GPS COMPLIANCE ASSESSMENT AND R2 MODEL VALIDATION TEST PLAN TEMPLATE

FOR CONVENTIONAL SYNCHRONOUS MACHINES

Published: **May 2016**

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

IMPORTANT NOTICE

Purpose

AEMO has prepared this document to provide information to help proponents prepare commissioning and R2 model validation test plan for synchronous machine technologies, as at the date of publication.

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CHAPTER 1. INTRODUCTION

This document has been prepared to provide guidance to proponents for preparing testing programs for synchronous machine technologies as required by National Electricity Rules (NER) clauses 5.8.4 and S5.2.4 (d). Tests required by these two clauses are often referred to as Generator Performance Standard (GPS) compliance and R2 model validation tests, respectively.

This document also applies when preparing test plans in accordance with rule clause 5.7.3 (tests to show generator compliance with connection requirements) and clause 5.7.6 (tests of generating units requiring changes to normal operation). Generators may also use this document in preparation for developing the routine compliance test program as set out in rule 4.15 (b).

The objective of the commissioning and GPS compliance testing program is to establish that the installed plant performs as expected, and complies with the performance requirements set out in the GPS, which are the technical requirements specified in the connection agreement and relevant Australian Standards. The proponent is also required to carry out tests to validate the R2 model and its parameters and ensure that the plant models represent the installed system.

In general, there are some inter-relations between the tests required for GPS compliance assessment, and R2 model and data validation. It is the proponents' responsibility to consider whether to combine the two test programs, or conduct each test program separately according to the timeframes set out in the NER.

This document is generic and can be applied to any tests carried out in relation to the above NER clauses, including the following applications:

- New and upgraded plant
- Prime mover technology based on gas turbine, steam turbine, conventional hydro, pumped storage hydro, diesel and gas reciprocating engines, biomass, and solar thermal
- Commissioning and compliance testing, and R2 model validation tests, and other tests carried out under clauses 5.7.3, 5.7.6 or 4.15 (b). Example of such other tests include:
  - Generating system parameter identification
  - Temporary changes to control system settings
  - Temporary changes to plant operating modes
- Synchronous generators and synchronous condensers
- Excitation system and turbine-governor

The document is not expected to cover all variations of excitation systems and turbine-governor systems for conventional synchronous machine technologies. Minor modifications to the test template are therefore acceptable when submitting it to AEMO and relevant Network Service Provider (NSP).

This document does not cover tests carried out due to changes in plant protection systems. It is also not expected to serve as a detailed test procedure (also referred to as Inspection and Test Procedure (ITP)) provided to test engineers for on-site testing.

This document is related to other policies, procedures and guidelines produced by AEMO and should be read in conjunction with these, as follows:

- Generating Systems Model Guidelines.
- Generating Systems Design Datasheets and Settings Datasheets.
- Commissioning Requirements for Generating Systems.
- R2 Testing Guideline.
- Turbine Governor Testing and Model Validation Guideline.
- Data and model requirements for generating systems less than 30 MW.

CHAPTER 2. GENERAL REQUIREMENTS

2.1 Pre-energisation requirements

The following information is required before commencement of compliance and/or R2 model validation testing.

- Registered GPS.
- Connection study report.
- Registered Generating System Design Data Sheets and Generating System Setting Data Sheets
- R1 model package:
  - Synchronous machine model.
  - Excitation system model including:
    1) Automatic Voltage Regulator (AVR) and exciter (if applicable).
    2) Power System Stabiliser (PSS).
    3) Limiters including over- and under-excitation limiters and other limiters such V/Hz and stator current limiter (if applicable).
  - Speed governor control system and turbine models.
- R1 block diagrams for the above models.
- R1 model source code.
- R1 model parameters.
- Releasable user guide (RUG).
- A commissioning program as per 5.8.4, and as described in subsequent sections of this document.

2.2 Test schedule

A test schedule includes all planned activities from the pre-energisation phase to returning the machine(s) to commercial operation. Please refer to Appendix A for a recommended template. The following information is generally included:

- Active and reactive output expected for each test at each Hold Point.
- A list of all GPS compliance assessment or R2 model validation tests conducted, including:
  - Off line tests.
  - On line tests for all Hold Points.
- Load profiles for each day of testing is required to be submitted, two business days prior, please refer to Appendix A for preferred template.

2.3 Test plan

The proponent is expected to submit a test plan for approval from AEMO and the relevant NSP before the test begins. CHAPTER 3 presents a list of typical tests and associated test procedures for conventional synchronous machines.

2.4 Hold Points

When commissioning a new or upgraded plant (as defined under clause 5.3.9 of National Electricity Rules) for the first time, or making a change to control system settings or mode of operation, a number of Hold Points are generally required whereby the generating system overall output is constrained to a

pre-defined megawatt (MW) level. At each Hold Point, a report is required to be submitted to AEMO and the relevant NSP for review and approval, before progressing further with the commissioning activities.

This process allows for staged release of capacity subject to:

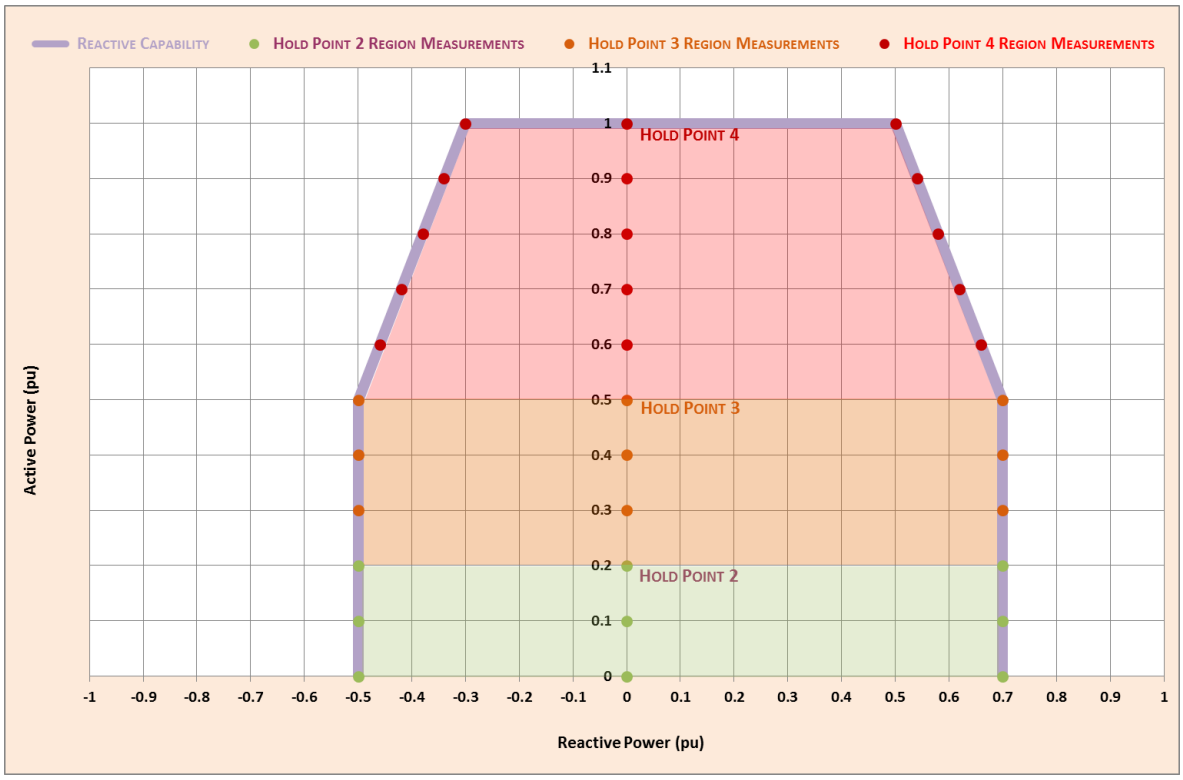
- Successful demonstration of applicable GPS clauses.
- Confirmation of simulation model(s) against measured responses for all tests which can be replicated by performing dynamic simulation.

The number of Hold Points could vary depending on the size of the generating system and its impact on the interconnected power system.

