Bonneville
POWER ADMINISTRATION

Interconnection Model Requirements

STD-N-000001 Number 05 REVISION 00

Standard/Technical Content Owner: TPP

DESCRIPTION:

This is a supporting document to the BPA STD-N-000001, "Technical Requirements for Interconnection to the BPA Transmission Grid." It details power flow, positive sequence transient (PST), and Electro-Magnetic Transient (EMT) model requirements for generation and load facilities seeking transmission interconnection service.

Questions should be directed to your Customer Service Engineer.

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1. REVISION HISTORY

- Revision 00 01/26/2026: Initial development of this supporting document.

2. INTENT

The intent of this supporting document is to detail the modeling requirements for loads and generating facilities seeking interconnection service. This is intended to be a publicly available document that aligns with FAC-001 documentation of interconnection requirements.

This document is intended to clarify what separates acceptable models from unacceptable models as pertain to interconnection studies. Model types covered in this document are power flow, positive-sequence transient (PST), and Electro-magnetic transient (EMT) models, which are used to perform interconnection studies.

The requirements herein are intended to align with industry best practices for Bulk Power System transient modeling including IEEE 2800 and NERC Reliability Guidelines.

This document does not explain the interconnection study process, model submission process, or information protection like Non-Disclosure Agreements in detail.

3. FACILITY DATA

The requirements in this section can be met by submitting, for example, datasheets, pictures of nameplates, and markups about site specific settings.

Item	Description	Check
1	List of: facility name, commercial operation date (or estimate), Energy Information Agency (EIA) plant code (if known), interconnecting Point of Interconnection (POI) bus name and nominal voltage, name and number of POI bus in the WECC model.	
2	Electrical one-line diagram The electrical one-line diagram should include but is not limited to: mechanically switched capacitors or reactors, dynamic reactive devices, equipment ratings, equipment connections, collector system, transformer configuration, generator configuration and grounding, bus, circuit breaker and disconnect switch arrangements, loads, facility tie line.	
3	Description of the energy source or load type with MW, MVA, kV nameplate values (nuclear, natural gas, hydro, wind, solar, biomass, geothermal, coal, energy storage, etc.)	
4	Operating temperatures, maximum and minimum ambient operating temperatures	
5	Station Service, station service load for plant auxiliaries (kW and kVAR), station service load connection description,	

Item	Description	Check
	including which distribution utility will provide service when all generation is off	
6	Generating facility plant level controls, description of plant level controls for voltage and frequency, including coordination of real and reactive power production from all sources: • Voltage control: if applicable, include set-point location and value, droop, line drop compensation or reactive current compensation, reactive capability curve in equation form • Frequency control: if applicable, governor settings for droop, dead-band, for Inverter-Based Resources (IBRs) fast frequency control description and operating status (on/off), governor manufacturer (if applicable). • Power System Stabilizer (if applicable)	
7	Inverter Units, number, type, model, manufacturer, nameplate ratings, de-rate curves based on temperature and elevation, and dc energy source of each inverter unit	
8	Inverter Loading Ratio, for solar photovoltaic projects the ratio of DC panel capability to AC inverter capability	
9	Turbine Generators, number, type, vendor, manufacturer, model of each turbine generator, nameplate data, governor manufacturer	
10	Additional Energy Storage requirements, plan to charge from the AC grid, ac-coupled or dc-coupled (for hybrid projects), nameplate ratings, total energy capacity, maximum allowable charge/discharge rate, and maximum/minimum state of charge. In addition,	
11	All facility transformer specifications • Generator Step-Up (GSU) (gen. terminal voltage to transmission level voltage), • Collector Substation Main Transformers (collector system voltage to transmission level voltage) • Unit Transformers (inverter/gen. terminal voltage to collector system voltage) • Load step-down transformers (for load interconnection requests) nameplate, type, winding configuration, winding ratio, X/R ratio, test report data from manufacturer, zero sequence information, number and size of fixed tap positions, actual fix-tap position, cooling type (ONAN/ONAF/OFAF) and ratings, and impedance, on-load tap changer (OLTC) number of taps up and down, OLTC tap size, OLTC regulating voltage and settings, OLTC tap timing	

Item	Description	Check
12	Other equipment behind the POI (e.g. mechanically-switched shunt capacitors or reactors, dynamic reactive devices), nameplate ratings, number, and locations which can be shown on the one-line diagram	

4. POSITIVE SEQUENCE POWER FLOW MODEL REQUIREMENTS

4.1 Attestation

Item	Description	Check
1	The Large Generator Interconnection (LGIP) Attachment A to Appendix 1 includes an attestation of positive sequence model accuracy meeting this standard. Provide the completed attestation.	

