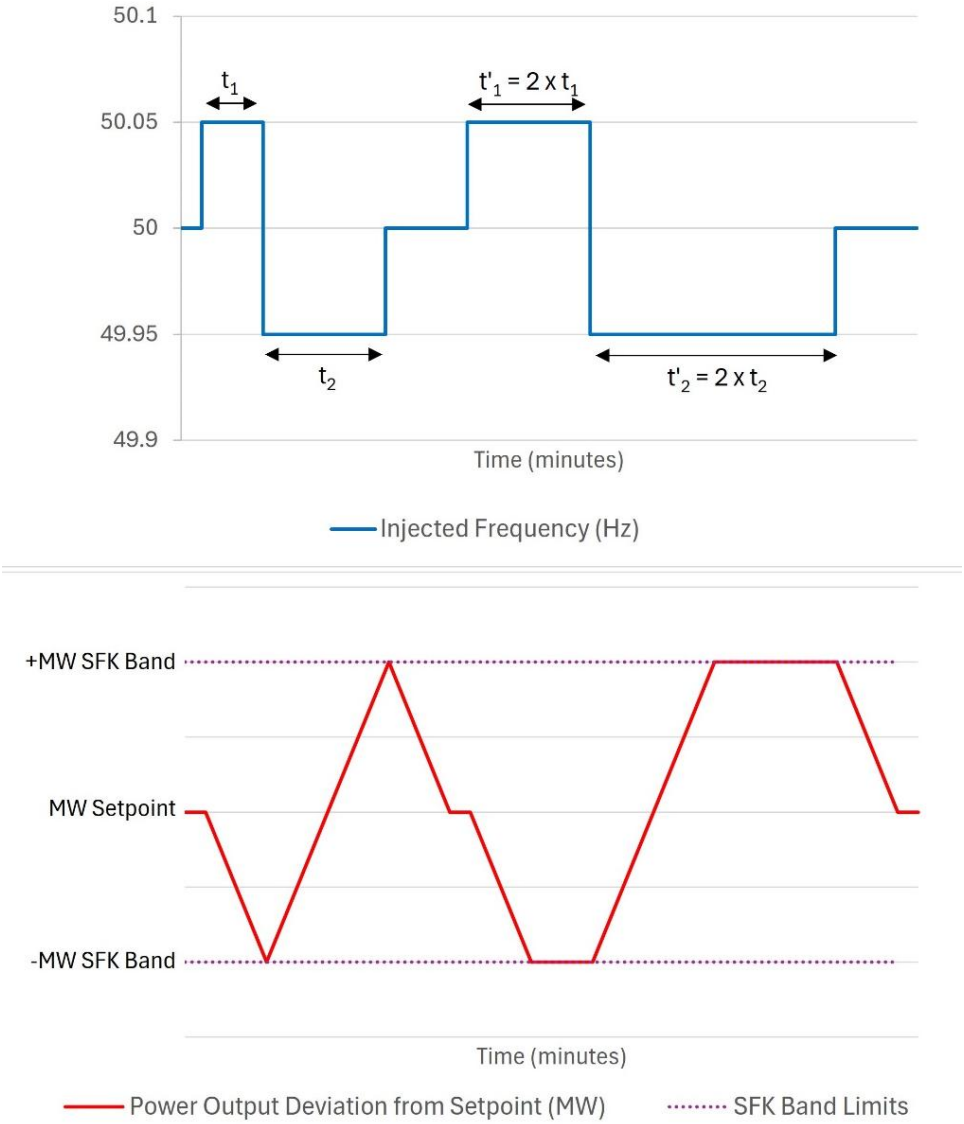

Figure 5: SFK Injected Frequency Curves

- The durations of each part of the signal are as follows, where:
  - ramp_rate is the contracted power change per minute of the generator.
  - bandwidth is the maximum power deviation that is required from the dispatch offer, so as an example for a frequency keeper with a bandwidth of ±50 MW the bandwidth variable would be 50.

Test 1 ramping within the band	▪ t_1 = bandwidth / (ramp_rate) ▪ t_2 = 2 x bandwidth / (ramp_rate)
Test 2 ramping from outside bandwidth limits	▪ $t'_1 = 2 \times t_1$ ▪ $t'_2 = 2 \times t_2$

4.2.2 Single Frequency Keeping Test (AS_SFK)

Purpose: This test aims to demonstrate…

- the response rate,
- the ability to ramp to and from the frequency keeping bandwidth limits, and
- the ramp response outside the frequency keeping bandwidth limits.

Regularity: This test must be performed…

Pre-testing:

- Agree with the System Operator the FK band values that will define the test signal to be used
- Check that an *SFK test plan* has been submitted to and accepted by the System Operator (these are reviewed on a case-by-case basis).
- Ensure that the monitoring equipment is available and measures and records in a time-tagged manner:
  - FK output at each FK site at least once every 1 second, each measurement accurate to within ±2% of the total expected FK output range of the FK site; and
  - Grid frequency at least once every 1 second (or such longer period as the System Operator may determine), each measurement accurate to within 0.01 Hz.

Monitoring Signals: Record the following:

- Electrical frequency – ft (Hz)
- Mechanical Speed – SPt (rpm)
- Generator terminal voltage – Vt (kV)
- Generator terminal active power – Pt (MW) (measured at least once a second)

Additional requirements for this test:

- Regulating signals or SFK control output command

(see *section 3* for signal measurement locations)

Methodology:

1. Run the generating unit online at the first agreed active power output.
2. Inject the test frequency as per section 4.2.1 for Test 1 ramping within the band.
3. Inject the test frequency as per section 4.2.1 for Test 2 ramping from outside bandwidth limits.
4. Record the monitoring signals until the generating unit has reached steady state conditions for both tests 1 and 2.
5. Repeat the test at other agreed active power outputs.

Notes:

Each unit that is part of a block dispatch group, station dispatch group or group of load sources must be tested.

The unit is not required to operate outside the limits of the MW band contained in the relevant dispatch instruction, or above the relevant control maximum, or below the relevant control minimum.

Acceptance Criteria: Demonstration of:

- active power measurements' accuracy to within ±2% of total expected output (band),
- the response rate of 10 MW per minute,
- a response time of less than 10 seconds to dispatched value,
- upon turn-around, a response time of less than 10 seconds.

After Testing:

Within 15 business days of completion of a test, you must contact the System Operator (via the *market.operations@transpower.co.nz* mailbox) and provide the corresponding test data and verification of meeting the relevant performance requirements. Test results should also be uploaded to ACS.

When submitting test results, include any calculations or charts to demonstrate the response of the unit.

5 Over-frequency Reserve

Applicability: generating units offering OFR.

Test Objective: perform testing to demonstrate over-frequency arming capability or control equipment capability.

Testing Outcomes: demonstration of:

- over-frequency arming indications' availability in Transpower SCADA,
- the operation of the arming signal,
- the correct application of frequency settings, time delay, and relay logic or control settings.

5.1 OFR Test Methodologies

Perform one of the tests below depending on your generation technology.

5.1.1 Synchronous Over-Frequency Reserve Test (AS_GEN_OFT)

Purpose: This test aims to demonstrate…

- over-frequency tripping capability and relay settings,
- that the over-frequency arming indications are visible in Transpower SCADA
- remote enable/disable control (if applicable).

