PSS®E and PSCAD™ Model Requirements

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Transmission Planning
Nova Scotia Power Inc.

REVISION RECORD

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2023-06-30	0	Joy Brake	Initial document
2023-12-04	1	Joy Brake	Updated by LJH and JCB to add requirements for additional model data
2024-05-06	2	Chris Milligan	Updated by Transmission Planning to ensure accurate and functional models system studies.
		Chris Milligan	

Contents

1.0 Background and Scope

NSPI is expecting a rapid transformation of its electrical grid to include up to 100% Inverter Based Resources (IBR) in some hours. Rapid expansion and the expected addition of IBR such as Wind Energy Conversion Systems (WECS), offshore WECS, Battery Energy Storage Systems (BESS), Solar PV, Hydrogen loads and various combinations of load and generation behind the meter will present significant technical challenges that must be identified at planning and operational stages.

To enable this analysis, it is critical that NSPI maintain 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 criteria.

2.0 Simulation and Study Model Requirements

The models provided by the vendor must be an accurate representation of the overall plant as well as specific components to the degree needed for the associated study. For a high-level preliminary assessment such as a Generator Interconnection Procedure (GIP) Feasibility Study (FEAS) a simplified PSSE model may be provided by the customer for load flow study. For all other System Impact Study (SIS) the models must include site specific settings and be accurate to study system level transients where the frequency range can be in the order of few Hz to potentially kHz range.

Model and data formats are listed in Table 1: Model Type and Data Format and must be provided for system study as noted in the table. The software versions will be specified at the time of the study.

Table 1: Model Type and Data Format

Model Type	System Study	Data Format
PSS®E load flow model	Steady-state analysis, Transient analysis	PSS®E .sav or PSS®E .raw format
PSS®E Standard (aka generic) library dynamic model	Transient analysis	PSS®E .dyr format
PSS®E User Defined (UDF) dynamic model	Transient analysis	PSS®E .dyr format and associated libraries
Short-circuit sequence data for all facility elements	Short Circuit calculations Ride-through analysis	PSS®E .seq format or Aspen .OLR
PSCAD™ UDF model	EMT (Electromagnetic Transient) analysis	PSCAD™ format and associated libraries
Harmonics performance model	Frequency scan for an oscillation test	.xlsx or text file

For specialised study, for example Sub-Synchronous Torsional Interaction Analysis, additional data and models may be required.

2.1. General Requirements

All technical models must represent the complete facility, including load and generation. At minimum, the following equipment, where applicable, must be included in the supplied model:

- Branches, such as tap circuit from Point of Interconnection (POI) to Point of change of Ownership (POC), and collector circuits).
- Plant transformer(s), such as step-up, intermediate, and interconnection transformers.
- Generation unit(s).
- Load units, such as hydrolyzers, power electronics control systems, synchronous motors.
- Reactive power compensation device(s).
- Power plant controller.

Note: Model aggregation may be applied is some instances. See *Section: 2.4 Model Aggregation*.

2.2. PSS®E Model Requirements

In addition to the general requirements above, the PSS®E models must have the following elements modelled:

2.2.1. Load Flow Model

The PSS®E load flow models must be supplied in PSS®E savecase (.sav) or RAW (.raw) format for the version as specified by NSPI at the time of the study.

Where applicable, at a minimum, the following elements must be modelled with associated parameters:

- Power lines (such as tap circuit from POI to POC and collector circuits):
  - Impedance data (positive, negative, and zero sequence).
  - Ratings.
- Transformer(s):
  - MVA base.
  - Impedance data (positive, negative, and zero sequence).
  - Winding ratios, nominal voltage.
  - Tap positions, regulated bus and control mode if using tap changer.
  - Vector group.
  - Ratings.
- Reactive power compensation device(s):
  - Fixed shunts: G-shunt (MW), B-shunt (MVAr).
  - Switched shunts: Voltage limits (Vhi and Vlow), models of operation (fixed, discrete, continuous), regulated bus, Binit (MVAr), steps and step size (MVAr).
- Generation unit(s):
  - Real power range[1] (Pmax, Pmin).
  - Reactive power range[2] (Qmax, Qmin).
  - Nameplate MVA.
  - Machine impedance (R source, X source).
  - Control mode.
  - Scheduled voltage and remote bus.
  - Short circuit impedance R and jX (subtransient, transient, and synchronous).