4.2 Model Requirements

Item	Description	Check
1	Complete and accurate power flow model: Generator and step-up transformer, and other equipment behind the POI such as discrete shunts, dynamic reactive devices (e.g. STATCOM), and tie-lines parameterized to most completely and accurately represent the facility. Equivalent model**,** if applicable, plant equivalent representation as described in WECC modeling guidelines, including other equipment behind the POI such as discrete shunts, dynamic reactive devices (e.g. STATCOM), and tie-lines parameterized to most completely and accurately represent the facility. WECC MVWG , "WECC Guide for Representation of Photovoltaic Systems in Large-Scale Load Flow Simulations," August 2010. [Online]. Available: https://www.wecc.org/sites/default/files/documents/program/2024/WECC%20PV%20Plant%20Power%20Flow%20Modeling%20Guide.pdf	
2	Reactive capability curve, reactive capability curve for each turbine generator explicitly modeled and each equivalent unit generator explicitly modeled (captures OEL, UEL, and Rated Power).	

Additionally, for load interconnections:

Item	Description	Check
3	The completed interconnection request form: LINE AND LOAD INTERCONNECTION REQUEST	
4	Complete the load forecast tables below as a Comma separated value (.csv) file	

Load Forecast Table (at energization and every year for twenty years)

Value for Year	1	2	3	4	5	6	7	8	9	10
Projected Peak Load (MW)										
Summer Peak Load (MW)										
Winter Peak Load (MW)										
Anticipated Power Factor										

Value for Year	11	12	13	14	15	16	17	18	19	20
Projected Peak Load (MW)										
Summer Peak Load (MW)										
Winter Peak Load (MW)										
Anticipated Power Factor										

Anticipated Peak Load Season (winter, spring, summer, fall): ___________________

Anticipated Peak Load Hours (hours: 1 to 24, all that apply): ___________________

4.3 Model Project Files and Submission Requirements

Item	Description	Check
1	Power flow models provided in PowerWorld format (*.aux) or PSLF format (*.epc)	
2	For Load Interconnection Requests, submit the Load Forecast Table as a Comma Separated Value file (.csv).	

5. POSITIVE SEQUENCE TRANSIENT MODELING REQUIREMENTS

5.1 Attestation

Item	Description	Check
1	The Large Generator Interconnection (LGIP) Attachment A to Appendix 1 includes an attestation of positive sequence model accuracy meeting this standard. Provide the completed attestation.	

5.2 Model Requirements

BPA requires WECC approved dynamic models that have been verified by the Interconnection Customer to be accurately structured and parameterized to best reflect the planned or installed equipment.

REPC_B models will not be accepted due to limitations explained in “Relative Limits” section of the WECC MVS Guideline “Clarification on Proper Use of REPC Models” here: Clarification on Proper Use of REPC models.pdf

BPA may provide a Model Acceptance Tool to customers. BPA uses this tool to help facilitate the model acceptance process for positive-sequence transient models. If available, the tool may facilitate the model acceptance process by fostering a collective understanding of the tests, their inputs, and the acceptance process. The tool is currently hosted at: NW Wind Modeling Tools and Documentation. If provided, the tool is provided “as is” and may be updated without warning.

Item	Description	Check
1	Generator Model parameters	
2	Governor Model parameters	
3	Excitation System Model parameters	
4	Power System Stabilizer (PSS) Model parameters	
5	Generator/Converter Model	
6	Electrical Controls Model	
7	Plant-level Control Model (REPC_B is not permitted)	
8	Applicable models for wind turbine generators (drivetrain, aero-dynamic, pitch-controller, and torque controller models)	
9	Relay Model parameters for: Overcurrent, Under Frequency, Low/High Frequency Ride Through, and Low/High Voltage Ride Through settings	
10	For IBRs including IBR storage facilities, IEEE Std 2800-2022 Clause 10, Modeling data, and Annex G, Recommendation for modeling data, apply	