Regularity: This test must be performed…

Pre-testing:

- Check that *a test plan* has been submitted to and accepted by the System Operator (these are reviewed on a case-by-case basis).
- Agree with the System Operator the over-frequency trip setting and time delay.
- Ensure that the monitoring equipment is available and continuously measures and transmits to the designated interface point arming information for the control equipment.

Monitoring Signals: Record the following:

- Electrical frequency – f_t (Hz)
- Mechanical Speed – SP_t (rpm)
- Generator terminal voltage – V_t (kV)
- Generator terminal active power – P_t (MW)
- Frequency reference – f_{ref} (p.u. or Hz)
- Governor output command – GOV_{com} (p.u. or %)
- Gate/valve position – POS (%)

Additional requirements for this test:

- Over-frequency arming signal
- Over-frequency relay status
- Unit circuit breaker (CB) status
- CB operating time, if not measured as part of this test

(see *section 3* for signal measurement locations)

Methodology:

Over-frequency arming signal test

1. Record the monitoring signals.
2. Request System Operator to arm the equipment under test.
3. Confirm that arming signal has been received.

Trip test and relay time delay determination

1. Inject a test signal.
2. Record the monitoring signals.
3. Repeat the test at least 3 times.

Notes:

The operation time of the circuit breaker equipment may be tested separately to the relay operating time, hold delay, and trip coil supervision.A range of over-frequency trip settings may be tested.

Acceptance Criteria: Demonstration that:

- over-frequency arming signal is successfully received,
- over-frequency relay equipment and circuit breaker operate within 0.5 seconds when frequency signal is injected and rises above the threshold,
- the time delay associated with the protection logic is as agreed with the System Operator
- the System Operator can control arming signal successfully (if applicable).

After Testing:

Within 15 business days of completion of a test, you must provide the System Operator with the corresponding test data and verification of meeting the relevant performance requirements. Use our prescribed *OFR test form*. Submit it to *market.operations@transpower.co.nz*. Test results should also be uploaded to ACS.

If the operation time of the circuit breaker equipment has been tested separately, then a separate test report must be provided.

When submitting test results, include any calculations or charts to demonstrate the response of the unit.

5.1.2 Over-Frequency Reserve Review of Trip Circuit and Relay Configuration Test (AS_GEN_OFR_RTC)

Purpose: This test aims to demonstrate…

- that the over-frequency arming indications are visible in Transpower SCADA
- remote enable/disable control (if applicable).

Regularity: This test must be performed…

Pre-testing:

- Ensure that the monitoring equipment is available continuously and continuously measures and transmits to the designated interface point arming information for the control equipment.

Monitoring Signals: Record the over-frequency arming signal.

Methodology:

A review of the trip circuit and relay configuration must be carried out and verified.

Over-frequency arming signal test

1. Record the monitoring signals.
2. Request System Operator to arm the equipment under test.
3. Confirm that arming signal has been received.

Over-frequency remote enable/disable contol test

1. Record the monitoring signals.
2. Request System Operator to enable the equipment under test.
3. Confirm that enable signal has been received.

Acceptance Criteria: Demonstration that:

- over-frequency arming signal is successfully received
- the System Operator can control arming signal successfully (if applicable).

After Testing:

Within 15 business days of completion of a test, you must provide the System Operator with the corresponding test data and verification of meeting the relevant performance requirements. Use our prescribed *OFR test form*. Submit it to *market.operations@transpower.co.nz*. Test results should also be uploaded to ACS.

When submitting test results, include any calculations or charts to demonstrate the response of the unit.

5.1.3 Inverter Over-Frequency Reserve Test (AS_ING_OFT)

Purpose: This test aims to…

- demonstrate over-frequency control equipment capability
- that the over-frequency arming indications are visible in Transpower SCADA
- remote enable/disable control (if applicable).

Regularity: This test must be performed…

Pre-testing:

- Check that *a test plan* has been submitted to and accepted by the System Operator (these are reviewed on a case-by-case basis).
- Agree with the System Operator the over-frequency trip setting and time delay.
- Generation is connected to the grid.
- Ensure that the monitoring equipment is available continuously and continuously measures and transmits to the designated interface point arming information for the control equipment.

Monitoring Signals: Record the following:

- PCC electrical frequency – fpcc (Hz)
- PCC voltage – Vpcc (kV or p.u.)
- PCC active power – Ppcc (MW)
- PCC reactive power – Qpcc (Mvar)

Additional requirements for this test:

- Injected signal
- Controller operation mode
- Over-frequency arming signal

(see *section 3* for signal measurement locations)

Methodology:

1. Run at the highest available output.
2. Inject the standard curve.
3. Record for 60 seconds or until output is stable.
4. Repeat the test at 30% and 70% rated capacity and at agreed hold points.

Acceptance Criteria: Demonstration that:

- over-frequency arming signal has been successfully received,
- over-frequency control equipment reduces real power within 0.5 seconds when frequency signal is injected and rises above the threshold,
- the rate of reduction in real power is at or above the ramp rate specified in the individual ancillary services procurement contract or as agreed with the System Operator,
- any time delay associated with the control logic is as agreed with the System Operator,
- the System Operator can control arming signal successfully (if applicable).

After Testing:

Within 15 business days of completion of a test, you must contact the System Operator (via the *market.operations@transpower.co.nz* mailbox) and provide the corresponding test data and verification of meeting the relevant performance requirements. Test results should also be uploaded to ACS.

When submitting test results, include any calculations or charts to demonstrate the response of the unit.

6 Instantaneous Reserve

The System Operator procures two instantaneous reserve (IR) products: Fast Instantaneous Reserve (FIR) and Sustained Instantaneous Reserve (SIR). FIR and SIR are as defined in Part 1 of the *Code*.

Note: *IR providers may not offer instantaneous reserves without a valid and enforceable ancillary service procurement contract, and only contracted quantities may be offered into the market. Additionally, for IL providers, any increase to offered IL quantities must be demonstrated by testing.*

Applicability: participants offering interruptible load (IL) and generation reserves, including (without limitation) part-loaded spinning reserve (PLSR), tail water depressed (TWD), and/or inverter systems.

Test Objective: perform testing to FIR and SIR capability when triggered at multiple active power outputs, and TWD capability (if applicable).

Testing Outcomes: demonstration of:

- FIR, SIR, and, where applicable, TWD, capability for use in ancillary services contracts,
- validate the governor and turbine model, if applicable,
- validate the inverter system model, if applicable,
- verify load tripping operation (for IL reserve providers).

6.1 Fast Instantaneous Reserve

6.1.1 Standard FIR Under-Frequency Injection Curve

Purpose: Demonstrate an asset or load's capability to provide FIR in accordance with the Procurement Plan.

Figure 6 below shows the curve used to demonstrate the FIR quantity that a generating unit or BESS can offer. It is defined by Equation 1 below:

Equation 1	$$Freq(t) = 49.25 + (0.75 - 0.8055t)e^{-0.1973t}$$

If the curve doesn't fully demonstrate completely the control logic of a governor or frequency controller, additional tests must be conducted using a modified curve as required. For reserve capability purposes, use the equation above.