Typical Hold Points, as shown in Figure 1 for illustrative purpose, include:

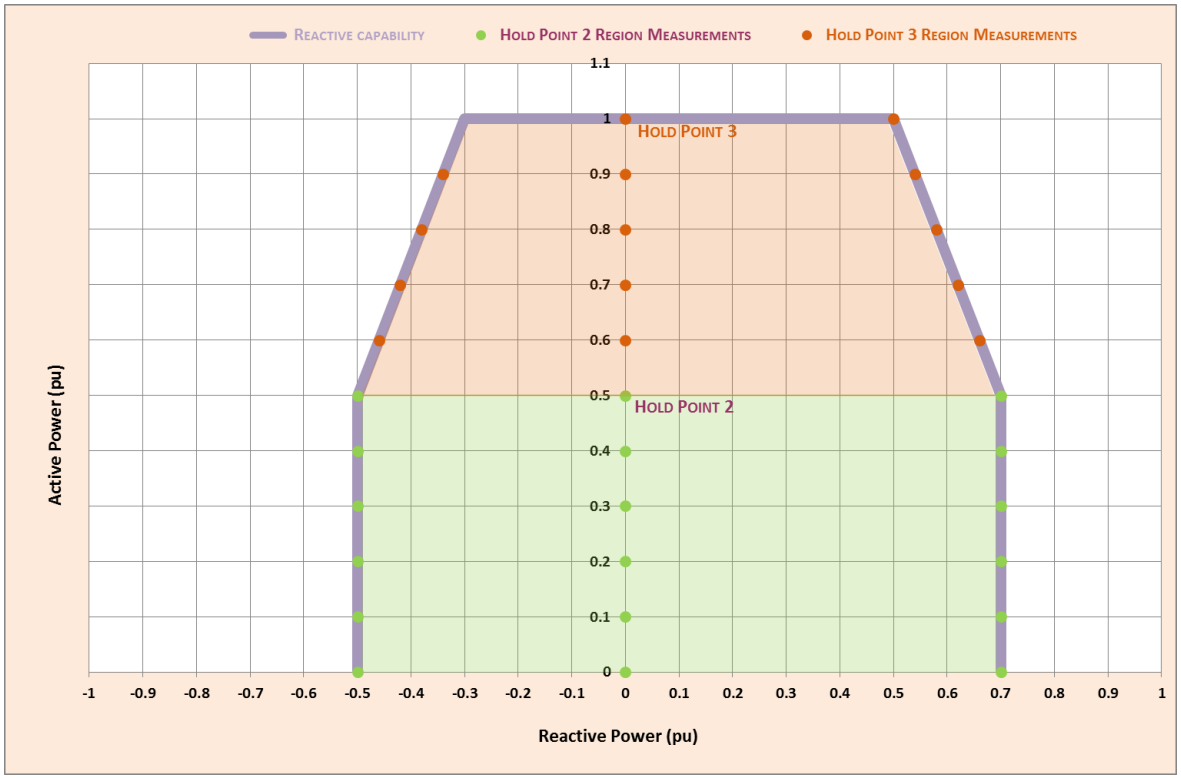
- HP 1 – Machine un-synchronised (off-line, 0 MW).
- HP 2 – Minimum stable loading of the plant.
- HP 3 – 50% of plant maximum output (if greater than the minimum stable loading of the plant).
- HP 4 – 100% of plant maximum output.

Figure 1. Typical Hold Point regions and measurements



Information provided is based on the assumption that three Hold Points are required, as illustrated in Figure 2. In practice, AEMO or the NSP can request more than three Hold Points based on the location and relative size of the power station/generating unit.

Figure 2. Hold Points 2 and 3, as described in this report



Note that Hold Points defined above are based on active power output level assuming that measured responses are stable, and that a reasonable correlation exists between measured and simulated responses. Additional Hold Points may be introduced if either of the above criteria is not met during Hold Point testing.

2.5 Measurement equipment and locations

This section presents information that needs to be provided on the measurement equipment and location as follows:

- Manufacture, model and serial number of the equipment.
- Valid calibration certificate of the measurement equipment.
- Type of equipment[1]:
  - Permanent or temporary (start and end date).
  - Continuous monitoring, or event triggering, or manual triggering or others.
- Locations of measurements.
- Typical measurement signals for alternator, AVR, PSS, excitation system limiters, governor control systems, and turbine for each test presented in CHAPTER 3 can be found in Appendix A.
- Sampling rate and time window available for configuration.
- Format of measurement data.
- The following data and information is made available for AEMO/NSP if requested.
  - All the pre-processed measurement (raw) data.
  - Scaling factors for all signals.

[1] It is expected that independent equipment are installed to collect test results separate from the device under test.

  - Information on post-processing of raw measurement data, such as re-sampling, filtering, averaging and calculations of the signals.
- Acceptance testing report for the measurement equipment (if permanently installed).
- Signals to be measured at each measurement location.
- Where multiple recorders are to be used, details as to how measurement results will be synchronised.
- Where there are multiple units at a power station, the status and terminal quantities of those units at the time of test should also be recorded (the use of SCADA data is acceptable for generating units not under test).

CHAPTER 3. TYPICAL TESTS FOR CONVENTIONAL SYNCHRONOUS MACHINES

Typical tests for conventional synchronous machines and associated control systems and information sought from the proponents for each test are highlighted below.

3.1 Off-line tests (HP1 tests)

3.1.1 Voltage step response tests (HP1_VSR)

Purpose

- To assess compliance with schedule S5.2.5.13 of the GPS that requires.
  - Regulated voltage to be maintained within 0.5% of the set point applied.
  - A settling time of 2.5 seconds or less for an off-line voltage response of 5%.
- To validate/identify the machine and excitation system model parameters including:
  - Direct axis open circuit transient time constant, T'd0.
  - Saturation characteristic, as determined in HP1_OCT.
  - AVR control gains, time constants and limits.
  - Exciter characteristics (if applicable).
  - Any other parameters validated by this test.

Pre-test condition

- Machine is off-line and runs at rated speed with AVR in automatic operation mode.
- Machine terminal voltage is 1.0 per unit (pu).
- Determine machine rotor and stator winding temperature.

Methodology and procedure

- Pre-test conditions are confirmed.
- Confirm the measurement system is ready.
- Apply +/- 2.5% steps to the voltage control set point initially, and ensure step responses are stable.
- Apply +/- 5% steps to the voltage control set point.
- Adjust machine terminal voltage to 0.95 and 1.05 per unit.
- Repeat the +5% and -5% voltage set point step tests respectively.
- Download and check the measurement data.
- At least 10 seconds pre-triggered recording required and allow at least 40 seconds recording time after the terminal voltage reached new steady-state conditions before the next test (step) commences.
- Perform the tests with both AVR channels.

Signals to be measured

Please refer to Appendix A for further details on various signals that need to be measured for off-line voltage step response tests.

Measured data file names and format

- PlantName_UnitNo_HP1_VSR_01.CSV.

Acceptance criteria

- Overlays of measured and simulated responses for the off-line voltage set-point test will be submitted as part of the Hold Point test report.
- To assess conformance with AEMO's Generating System Model Guidelines, +/- 10% accuracy bands needs to be superimposed on the graphs which include overlays of measured and simulated responses.
- The machine is able to return to stable operation after each step change.
- Settling time for a 5% step response complies with the GPS clause S5.2.5.13, i.e. a settling time of 2.5 seconds or less for an off-line step response.
- Signals and scaling factors documented.
- Measurement data is successfully downloaded and confirmed.

3.1.2 Open circuit characteristic tests (HP1_OCT)

Purpose

- To determine synchronous machine saturation characteristics, and validate/identify associated model.

Pre-test condition

- Machine is off-line and runs at rated speed with AVR in manual operation mode.

Methodology and procedure

- Pre-test conditions are confirmed.
- Confirm the measurement system is ready.
- Increase terminal voltage over a wide range (e.g. from 0 to 1.2 pu) in steps of 0.05 pu.
- Ensure terminal voltage has reached steady-state conditions before the next step commences.
- Download and check the measurement data.

Signals to be measured

Please refer to Appendix A for further details on various signals to be measured for open circuit characteristic tests.

Measured data file names and format

- Plantname_unit No_HP1_OCT.CSV.

Acceptance criteria

- Signals and scaling factors documented and successfully downloaded.
- Measurement data is successfully downloaded and confirmed.

3.1.3 Short circuit characteristic tests (HP1_SCT)[2]

Purpose

- To confirm machine's short circuit characteristic.
- To confirm machine's synchronous impedance, Xd.

The test setup and procedure provided below is for illustrative purposes. Detail test setup and procedure should be developed in consultation with the synchronous machine manufacturer.

Pre-test condition

- Machine terminals are shorted.
- Machine is off-line and runs at rated speed.

Methodology and procedure

- Pre-test conditions are confirmed.
- Energise excitation system.
- Confirm the measurement system is ready.
- Vary field current to achieve armature current of 0 to 1.25 pu.

  The maximum testing current is typically set at 1.25 pu, but should be confirmed with the synchronous machine manufacturer.
- Ensure armature current has reached steady-state conditions before the next step commences.
- Download and check the measurement data.

