Information Document
Model Validation and Reactive Power Reporting Guidance
ID #2017-013R

Information documents are not authoritative. Information documents are for information purposes only and are intended to provide guidance. If there is a discrepancy between an information document and any authoritative document[1] in effect, the authoritative document governs.

1 Purpose

This information document relates to the following authoritative documents:

- Section 503.19 of the ISO rules, *Reactive Power Verification Testing* ("Section 503.19"); and
- Section 503.20 of the ISO rules, *Baseline and Model Validation Testing* ("Section 503.20").

The purpose of this information document is to provide guidance to the legal owner of a generating unit, the legal owner of an aggregated facility and the legal owner of a energy storage resource on the content of the Model Validation and Reactive Power Verification Report, pursuant to Sections 503.19 and 503.20.

1.1 Applicably of NERC Reliability Standards

The AESO reviewed NERC reliability standards MOD-025-2, *Verification and Data Reporting of Generator Real and Reactive Power Capability and Synchronous Condenser Reactive Power Capability* ("MOD-025-2"), and MOD-026-1, *Verification of Models and Data for Generator Excitation Control System or Plant Volt/Var Control Functions* ("MOD-026-1") and determined that the rules referenced above collectively adequately cover the requirements of MOD-025-2 and MOD-026-1. Subsequently, MOD-025-2 and MOD-026-1 were rejected for adoption for Alberta.

The AESO generally agrees with the information contained in the NERC technical reference documents[2] and recognizes that the documents may be a useful reference for the legal owner of a generating unit, the legal owner of an aggregated facility and the legal owner of a energy storage resource in the testing and reporting of Sections 503.19and 503.20.

2 Generating Unit Model Validation and Reactive Power Verification Report Content

The *Generating Unit Model Validation and Reactive Power Verification Report*, also known as *MVQ Report* described in subsection 4 of Section 503.19 and subsection 7 of 503.20. It serves to document the purpose of the tests, description of the generating unit at the time of the tests, test processes employed, model derivation process, resulting simulation models, and the limitation of these models.

If the legal owner of the generating unit includes more than one generating unit's test results in the report, the AESO suggests that the legal owner provide the items listed in 2.1 through 2.8 below for each generating unit.

Pursuant to section 4 of Section 503.19 and section 7 of 503.20, the A *Model Validation and Reactive Power Verification Repo*rt will include the following information unless identified as optional:

2.1 a cover page that contains:

(a) **the generating facility name, generating unit name, energy storage resource name or in the case of an aggregated facility, the facility name;**

(b) **the name of the legal owner;**

[1] "Authoritative document" is the general name given by the AESO to categories of documents made by the AESO under the authority of the *Electric Utilities Act* and associated regulations, and that contain binding legal requirements for either market participants or the AESO, or both. Authoritative documents include: the ISO rules, the reliability standards, and the ISO tariff.

[2] NERC, *Reliability Guideline Power Plant Model Verification using PMUs*, dated September 2016 and *Reliability Guideline Power Plant Model Verification and Testing for Synchronous Machines*, dated July 2018, Available on www.nerc.com

(c) **Authentication and validation by a Professional Engineer licensed to practice engineering in the province of Alberta, who takes the engineering responsibility for the *Model Validation and Reactive Power Verification R*eport in accordance with the Association of Professional Engineers and Geoscientists of Alberta professional practice standards;**

(d) **the date on which the tests were performed;**

(e) **the report date;**

(f) **the revision number of report; and**

(g) **additional information may be provided in the report itself;**

2.2 for non-aggregated facilities, a detailed description of each generating unit that contains:

(a) **the generating unit name and ID;**

(b) **the name of the legal owner;**

(c) **the location of the generating facility including the station name;**

(d) **the generating unit maximum authorized real power;**

(e) **nameplate data of the components of the generating unit:**

(i) the generator nameplate data, including:

(A) manufacturer (optional);

(B) frame/model number (optional);

(C) serial number (optional);

(D) ratings including MVA, MW, RPM, kV, and P.F.;

(E) rated field current;

(F) rated field voltage;

(G) temperature rise;

(H) cooling;

(I) insulation class; and

(J) date of manufacture;

(ii) the excitation system nameplate, including:

(A) type of excitation system;