[1] The difference between the MW amount requested by the IC and the facility MW nameplate shall be noted for Pmax. The same applies for Pmin in the case of bidirectional units. Some dynamics models are dependent on the facility's MW nameplate values corresponding to the machine's Pmax/Pmin fields.

[2] Any differences in the reactive power Qmax/Qmin shall be noted similar to the active power Pmax/Pmin.

  - Machine active/reactive power capability in PSS®E .gcp format is preferred but plain text format is also acceptable.

2.2.2. Standard Dynamic Library Model

The PSS®E standard library dynamic models must meet the following requirements:

- All models must be standard library models in PSS®E.
- The dynamic model must be provided for PSS®E versions as specified by NSPI in dyr format.
- The project must be modelled at full output per the project's Interconnection Request.
- Standard library dynamic models must accurately model all relevant control modes and characteristics of the equipment, such as:
  - All available voltage/reactive power control modes.
  - Frequency/governor response control modes.
  - Voltage and frequency ride-through characteristics.
  - Power plant controller functionality.
  - Appropriate aggregate model capability.
  - In the case of BESS, guidance must be provided on how to simulate the charging at full input per the project's Interconnection Request.
- The dynamic model must correctly initialize and be capable of correctly initializing and running in the following conditions:
  - "Flat start" test using a 30 second no-fault simulation. This consists of a 30 second simulation with no disturbance applied in a SMIB (Single Machine Infinite Bus) case, using a GENCLS synchronous machine at the POI.
  - "Ring down" test in a 60 second disturbance simulation. This consists of a 60 second simulation with the application of a 6 cycle 3-phase fault at the POI bus.
  - Through the range of expected steady state conditions without additional adjustments.

2.2.3. User Defined Dynamic Model

In addition to the requirements in *Section 2.2.2 Standard Dynamic Library Model*, the following is required for User Defined PSS®E dynamic models:

- Dynamic model source code (.flx, .for, .f90, .f, etc) or dynamic linked library (.dll) must be provided.
- User Defined models related to the facility's equipment must be editable in the PSS®E user interface. All model parameters (CONS, ICONS, and VARS) must be accessible and match the models' accompanying documentation.
- All data from User Defined models must be reportable in the "DOCU" listing of dynamics model data, including the range of CONS, ICONS, and VARS indices. This includes models that apply to multiple elements (such as plant controller).

2.3. PSCAD™

In addition to the general requirements above, the PSCAD™ models must have the following elements:

- The model must be compatible across a range of FORTRAN compliers and PSCAD™ software versions as specified by NSPI.
- The simulation time step must not be hard-coded. The model must be able to produce accurate dynamic response results at a time step of 10 µs and higher. The vendor must specify the recommended range of simulation time step.
- The model must be scalable to represent a number of units operating in parallel.

- It is expected that the model can reach the expected (user setting) steady state in less than 3s from the start of the simulation. The vendor must make necessary efforts to ensure that the model will be compatible with the 'snapshot' feature of PSCAD^{TM}.
- The user must be able to use multiple instances of the model in a single simulation setting (without having to revert to parallel core simulations).

2.4. Model Aggregation

Load and generation may be modeled in detail or aggregated as outlined in this section.

2.4.1. Generation

Industry practice for dispersed generation, such as WECS, BESS, solar PV sites, and hybrid systems, is to aggregate identical units into logical groups, based on the discretion of the facility owner and agreement from NSPI. However, elements of differing types cannot be aggregated as a combined unit.

The standard methodology for aggregating wind farms is documented in the WECC Wind Power Plant Power Flow Modelling Guide[3]. Other methodologies may be applied with NSPI's agreement.