Signals to be measured

Please refer to Appendix A for further details on various signals to be measured for the short circuit characteristic tests.

Measured data file names and format

- PlantName_UnitNo_HP1_SCT_01.CSV.

Acceptance criteria

- Signals and scaling factors are documented and successfully downloaded.
- Measurement data is successfully downloaded and confirmed.

[2] Load rejection tests may be used as an alternative if short-circuit tests are not practicable.

3.1.4 Speed response tests (HP1_SRT)

Purpose

- To validate the R2 data specified in Section 12 of Generating System Data Sheets (Prime Mover and Primary Mechanical Control Systems).
- To validate turbine-governor model parameters such as:
  - Governor gains.
  - Valve/gate control characteristics.
  - Turbine characteristics.

    [Note: The above governor model parameter list is provided for illustrative purposes. The proponent is requested to list all relevant turbine and governor model parameters verified by this test].

Pre-test condition

- Machine is off-line and runs at rated speed.

Methodology and procedure

- Pre-test conditions are confirmed.
- Confirm the measurement system is ready.
- Apply a positive step to the governor speed reference set point.
- Wait until the response settles.
- Return the speed reference set point to pre-test value.
- Wait until the response settles.
- Download and check the measurement data.
- Repeat the test with a negative step.

Signals to be measured

Please refer to Appendix A for further details on various signals that need to be measured for off-line speed response tests.

Measured data file names and format

- PlantName_UnitNo_HP1_GSR_01.CSV.

Acceptance criteria

- Machine's speed correctly follows the speed reference.
- The machine is able to return to stable operation after each step change.
- Signals and scaling factors are documented.
- Measurement data is successfully downloaded and confirmed.

3.1.5 Standstill valve response tests (HP1_VRT)

Purpose

- To validate the R2 data specified in Section 12 of Generating System Data Sheets (Prime Mover and Primary Mechanical Control Systems).
- To validate the governor model parameters related to valve/gate control.

Pre-test condition

- Machine is at standstill with valve/gate positioning enabled.

Methodology and procedure

- Pre-test conditions are confirmed.
- Confirm the measurement system is ready.
- Position the valve/gate according to Table 1.
- Apply an appropriate step[3] to the valve/gate position reference.
- Ensure the valve/gate has reached steady state before applying the next step.
- Download and check the measurement data.

Signals to be measured

Please refer to Appendix A for further details on various signals that need to be measured for the standstill valve response tests.

Measured data file names and format

- PlantName_UnitNo_HP1_VRT_01.CSV.

Acceptance criteria

- Valve follows the set point command.
- Response is adequately damped.
- Signals and scaling factors are documented.
- Measurement data is successfully downloaded and is confirmed.

[3] A common practice is to start with step size of +/-5% and gradually increase the step size.

Table 1: Operating conditions for Hold Point 1 standstill valve response tests

Test	Valve/gate position	Step size	Data file name	Comments
1				
2				
3				
4				
5				
Others				

3.1.6 V/Hz limiter tests (HP1_VHT)

Purpose

- To confirm the performance of the V/Hz limiter.
- To validate/identify R2 data specified in Section 11.2 of Generating System Data Sheets (Other Generating Unit Control Systems).

Pre-test condition

- Machine is off-line and runs at rated speed. Terminal voltage is 1 pu.

Methodology and procedure

- Pre-test conditions are confirmed.
- Confirm the measurement system is ready.
- Gradually reduce machine speed until the V/Hz limiter operates. Depending on the type of synchronous machine under test, a voltage step reference change can also be applied to activate and demonstrate stable operation of the V/Hz limiter.
- Perform tests with both AVR channels.
- Return to rated machine speed after tests are complete.
- Signals and scaling factors are documented.
- Download and check measurement data.

Signals to be measured

- Please refer to Appendix A for further details on various signals that need to be measured for the V/Hz limiter tests.

Measured data file names and format

- PlantName_UnitNo_HP1_VHT_01.CSV.

Acceptance criteria

- The V/Hz limiter responds according to expected design characteristics.
- Response is adequately damped[4].
- V/Hz protection does not operate.
- Machine capability does not reduce compared to that before activation of the V/Hz limiter while operating under the continuous uninterrupted operating range.
- Overlays of measured and simulated responses for the off-line V/Hz test will be submitted as part of the Hold Point test report.

  To assess conformance with AEMO's Generating System Model Guidelines, +/- 10% accuracy bands needs to be superimposed on the graphs which include overlays of measured and simulated responses.

[4] Refers to NER Chapter 10 Glossary: In relation to a *control system*, when tested with a step change of a feedback input or corresponding reference, or otherwise observed, any oscillatory response at a *frequency* of:

(a) 0.05 Hz or less, has a damping ratio of at least 0.4;
(b) between 0.05 Hz and 0.6 Hz, has a halving time of 5 seconds or less (equivalent to a damping coefficient –0.14 nepers per second or less); and
(c) 0.6 Hz or more, has a damping ratio of at least 0.05 in relation to a *minimum access standard* and a damping ratio of at least 0.1 otherwise.

- Signals and scaling factors are documented.
- Measurement data is successfully downloaded and confirmed.

3.1.7 Other off line tests (HP1 tests)

Other common off line tests include:

- **Standstill frequency response tests**

  This is an alternative test to identify synchronous machine model parameters. The machine must be shut down, off-turning gear and electrically isolated. The machine rotor is required to turn to a precise position before the tests. *IEEE Std 115-2009 IEEE Standard Procedures for Obtaining Synchronous Machine Parameters by Standstill Frequency Response Testing* provides details about typical testing conditions, required measurements, typical test setups, and a step-by-step test procedure.

- **Negative sequence impedance tests**

  There are five methods to measure synchronous machine negative sequence impedance as presented in reference *IEEE Std 115-2009,* Method 3, Single-Phase Line-to-Line Sustained Short Circuit Test, which is the most commonly method implemented for on-site testing. The machine needs to run at the rated speed with a sustained single-phase short-circuit between two of the armature line terminals and excited at reduced field current. This standard also provides details about typical testing conditions, required measurements, typical test setups, and a step-by-step test procedure.

- **Power quality tests**

  Power quality tests are conducted to determine background power quality signature of the grid before the generating system is connected as required by AS/NZS 61000.3.6. When compared with the corresponding post-connection power quality signature of the generating system, these measurements allow demonstrating compliance with the GPS clauses S5.2.5.2 and S5.2.5.6.

  Measurements conducted include:

  – Voltage flicker.
  – Harmonic voltage distortion.
  – Voltage unbalance (negative sequence component).
  – Zero sequence component.

  Continuous measurement must be captured at the connection point for a suitable period as per the method described in AS/NZS 61000.4.7:2012 and AS/NZS 61000.4.15:2012.

  Background power quality measurements are sometimes available from the connecting NPS. Otherwise measurements need to be conducted by the proponent before the first energisation of the generating system.

- **Off-line frequency sweep (transfer function) tests**

  Purpose

  – To validate the transfer function block diagram of the AVR and PSS loops.

  Pre-test condition

  – Machine is off-line.
  – Excitation system is off-line.
  – Confirm the measurement system is ready.

  Methodology and procedure

  – Frequency response of the excitation system is assessed over a frequency bandwidth of at least 0.01 – 10.0 Hz by injecting sinusoidal signals with the specific bandwidth into the control blocks. The gain and phase variations with frequency of each measured transfer function are then compared with those obtained from the model.

- Ensure the following steps per bandwidth:
  - 0.01– 0.09 Hz in 9 steps.
  - 0.1 – 1 Hz in 19 steps.
  - 1 – 2 Hz in 11 steps.
  - 2.5 – 10 Hz in 16 steps.

  Each point shall be configured so the calculation is performed over four cycles averaging per measurement point.

Note: Apart from the negative-sequence impedance tests outlined above, all other tests highlighted in this section are commonly carried out before all other off-line tests described in section 3.1.

3.2 On-line test 1 (HP2 tests)[5]

3.2.1 Partial load rejection tests (HP2_LRT)

Purpose

- To validate R2 model parameters of the synchronous machine[6], excitation system and turbine-governor control system, including:
  - Stator leakage reactance (Xl).
  - Direct axis unsaturated synchronous reactance (Xdu).
  - Direct axis unsaturated transient reactance (X'du).
  - Direct axis unsaturated sub-transient reactance (X''du).
  - Direct axis open circuit transient time constant (T'd0).
  - Direct axis open circuit sub-transient time constant (T''d0).
  - Quadrature axis unsaturated synchronous reactance (Xqu).
  - Quadrature axis unsaturated transient reactance (X'qu).
  - Quadrature axis unsaturated sub-transient reactance (X''qu).
  - Quadrature axis open circuit transient time constant (T'q0).
  - Quadrature axis open circuit sub-transient time constant (T''q0).
  - Saturation characteristic and parameters (e.g. S1.0, S1.2).
  - Combined inertia constant of the synchronous machine and prime-mover (H).
  - Excitation system model and parameters, such as:
    - AVR control gains, time constants and limits.
    - Exciter characteristics (if applicable).
  - Governor and turbine model parameters including:
    - Governor gains.
    - Valve or gate characteristics.
    - Turbine characteristics.