(B) manufacturer (optional);

(C) rotating exciter ratings including kV and A.;

(D) excitation transformer name plate data including kVA, kV, and impedance;

(E) rated and maximum voltage and current; and

(F) excitation control system including manufacturer, type, and model number;

(iii) the power system stabilizer nameplate data, if applicable, including:

(A) manufacturer (optional);

(B) type; and

(C) model number (optional);

(iv) the prime mover nameplate, including:

(A) manufacturer (optional);

(B) frame/model number (optional);

(C) ratings including MW, RPM, pressure, and temperature;

(D) model number (optional);

(E) fuel source; and

(F) turbine type;

(v) the turbine controller or governor nameplate, including:

(A) manufacturer (optional);

(B) type; and

(C) model number (optional);

(f) **if any item on the list is not applicable, the market participant must provide an explanation.**

(g) **If any item on the list deviates from the models or facility configuration provided in the Stage 5 Project Data Update Package (PDUP) submission or the previous MVQ report, the market participant should highlight these discrepancies in the report. Additionally, the market participant should attach the updated PSS/E idev files that incorporate the complete power flow model and sequence model data for the facility.**

2.3 for aggregated facilities a detailed description of each generating unit that contains:

(a) **the aggregated facility name and code;**

(b) **the name of the legal owner;**

(c) **the name and location of the connecting substation of the aggregated facility;**

(d) **the aggregated facility maximum authorized real power;**

(e) **the modeled single line diagram of the aggregated facility showing the reduced representation diagram of collector system or systems and aggregated machine modeled at each collector bus and their ID;**

(f) **equivalent impedance of the collector system; and**

(g) **nameplate data of each type of generator or inverter if there is more than one type in the aggregated facility:**

(h) **the generator/inverter nameplate data, including:**

a. generator or inverter type;

(i) number of generating units with the aggregated facility;

(ii) manufacturer;

(iii) frame/model number (optional);

(iv) ratings including MVA, RPM, kV, P.F., maximum and minimum real power, and reactive power;

(v) rated field current (if applicable);

(vi) rated field voltage (if applicable);

(vii) temperature rise (if applicable); and

(viii) cooling if applicable (optional);

(i) **the excitation system nameplate (if applicable), including:**

(i) type of excitation system;

(ii) manufacturer (optional);

(iii) rotating exciter ratings including kV, and A;

(iv) excitation transformer name plate data including kV, impedance, and A;

(v) rated and maximum voltage, including current; and

(vi) excitation control system including manufacturer, type, and model number;

(j) **the power system stabilizer nameplate data (if applicable), including:**

(i) manufacturer (optional);

(ii) type; and

(iii) model number (optional);

(k) **the prime mover including photo voltaic module nameplate, including:**

(i) manufacturer (optional);

(ii) frame or model number (optional);

(iii) ratings including MW, RPM, pressure, and temperature;

(iv) fuel source; and

(v) turbine type;

(l) **the turbine controller (governor) or plant controller nameplate (if applicable), including:**

(i) manufacturer (optional);

(ii) type; and

(iii) model number (optional);

(m) **reactive compensation devices (if applicable), including**:

(i) manufacturer;

(ii) type such as mechanically switched capacitor banks, TCR, TSC, or STATCOM; and

(iii) ratings including MVAr and kV;

(n) **If any item on the list is not applicable, the market participant is expected to provide an explanation**.

(o) **If any item on the list deviates from the models or facility configuration provided in the Stage 5 PDUP submission or the previous MVQ report, the market participant should highlight these discrepancies in the report. Additionally, the market participant must attach the updated PSS/E idev files, incorporating the complete power flow model and sequence model data for the facility.**

2.4 a description for each of the transmission system step-up transformers in the generating facility that contains:

(a) **the nameplate information including the MVA, nominal voltage and operational range, impedance, tap changer type (such as no-load tap changers, on-load tap changers) and tap positions;**

(b) **the transformer type, three 1-phase or one 3-phase, and also an indication of whether the transformer is an auto-transformer; and**

(c) **the number of windings, 2 or 3;**

2.5 a description of the testing and model validation process used to determine or validate the model parameters that contains:

(a) **a summary paragraph identifying how any test meets the AESO's testing requirements as stated in:**