2.4.2. Load

Generally, parameterization of the Composite Load Model (CMLD) specific to the load facility's configuration can be used when a simple load facility model is submitted. For larger facilities parameterized models may be required for equipment such as large induction motors. Inverter Based plant and Power Electronics control systems must be modelled in detail if requested by NSPI for control interactions and ride-through assessment.

2.4.3. Hybrid Facilities

Facilities with load and generation can have components of the model aggregated as per the two bullets above.

2.5. Harmonic Performance Model

Data requirements:

- The harmonic injection from the plants is to be provided by the plant owner in the form of a guaranteed maximum harmonic current injection table covering the range up to the 100th harmonic.
- The frequency-dependent impedance to develop a Norton equivalent current source must also be provided for each unit in a power plant module or IBR facility.
- An illustrative harmonic data table is listed below in Table 2: Guaranteed Maximum Harmonic Injection Levels.
- The PSCAD^{TM} model release version and the applicable corresponding hardware firmware version will be specified by NSPI.

[3] https://www.wecc.org/Reliability/WECCWindPlantPowerFlowModelingGuide.pdf

Table 2: Guaranteed Maximum Harmonic Injection Levels		
Harmonic Order	% of rated current	Phase (Deg)
1	100	0
2		
3		
125		

Provide an illustrative simulation example where the plant model is connected to an equivalent Thevenin voltage source. The model is to display stable fault recovery when the Thevenin source impedance is set to represent the minimum short circuit current condition at the POI.

3.0 Documentation

The documentation is to include:

- Description of all files provided.
  - PSS®E load flow model files.
  - PSS®E dynamic files for the plant and related auxiliary models such as plant control, frequency response, governor, protective relays etc.
  - PSCAD™ model files.
  - Harmonic Data files.
- Manual/technical bulletins for all technical models.
- User guide for setup and running for each model.
  - Description of various models' details, input parameters and output parameters.
  - Default settings and instruction on tuning the models.
  - Minimum Short Circuit Ratio (SCR) required for the plant to operate.
  - Short circuit model of the plant for modelling fault current contribution from the plant.
  - List of plant-specific settings, including:
    - Ride-through thresholds and parameters.
    - Plant-level voltage controller settings.
    - Ramp rate settings.
    - PSS®E ICON flag parameters for specific control modes.
    - Deadbands.
    - In the case of BESS, initial state of charge.
- Manuals, one-line diagram and other facility documentation to support understanding of the facility.
- Generation unit.
    - Manufacturer datasheet(s)/technical bulletin(s). Operating temperature range.
    - Reactive power capability curve(s) including in table format.
    - Short circuit behaviour, including minimum SCR operating requirements.
    - Voltage flicker coefficients.
    - Technical model and benchmarking output data for three-phase fault and single-phase fault.
- Technical bulletins for the plant and any related auxiliary models.

- Reactive power capability curves.
- Operating temperature range.
- Voltage flicker coefficients.
- Short circuit characteristics.
- Minimum operational SCR requirements.
- GSU rating, impedance, and X/R (we can use an assumed X/R).

4.0 Model Testing and Benchmarking

Upon receipt of the models required for study, NSPI will perform model quality testing. Any deficiencies must be remedied by the Facility owner prior to the commencement of study.

NSPI will use the PSS®E model for a wide range of planning and operational studies. Thus, the PSS®E model must be an accurate representation on the plant response for the purpose of such studies. The PSS®E model will be benchmarked against the validated PSCAD™ model. The model validation will at a minimum consider three phase to ground fault response at 0%, 10%, 50% and 80% residual voltage levels.

At a minimum, the response of voltage power and reactive power will be compared. The comparison must be acceptable to NSPI and ideally lie within the 5% tolerance band. The model must comply with NERC requirements and any noticeable deviations must be documented to the satisfaction of NSPI.

5.0 Commissioning and Operations Model Submission

PSCAD™ model results will be benchmarked against any factory acceptance test data and against field results during commissioning. The model should include site specific settings and the model response must be comparable to field test results. Any deficiencies must be remedied by the facility owner.

Over the life of the facility, updated models will be required as the NSPI simulation software vendors update the software.