    [Note: Synchronous machine, excitation system and turbine-governor model parameters listed above is provided for illustrative purposes. The proponent is expected to list all model parameters validated by this specific test]

Pre-test condition

- The machine is on-line and under partial load conditions specified in Table 2.
- Rotor angle can be measured.

Methodology and procedure

- Pre-test conditions are confirmed.
- Confirm the measurement system is ready.
- Liaise with AEMO/NSP Control Centre before conducting load rejection tests.

[5] For power stations with multiple conventional generating units, as agreed with AEMO and NSP, other generating units not under tests, may be dispatched so that any changes induced to the grid by the tests can be compensated.
[6] IEEE Guide: Test Procedures for Synchronous Machines, IEEE Std 115-2009

Power plant substation HV bus voltage will be impacted by reactive power rejection. AEMO/NSP control centre must be consulted before the test so that mitigation measures can be implemented if necessary.

- Place the machine into manual control mode.
- Start recorders just before the circuit breaker is opened.
- Reject load by tripping the machine circuit breaker manually.
- Record until after the terminal voltage and generator speed have settled in steady state.
- After each load rejection, view the test data file to ensure it has been successfully saved before conducting the next load rejection.
- Re-synchronise the machine to the power system.
- Repeat the process for all operating conditions stated in Table 2.

Signals to be measured

Please refer to Appendix A for further details on various signals that need to be measured for the partial load rejection tests. The signal list will vary depending on which R2 model parameters are being validated through partial load rejection tests.

Measured data file names and format

- PlantName_UnitNo_HP2_LRT_0X.CSV.

Acceptance criteria

- The synchronous machine must be returned to a stable off-line operating condition after load rejection.
- Signals and scaling factors are documented.
- Measurement data is successfully downloaded and confirmed.

Table 2: Operating conditions for Hold Point 2 partial load rejection tests

Test	Initial MW	Initial MVAr	Excitation control mode	Data file name	Comments
1					
2					
3					
4					
others					

3.2.2 Machine Capability tests (HP2_MCT)

Purpose

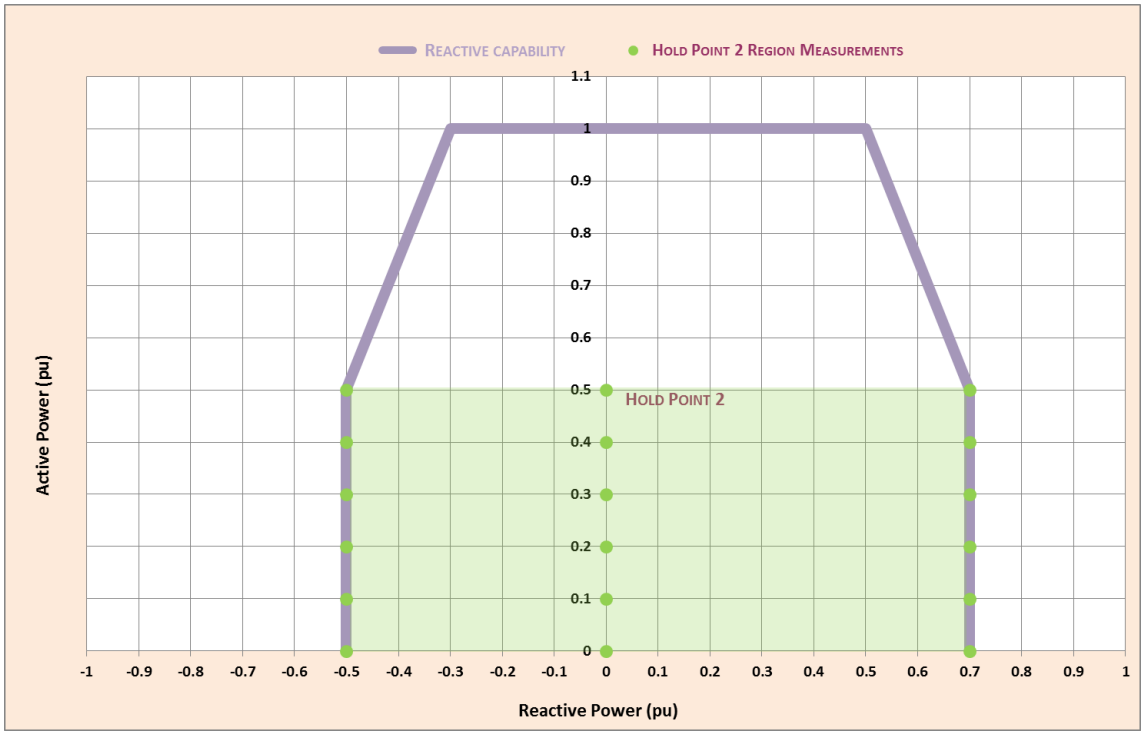
- To validate the Generator Capability Diagram specified in Section 7 of Generating System Data Sheets.
- To validate R2 model parameters of the generator including:
  - Stator leakage reactance (Xl).
  - Direct axis unsaturated synchronous reactance (Xdu).
  - Quadrature axis unsaturated synchronous reactance (Xqu).
  - Saturation characteristic and parameters.

  [Note: Synchronous machine model parameters listed above are provided for illustrative purposes. The proponent is expected to list all model parameters validated by this specific test.]

R1 Generator Capability Diagram

Reactive power capability diagram proposed in the Generating Unit Data Sheets (R1 data) should be presented with the proposed measurement points superimposed on the diagram. Typical reactive power capability diagram with likely HP2 measurement points is shown in Figure 3.

Figure 3: Typical reactive capability diagram with HP2 measurement locations



Pre-test condition

The machine is on-line and the active and reactive power outputs are consistent to those specified in Table 3.

Methodology and procedure

- Confirm the measurement system is ready.

- Load the machine according to the operating conditions specified in Table 3.
- If required, change the tap position on the generator transformer and/or upstream transformer (coordination with the NSP is necessary).
- Modify terminal voltage.
- Wait until the response settles.
- Record the signals specified in Appendix A and record the rotor temperature if feasible.
- Ensure the recording system continues for at least 40 seconds after the response has reached new steady-state conditions.
- Allow the machine to run continuously for 10-15 minutes at each operating point.
- View the test data file to ensure it has been successfully saved before moving forward to the next operating condition.

Signals to be measured

Please refer to Appendix A for further details on various signals that need to be measured for the machine capability tests.

Measured data file names and format

- PlantName_UnitNo_HP2_MCT_XY.CSV.

Acceptance criteria

- The machine operates stably at each specified operating condition.
- Signals and scaling factors are documented.
- Measurement data is successfully downloaded and confirmed.
- Measured reactive power capability is consistent with the registered capability as specified in GPS clause S5.2.5.1.

Table 3: Operating conditions for Hold Point 2 machine capability tests

Test	Terminal voltage (pu)	Initial MW*	Initial MVAr*	Data file name	Comments
1					
2					
3					
4					
Others					

*Note:

The initial MW levels shown in Table 3 are required to have a minimum of three reactive values at each MW level: 0 MVAr and at the boundaries of the R1 Generator Capability Diagram specified at the agreed Generating System Design Data Sheets.

3.2.3 Voltage step response tests (HP2_VSR)

Purpose

- To assess compliance with GPS clause S5.2.5.13 with respect to online step response performance characteristics including.
  - Regulated voltage is maintained within 0.5% of the set point.
  - Allow the voltage set point to be continuously controllable in the range of at least 95% to 105% of the normal voltage.
  - Settling times for voltage, active power and reactive power for a 5% voltage step are within 5.0 seconds.
  - Response is adequately damped.
- To validate the machine, excitation system and PSS model parameters including
  - AVR control characteristics including.
    - Control gain, time constants and limits.
  - Exciter characteristics (if applicable).
  - Confirm the inputs signals, the washout filters for each inputs and transfer functions of the PSS.

    [Note: The machine, excitation system and PSS model parameters listed above is provided for illustrative purposes. The proponent is expected to list all model parameters validated by this specific test.]
- To confirm the stability and performance of the PSS.