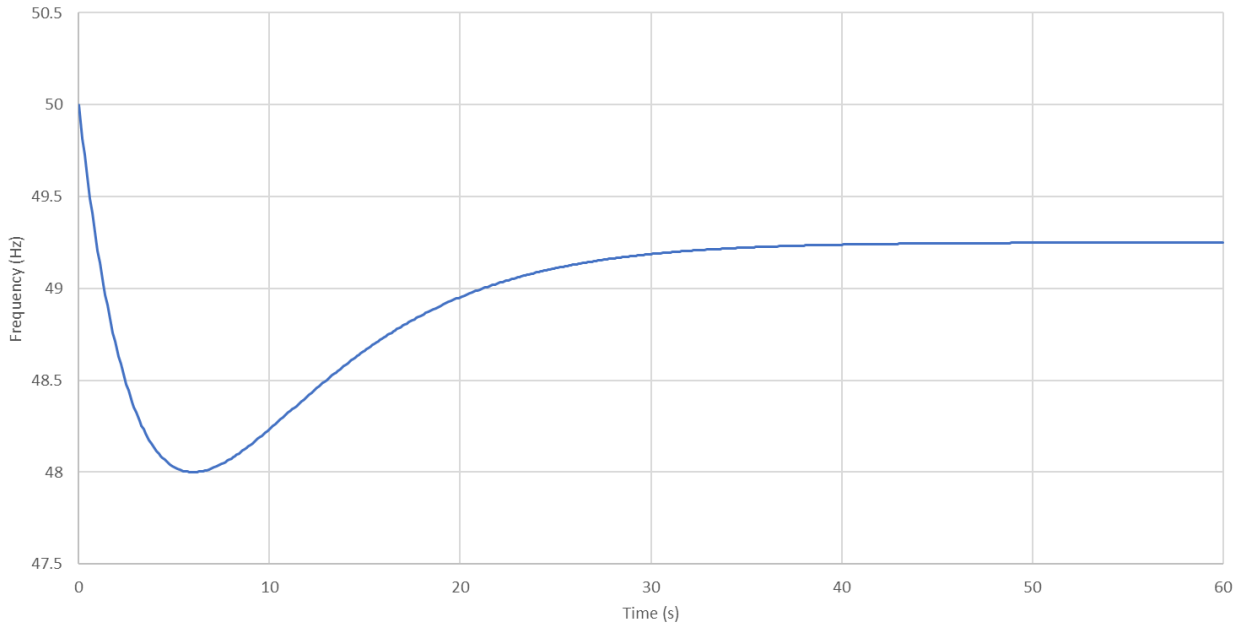

Figure 6: Commonly Injected Frequency Curve to Demonstrate FIR Response

6.1.2 Synchronous Fast Instantaneous Reserve Test (AS_GEN_FIR)

Purpose: This test aims to…

- demonstrate the generating unit FIR capability and functionality,
- validate the governor/turbine model

Regularity: This test must be performed…

Pre-testing:

- All governor testing has been completed, where applicable.
- Agree TWD set/reset logic with the System Operator, if applicable.
- Agree governor settings with the System Operator.
- Governor is in frequency control mode.
- Check that *a test plan* has been submitted to and accepted by the System Operator (these are reviewed on a case-by-case basis).
- Ensure that the monitoring equipment is available and:
  - measures and records the IR response (in MW) at no greater than 0.1 second intervals. The response must commence at minimum 15 seconds prior to (up to 60 sec of pre-event data will be accepted), and continuing until 60 seconds after, the agreed frequency setpoint has been reached;
  - includes measurement of locally measured frequency at ±0.01 Hz resolution and the relay activation signal;
  - is either GPS clock time-tagged or aligned with the time-tagged frequency measurement from the same device;
  - where possible, measures net of demand or supply response from other sources at the same point of connection to the grid.

Monitoring Signals: Record the following:

- Electrical frequency – ft (Hz)
- Mechanical Speed – SPt (rpm)
- Generator terminal voltage – Vt (kV)
- Generator terminal active power – Pt (MW)
- Frequency reference – fref (p.u. or Hz)
- Governor output command – GOV_{com} (p.u./%)
- Other internal signals of the governor, if applicable (e.g. TWD set and reset signals)
- Turbine head/pressure levels for hydro generating units
- Governor valve position/steam pressure for steam generating units

▪ Gate/valve position – POS (%) Additional requirements for this test: ▪ Governor mode	▪ Guide vanes for gas turbine generating units (see *section 3* for signal measurement locations)

Methodology:	**Note:**
This test simulates an under-frequency event by injecting a decaying frequency signal into the relay. Repeat tests below for each governor mode providing reserve whilst connected to the power system. *PLSR FIR testing* 1. Set generating unit online at 20% of rated capacity. 2. Ensure that grid frequency is within 50 ± 0.1 Hz. 3. Inject the under-frequency curve (see section 6.1.1) for 60 seconds. 4. Record the monitoring signals. 5. Repeat test with active power output at 40%, 60%, and 80% of rated active power. *TWD FIR testing* 1. Run the generating unit online. 2. Ensure that the generating unit is in TWD mode. 3. Ensure that grid frequency is within 50 ± 0.1 Hz. 4. Inject the under-frequency curve (see *section 6.1.1*) for 60 seconds. 5. Record the monitoring signals.	If grid frequency goes outside 50 ±0.1 Hz during testing, then the test must be repeated.

Acceptance Criteria: Demonstration of:
- FIR capability,
- monitoring equipment compliance with the requirements set out in the ancillary services procurement contract,
- validation of the governor/turbine model, and
- measured frequency accuracy to within ± 0.1 Hz.

After Testing:

Within 15 business days of completion of a test, you must contact the System Operator (via the *market.operations@transpower.co.nz* mailbox) and provide the corresponding test data and verification of meeting the relevant performance requirements. Test results should also be uploaded to ACS.

When submitting test results, include any calculations or charts to demonstrate the response of the unit.

Using your final test results, validate your model and submit it to the System Operator. This also applies when undergoing routine testing. Advise us if asset performance differs from your model. Refer to *GL-EA-716* for more information on modelling requirements.

You must also submit a test report, which should follow the structure in the *appendix*.

6.1.3 Inverter Fast Instantaneous Reserve Test (AS_ING_FIR)

Purpose: This test aims to…

- demonstrate the reserve FIR capability and functionality,
- validate the inverter control system model.

Regularity: This test must be performed…

Pre-testing:

- Control system is in frequency control mode.
- Control settings must be agreed with the System Operator.
- Check that *a test plan* has been submitted to and accepted by the System Operator (these are reviewed on a case-by-case basis).
- Ensure that the monitoring equipment is available and:
  - measures and records the IR response (in MW) at no greater than 0.1 second intervals. The response must commence at minimum 15 seconds prior to (up to 60 sec of pre-event data will be accepted), and continuing until 60 seconds after, the agreed frequency setpoint has been reached;
  - includes measurement of locally measured frequency at ±0.01 Hz resolution and the relay activation signal;
  - is either GPS clock time-tagged or aligned with the time-tagged frequency measurement from the same device;
  - where possible, measures net of demand or supply response from other sources at the same point of connection to the grid.