For load interconnections:

Item	Description	Check
11	Relay Model parameters for: Overcurrent, Under Frequency, Low/High Frequency Ride Through, and Low/High Voltage Ride Through settings	
12	Maximum ramp rate during normal operations	
13	Maximum ramp rate during a power system event	
14	Post-event ramp rates when returning to normal operations	
15	WECC Composite Load Model type and region (for selection of the composite load model of the plant)	

5.3 Submission Requirements

Item	Description	Check
1	Transient models provided in PSLF format (*.dyd)	

2	(Optional) BPA Model Acceptance Tool report, input files	

6. FULL-SEQUENCE FAULT STUDY MODELS

6.1 Attestation and Process

Item	Description	Check
1	The Large Generator Interconnection (LGIP) Attachment A to Appendix 1 includes an attestation of model accuracy meeting this standard. Provide the completed attestation.	
2	The models for the Generating Facility shall provide short circuit models: a) that are accurate and validated, by Interconnection Customer, to represent the performance characteristics of the Generating Facility b) that are re-validated, updated, and submitted to Transmission Provider, by Interconnection Customer, after a Qualified Change to the Generating Facility as required by BPA in STD-N-000001 c) on the same timeline as the other models in STD-N-000001-05.	
3	Subsequent to Commercial Operation, Interconnection Customer shall provide "as-built" ASPEN OneLiner models that are accurate and validated, by Interconnection Customer, to represent the performance characteristics of the Generating Facility, including disturbance ride through and short circuit characteristics, as required by STD-N-000001	

6.2 Model Requirements

Item	Description	Check
1	ASPEN version 15 (or later) model that includes an aggregated equivalent generator or energy storage model of total power in MW and apparent power in MVA output at each collection transformer secondary winding where primary winding connects to BPA at the system voltage and at the POI. SEE: Large Generator Interconnection Procedures (LGIP) - Bonneville Power Administration	
2	Model aggregated equivalent of Type IV wind, solar, and energy storage as either Voltage Controlled Current Source generator type (VCCS) or the Converter-Interface Resource generator type (CIR). The Current Limited generator model is no longer a valid model representation of Type IV wind, solar, and energy storage.	

3	Model aggregated equivalent of Type III wind generation as a Type III Wind Plant generator model.	
4	Include a model of the grid connected collector transformer winding configuration with the positive and zero sequence impedances for all winding configurations to which the aggregated equivalent generator model is attached. For line connected projects include any neutral grounding device needed to maintain fault detection relay sensitivity at adjacent substations.	
5	Perform base case simulations to show that the model accurately simulates steady-state fault duty at collection site.	

6.3 Model Project Files and Submission Requirements

1	ASPEN OneLiner model using version 15 (or later)	
2	Provide a One-Line diagram up to POI showing the project equipment, connecting lines, voltage, and ratings.	
3	Provide a summary of the Project protective strategies and control system philosophy affecting the grid at the POI.	
4	Provide a summary of the Project operation related to fault ride through, reactive power capability, and voltage regulation.	
5	Provide the allowable range of inverter short current capabilities over the first 20 cycles during a transmission line fault immediately adjacent to the project. This would normally be provided by the inverter manufacturer and used for slope calculations.	
6	Provide length in miles, positive, and zero sequence of any customer-owned lines from the project to the point of interconnect.	

7. ELECTRO-MAGNETIC TRANSIENT (EMT) MODELING REQUIREMENTS

7.1 Attestation

Item	Description	Check
1	The Large Generator Interconnection (LGIP) Attachment A to Appendix 1 includes an attestation of EMT model accuracy meeting this standard. Provide the completed attestation.	

7.2 Model Requirements

Item	Description	Check
1	PSCAD model using PSCAD version 5.0.2 or later.	
2	Be compiled using Intel Fortran compiler and capable of running in Intel Fortran version 15 and higher and Microsoft Visual Studio 2015 and higher	
3	Provide 32-bit and 64-bit versions of libraries. Intel will eventually discontinue their 32-bit Fortran compiler.	

4	Support the PSCAD “snapshot” feature.	
5	Support the PSCAD “multiple run” feature.	
6	Allow replication in different PSCAD cases or libraries through the “copy” or “copy transfer” features.	
7	Avoid using PSCAD simulation sets, as these are difficult to incorporate into large cases.	
8	Accurately simulates for a timestep between 5 μs and 20 μs. Model does not require a specific timestep.	