Pre-test condition

- The machine is on-line with an initial terminal voltage of 1 pu and a rated speed of 1 pu.
- Initial levels of active and reactive power are consistent with those specified in Table 4.

Methodology and procedure

- Confirm the measurement system is ready.
- Load the machine according to the operating conditions specified by the proponent in Table 4.
- Ensure PSS is on with AVR in Automatic operation mode.
- Confirm the terminal voltage, active and reactive power are in steady-state conditions.
- Apply +/- 2.5% steps to the voltage control set point initially, and ensure step responses are stable.
- Allow the terminal voltage, active and reactive power to reach steady state conditions.
- Step the voltage set point back to its original value.
- Confirm the terminal voltage, active and reactive power have reached steady-state conditions
- Apply +/- 5% steps to the voltage control set point in the same manner as the +/- 2.5% steps.
- Repeat the +/- 5% voltage set point step tests.
- Download and check measurement data.
- At least 10 seconds pre-triggered recording required and allow at least 40 seconds recording time after the terminal voltage reached new steady-state conditions before the next test (step) commences.
- Repeat the above tests with PSS off.
- Perform the tests with both AVR channels.

Signals to be measured

Please refer to Appendix A for further details on various signals that need to be measured for on line step response tests.

Measured data file names and format

- PlantName_UnitNo_HP2_VSR_XY.CSV.

Acceptance criteria

- Overlays of measured and simulated responses for the on-line voltage set-point test will be submitted as part of the Hold Point test report.

  To assess conformance with AEMO's Generating System Model Guidelines, +/- 10% accuracy bands need to be superimposed on the graphs which include overlays of measured and simulated responses.
- The machine is able to return to stable operation after each step change.
- The machine can be run continuously within the voltage range between 95% and 105% of normal voltage.
- Response is adequately damped.
- Settling time of the voltage response for a 5% voltage step complies with GPS clause S5.2.5.13, i.e. a settling time of 5 seconds or less for an on-line set point step response test.
- Signals and scaling factors are documented.
- Measurement data is successfully downloaded and confirmed.

Table 4: Operating conditions for Hold Point 2 on line voltage step response tests

Test	Terminal voltage (pu)	Initial P	Initial Q	PSS Status	Step Size	Data file name	Comments
1							
2							
3							
4							
Others							

3.2.4 OEL tests (HP2_OEL)

Purpose

- To assess compliance with GPS clause S5.2.5.13 with respect to voltage and reactive power control characteristics accounting for the OEL action where:
  - Settling time is less than 7.5 seconds for a 5% voltage disturbance when operating into the OEL from an operating point where a voltage disturbance of 2.5% would just cause the OEL to operate.
- Confirm the adequacy and stability of OEL performance (including both maximum current and thermal OEL characteristics).
- Obtain suitable online data for validation of the machine and excitation system (including OEL) model parameters including:
  - AVR control characteristics, such as control gains, time constants and AVR limits.
  - Exciter characteristics (if applicable).
  - OEL control gains and limits.
  - Time delays and time constants of the OEL control.

    [Note: Machine and excitation system (including OEL) model parameters listed above are provided for illustrative purposes. The proponent is expected to list all model parameters validated by this specific test.]

Pre-test condition

- The machine is on-line and the initial level of active and reactive power is according to Table 5.

Methodology and procedure

- Confirm the measurement system is ready.
- Load the machine according to the operating conditions specified in Table 5 such that the voltage set point applied allows the machine to marginally operate on the OEL limit.
- Record the status of PSS.
- Confirm the terminal voltage, active and reactive power have reached steady-state conditions.
- Confirm OEL is enabled.[7]
- Reduce the voltage reference set point by 2.5%.
- If required, change the tap position on generator transformer and/or upstream transformer (coordination with the NSP is necessary).
- Confirm the terminal voltage, active and reactive power have reached steady-state conditions.
- Apply a positive 2.5% step to the voltage reference set point.
- Confirm OEL operation (OEL should be marginally activated).
- Confirm the terminal voltage, active and reactive power have reached new steady-state conditions.
- Apply a negative 2.5% step to the voltage reference set point.[8]
- Confirm the terminal voltage, active and reactive power have reached new steady state conditions.
- Apply a positive 5.0% step to the voltage reference set point.
- Confirm operation of the OEL.

[7] An acceptable practice is to temporarily reduce the OEL settings provided that the OEL cannot be engaged with normal settings.
[8] Application of a single +5% step is permitted in circumstances where the excitation system is designed such that it cannot facilitate application of multiple steps.

- Confirm the terminal voltage, active and reactive power have reached steady-state conditions.
- Step the voltage set point back to its pre-test value.
- Perform tests with both AVR channels.
- At least 10 seconds pre-triggered recording required and allow at least 40 seconds recording time after the terminal voltage reached new steady-state conditions before the next test (step) commences.
- View the test data file to ensure it has been successfully saved.

Signals to be measured

Please refer to Appendix A for further details on various signals that need to be measured for the HP2 OEL tests. Rotor temperature at the time of test should also be noted if available.

Measured data file names and format

- Channel A: PlantName_UnitNo_HP2_OEL_XY_A.CSV.
- Channel B: PlantName_UnitNo_HP2_OEL_XY_B.CSV.

Acceptance criteria

- Confirm operation and performance of the OEL:
  - OEL is activated for a 2.5% voltage step applied.
  - Settling time of reactive power for a 5% voltage step in respect to OEL operation is less than 7.5 seconds.
  - Response is adequately damped.
  - The generator/exciter field current and reactive power output are limited to the predicted values.
- Over-excitation (V/Hz) relay does not operate.
- Overlays of measured and simulated responses for the OEL set-point test will be submitted as part of the Hold Point test report.

  To assess conformance with AEMO's Generating System Model Guidelines, +/- 10% accuracy bands needs to be superimposed on the graphs which include overlays of measured and simulated responses.
- Signals and scaling factors are documented.
- Measurement data is successfully downloaded and is confirmed.

Table 5: Operating conditions for HP2 OEL tests

Test	Initial P	Initial Q	PSS Status	Step size	Data file name	Comments
1						
2						
3						
4						
Others						

3.2.5 UEL tests (HP2_UEL)

Purpose

- To assess compliance with GPS clause S5.2.5.13 with respect to voltage and reactive power control characteristics accounting for the UEL action:
  - The settling time of less than 7.5 seconds for a 5% voltage disturbance when operating into the UEL from an operating point where a voltage disturbance of 2.5% would just cause the UEL to operate.
- Confirm the adequacy and stability of the UEL performance.
- Obtain suitable online data for validation of the machine and excitation system (including UEL) model parameters including:
  - AVR control characteristics, such as control gains, time constants and limits.
  - Exciter characteristics (if applicable).
  - UEL control gains and limits.
  - Time delays and time constants of the UEL control.

    [Note: Synchronous machine and excitation system (including UEL) model parameters listed above are provided for illustrative purposes. The proponent is expected to list all model parameters validated by this specific test.]

Pre-test condition

- The machine is on-line and the initial level of active and reactive power is according to Table 6.

Methodology and procedure

- Confirm the measurement system is ready.
- Load the machine according to the operating conditions specified in Table 6, such that the voltage set point applied allows the machine to marginally operate on the UEL limit (use tap changing transformer if necessary).
- Record the status of PSS.
- Confirm the terminal voltage, active and reactive power have reached steady-state conditions.
- Confirm UEL is enabled.[9]
- Increase the voltage reference set point by 2.5%.
- Confirm the terminal voltage, active and reactive power have reached steady-state conditions.
- Apply a negative 2.5% step to the voltage reference set point.
- Confirm UEL operation (UEL should be marginally activated).
- Confirm the terminal voltage, active and reactive power have reached new steady-state conditions.
- Apply a positive 2.5% step to the voltage reference set point.[10]
- Confirm the terminal voltage, active and reactive power have reached steady-state conditions.
- Apply a negative 5.0% step to the voltage reference set point.
- Confirm UEL operation.
- Confirm the terminal voltage, active and reactive power have reached steady-state conditions.
- Step the voltage set point back to its pre-test value.

[9] An acceptable practice is to temporarily reduce the UEL settings provided that the UEL cannot be engaged with normal settings.
[10] Application of a single -5% step is permitted in circumstances where the excitation system is designed such that it cannot facilitate application of multiple steps.

- Perform the tests with both AVR channels.
- At least 10 seconds pre-triggered recording required and allow at least 40 seconds recording time after the terminal voltage reached new steady-state conditions before the next test (step) commences.
- View the test data file to ensure it has been successfully saved.

Signals to be measured

Please refer to Appendix A for further details on the various signals that need to be measured for HP2 UEL tests.