Monitoring Signals: Record the following:

- PCC Electrical frequency – fpcc (Hz)
- PCC voltage – Vpcc (kV or p.u.)
- PCC active power – Ppcc (MW)
- Control system error signal – (signal/s driving the response)
- Control system output signal – (signal/s to device)

(see *section 3* for signal measurement locations)

Methodology:

This test simulates an under-frequency event by injecting a decaying frequency signal into the relay. Repeat the test below for each operating mode providing reserve whilst connected to the power system.

1. Ensure device is online.
2. Set active power output at 0% of rated capacity.
3. Ensure that grid frequency is within 50 ± 0.1 Hz.
4. Inject the under-frequency curve in section 6.1.1 for 60 seconds.
5. Record the monitoring signals.
6. Repeat test with active power output at 20%, 40%, 60%, and 80% of rated active power.
7. Repeat tests under load for battery energy storage systems, as agreed with the system operator.

Notes:

If grid frequency goes outside 50 ±0.1 Hz during testing, then the test must be repeated.

Acceptance Criteria: Demonstration of:

- FIR capability,
- validation of power plant controller and inverter control system model, and
- confirmation that the MW/sec and MW/Hz responses present no frequency stability risk.

After Testing:

Within 15 business days of completion of a test, you must contact the System Operator (via the *market.operations@transpower.co.nz* mailbox) and provide the corresponding test data and verification of meeting the relevant performance requirements. Test results should also be uploaded to ACS.

When submitting test results, include any calculations or charts to demonstrate the response of the unit.

Using your final test results, validate your model and submit it to the System Operator. This also applies when undergoing routine testing. Advise us if asset performance differs from your model. Refer to GL-EA-1311 more information on modelling requirements.

You must also submit a test report, which should follow the structure in the *appendix*.

6.1.4 Interruptible Load Fast Instantaneous Reserve Test (AS_IL_FIR)

Purpose: This test aims to…

- demonstrate the functionality, monitoring, and capability of the IL FIR.

Regularity: This test must be performed…

Pre-testing:

- Determine IL profile to ensure testing is carried out at an appropriate time.
- Configure IL-frequency relay to operate in normal mode.
- Review equipment information, including relay settings.
- Verify test equipment connections are correct.
- Ensure that appropriate tripping isolation is applied.
- Ensure that the monitoring equipment is available and:
  - measures and records the IR response (in MW) at no greater than 0.1 second intervals. The response must commence at minimum 15 seconds prior to (up to 60 sec of pre-event data will be accepted), and continuing until 60 seconds after, the agreed frequency setpoint has been reached;
  - includes measurement of locally measured frequency at ±0.01 Hz resolution and the relay activation signal;
  - is either GPS clock time-tagged or aligned with the time-tagged frequency measurement from the same device;
  - where possible, measures net of demand or supply response from other sources at the same point of connection to the grid.

Monitoring Signals: Record the following:

- Injected frequency/test signal – (Hz)
- Frequency – (Hz)
- Time – (seconds)
- GXP/Feeder/ICP active power (MW)
- Circuit breaker signal or trigger signal (including time delay)

Additional requirements for this test:

- Measurement location

(see *section 3* for signal measurement locations)

Methodology:

This test simulates an under-frequency event by injecting a decaying frequency signal into the relay.

1. Inject the under-frequency curve (see section 6.1.1) to initiate the test.

2. Repeat the test at least 3 times to confirm operation characteristics.

Individual tests are required for all separately armed IL, whether triggered by the same or a different under-frequency relay, so that each complete chain of IL is proven to work as expected.

Carry out testing independent of any other load control systems that may operate, such as to manage peak loads.

IL FIR estimation method

Calculate the initial load (pre-trigger) as the average load over 15 seconds. For example, take the initial load value as the average of the last 150 (15/0.1) sampling points immediately prior to the inception of an under-frequency event.

Notes:

To ensure sufficient data is captured for determining the IL quantity that may be offered, ensure your plot and results table include time, load (kW or MW), frequency and circuit breaker or trigger signal.

Calculate the FIR capability as the difference between the initial load and the maximum load recorded between 1 second and 60 seconds after the frequency dropped to 49.2 Hz, or the trip time agreed in your ancillary service contract. See Figure 7 for examples of FIR tests and Figure 6 for an example of the estimation method. See the *event template* for the full calculation example.	