(i) subsections 2 to 3 of Section 503.19; and

(b) subsections 3 to 6 of Section 503.20; any additional testing requirements articulated in the AESO's Functional Specification for the project, **a plot of the performance of each model, overlaid on the test result for the same conditions;**

(c) **the actual test data recorded during the test, in electronic tabular form;**

(d) **in the case of a re-test report, the model parameters and model plot submitted may be taken directly from a prior test report, provided that the test data matches the test data from the prior test report;**

(e) **a description of the deficiencies and or limitations of each model when compared to the test data, including an assessment of the quality of fit between the test data and modelled data;**

(f) **discussion on any limitations encountered during the test and their effect on the model validation and reactive power testing; and**

(g) **the reason for testing in accordance with subsection 3(2) and 4(2) of Section 503.20 and additional performance requirement outlined in AESO's Functional Specification for the project. This assists the AESO's review process.**

(h) **description of the initial test conditions, including, but not limited to, the voltages at each bus within the facility, voltage setpoint and the bus number where the voltage is regulated, tap positions for each transformer, the active and reactive power at the generator terminal, and the status of reactive power compensation devices (if applicable).**

2.6 simulation models for each generating unit that contains:

(a) **the exact model being submitted to produce the performance plot;**

(b) **block diagrams representing:**

(i) a standard PSS/E model, run with quarter-cycle time step; and

(ii) a standard PSLF model, run with a quarter-cycle time step;

(c) **a tabular listing of the parameters for each block diagram, including the validated values for all parameters for each PSS/E and PSLF model, with no parameters left blank;**

(d) **the model as provided by the manufacturer or prior test reports. If a parameter chosen for the block diagram conflicts with manufacturer's datum or prior report for that parameter, provide an explanation for the difference; and**

(e) **any limitation of the models due to the generating unit operation modes. For example applicability of a turbine governor for steam turbines operating in sliding pressure mode;**

(f) **any protection relay model applied for the generator tripping in response to voltage or frequency excursions;**

Models are expected to cover a wide range of operations, including maximum authorized real power.

No specific software package is mandated for performing the simulation and plot. Regardless of the software used to plot the model performance, the AESO expects the models to comply with the applicable PSS/E or PSLF model data as stated in the *List of Electrical and Physical Parameters* referred to in Section 503.21 of the ISO rules, *Reporting Facility Modelling Data*. This includes the usage of the WECC's list of accepted standard PSS/E and PSLF library models.[3]

The AESO may validate the test results using the provided data in DYR and DYD files accompanied with the test report as follows:

2.6.1 for each synchronous generating unit:

(a) **the generator's MVA and kV used for per-unit calculations;**

(b) **the generator's winding resistance, reactance (unsaturated) and time constants including Xd, Xq, X'd, X'q, X"d, X"q, Xl, T'do, T'qo, T"do, T"qo, Ta, and saturation factors;**

(c) **the inertia of the generating unit including generator, turbine, rotating exciter and gearbox, if applicable;**

(d) **the open circuit saturation curve with air-gap line;**

(e) **the generator's reactive power capability curve; and**

(f) **the saturated positive, negative, and zero-sequence impedances from manufacturer's data;**

This data can be found on generator name plates and manufacturer's data sheets. The market participant is expected to include the units of measure for each data point including per-unit base value.

2.6.2 the generator capability curve (D Curve) at rated voltage is expected to be superimposed with control limiter and protection curves:

(a) **generator capability curve;**

(b) **the generating unit's defined operating reactive power capability;**

[3] WECC, *Approved Dynamic Model*, Version January 2024, , as amended from time to time, Available on www.wecc.org

(c) **the generating unit's maximum authorized real power line;**

(d) **the AESO's reactive power requirements limits in accordance with subsection 2(3) Section 503.3 of the ISO rules;**

(e) **the generating unit's under-excitation limiter and over-excitation limiter setting curves; and**

(f) **the effects of relays that encroach into the generating unit capability curve, for example loss of excitation relay curves;**

2.6.3 control systems are the major components of the generating unit directly controlling its terminal outputs. The AESO may validate provided data in DYR and DYD files for the following components of the generating unit's control systems:

(a) **the turbine and controller, for example a governor or governor system;**

(b) **the excitation system and automatic voltage regulator;**

(c) **the power system stabilizer;**

(d) **the compensators; and**

(e) **other important control functions such as limiters**.