Measured data file names and format

- Channel A: Plantname_UnitNo_HP2_UEL_XY_A.CSV.
- Channel B: Plantname_UnitNo_HP2_UEL_XY_B.CSV.

Acceptance criteria

- Confirm operation and performance of the UEL.
  - UEL is activated for a 2.5% voltage step applied
  - Settling time of voltage, active and reactive for a 5% voltage step in respect of the UEL operation is less than 7.5 seconds
  - Response is adequately damped
  - Reactive power output and terminal voltage are limited to the predicted values
- Loss-of-excitation and out-of-step (pole slip) relays do not operate.
- Overlays of measured and simulated responses for the UEL set-point test will be submitted as part of the Hold Point test report.

  To assess conformance with AEMO's Generating System Model Guidelines, +/- 10% accuracy bands need to be superimposed on the graphs which include overlays of measured and simulated responses.
- Signals and scaling factors are documented.
- Measurement data is successfully downloaded and confirmed.

Table 6: Operating conditions for HP2 UEL tests

Test	Terminal voltage (pu)	Initial P	Initial Q	PSS Status	Step size	Data file name	Comments
1							
2							
3							
4							
Others							

3.2.6 Frequency step tests (HP2_FST)

Purpose

- To assess compliance with GPS clause S5.2.5.11 with respect to frequency control.
- To validate the R2 data specified in Section 12 of Generating System Data Sheets (Prime Mover and Primary Mechanical Control Systems).
- To validate the turbine and governor model parameters including:
  - Dead band.
  - Governing droop.
  - Governor gains.
  - Valve or gate characteristics.
  - Turbine characteristic.

  [Note: The above governor model parameter list is provided for illustrative purposes. The proponent is expected to list all model parameters validated by this specific test.]

Pre-test condition

- The machine is on-line and operates as per the operating conditions specified in Table 7.
- Low reactive power output.
- No ramp rate limits introduced into the input step signal when applying the test sequence.

Methodology and procedure

- Confirm the measurement system is ready.
- Load the machine according to the operating conditions specified in Table 7.
- Apply an appropriate step/ramp to the speed/frequency set point or feedback signal which is the actual measurement signal, such as speed, angle or frequency to be fed into the Governor control.
- Wait until the response reaches new steady-state conditions.
- Return the speed/frequency set point or feedback to pre-test value.
- Wait until the response reaches new steady-state conditions.
- Download and view the test data file to ensure it has been successfully saved.

Signals to be measured

Please refer to Appendix A for further details on various signals that need to be measured for the HP2 frequency step tests. Refer to AEMO document: Turbine Governor Testing and Model Validation Guideline for examples of signals to be measured for different prime mover technologies.

Measured data file names and format

- Channel A: Plantname_UnitNo_HP2_GSR_XY_A.CSV.
- Channel B: Plantname_UnitNo_HP2_GSR_XY_B.CSV.

Acceptance criteria

- The steady-state change in active power is as expected and complies with the registered GPS clauses S5.2.5.11.
- Response is adequately damped.
- Measurement data is successfully downloaded and confirmed.

- Signals and scaling factors are documented.
- Overlays of measured and simulated responses for the frequency set-point test will be submitted as part of the Hold Point test report.

  To assess conformance with AEMO's Generating System Model Guidelines, +/- 10% accuracy bands needs to be superimposed on the graphs which include overlays of measured and simulated responses.

Table 7: Operating conditions for Hold Point 2 frequency step tests

Test	Initial MW	Frequency deviation	Deviation shape (step or ramp)	Data file name	Comments
1					
2					
3					
4					
Others					

3.2.7 Active power tests (HP2_APT)

Purpose

- To assess compliance with GPS clause S5.2.5.14 with respect to active power control.

Pre-test condition

- The machine is on-line and output is at PMIN (specified in Generating System Data Sheets).
- Low reactive power output.
- No ramp rate limits are introduced into the input step signal when applying the test sequence.

Methodology and procedure

- Confirm the measurement system is ready.
- Load the machine according to the operating conditions specified in Table 8.
- Apply the step/ramp, specified in Table 8 to the generator's dispatch target (ensuring the control system for normal dispatch is used).
- Wait until the next 5 minute dispatch interval before applying the next step/ramp in.
- Ensure that at least one dispatch target is held for 10 minutes.
- Download and view the test data file to ensure it has been successfully saved.

Signals to be measured

Please refer to Appendix A for further details on various signals to be measured for the HP2 active power step response tests.

Measured data file names and format

- Channel A: Plantname_UnitNo_ HP2_APT_XY_A.CSV.
- Channel B: Plantname_UnitNo_ HP2_APT_XY_B.CSV.

Acceptance criteria

- Generating unit achieves and maintains the intended dispatch target.
- If required, the generating unit ramps linearly from one dispatch target to another.
- Response is adequately damped.
- Signals and scaling factors are documented.
- Measurement data is successfully downloaded and confirmed before the next test commences.

Table 8: Operating conditions for Hold Point 2 active power tests

Test	Initial dispatch target	Final dispatch target	Data file name	Comments
1				
2				
3				
4				
Others				

3.2.8 Stator current limiter tests (HP2_SCL)

Purpose

- To assess compliance with the GPS clause S5.2.5.13 with respect to the voltage and reactive power control accounting for the action of stator current limiter (SCL) whereby:
  - Settling time is less than 7.5 seconds for a 5% voltage disturbance when operating into the stator current limiter from an operating point where a voltage disturbance of 2.5% would just cause the stator current limiter to operate.
- Confirm adequacy and stability of the stator current limiter.

Pre-test condition

- The machine is on-line and operates such that stator current limiter is active.

Methodology and procedure

- Confirm the measurement system is ready.
- Load the machine according to the operating condition specified in Table 9, such that the voltage set point enables the generator to marginally operate on the stator current limit.
- Record the status of PSS.
- Confirm the terminal voltage, active and reactive power have reached steady-state conditions.
- Confirm stator current limiter is enabled[11].
- Reduce voltage reference set point by 2.5%
- Confirm the terminal voltage, active and reactive power have reached steady-state conditions.
- Apply a positive 2.5% step to the voltage reference set point.
- Confirm operation of the stator current limiter.
- Confirm the terminal voltage, active and reactive power have reached steady-state conditions.
- Apply a negative 2.5% step to the voltage reference set point.
- Confirm the terminal voltage, active and reactive power have reached steady-state conditions.
- Apply a positive 5.0% step to the voltage reference set point.
- Increase the step size by increments of 1% if the initial 5% step is not adequate to engage the SCL.
- Confirm operation of the stator current limiter.
- Confirm the terminal voltage, active and reactive power have reached steady-state conditions.
- Step the voltage set point back to its pre-test value.
- View the test data file to ensure it has been successfully saved.
- Perform the test with both AVR channels.
- Repeat the above tests with opposite step sizes if SCL applies to under-excited as well as the over-excited operating range.

Signals to be measured

Please Refer to Appendix A for further details on various signals that need to be measured for the stator current limiter tests. Rotor temperature at the time of test should also be noted if available.

[11] An acceptable practice is to temporarily reduce the SCL settings provided that the SCL cannot be engaged with normal settings.

Measured data file names and format

- Channel A: Plantname_UnitNo_ HP2_APT_XY_A.CSV.
- Channel B: Plantname_UnitNo_ HP2_APT_XY_B.CSV.

Acceptance criteria

- Confirm operation and performance of the stator current limiter with respect to:
  - Operation of the stator current limiter with 2.5% voltage step applied.
  - Settling time of voltage and reactive for a 5% voltage step in respect to stator current limiter operation is less than 7.5 seconds.
  - Response is adequately damped.
  - Stator current is limited to the predicted values.
- No protective function operates.
- Signals and scaling factors are documented.
- Measurement data is successfully downloaded and confirmed.