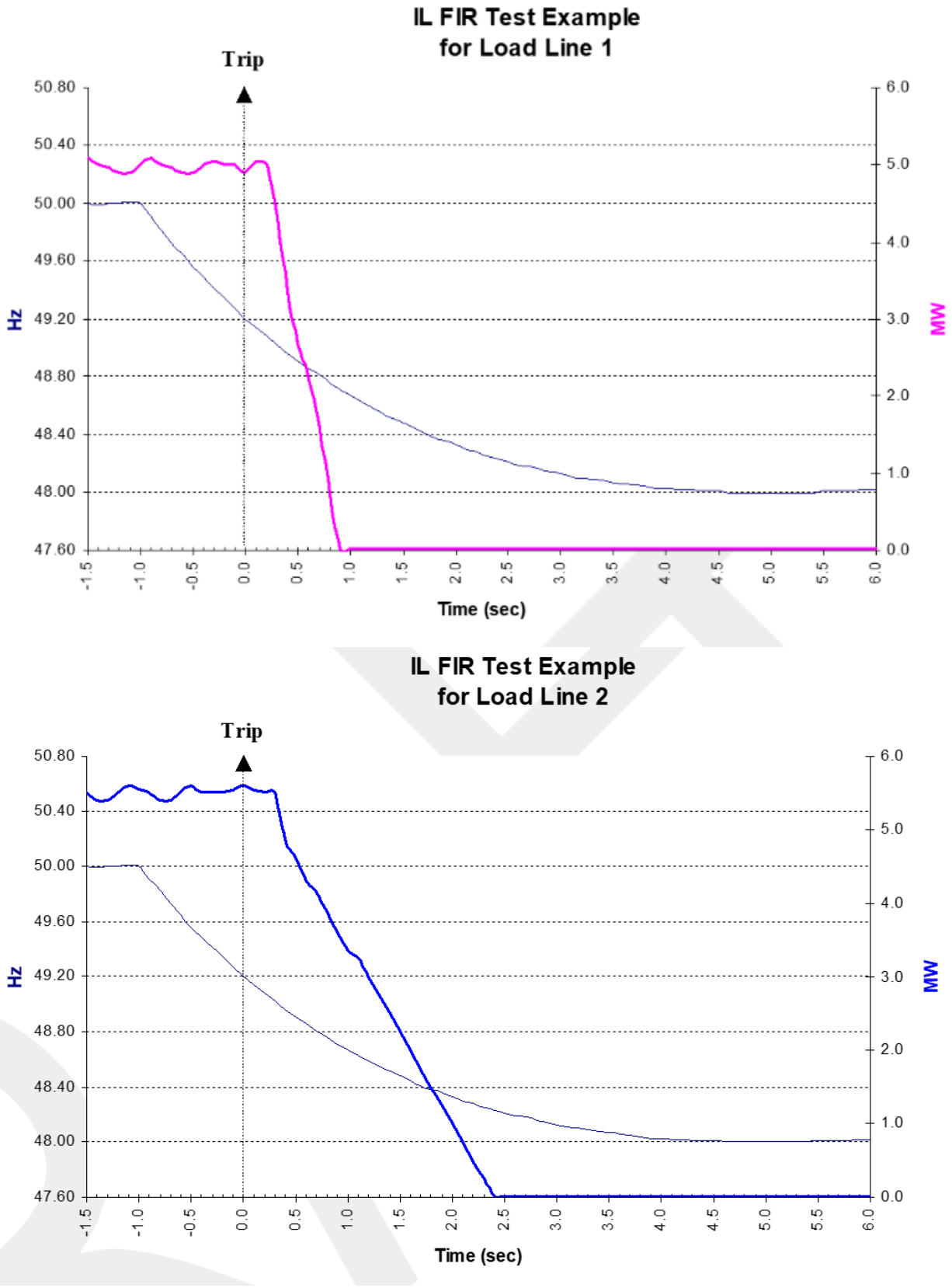

Figure 7: Example FIR Tests

Event Start		10:01:36					
Trip Time:		10:01:37					
Time		t (secs)	Frequency (Hz)	Load Line 1(MW)	15 sec pre event average Load 1(MW)	Load Line 2(MW)	15 sec pre event average Load 2 (MW)
	10:00:21.5	-15	50	5		5.5	
	...	...	...	...		...	
	10:00:35.5	-1.5	50	5.1		5.5	
	10:00:35.6	-1.4	49.99	5.1		5.4	
	10:00:35.7	-1.3	50	5		5.4	
	10:00:35.8	-1.2	50	4.9		5.5	
	10:00:35.9	-1.1	50.01	4.9		5.6	
	10:00:36.0	-1	50	5	5	5.6	5.5
	10:00:36.1	-0.9	49.91	5.1		5.5	
	10:00:36.2	-0.8	49.82	5		5.4	
	10:00:36.3	-0.7	49.73	5		5.4	
	10:00:36.4	-0.6	49.65	4.9		5.5	
	10:00:36.5	-0.5	49.56	4.9		5.6	
	10:00:36.6	-0.4	49.49	5		5.5	
	10:00:36.7	-0.3	49.41	5.1		5.5	
	10:00:36.8	-0.2	49.34	5		5.5	
	10:00:36.9	-0.1	49.27	5		5.5	
	10:00:37.0	0	49.2	4.9		5.6	
	10:00:37.1	0.1	49.14	5.1		5.5	
	10:00:37.2	0.2	49.08	5		5.5	
	10:00:37.3	0.3	49.02	4.3		5.5	
	10:00:37.4	0.4	48.96	3.4		4.9	
	10:00:37.5	0.5	48.91	2.7		4.6	
	10:00:37.6	0.6	48.86	2.3		4.3	
	10:00:37.7	0.7	48.81	1.6		4.2	
	10:00:37.8	0.8	48.76	0.7		3.9	
	10:00:37.9	0.9	48.71	0		3.6	
	10:00:38.0	1	48.67	0		3.3	

Summary of Results

	Line 1	Line 2
FIR provided (MW)	5	2.2

Note 1: During testing the frequency is required to be within +/-0.01Hz so the 15 second pre-event average load can start before the trip time
Note 2: This example assumes that the load doesn't increase after one second.

Figure 8: FIR Estimation Example

Acceptance Criteria: Demonstration of:

- FIR capability,
- IL operation within 1 second when injected frequency drops below 49.2 Hz or the trip frequency agreed in your ancillary services contract.
- measured load (MW) being no less than 1% of the maximum IL block MW or 0.1 MW, whichever is larger,
- intentional time delay ±2% of the time delay setting.

After Testing:

Within 15 business days of completion of a test, you must provide the System Operator with the corresponding test data and verification of meeting the relevant performance requirements. Use *our event template* to hold the data. Submit it to *market.operations@transpower.co.nz*. Test results should also be uploaded to ACS.

When submitting test results, include any calculations or charts to demonstrate the response of the load.

You must also submit a test report, which should follow the IL structure in the *appendix*.

6.2 Sustained Instantaneous Reserve

6.2.1 Standard SIR Injection Curves

Purpose: Demonstrate an asset or load's capability to provide SIR in accordance with the Procurement Plan.

For synchronous generation with conventional governor-based control systems, the under-frequency curve used for FIR (see section 6.1.1) **can** be extended in time to demonstrate SIR delivery of the control system. This retains the historical basis for the procurement of SIR from synchronous generation, and recognises that governor control systems on synchronous machines do not have the controllability of inverter control systems. By contrast, for inverter-interfaced generation, the same under-frequency curve **cannot** be extended in time to demonstrate SIR delivery if the control system action would substantially reduce the delivered power before frequency recovered to the normal band.

Figure 9 below shows the initial four minutes of a suitable test curve to demonstrate the quantity of SIR that can offer from highly frequency-responsive control systems. For such control systems, the FIR injection curve should be extended with a frequency recovery component, as defined by equation 2 below. The curve has g=0.07, t1=100 and n=1, which provides a suitable result with minimal computation. Alternative parameters are also acceptable in the curve component.

Equation 2	$$Freq(t) = 49.25 + (0.75 - 0.8055t)e^{-0.1973t} + 0.75/(1 + e^{-g(t-t1)})^{n}$$

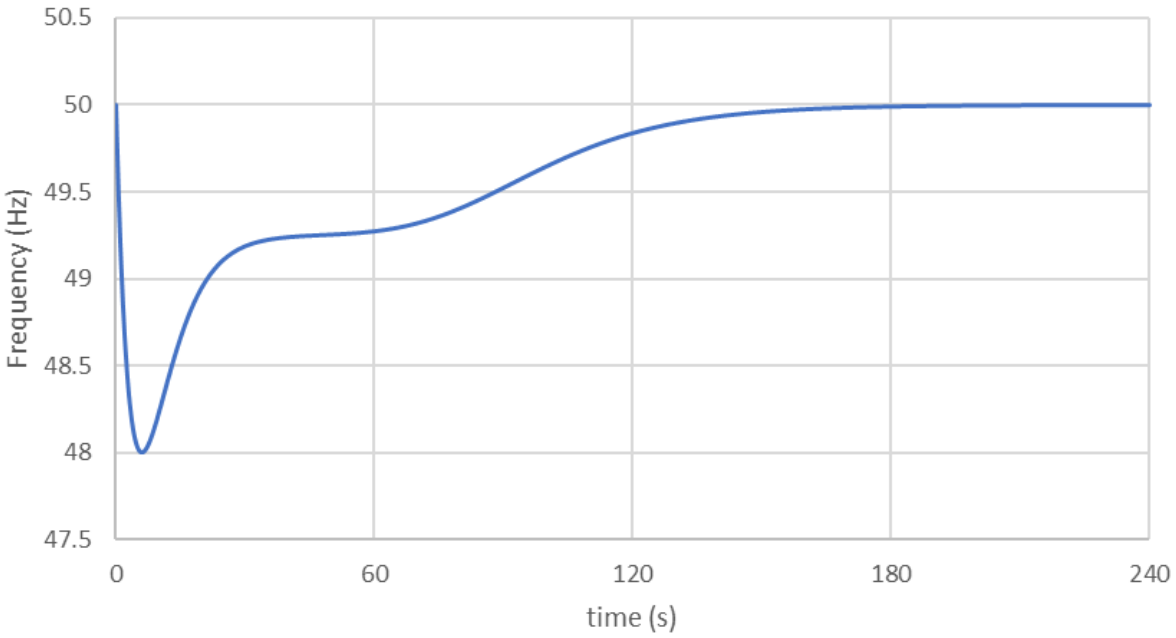

Figure 9: Commonly Injected Frequency Curve to Demonstrate SIR Response from Highly Frequency-Responsive Control System

To sustain SIR output during a frequency event, frequency-responsive (droop-based) control systems generally require some form of "latching" ensuring the response is maintained until the frequency has recovered.