The type and settings of the over-excitation limit, under-excitation limit, stator current limiter and load compensator within automatic voltage regulator are also expected to be provided if applicable.

Where manufacturer's data is not available, the AESO expects the report to explain the circumstances resulting in the omission and the assumptions made to compensate for the missing data.

A power system stabilizer validation report that contains plots of:

(i) system performance measured response without power system stabilizer in service overlaid on system performance measured response with power system stabilizer in service, showing effective damping;

(ii) system simulated response without power system stabilizer in service overlaid on system performance measured response without power system stabilizer in service; and

(iii) system simulated response with power system stabilizer in service overlaid on system performance measured response with power system stabilizer in service.

A positive effect on system stability is expected from power system stabilizer validation reporting.

2.6.4 for inverter based generating units:

(a) **for solar photo voltaic plants [4]:**

(i) the example power flow single line diagram as shown in Figure 1;

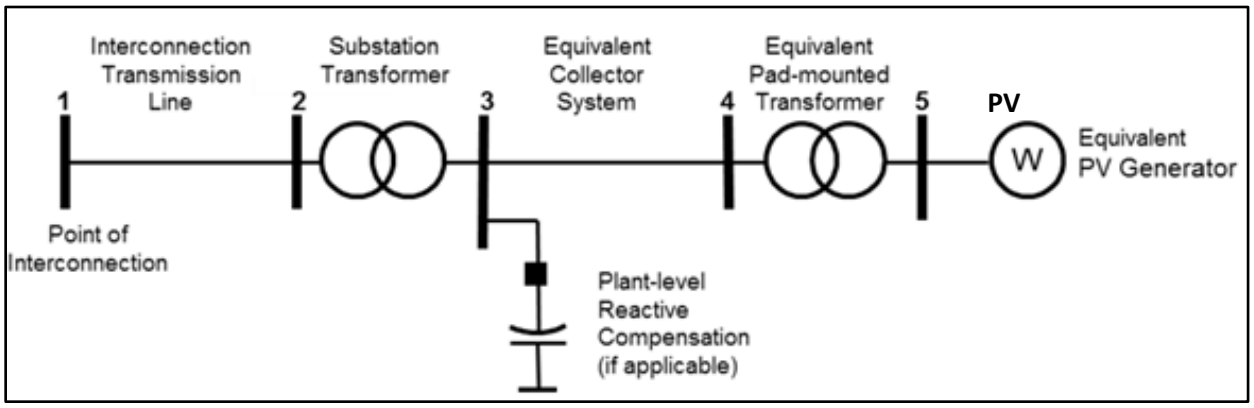

Figure 1 Example Single-Generator Equivalent Power Flow Representation for a PV Power Plant

(from WECC Guideline)

(ii) the equivalent collector system parameters;

(iii) the reactive power compensator type, model, capabilities at the nominal voltage, and dynamics model and data;

(iv) in addition to the transmission system step-up transformers in the aggregated facility, the equivalent pad mounted transformer model; and

(v) the photo voltaic plant's renewable energy control modules dynamics data as listed in Table 1;

Table 1 Renewable Energy Control Modules for solar and wind power plants implemented in the PSLF™, PSS®E, and PowerWorld platforms (from WECC Guideline)

Module	PSLF™modules	PSS®E modules	PowerWorld
Grid interface	regc_a	REGCAU1	regc_a
Electrical controls	reec_b	REECBU1	reec_b
Plant controller (if applicable)	repc_a	REPCAU1	repc_a

[4] There are two generic dynamic models for photo voltaic plants approved by WECC to be used in planning studies:
1) model consisting of plant controller, electrical controls, and grid interface modules, intended for large-scale photo voltaic plants, and
2) simplified model intended for distribution-connected, aggregated photo voltaic plants.
This information document intends to provide guidance for large-scale photo voltaic plants connected to the transmission system only. As described in *WECC Solar Plant Dynamic Modeling Guidelines* dynamic representation of large-scale photo voltaic plants requires the use of 3 renewable energy control modules as explained in this WECC guideline. Version April 2014, Dated April 2014, as amended from time to time, available at www.wecc.org