Table 9: Operating conditions for HP2 stator current limiter tests

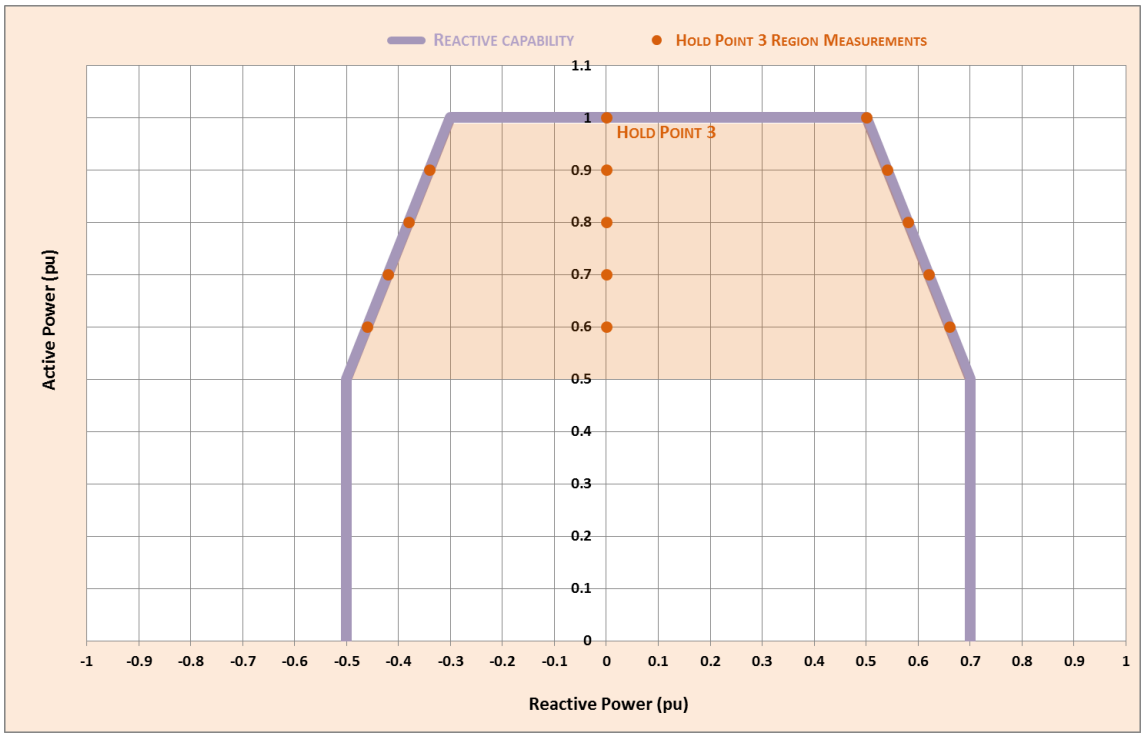
Test	Terminal voltage (pu)	Initial P	Initial Q	PSS Status	Step size	Data file name	Comments
1							
2							
3							
4							
Others							

3.3 On-line test 2 (HP3 tests)[12]

3.3.1 Machine Capability tests (HP3_MCT)

Refer to section 3.2.2 for specifics; the same methodology is to be used as applied for Hold Point 2.

Figure 4: Typical reactive capability diagram with HP3 measurement locations



3.3.2 Voltage step response tests (HP3_VSR)

Refer to section 3.2.3 for specifics; the same methodology is to be used as applied for Hold Point 2.

3.3.3 OEL tests (HP3_OEL)

Refer to section 3.2.4 for specifics; the same methodology is to be used as applied for Hold Point 2.

3.3.4 UEL tests (HP3_UEL)

Refer to section 3.2.5 for specifics; the same methodology is to be used as applied for Hold Point 2.

3.3.5 Field voltage ceiling tests (HP3_FVC)

Purpose

- To assess compliance with the GPS clause S5.2.5.13 with respect to the excitation ceiling voltage with the following characteristics, at least:
  - For a static excitation system, 2.4 times; or
  - For other excitation control systems, 1.5 times.

[12] For power stations with multiple conventional generating units, with agreed with AEMO and NSP, other generating units not under tests, may be dispatched so that any changes induced to the grid by the tests can be compensated.

The excitation required to achieve generation at the nameplate rating for rated power factor, rate speed and nominal voltage.

- The excitation system can rise from rated field voltage to excitation ceiling voltage in less than:
  - 0.05 second for a static excitation system; or
  - 0.5 second for other excitation control systems.

Pre-test condition

- The machine is on-line and at its nameplate rated conditions.

Methodology and procedure

- Confirm the measurement system is ready
- Confirm the terminal voltage, active and reactive power have reached steady-state conditions
- Apply an impulse to the voltage reference set point sufficiently large, e.g. 10%, to reach the excitation ceiling
- Check the test data to ensure field voltage has successfully reached ceiling
- Save the measurement data before moving on to the next test
- Record the signals specified in Appendix A and record the rotor temperature if possible.
- Perform the test with both AVR channels.

Signals to be measured

Please Refer to Appendix A for further details on various signals that need to be measured for field voltage ceiling tests.

Measured data file names and format

- Plantname_UnitNo._HP3_FVC_XY_A.CSV.

Acceptance criteria

- The ceiling field voltage complies with GPS clause S5.2.5.13, i.e.
  - For a static excitation system is 2.3 times or 1.5 times for other excitation systems.
  - Field voltage from rated field voltage to ceiling is 0.05 seconds for a static excitation system or 0.5 seconds for other excitation systems.
- The machine is able to return to stable operation after the step change.
- Signals and scaling factors are documented.
- Measurement data is successfully downloaded and confirmed.

3.3.6 Frequency step tests (HP3_FST)

Refer to section 3.2.6 for specifics; the same methodology is to be used as applied for Hold Point 2.

3.3.7 Active power tests (HP3_APT)

Refer to section 3.2.7 for specifics; the same methodology is to be used as applied for Hold Point 2.

3.3.8 Stator current limiter tests (HP3_SCL)

Refer to section 3.2.8 for specifics; the same methodology is to be used as applied for Hold Point 2.

3.3.9 Other HP3 tests

Other on line tests commonly conducted at Hold Point 3 include:

- **Power quality tests**

  The methodology applied for this test is the same as that discussed in Section 3.1.7 on grid background power quality measurements except that measurements are taken with the generating system being connected to the grid. Measurements are expected to include a wide range of operating conditions including maximum and minimum active power output. Comparing these results against corresponding background measurements allows demonstrating GPS clauses S5.2.5.2 and S5.2.5.6.

3.4 On-line test 3 (HP3 tests 4)

On-line tests required for Hold Point 4 are identical to those described in section 3.3 for Hold Point 2. These tests are necessary only if four Hold Points are required by AEMO and/or relevant NSP.

APPENDIX A.

A.1 Main points of contact

Table 10: Key test roles for GPS compliance assessment and R2 data validation tests

Description	Abbreviation	Nominated personnel	Land line number	Mobile number	Email contact
Stakeholders contact	-				
Test coordinator	TC				
Test manager	TM				
Plant operator	PO				
AEMO control room	AEMO_SC	Duty Operator			
NSP control room	NSP_SC	Duty Operator			
Others					

A.2 Overview of GPS compliance assessment tests

Table 11: GPS Compliance assessment tests

Generator Performance Standard clauses	HP 1 (0 MW)	HP2 (XX MW)	HP3 (YY MW)	HP4 (ZZ MW)	Alternative assessment methodology	Descriptions/notes Test conducted at each Hold Point: Notes on alternative assessment methodology if required	Governor System Upgrade	Excitation System Upgrade	Machine Rewinding	Auxiliary Supply Upgrade	Turbine Upgrade/Capacity upgrade
Reactive Power Capability (S5.2.5.1)								✓	✓	✓	✓
Quality of electricity generated(S5.2.5.2)								✓	✓	✓	✓
Response to frequency disturbances (S5.2.5.3)	Response to frequency and voltage disturbances and response to contingency event is unlikely to be demonstrated on-site through commissioning tests; however, the limits of the protection systems that impact on this performance standard may be demonstrated.										
Response to voltage disturbances (S5.2.5.4)											
Generating system response to disturbances following contingency events (S5.2.5.5)											
Quality of electricity generated and continuous uninterrupted operation (S5.2.5.6)											
Partial load rejection (S5.2.5.7)							✓	✓			✓
Protection of generating systems from power system disturbances (S5.2.5.8)	Not demonstrated on-site										
Protection systems that impact on power system security (S5.2.5.9)	Pre-commissioning testing, not demonstrated during commissioning works										
Protection to trip plant for unstable operation (S5.2.5.10)											
Frequency Control (S5.2.5.11)							✓				✓
Impact on network capability (S5.2.5.12)	Not demonstrated on-site										
Voltage and reactive power control (S5.2.5.13)								✓			✓
Active power control (S5.2.5.14)							✓				✓
Monitoring and control requirements (S5.2.6)	Pre-commissioning requirement: done as part of the SCADA commissioning activities and subsequently checked during commissioning testing (primarily applied to wind and solar generation technologies)										
Power station auxiliary supplies (S5.2.7)	Not demonstrated on-site										
Fault current (S5.2.8)	Not demonstrated on-site										