We recommend sustaining the response until frequency has risen back to 50 Hz as this minimises the likelihood of further control action before re-dispatch. Selecting other release points may affect how much SIR is delivered during the test.

When the SIR response is released, the asset's output must transition in a controlled manner. Typically, changes should occur slowly, such as using ramp rates similar to those applied during dispatch. Use the test injection signal in Figure 10**Error! Reference source not found.** below (as defined by equation 3 below) to demonstrate the control action of limiting the SIR response to prevent over-frequency when frequency recovery has occurred.

Equation 3	$$Curve\ to\ check\ the\ control\ action\ (t) = 50 - 2.3Sin(0.25t)e^{-0.0245t}$$

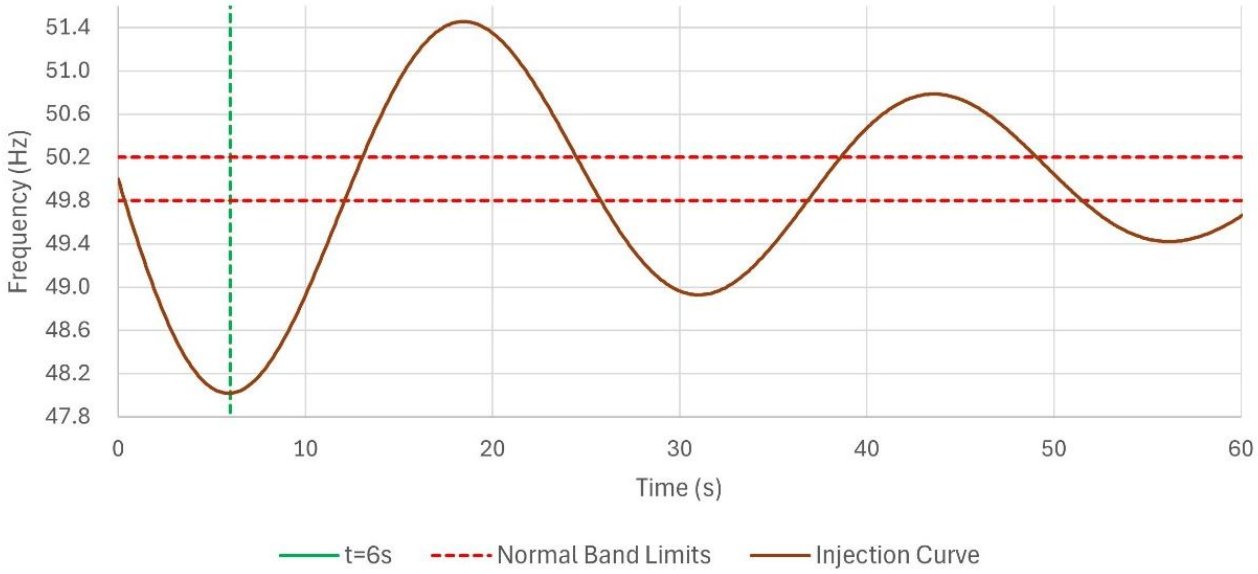

Figure 10: Injection Curve to Check Control Action

6.2.2 Synchronous Sustained Instantaneous Reserve Test (AS_GEN_SIR)

Purpose: This test aims to…

- demonstrate the generating unit SIR capability and functionality,
- validate the governor/turbine model.

Regularity: This test must be performed…

Pre-testing:

- All governor testing has been completed.
- Agree TWD set/reset logic with the System Operator.
- Governor settings must be agreed with the System Operator.
- Governor is in frequency control mode.
- Check that *a test plan* has been submitted to and accepted by the System Operator (these are reviewed on a case-by-case basis).
- Ensure that the monitoring equipment is available and:
  - measures and records the IR response (in MW) at no greater than 0.1 second intervals, commencing at minimum 15 seconds prior to, and continuing until 60 seconds after the trip time, and then continuing at no greater than 1 second intervals until after 15 minutes;
  - includes measurement of locally measured frequency at ±0.01 Hz resolution and the relay activation signal;

- is either GPS clock time-tagged or aligned with the time-tagged frequency measurement from the same device;
- where possible, measures net of demand or supply response from other sources at the same point of connection to the grid.

Monitoring Signals: Record the following:

- Electrical frequency – ft (Hz):
- Mechanical Speed – SPt (rpm)
- Generator terminal voltage – Vt (kV)
- Generator terminal active power – Pt (MW)
- Frequency reference – fref (p.u. or Hz)
- Governor output command – GOVcom (p.u. or %)
- Gate/valve position – POS (%)

Additional requirements for this test:

- Governor mode
- Other internal signals of the governor, if applicable (e.g. TWD set and reset signals)
- Turbine head/pressure levels for hydro generation
- Governor valve position/steam pressure for steam generation
- Guide vanes for gas turbine generation

(see *section 3* for signal measurement locations)

Methodology:

This test simulates an under-frequency event by injecting a decaying frequency signal into the relay.

Carry out the SIR testing with with an injection signal, which is the standard FIR injection curve (see section 6.1.1) extended for a longer period of time.

Repeat tests below for each governor mode providing reserve whilst connected to the power system.

PLSR SIR testing

1. Set generating unit online at 20% of rated capacity.
2. Ensure that grid frequency is within 50 ± 0.1 Hz.
3. Inject the under-frequency curve in section 6.1.1 (FIR) and maintain it for 15 minutes.
4. Record the monitoring signals.
5. Repeat test with active power output at 40%, 60%, and 80% of rated active power.

TWD SIR testing

1. Run the generating unit online.
2. Ensure that the generating unit is in TWD mode.
3. Ensure that grid frequency is within 50 ± 0.1 Hz.
4. Inject the under-frequency curve in section 6.1.1 (FIR) and maintain it for 15 minutes.
5. Record the monitoring signals.

Notes:

If grid frequency goes outside 50 ±0.1 Hz during testing, then the test must be repeated.

Acceptance Criteria: Demonstration of:

- SIR capability,
- the governor responding predictably and in a stable manner, and
- measured frequency accuracy within ± 0.1 Hz.

After Testing:

Within 15 business days of completion of a test, you must provide the System Operator with the corresponding test data and verification of meeting the relevant performance requirements. Use our prescribed test form. Submit it to *market.operations@transpower.co.nz*. Test results should also be uploaded to ACS.

When submitting test results, include any calculations or charts to demonstrate the response of the unit.

Using your final test results, validate your model and submit it to the System Operator. This also applies when undergoing routine testing. Advise us if asset performance differs from your model. Refer to *GL-EA-716* for more information on modelling requirements.

You must also submit a test report, which should follow the structure in the *appendix*.