(b) **for wind power plants [5]:**

(i) the example power flow single line diagram as shown in Figure 2;

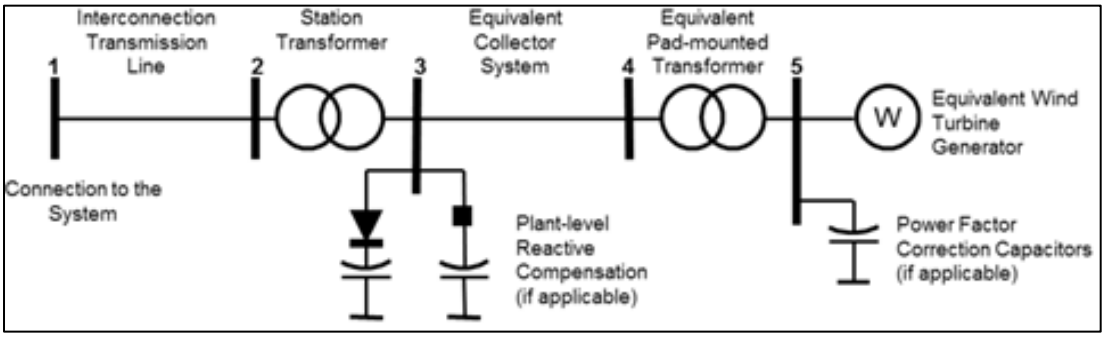

Figure 2 Example Single-Generator Equivalent Power Flow Representation for a Wind Power Plant

(ii) type of wind turbine technology;

(iii) the equivalent collector system parameters;

(iv) the reactive power compensator type, model, capabilities at the nominal voltage, dynamics model, and data;

(v) the equivalent pad-mounted transformer model;

(vi) the wind plant's renewable energy control modules dynamics data as listed in Table 1; and

(vii) the power factor correction capacitor capacity;

2.7 all plots, raw data from test and simulation of the report:

(a) **detailed and precise labels for the axes and traces;**

(b) **traces distinguishable in a black-and-white printed copy;**

(c) **clear titles for each graph indicating the test that was performed;**

(d) **appropriate scales for both axes; and**

(e) **the measured response of the test over an adequate period to confirm the modelled results;**

[5] This information document provides guidance fore commercial wind power plants which use one of the 4 types of wind turbine-generator technologies. For more information about the wind power plant power flow or dynamics modeling, please refer to the following WECC documents:
WECC, *Wind Plant Dynamic Modeling Guidelines*, Version April 2014, Date May 8, 2014, as amended from time to time, Available on www.wecc.org
WECC, *Wind Power Plant Power Flow Modeling Guide*, Version May 19, 2010, Date May 2008, as amended from time to time, Available on www.wecc.org

2.8 include an accompanying data-file containing all test data and model simulation data in machine-readable tabular form such as a comma-separated-variable text file and .DYR or .DYD files.

2.9 Benchmarking Positive Sequence Dynamic Models

A validated Electromagnetic transient (EMT) model can better represent the dynamics of the field equipment with detailed control logics being modeled. Compared with the other conventional positive sequence RMS models, an EMT model is generally considered as the highest fidelity models applied for system stability studies.

During the model submission for inverter-base resources, the positive sequence dynamic models should be benchmarked against verified EMT models to improve their quality and to ensure that the model performance is consistent across the simulation platforms.

In general, the following simulations must be run in PSS/E and benchmarked against PSCAD results to demonstrate basic reasonable model performance:

- Flat Start Test (no disturbance test)
- Small Voltage Disturbance Test
- Small Frequency Disturbance Test
- Voltage Ride-Through Test (HVRT & LVRT)
- Reference Setpoint Step Change Test
- System Strength Test (SCRs)
- Fault and Fault Clearing Test

3 Model Revalidation and Partial Baseline Testing Reports

Model revalidation and partial baseline testing for conditions listed in subsections 3(2) and 4(2) of Section 503.20 may refer to the previously submitted *Model Validation and Reactive Power Verification Report* if the data source is appropriately referenced.

