New York ISO
Independent System Operator

UG 28

NYISO Electromagnetic Transient (EMT) Modeling Guideline

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Revision History

Version	Effective Date	Revisions
1.0	11/11/2024	Initial Release
1.1	02/14/2025	Global ➢ Updated and corrected broken hyperlinks
2.0	06/25/2025	Section 7.4 ➢ Updated Figure 6

Acknowledgement

The NYISO would like to express its gratitude to Electranix Corporation for allowing the NYISO to partially replicate portions of its original "PSCAD Model Requirements Rev. 12" document.

1. Objectives

The purpose of this guideline is to introduce guidelines and verification tests that will be used to assess the quality of EMT models submitted to the NYISO. Through these tests, it is expected that the amount of modeling related issues will be significantly reduced upfront, prior to studies being conducted. The expectation is that by addressing potential modeling issues and EMT model conflicts early, study delays will be minimized.

All EMT models submitted to NYISO must follow these guidelines and entities submitting EMT models are instructed to procced as follows: Compile all answers to questions in Section 6 and Section 7 (including test results) into a document and submit it as a separate attachment to the NYISO. Plots for all tests must be submitted in the same sequence in which they appear in the tests.

2. Applicability

These guidelines apply to all EMT models submitted to the NYISO, at the time of EMT model submission. All EMT models submitted must align with the baseline performance specified for each test.

In most cases, the tests attempt to verify functionalities associated with IBR generation plants, since those are the vast majority of EMT models received by the NYISO. For generation plants that include other power electronics assets as part of the plant (i.e., supplemental devices behind the plant point of interconnection), the aggregate plant model must include a representation of those supplementary devices.

EMT models for generation plants that utilize well established prime mover technology (non-IBRs, such as hydro turbine-generator, combined cycle units, nuclear units, etc.) are exempt from performing these tests and will be evaluated separately on a case-by-case basis.

For non-generation devices (or transmission devices), if an EMT model of a particular device does not render itself to a specific test, that test may be dismissed, as long as reasonable justification is provided. For instance, a STATCOM is not expected to have to comply with tests related to active power variations since it is not expected to have an active power setpoint reference that could be adjusted. Equal considerations should be made to other devices, such as point to point HVDC, load models, as well as any other non-generation power electronics EMT models. When in doubt, the model submitter is encouraged to reach out to NYISO Stakeholder Services at stakeholder_services@nyiso.com seeking clarification.

3. General Guidelines

The following elements are required to improve study efficiency, model compatibility, and enable the use of multiple EMT models in a particular case/study. Some items may require additional discussion and clarification.

a. Model must be able to compile with Intel Fortran compiler oneAPI 2021.0.0 and newer.

b. Model must be compatible with PSCAD version 5.0.2 or newer.

c. Model must support multiple instances of its own definition in the same simulation case.

d. Model must support the PSCAD "timed snapshot" feature accessible through project settings.

e. Model must not use or rely upon global variables in the PSCAD environment.

f. Model must not utilize multiple layers in the PSCAD environment, including 'disabled' layers.

g. Model must be compiled with Visual Studio 2022 or newer.

4. Model Accuracy Guidelines

4.1 Represent All Control Loops in Detail

Models which embed the actual hardware/firmware code (i.e., “real code”) into a PSCAD component are strongly preferred. However, models that are not “real code” but accurately capture equipment behavior are also acceptable.

If the model is developed by manually creating a block diagram/code from a larger, more complex product code or firmware, the model cannot use approximations typically used in transient stability modeling (e.g., simplifying current regulators with time delay blocks, not include PLLs, not including transient current limits, etc.). It must represent all controls as implemented in the actual individual inverter units, turbine controllers, plant controllers and multi-plant controllers, as applicable.

The NYISO does not restrict EMT model origins or attempts to classify models using general terms, such as “generic models”, “user-written” models, “real-code” (firmware) models, etc. All EMT models, regardless of its type or source of origin, are required to be accurate and will be validated against a combination of field data, lab tests (type tests, acceptance tests, etc.) and field recordings to ensure they accurately capture actual equipment behavior. This validation will likely take place towards the end of the plant construction process, when the plant can be tested, but prior to plant/equipment entering commercial operation. At that point, equipment settings and model parameterization should be well defined. Additional guidance on how to perform these tests will be provided in the future.