The following requirements were tailored from 1.1 of NERC’s “Reliability Guideline: Electromagnetic Transient Modeling for BPS Connected Inverter-Based Resources—Recommended Model Requirements and Verification Practices” published March 2023. https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Reliability_Guideline-EMT_Modeling_and_Simulations.pdf

Item	Description	Check
	Usability	
10	Pertinent control functions and associated parameters are accessible.	
11	Maximum simulation time step to retain model accuracy is specified.	
12	It is easy to identify product variants or specific configuration intended for the facility.	
13	Model can be easily dispatched with various commands, such as power commands and voltage control set point.	
14	Model comes with comprehensive documentation, such as user guide covering software dependencies and model limitations	
15	Model package simulation includes all required files (Dynamic Link Library (DLL) and other libraries) to run a quick test simulation to verify.	
16	Easy to scale the plant model to represent smaller or larger plant capacity.	
17	Multiple instances of the model can coexist in a single simulation.	
	Efficiency	
18	Model can initialize itself to a dispatched level and can reach steady state quickly (< 5 seconds, wall clock time).	
19	Model does not cause unusual or unreasonable computational burden.	
	Accuracy	
20	Plant collector system and inverter GSU equivalencing techniques are documented, and ratings are visible to the end-user	

Item	Description	Check
21	Aggregation and scaling techniques used to develop the aggregate inverter model, and their limitations are clear to the end-user and documented	
22	Main power transformers, substation components, and generator tie lines are modeled explicitly and visible to the end-user for verification purposes	
23	Transformer nameplate values match transformer test report and winding configurations match site design	
24	Transformer models should include saturation characteristics to the extent that they are known.	
25	Detailed fast control loops of the power electronics are implemented as installed in the actual equipment in the field.	
26	DC side and any current, power or energy limitations are represented in the model (Modeling dc side with an ideal voltage source is not acceptable if such a representation prevents the possibility of protection operation)	
27	All pertinent control features and operating modes of the actual installed equipment (both inverter and plant-level) are included in the model.	
28	Control settings are agreed upon and “certified” by the equipment manufacturers as being configured appropriately in the field.	
29	All protection functions relevant to the performance of the facility are included. (Actual firmware code is recommended to be implemented in the model for these features.)	
30	Inverter-level protections (software and hardware), including all hardware limitations and protections	
31	Plant level protection, which could result in the plant tripping, such as current, voltage and frequency elements, with as detailed vendor-specific protective functions as possible.	
32	Each equipment installed in the field is traceable back to a specific inverter make, model, and software version.	
33	Equipment manufacturer certification that the EMT model matches the equipment that is (or will be) installed in the field.	
34	Communications delays between devices and sampling delays—inverters, plant-level controllers, automation controllers, metering, and protective relaying are modeled and match the equipment that is (or will be) installed in the field.	
Site-specific Plant and Model Documentation		
35	Type of facility (e.g., solar PV, wind, battery energy storage system, hybrid)	

Item	Description	Check
36	List of all equipment manufacturers (particularly for the inverter, plant-level controller, and any other significant controls within the facility) installed at the site	
37	Points of contact and contract information for model-related questions for all equipment manufacturers involved in the facility	
38	List of all makes and models of inverters with versions of firmware and plant-controllers within the facility	
39	Documentation of plant name(s), commercial operation date(s), Energy Information Agency plant name and code, interconnecting TO bus name and nominal voltage, defined POI location	
40	Equipment specification sheets and user manuals	
41	Equipment protection settings	
42	Equipment controls descriptions (e.g., plant-level controls hierarchy, voltage control strategy, theory of operation)	
43	Inverter or plant-level controller screenshots or settings sheets and mapping of product settings to model settings for all relevant functions	
44	Facility one-line diagrams	
45	Communications delays between devices and sampling delays: inverters, plant-level controllers, automation controllers, metering, and protective relaying	
46	Controls are black-boxed, and no PSCAD master library control blocks are visible within control circuits. If the model is not based on "real code", a separate validation report is required showing model comparison against hardware tests. -Model documentation shall contain information confirming the use of real code in the model, or -Model documentation shall include a validation of the model by utilizing hardware in loop platform or other hardware test systems.	
47	List of EMT model files provided and their intended purpose	
48	User manual for EMT model that describes all aspects of the functional use of the model in BES reliability studies	
49	Description of inverter- and plant-level settings with units for any applicable settings	
50	Description of control modes, which may be supplemented by control block diagrams (block diagrams for plant-level active and reactive power control loops and any grid support functions should be included)	
51	Model limitations, including maximum solution time step	

