Model Quality Test Criteria

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Transmission Planning

Nova Scotia Power Inc.

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1 Purpose

This Guideline lists the minimum requirements that must be met by a proponent submitting simulation models of plants that are to be connected to the electric network operated by NSPI. The plant can include generation, load or other major equipment for which the connecting party is expected to provide simulation models in PSS®E and PSCAD™ format. The requirements listed in the document are in addition to the general model feature requirements listed in 'PSSE and PSCAD Model Requirements' document published by the NSPI.

This document outlines the model response tests to be performed, test procedure to be followed and the test results that are to be submitted along with the software models for NSPI review and approval.

2 Background and Scope

NSPI is expecting a rapid transformation of its generation fleet to include up to 100% Inverter Based Resources (IBR) in some hours. Rapid expansion and the expected addition of Wind, Battery Energy Storage Systems (BESS) and Solar PV generation will present significant technical challenges that must be identified at planning and operational stages. To enable this analysis, it is critical that NSPI maintains an accurate network model of the power system. In an IBR heavy power system, the dynamic response characteristics of IBR plants will have a significant impact on overall stability and security of the power system. In addition, NSPI will confirm that the specific plant will operate stably, meeting dynamic response characteristics outlined by NSPI in the Transmission System Interconnection requirements and other applicable documents. Thus, NSPI will be depending on the third-party proponents who are connecting plant and equipment to the NSPI network to provide accurate and robust simulation models that close captures the repose of the plant under a variety of potential operating conditions.

The main objective of the tests outlined in the document is to ensure that the models provided are:

- Robust and compliant with NSPI model requirements (as outlined in 'PSSE and PSCAD Model Requirements')
- Accurate representation of the plant response under a range of operating conditions
- The plant design meets the minimum dynamic response requirements.
- Meet plant characteristics as outlined in the Grid Code and other applicable documents.
- Model documentation and model structure and model data are in accordance with NSPI guidelines or established industry practice.
- The models provided can be readily incorporated into the overall network model of the NSPI Power system to perform power system planning, operation and connection studies.

This document covers the Model Acceptance Tests for both Root Mean Square (RMS) and Electromagnetic Transient (EMT) type models that are to be provided to NSPI. The models should be provided in PSS®E (RMS) and PSCAD™ (EMT) software platforms. If the project proceeds to Operations, ASPEN OneLiner modelling data may be required at that time.

The Model Acceptance Tests are performed with the Plant Model connected to a simplified representation of the rest of the system. Thus, it is important to note that the submission and subsequent acceptance of the MQDRT report by NSPI does not imply that;

- The plant design meets final compliance and acceptance.
- The Models provided are fully compliant – all models are to be further updated as required by NSPI based on design modifications and test results during commissioning.

3 Related Policies and Procedures

The models provided should be an accurate representation of the physical plant. In addition to demonstrating the robustness and accuracy of the model through the tests outlined in this document, the model response should be aligned with the Grid code, interconnection agreements, as well as protection and measurement requirements.

NSPI will inform the proponent if the model and the test results are acceptable to NSPI.

NSPI will not disclose model test results nor specific proprietary details embedded in the model with third parties.

4 Acceptance Criteria

The Model Acceptance Tests are designed to ensure that the models provided are, robust and compliant with NSPI model requirements (as outlined in Power System Model Guidelines) and that the model is an accurate representation of the plant response under a range of reasonable operating conditions.

The tests outlined below are designed to verify different aspects of the model and the plant response that the model represents:

- Robustness of the model
- Steady state response
- Dynamic response
- Robustness of the control system and the overall plant design
- Response under large disturbances
- Specific tests to verify specific compliance requirements.

The tests that should be performed as minimum for NSPI approval are listed in the following sections. All tests will be performed with the plant model connected to a simplified representation of the external NSPI network. Unless otherwise directed by the NSPI, all tests will be carried out on a Single Machine- Infinite Bus (SMIB) type test setup as shown in figure xx.

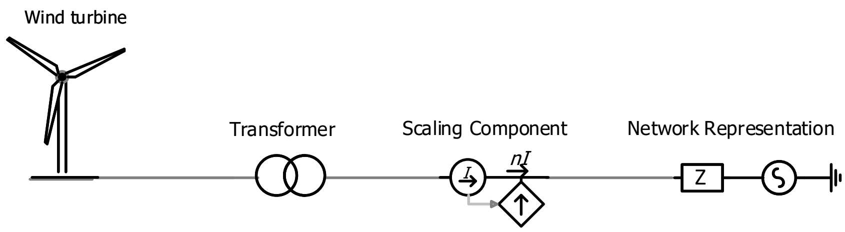

Figure 1: Overview of a SMIB setup used for IBR generation testing

5 Acceptance Tests

All tests will be performed on the version of the software specified by NSPI. NSPI will also specify the required Fortran complier compatibility. The POI voltage should be set to 1 PU and the equivalent voltage source frequency set to 60 Hz.