A.3 Test schedule example

Table 12: Sample test schedule

Item	Day	Date	Activity	Initial Operating Conditions	Test Reference	GPS Clause Validation	MW Initial	MW Change	MVAr Initial	MVAr Change	Start (Market Time)	Finish (Market Time)
	Offline Testing											
1	1	01/01/2016	Offline AVR step response test	Generator unsynchronised (full speed no load)	HP1_VSR		-	-	-	-	07:30	08:00
2	2	02/01/2016	Open Circuit saturation test	The generator is off-line and at rated speed, AVR is in manual operation mode	HP1_OCT		-	-	-	-	08:00	08:30
4	2	02/01/2016	Transfer function testing	The generating unit is off-line. The measurement systems of the generating unit are continuously recording	HP1_TFT		-	-	-	-	08:30	09:00
5	2	02/01/2016	V/Hz limiter tests	AVR in AUTO mode. Ensure generating unit at rated speed and voltage.	HP1_VHT						09:00	09:30
	(other tests – this includes governor testing)											
6	2	02/01/2016	Offline Hold Point 1 submission – Proceed only after, AEMO and NSP approval		HP1_TFT						11:00	-
7	2	02/01/2016	Excitation removal tests		HP1_ERT							
8	2	02/01/2016	Unit shut down - Site work completed for the day									
...	**Online Testing**											
9	3	03/01/2016	Synchronisation up to PMIN									
10	3	03/01/2016	Direct-axis load rejection test	The generator is on-line and under partial load conditions								

11	3	03/01/2016	±5% AVR reference steps from selected operating point	The generator is on-line and the measurement signals recorded.	HP2_VSR	S5.2.5.13	30	-	5	+/- 50		
12	3	03/01/2016	OEL Step Test	The generator is on-line and operates at the OEL	HP2_OEL	S5.2.5.13	30	-		+/- 50		
13	3	03/01/2016	UEL Step Test	…	HP2_UEL	S5.2.5.13	30	-				
	(other tests – this includes governor testing)											
15	5	05/01/2016	Hold Point 2 submission – Proceed only after, AEMO and NSP approval									
16	5	03/01/2016	Synchronisation up to 50% of maximum generation				60	-				
17	5	05/01/2016	±5% AVR voltage reference steps	…	HP3_VSR	S5.2.5.13	60	-				
18	5	05/01/2016	OEL Step Test	…	HP3_OEL	S5.2.5.13	60	-				
19	5	05/01/2016	UEL Step Test	…	HP3_UEL	S5.2.5.13	60	-				
…	**(other tests – this includes governor testing)**											
22	6	06/01/2016	Synchronisation up to maximum generation									
23	6	06/01/2016	±5% AVR voltage reference steps	…	HP4_VSR	S5.2.5.13	120	-				
24	6	06/01/2016	OEL Step Test	…	HP4_OEL	S5.2.5.13	120	-				
25	6	06/01/2016	UEL Step Test	…	HP4_UEL	S5.2.5.13	120	-				
…	**(other tests – this includes governor testing)**											
27	8	08/01/2016	Hold Point 4 submission – Unrestricted commercial operation based on the approval of AEMO and NSP									
28	8	08/01/2016	**Machine returns to commercial operation**									

A.4 Load profile example

Figure 5: Sample load profile

A.5 Typical measurement signals

Table 13: List of measurement signals for each test

	Sampling rate	Record time window	Stator voltage	Active power	Reactive power	AVR/OEL/UEL /SCL/PSS/V/Hz output	Main field voltage	Main field current	Exciter field voltage	Exciter field current	Armature current	Generator speed	Valve/gate position set-point	Valve/gate position feedback	Speed reference	Dispatch target	Load (rotor) angle	frequency	internal control variables	Other signals
Open circuit characteristic tests	Min. 20 Hz sampling rate	Min. 40 seconds after the terminal quantities settled	✓ C|R2				✓ C|R2	✓ C|R2	✓ C|R2	✓ C|R2		✓								
Offline voltage step response tests	Min. 2 kHz sampling rate	Min. 40 seconds after the step applied	✓ C|R2			✓ C|R2 *AVR only*	✓ C|R2	✓ C|R2	✓ R2	✓ R2		✓							✓ R2 *Internal control signals including both regulating and excitation system stabilising functions such as rate feedback or lead-lag compensation*	
Short circuit characteristic tests	Min. 20 Hz sampling rate	Min. 40 seconds after the terminal quantities settled					✓ C|R2	✓ C|R2	✓ C|R2	✓ C|R2	✓ C|R2	✓ C								
Off-line speed reference step tests	Min. 20 Hz sampling rate	Min. 40 seconds after the step settled										✓C	✓C/R2	✓C/R2	✓C					✓ *Refer to Turbine Governor Testing and Model Validation Guideline [5] for examples of signals relevant to each turbine type*

	Sampling rate	Record time window	Stator voltage	Active power	Reactive power	AVR/OEL/UEL /SCL/PSS/V/Hz output	Main field voltage	Main field current	Exciter field voltage	Exciter field current	Armature current	Generator speed	Valve/gate position set-point	Valve/gate position feedback	Speed reference	Dispatch target	Load (rotor) angle	frequency	internal control variables	Other signals
V/Hz limiter test	Min. 100 Hz sampling rate	Min. 40 seconds after the limiter operation settled	✓ C|R2			✓ C|R2 *V/Hz and AVR*	✓ C|R2	✓ C|R2	✓ C|R2	✓ C|R2		✓C|R2								
Standstill valve response tests[1]	Min. 20 Hz sampling rate	Min. 40 seconds after the step applied											✓C	✓C					✓C	
Partial load rejection tests	Min. 2 kHz sampling rate	Min. 40 seconds after the terminal quantities settled	✓ C|R2	✓ C|R2	✓ C|R2		✓ C|R2	✓ C|R2	✓R2	✓R2		✓ C|R2					✓R2	✓R2	✓R2	
Machine capability tests	Min. 10 Hz sampling rate	Min. 40 seconds after the terminal quantities settled	✓ C|R2	✓ C|R2	✓ C|R2		✓ C|R2	✓ C|R2	✓ C|R2	✓ C|R2		✓					✓R2			
On-line voltage step response tests	Min. 2 kHz sampling rate	Min. 40 seconds after the step applied	✓C|R2	✓C|R2	✓C|R2	✓ C|R2	✓C|R2	✓C|R2	✓ R2	✓ R2										
Limiter tests (i.e. OEL and UEL)	Min. 2 kHz sampling rate	Min. 40 seconds after the terminal quantities settled	✓ C|R2	✓ C|R2	✓ C|R2	✓ C|R2	✓ C|R2	✓ C|R2	✓ C|R2	✓ C|R2		✓							✓ R2	
Frequency step tests[1]	Min. 20 Hz sampling rate	Min. 40 seconds after the response has settled	✓ C|R2	✓ C|R2	✓ C|R2	✓ *PSS only*						✓ C|R2	✓ C|R2	✓ C|R2					✓ C|R2	*Load/speed reference required*

	Sampling rate	Record time window	Stator voltage	Active power	Reactive power	AVR/OEL/UEL /SCL/PSS/V/Hz output	Main field voltage	Main field current	Exciter field voltage	Exciter field current	Armature current	Generator speed	Valve/gate position set-point	Valve/gate position feedback	Speed reference	Dispatch target	Load (rotor) angle	frequency	internal control variables	Other signals
Active power tests	Min. 20 Hz sampling rate	Min. 40 seconds after the response has settled	✓ C|R2	✓ C|R2	✓ C|R2	✓ *PSS only*						✓ C|R2				✓C			✓ C|R2	
Stator current limiter test	Min. 2 kHz sampling rate	Min. 40 seconds after the terminal quantities settled	✓ C|R2	✓ C|R2	✓ C|R2	✓ C|R2	✓ C|R2	✓ C|R2	✓ C|R2	✓ C|R2		✓							✓ C|R2	
Field voltage ceiling	Min. 2 kHz sampling rate	Min. 10 seconds after the step applied	✓ C|R2	✓ C|R2	✓ C|R2		✓ C|R2	✓ C|R2	✓ C|R2	✓ C|R2		✓							✓ C|R2	

✓ – Signals to be measured during commissioning

✓ C – Signals to be measured and included in the commissioning report

✓ C|R2 – Signals to be measured and included in both the commissioning and R2 report

MEASURES AND ABBREVIATIONS

Abbreviation	Expanded name
AEMO	Australian Energy Market Operator
AVR	Automatic Voltage Regulator
GPS	Generator Performance Standard
HP	Hold Point
ITP	Inspection and Testing Procedure
NER	National Electricity Rules
OEL	Over Excitation Limiter
PSS	Power System Stabiliser
pu	Per-unit
RUG	Releasable User Guide
SCADA	Supervisory Control and Data Acquisition
SCL	Stator Current Limiter
UEL	Under Excitation Limiter
V/Hz	Volts per Hertz