Item	Description	Check
52	Software requirements, including versions	
53	Instructions on how to set up and use the model	

8. MODELING BEYOND THE INTERCONNECTION STUDY PROCESS

STD-N-000001 covers modeling during the interconnection process. In addition, NERC MOD standards cover model validation and reporting requirements. As a Planning Coordinator, BPA posts requirements and process information regarding MOD-032, MOD-026/-027, and others at this linked location (under the Planning Coordinator project): Reliability NERC Standards - Bonneville Power Administration. One important requirement to highlight is that a new model must be submitted each time a change to the generation facility alters the equipment response characteristic.

9. REFERENCES

North American Electric Reliability Corporation (NERC), "Reliability Guideline: Electromagnetic Transient Modeling for BPA-Connected Inverter-Based Resources—Recommended Model Requirements and Verification Practices" https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Reliability_Guideline-EMT_Modeling_and_Simulations.pdf (Accessed 07/22/2024)

North American Electric Reliability Corporation (NERC), "Reliability Guideline: Recommended Practices for Performing EMT System Studies for Inverter-Based Resources" https://www.nerc.com/comm/RSTC_Reliability_Guidelines/1_08%20Draft_Reliability%20Guideline%20Recommended%20Practices%20for%20EMT%20%20Studies%20for%20IBR_RSTC.pdf (Accessed 07/22/2024)

Institute of Electrical and Electronics Engineers (IEEE), "IEEE 2800-2022: IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems" https://standards.ieee.org/ieee/2800/10453/ (Accessed 07/11/2024)

Electric Reliability Council of Texas (ERCOT), "ERCOT PSCAD Model Submittal Guidelines" version 1.8, https://www.ercot.com/services/rq/re then go to "Model Quality Guide" then open file "PSCAD_Guideline_Checksheet_2024.docx" (Accessed 07/22/2024)

Western Electricity Coordinating Council (WECC) Modeling and Validation Working Group (MVWG), "Solar Photovoltaic Power Plant Modeling and Validation Guideline" December 9, 2019, https://www.wecc.org/sites/default/files/documents/meeting/2024/Solar%20PV%20Plant%20Modeling%20and%20Validation%20Guidline.pdf (Accessed 08/15/2024)

Western Electricity Coordinating Council (WECC) Modeling and Validation Working Group (MVWG), "WECC Wind Power Plant Power Flow Modeling Guide" May 2008. https://www.wecc.org/sites/default/files/documents/program/2024/WECC%20Wind%20Plant%20Power%20Flow%20Modeling%20Guide.pdf (Accessed 08/15/2024)

Bonneville Power Administration, "NW Wind Modeling Tools and Documentation: Interconnection Model Acceptance Tool" https://transmission.bpa.gov/Business/Operations/GridModeling/default.aspx (Accessed 10/31/2025).

Western Electricity Coordinating Council (WECC) Modeling and Validation Subcommittee (MVS), "Clarification on Proper Use of REPC models" December 2021

https://www.wecc.org/sites/default/files/documents/meeting/2024/Clarification%20on%20Proper%20Use%20of%20REPC%20models.pdf (Accessed 10/31/2025).

Bonneville Power Administration, "Large Generator Interconnection Procedures (LGIP)"

https://www.bpa.gov/energy-and-services/transmission/interconnection/large-generator (Accessed 10/31/2025)

"Reliability Guideline: Electromagnetic Transient Modeling for BPS Connected Inverter-Based Resources—Recommended Model Requirements and Verification Practices" published March 2023.

https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Reliability_Guideline-EMT_Modeling_and_Simulations.pdf (Accessed 10/31/2025)

Bonneville Power Administration, "Reliability and NERC Standards" https://www.bpa.gov/energy-and-services/transmission/reliability-nerc-standards (Accessed 10/31/2025)