6.2.3 Inverter Sustained Instantaneous Reserve Test (AS_ING_SIR)

Purpose: This test aims to…

- demonstrate the reserve SIR capability and functionality,
- validate the inverter control system model.

Regularity: This test must be performed…

Pre-testing:

- Control system is in frequency control mode.
- Control settings must be agreed with the System Operator.
- Check that *a test plan* has been submitted to and accepted by the System Operator (these are reviewed on a case-by-case basis).
- Ensure that the monitoring equipment is available and:
  - measures and records the IR response (in MW) at no greater than 0.1 second intervals, commencing at minimum 15 seconds prior to, and continuing until 60 seconds after the trip time, and then continuing at no greater than 1 second intervals until after 15 minutes;
  - includes measurement of locally measured frequency at ±0.01 Hz resolution and the relay activation signal;
  - is either GPS clock time-tagged or aligned with the time-tagged frequency measurement from the same device;
  - where possible, measures net of demand or supply response from other sources at the same point of connection to the grid.

Monitoring Signals: Record the following:

- PCC Electrical frequency – fpcc (Hz)
- PCC voltage – Vpcc (kV or p.u.)
- PCC active power – Ppcc (MW)
- Control system error signal – (signal/s driving the response)
- Control system output signal – (signal/s to device)

(see *section 3* for signal measurement locations)

Methodology:	**Notes:**
This test simulates an under-frequency event by injecting a decaying frequency signal into the relay. Repeat the test below for each operating mode providing reserve whilst connected to the power system. 1. Ensure device is online. 2. Set active power output at 0% of rated capacity. 3. Ensure that grid frequency is within 50 ± 0.1 Hz.	If grid frequency goes outside 50 ±0.1 Hz during testing, then the test must be repeated.

4. Inject the under-frequency curve in section 6.2.1 relevant to inverter-based generators.
5. Record the monitoring signals.
6. Repeat test with active power output at 20%, 40%, 60%, and 80% of active power range.
7. Repeat tests under load for battery energy storage systems, as agreed with the system operator.
8. Perform a control action test at 60% of active power output by injecting the test signal as given in Figure 9 from section 6.2.1.
9. Repeat the control action test at 40% of active power output.

Acceptance Criteria: Demonstration of:

- SIR capability,
- validation of power plant controller and inverter control system model, and
- confirmation that the MW/sec and MW/Hz responses present no frequency stability risk.

After Testing:

Within 15 business days of completion of a test, you must provide the System Operator with the corresponding test data and verification of meeting the relevant performance requirements. Use our prescribed test form. Submit it to *market.operations@transpower.co.nz*. Test results should also be uploaded to ACS.

When submitting test results, include any calculations or charts to demonstrate the response of the unit.

Using your final test results, validate your model and submit it to the System Operator. This also applies when undergoing routine testing. Advise us if asset performance differs from your model. Refer to GL-EA-1311 more information on modelling requirements.

You must also submit a test report, which should follow the structure in the *appendix*.

6.2.4 Interruptible Load Sustained Instantaneous Reserve Test (AS_IL_SIR)

Purpose: This test aims to…

- demonstrate the functionality, monitoring, and capability of the IL SIR.

Regularity: This test must be performed…

Pre-testing:

- Determine IL profile to ensure testing is carried out at an appropriate time.
- Configure the IL-frequency relay to operate in the normal mode.
- Review station single line diagram and switch/outage program with System Operator.
- Review equipment information, including relay settings
- Verify test equipment connections are correct.
- Ensure that appropriate tripping isolation is applied.
- Ensure that the monitoring equipment is available and:
  - measures and records the IR response (in MW) at no greater than 0.1 second intervals, commencing at minimum 15 seconds prior to (up to 60 sec of pre-event data will be accepted), and continuing until 60 seconds after the trip time, and then continuing at no greater than 1 second intervals until after 15 minutes;
  - includes measurement of locally measured frequency at ±0.01 Hz resolution and the relay activation signal;
  - is either GPS clock time-tagged or aligned with the time-tagged frequency measurement from the same device;
  - where possible, measures net of demand or supply response from other sources at the same point of connection to the grid.

Monitoring Signals: Record the following:

- Injected frequency/test signal (Hz)
- Trigger frequency – (Hz)
- Trigger time – (seconds)
- GXP/Feeder/ICP active power (MW)
- Circuit breaker signal or trigger signal

Additional requirements for this test:

- Measurement location

(see *section 3* for signal measurement locations)

Methodology:	**Notes:**
This test simulates an under-frequency event by injecting a decaying frequency signal into the relay. 1. Inject the under-frequency curve in section 6.1.1 to initiate the test. 2. Repeat the test at least 3 times to confirm operation characteristics. Individual tests are required for all separately armed IL, whether triggered by the same or a different under-frequency relay, so that each complete chain of IL is proven to work as expected. Carry out testing independent of any other load control systems that may operate, such as to manage peak loads. *IL SIR estimation method* Calculate the initial load (pre-trigger) as the average load over 15 seconds. For example, take the initial load value as the average of the last 150 (15/0.1c) sampling points immediately prior to the inception of an under-frequency event. Calculate the SIR capability as the average drop in load MW that occurs over 60 seconds of the frequency falling to or below 49.2 Hz, or the trip time agreed in your ancillary service contract. See Figure 11 for an examples of a SIR test. See the *event template* for the full calculation example.	To ensure sufficient data is captured for determining the IL quantity that may be offered, ensure your plot and results table include time, load (kW or MW), frequency and circuit breaker or trigger signal.

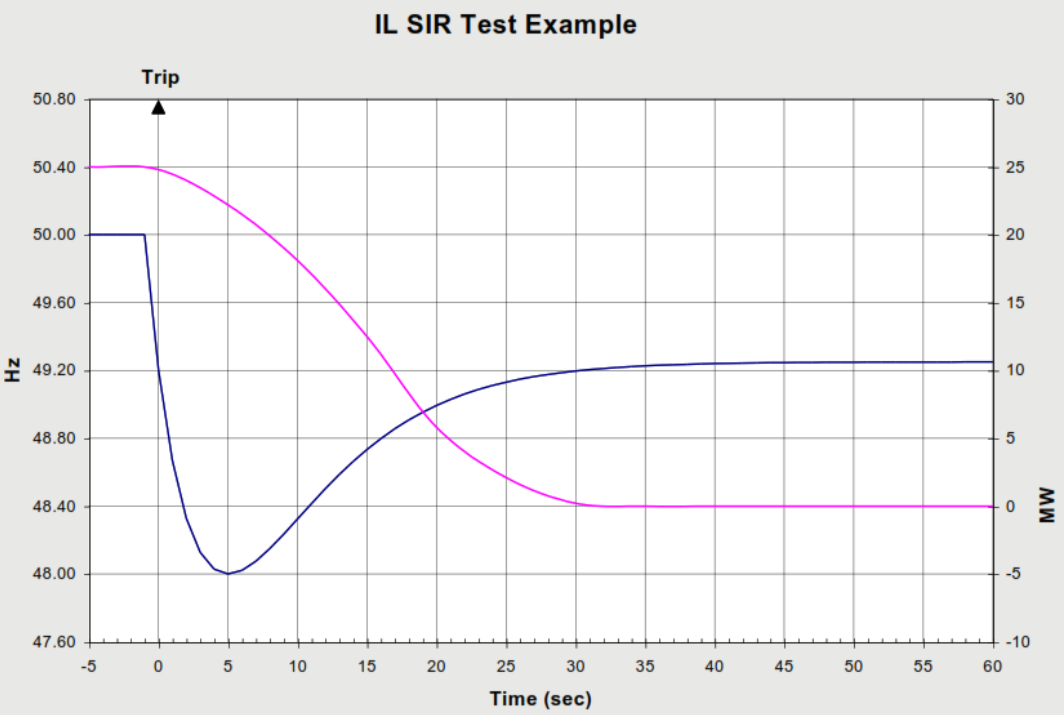

Figure 11: SIR Test Example

Acceptance Criteria: Demonstration of:

- SIR capability,
- IL operation within 1 second when injected frequency drops below 49.2 Hz or the trip frequency agreed in your ancillary services contract.
- measured load (MW) no less than 1% of the maximum IL block MW or 0.1 MW, whichever is larger
- intentional time delay ±2% of the time delay setting.