For BESS systems or other forms of energy storage, some of the tests may require to be performed under both discharging and charging conditions. Unless specifically stated, the tests for BESS and energy storage systems are performed under a discharging condition.

Unless stated specifically, the tests described below are applicable for both PSS®E and PSCAD™.

5.1 Robustness of the model

T01: The Model should reach the expected steady state.

- The PSCAD™ simulation should reach the expected steady state in less than 3 s of simulation time. This test should be performed at 10 µs and at the largest time step recommended by the proponent.
- The PSS®E model should 'flat start' without any uninitialized states for transient stability studies with a time range of up to 20 s.

T02: The PSCAD™ model should be able to start from a saved 'snapshot' file. Run the simulation under T01 with a snapshot taken when the system has reached a steady state.

5.2 Steady State response

The objective of the steady state tests is to verify that the plant can operate while meeting steady state operating criteria. The steady state tests should be run for a minimum of 5s after the simulation has reached steady state.

T03: With Plant power output at 100%, operate the plant at maximum expected lagging reactive power output. This test will be performed with the plant operating under voltage reference setting or reactive power reference setting, as applicable.

T04: With Plant power output at 100%, operate the plant at maximum expected leading reactive power output. This test will be performed with the plant operating under voltage reference setting or reactive power reference setting, as applicable.

T05: For BESS plants, with the BESS charging at 100%, operate the plant at maximum expected lagging reactive power output. This test will be performed with the plant operating under voltage reference setting or reactive power reference setting, as applicable.

T06: For BESS plants, with the BESS charging at 100%, operate the plant at maximum expected leading reactive power output. This test will be performed with the plant operating under voltage reference setting or reactive power reference setting, as applicable.

T07: Continuous operation under over voltage conditions – This test should be performed with the power output at 100%. The POI voltage should be set to 1.1 PU. The plant will be operated in either Q or V reference control mode as applicable to the facility.

T08: Continuous operation under low voltage conditions – This test should be performed with the power output at 100%. The POI voltage should be set to 0.9 PU. The plant may be operated in either Q or V reference control mode.

The operation under frequency deviations will be covered under dynamic response tests.

5.3 Dynamic response

T09: Voltage step response – (High voltage) – Once the simulation is in steady state (Power output close to 100%), apply a step change from 1 PU to 1.1 PU to the POI voltage. This may be achieved by changing the equivalent voltage source magnitude or by changing the transformer tap setting. The plant should be set to voltage control mode. The plant should be capable of operating at full MVA capacity.

T10: Voltage step response – (low voltage) – Once the simulation is in steady state (Power output close to 100%), apply a step change from 1 PU to 0.9 PU to the POI voltage. This may be achieved by changing the equivalent voltage source magnitude or by changing the transformer tap setting. The plant should be set to voltage control mode. The plant should be capable of operating at full MVA capacity.

T11: Voltage step response – (High voltage) – repeat **T09** with plant in Q control mode.

T12: Voltage step response – (low voltage) – – repeat **T10** with plant in Q control mode.

T13: PF control model – Set up the plant to operate in PF control mode with power output at 100%. PF may be set to 1. Change the PF reference to 0.95 lagging and verify the response.

T14: PF control model – Set up the plant to operate in PF control mode with power output at 100%. PF may be set to 1. Change the PF reference to 0.95 leading and verify the response.

T15: Voltage step response – (high voltage) – repeat **T09** with the external system SCR = 15. The plant should be capable of operating at full MVA capacity.

T16: Voltage step response – (low voltage) – repeat **T10** with the external system SCR = 15. The plant should be capable of operating at full MVA capacity.

T17: Frequency response – (over frequency) – Once the simulation is in steady state (Power output close to 100%), apply a step change (at a rate of change of 4 Hz/s) of 1 Hz to the equivalent voltage source frequency (60 Hz to 61 Hz). The power output should remain at pre disturbance level or ramp down if NSPI has requested over frequency response to be activated.