Full switching models that account for the representation of power electronic switches (e.g., IGBT, Thyristors, etc.) are preferred, but accurate average models are acceptable, as long as they include the appropriate level of detail required by the studies being performed. The type of model provided must be disclosed upon submission.

4.2 Represent All Control Features Pertinent to the Type of Study Being Done

Examples include external voltage controllers, customized PLLs, ride-through controllers, SSCI damping controllers and others, dynamic breaking resistors (e.g., “DC choppers”) and their protective devices, etc. Operating modes that require system specific adjustment must be user accessible, properly configured and well documented via a model user guide. The model will be used to perform typical planning studies and will be exposed to faults, switching transients, control reference/setpoint changes, etc. As such, it must capture all features that affect plant performance during those events.

4.3 Include Representation of Plant Level Controls or Multi-Plant Controllers, As Applicable

Power Plant Control (PPC), as well as any other outer loop controls (e.g., multi-plan coordination controllers) that affects equipment performance in timeframe of interest for the studies being conducted, must be included in the model. Plant controllers must be represented in sufficient detail to accurately represent short term transient performance, including specific measurement methods, measurement and communication latencies, transitions into and out of ride-through modes, settable control parameters or control modes, and any other specific implementation details which may impact plant performance. If multiple plants are controlled by a common controller, or if the plant includes multiple types of IBRs (e.g. Hybrid BESS/PV), this functionality must be included in the plant control model. If supplementary voltage control devices (e.g. STATCOM) are included in the plant, these should be coordinated with the PPC. If additional outer control layers exist and respond within the timeframes of the studies being performed, they must also be represented in the model.

4.4 Represent All Pertinent Electrical and Mechanical Components

This includes any filters and specialized transformers. There may be other mechanical features such as gearboxes, pitch controllers, drivetrain, or others which must be modelled if they impact electrical performance within the timeframe and electrical purview of certain studies. Any control or dynamic features of the actual equipment which may influence behavior in the simulation period which are not represented, or which are approximated must be identified and an explanation of why it was left out must be provided. The DC “chopper” circuit (i.e., dynamic breaking resistor) and its protective functions (e.g., thermal overload protection, etc.) must be represented in detail.

4.5 Have All Pertinent Protections Modeled in Detail

This typically includes various under and over voltage protections (individual phase and RMS), frequency protections, DC bus voltage protections, converter overcurrent protections, and other inverter specific protections. Any protective function that can impact dynamic performance in timeframe of interest for the study must be accounted for. As previously mentioned, actual hardware code (i.e., “real code”) is strongly preferred to be used for these protection features. Real code in EMT models exponentially increases the chances of identical performance between the EMT model and field equipment, which is highly desirable. To the extent possible, protection of plant/device auxiliaries must also be considered if they are known to be critical to the ability of the plant/device to remain in operation after disturbances. Explicitly modeling plant auxiliaries may not be necessary if proxy protective functions can be used. For instance, over and under frequency/voltage relays could be used to account for limited plant/device ride through capability due to its auxiliaries.

4.6 Model Must Be Configured to Match Site-Specific Equipment Settings

All EMT models shall be configured in accordance with field settings used by the equipment at each site. Any user-tunable parameters or options must be set in the model to match the equipment at the specific site being evaluated. Default parameters that do not reflect actual field settings are strongly discouraged as they may introduce discrepancies between plant and model performance during model validation steps.

4.7 EMT Model Response Must Align With Positive Sequence Phasor Domain (PSPD) Model

The behavior of the EMT model and the PSPD model used to represent the plant/equipment is expected to be in close alignment and will be verified by the NYISO. **The models are used to represent the same plant and therefore should behave in a similar fashion.** Selected tests in Section 7 will be used to verify alignment between the EMT model and the PSPD model. **The NYISO and the model submitter must use the same PSPD model for the asset for this comparison**. The NYISO will use the latest PSPD model submitted for the facility in this verification. As such, PSPD models do not need to be re-submitted at this stage.