4 EMT Model Baseline Testing and Revalidation Testing Reports

The EMT model for inverter-based resources with an in-service date after January 1, 2021 needs to be validated when a baseline testing or revalidation testing is performed per subsections of 2 to 4 of Section 503.19 and subsections of 3, 5 and 7 of Section 503.20. The PSCAD model of the entire facility needs to be validated against the small signal tests performed in the field to demonstrate that the EMT model mimics the response observed from the tests.

Figure 3 illustrates various triggers for when the submission of new EMT model or an updated EMT model for an existing facility may be required. This figure also includes the required reports, which must accompany the submitted EMT model. It is the responsibility of MPs to provide the model along with requested documentation and reports.

In general, the inverter-based facility owner must commit to updating the model for the entire period during which the equipment in question will remain in service. Any equipment changes, updates to plant software firmware or settings that alter dynamic performance or protection operation must be captured in a revised model(s) submission to AESO.

Any update to the previous models by the Original Equipment Manufacturer (e.g., version change, control system representation change, etc.) would also require a submission of the updated model. The revised model(s) must be accompanied by appropriate reports.

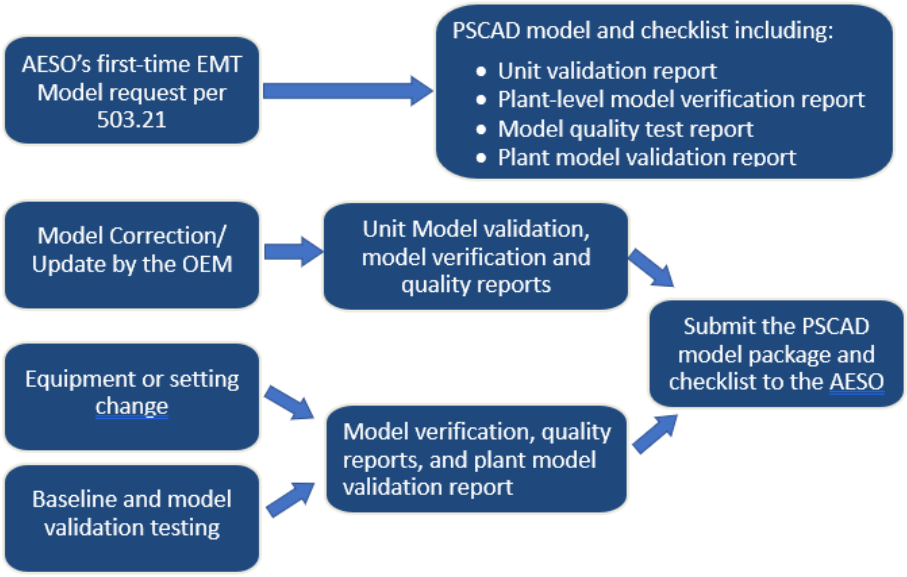

Figure 3 PSCAD model submission requirement for existing IBR resources in operations.

Refer to the detailed descriptions in Appendix 4 of ID #2010-001R for a comprehensive understanding of the reports (unit validation report, plant-level model verification report, and model quality test report) required as part of the PSCAD model submission to the AESO.

5 Contact Information

The legal owner may email the *Model Validation and Reactive Power Verification Reports* and associated data electronically to the AESO at psmm@aeso.ca in accordance with Sections 503.19 and subsection 7 of Section 503.20. For *Model Validation and Reactive Power Verification Reports* conducted as part of an AESO connection project, the legal owner may submit the *Model Validation and Reactive Power Verification Report* and associated data to the AESO Project Manager.

Revision History

Posting Date	Description of Changes
2024-04-19	Amended to align with Energy Storage Resource amendments to the ISO rules. Added the description of the initial test conditions, in subsection 2.5 (h).
2024-03-13	Added the EMT model baseline testing and revalidation testing reports in section 4. Added benchmarking positive sequence dynamic models with EMT simulation in subsection 2.9. Added additional verification process in subsections 2.2 (g), 2.3 (p), 2.5(b) (g), and 2.6(f).
2022-01-14	Clarified content that is optional for legal owners to provide in subsections 2.2 and 2.3 of this information document. Administrative amendment to align with current AESO drafting principles, update references to ISO rules.
2018-09-04	Aggregated generation facilities included.
2017-11-21	Initial release.