T18: Frequency response – (under frequency) – Once the simulation is in steady state (Power output close to 100%), apply a step change (or a at a rate of change of 4 Hz/s) of 1 Hz to the equivalent voltage source frequency (60 Hz to 59 Hz). The power output should remain at pre disturbance level or ramp up if NSPI has requested frequency response under maximum power output conditions.

T19: Frequency response – (under frequency) – repeat **T18** with the power output set to less than 100%. The power output should remain at pre disturbance level or ramp up if NSPI has requested frequency response.

5.4 Robustness of the control system and the overall plant design

T20: Phase angle jump – Once the simulation is in steady state with plant power at 100%, implement a step change of +/- 50 deg to the POI bus voltage phase. This can be achieved by changing the phase angle of the equivalent voltage source. The plant should operate stably and continue to maintain pre-disturbance output conditions for P and Q.

T21: Step change to power set point. Once the simulation is in steady state with power output close to 100%, change the power reference point to 10%. Once the system has reached the steady state, again change the power reference point close to 100%. The plant output should follow the requested output power. The response time should not be greater than 300 ms. The overall responses (P,Q, V_{rms}) should be well damped.

T22: – Step change to wind speed or solar irradiation – Once the simulation is in steady state, apply a 25% step change to the wind speed or solar irradiation. If this test cannot be readily implemented due to model limitations, the proponent may obtain NSPI consent to omit this test.

5.5 Response under large disturbances

The following tests should be performed at SCR = 2.5 (unless NSPI identifies a different SCR based on the POI short circuit conditions) and an X/r = 10. The plant should recover from the fault and reach pre fault operating condition in less than 300 ms.

T23: Balanced 3-ph to ground fault applied for 0.12 ms at the POI.

T24: Balanced 3-ph to fault applied for 0.15 ms at the POI. The remaining voltage at POI = 20%. The fault impedance should be reactive.

T25: Balanced 3-ph to ground fault applied for 0.12 ms at the POI. The remaining voltage at POI = 60%. The fault impedance should be reactive.

T26: Phase AB to ground fault applied for 0.12 ms at the POI.

T27: Phase A to ground fault applied for 0.12 ms at the POI.

The following tests should be performed at SCR =15 (unless NSPI identifies a different SCR based on the POI short circuit conditions) and an X/r = 10.

T28: Balanced 3-ph to ground fault applied for 0.12 ms at the POI.

T29: Phase AB to ground fault applied for 0.12 ms at the POI.

T30: Phase A to ground fault applied for 0.12 ms at the POI.

5.6 Specific tests to verify compliance requirements

NSPI may identify specific tests to verify that the plant design complied with NSPI requirements. Some specific tests are listed below.

T31: Verification of current injection during low voltage conditions – The proponent should verify that the plant injects reactive current as outlined by NSPI in the Interconnection Requirements or other required specification. This can be realized by plotting the instantaneous current waveforms under **T23** to **T30**.

T32: Fast frequency response – If specified by NSPI. The test set is similar to **T17**, **T18** or **T19**.

T33: Limited frequency sensitive mode (LFSM_U) – If specified by NSPI. The test set is similar to **T17**, **T18** or **T19**.

T34: Limited frequency sensitive mode (LFSM_O) – If specified by NSPI. The test set is similar to **T17**, **T18** or **T19**.

6 Model Benchmark Tests

NSPI will use the PSS®E model for a wide range of planning and operational studies. Thus, the PSS®E model should be an accurate representation of the plant response for the purpose of such studies. The PSS®E model should be benchmarked against the validated PSCAD™ model.

At a minimum, the response of voltage, power and reactive power will be compared between PSS®E and PSCAD™ at the inverter terminal and POC level. The comparison should be acceptable to NSPI and should lie within a 10% tolerance band. The model should comply with NSPI requirements, and any noticeable deviations should be documented to the satisfaction of NSPI.

At a minimum, the following test results of PSS®E and PSCAD™ are to be benchmarked in the same plot for comparison. For each test, at a minimum, P,Q, V_{rms} should be compared:

- Voltage reference step test
- Active power reference test
- Over voltage step response test
- Under voltage step response test
- Balanced fault tests
  - ABC to ground fault at POI
  - ABC to ground fault at POI with a remaining voltage
- Unbalanced fault tests
  - AB to ground fault
  - A to ground fault

7 Test Result Documentation

The documentation shall be in report form and include:

- The model and test case configuration, complete with graphics and descriptions as necessary to recreate the test scenario.
- A concise listing of each test performed or listed as not applicable.
- Test results, including data files as may be needed to fully review compliance with requirements.