After Testing:

Within 15 business days of completion of a test, you must provide the System Operator with the corresponding test data and verification of meeting the relevant performance requirements. Use *our event template* to hold the data. Submit it to *market.operations@transpower.co.nz*. Test results should also be uploaded to ACS.

When submitting test results, include any calculations or charts to demonstrate the response of the load.

7 Black Start

Applicability: generating stations offering black start (BS).

Testing Outcomes: demonstration of:

- startup when de-energised and disconnected from both the power system and any local auxiliaries,
- re-livening of a de-energised part of the power system,
- reaching stable steady-state operation without incident with both the generator and the islanded transmission network energised,
- achievement of the response times to synchronous speed and the capabilities specified in your ancillary service procurement contract,
- management of frequency and voltage of both the generators and the island as a whole within acceptable limits,
- pick-up of initial load without de-stablising the black start island,
- recording of test data that enables engineering assessment of asset stability under black start conditions

7.1 BS Test Methodology

7.1.1 Black Start Test (AS_BST)

Purpose: This test aims to…

- assess the capability of a station to start up when de-energised and disconnected from both the power system and any local auxiliaries
- assess the ability to liven transmission circuits following a partial or total shutdown of the power system
- assess asset stability under black start conditions.

Regularity: This test must be performed…

Pre-testing:

- Asset owner to advise mode(s) required.
- Check that *a test plan* has been submitted to and accepted by the System Operator (these are reviewed on a case-by-case basis).
- A desktop run has been completed with NCC and provider.
- Ensure monitoring equipment is available and continuously measures the monitoring signals required (as below).

Monitoring Signals: Record the following:

- Electrical frequency – ft (Hz)
- Mechanical Speed – SPt (rpm)
- Generator terminal voltage – Vt (kV)
- Generator voltage setpoint – Vsp (kV)
- Generator terminal active power – Pt (MW)
- Generator active power setpoint – Psp (MW)
- Generator terminal reactive power – Qt (Mvar)

Additional requirements for this test:

- Governor mode
- Gate position
- AVR mode
- Status of PSS, UEL, OEL
- OEL output command – OELcom (p.u.)
- UEL output command – UELcom (p.u.)
- PSS output command – PSScom (p.u.)
- Other signals as requested

(see *section 3* for signal measurement locations)

Methodology:	**Notes:**
1. Ensure each item of equipment starts without power being obtained from the grid or any local network and achieves the relevant response time to synchronous speed.	*Data Requirements:*

2. Operate the black start unit at zero load synchronous speed/nominal frequency for 15 minutes (or such shorter period as instructed by the System Operator). 3. Switch the black start unit to the relevant de-energised network busbar(s). 4. Starts any remaining black start units and synchronise them to the network busbar(s) and progressively energise the grid from those network busbar(s); 5. Ensure the black start unit provides the reactive power capability specified in clause 8.23 of the Code. 6. Control grid voltage as instructed by the System Operator. 7. Provide an emergency frequency regulation service by maintaining the grid frequency between 49.25 Hz and 50.75 Hz, to the extent practicable.	To be agreed with the System Operator.

Acceptance Criteria: Demonstration of:

- the stability of voltage and frequency in any equipment energised as part of the test

After Testing:

Within 15 business days of completion of a test, you must contact the System Operator (via the *market.operations@transpower.co.nz* mailbox) and provide the corresponding test data and verification of meeting the relevant performance requirements. The results should clearly identify the equipment they refer to. Test results should also be uploaded to ACS.

When submitting test results, include any calculations or charts to demonstrate the response of the unit.

You must retain the test data for at least 2 years.

7.1.2 Black Start Auxiliary Generator Test (AS_BST_AUX)

Purpose: This test aims to…

- assess the capability of an auxiliary hydro generator to start up when de-energised and disconnected from both the power system and any local auxiliaries; or
- auxiliary diesel generator in standby mode to start up.

Regularity: This test must be performed…

Pre-testing:

- Asset owner to ensure fuel supply availability,

Methodology:

1. Start up auxiliary hydro generator or auxiliary diesel generator.

2. Confirm that correct functionality has been demonstrated.

Acceptance Criteria: Demonstration that the generating station can:

- start up when de-energised and disconnected from both the power system and any local auxiliaries.

After Testing:

Within 5 business days of the completion of the test, you must provide the System Operator (via *market.operations@transpower.co.nz*) with the corresponding test data and verification of meeting the relevant performance requirements.

Appendix: Sample Instantaneous Reserve Report Structure

Submit your IR test reports electronically in Adobe Portable Document format (PDF) or Word Document format (DOCX).

Generation Reserve Test Report Structure

After testing, owners of synchronous generating assets and inverter-based resources intending to provide IR must submit a test report. The report should follow the structure below:

Section	Contents
Document Control	▪ A cover page ▪ A table of contents ▪ Version and revision history

Key Asset Information	▪ Electrical details:
	  ▪ rated MW and MVA, and
	  ▪ rated terminal voltage
	▪ Plant overall single-line diagram showing electrical connectivity between the generator, transformer, substation layout, switch-gear, grid interface circuit breaker, and/or electrical equipment interfacing the asset with the grid, unit and station auxiliary loads, excitation source
	▪ Any other asset information relevant to the specific testing performed

Test Specifications	▪ Test ID ▪ Test objectives and methodology (only if different from what has been included in this guideline document) ▪ Test signal descriptions ▪ Test results organised and clearly labelled in agreement with the test methodology/ies ▪ A supporting summary set of test responses to complement raw data files

Validation of Test Results	▪ A clear statement on whether testing met all the test objectives
	▪ Analysis, observations and recommendations
	▪ Any other information that demonstrates the performance of the equipment you have tested and that the System Operator would reasonably require to assess the test results such as:
	  ▪ asset capability information that is not in the ACS visible to the System Operator at the time of testing;
	  ▪ an explanation where any assumptions have been made (and why they have been made) particularly when manufacturer's data is not available;
	  ▪ an explanation of any deviations observed since the previous tests were carried out. You may refer to factory acceptance tests, type tests and previous test results as required;
	  ▪ an explanation of any discrepancies in plant performance or responses you observed during online and offline testing. You must also include these in the model validation report.