Differences that arise from increased modeling bandwidth in EMT domain are known to exist and will be allowed, as long as they can be justified. Differences in model response trends, post-transient steady state settling values, or any behavior in a timeframe that can be accurately captured by PSPD models with typical integration time steps used in those simulations (1-4ms) are not allowed and any discrepancies will require further explanation.

All EMT and PSPD channels delivered must be overlayed (in the same plot) for each channel type (i.e., active power, reactive power, voltage, etc.). A qualitative criterion will be used to determine if the models are in good alignment and no quantitative criterion (e.g., signal envelopes, peak values, etc.) will be employed at this time.

5. Model Usability Guidelines

All PSCAD models submitted must:

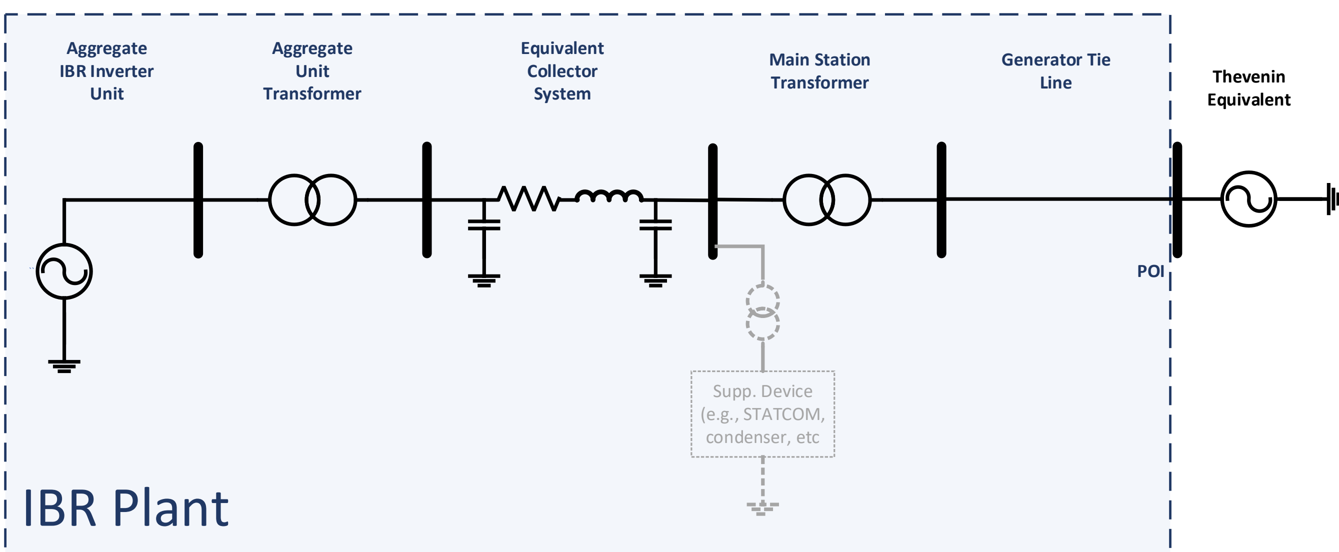
5.1 Reflect an Aggregate Representation of the Plant

Unless otherwise specified by NYISO, an aggregate IBR plant representation will be required by default. An example of aggregate representation when a single type of inverter is present in the plant is shown in Figure 1.

The aggregate representation will typically include:

- An aggregate voltage source converter (VSC) for each inverter type in the plant
- An aggregate inverter unit transformer for each aggregate inverter type in the plant
- An equivalent collector system
- One (or more) station step-up transformers (if more than one is present)
- Generator tie line connecting the plant to the rest of the system.
- Supplemental devices or equipment that may exist to support the plant performance (e.g., STATCOMs, synchronous condensers, capacitor and reactor banks, etc.).
- Any other existing equipment that is part of the IBR plant must be included in the aggregate model

Figure 1: Aggregate Representation of IBR Plant



If multiple inverter types are used in a plant, an aggregate representation must be developed for each individual type. For instance, if a wind plant uses two types of wind turbines, then an aggregate model with two distinct VSCs representing each wind turbine type will be required. In exceptional circumstances, the NYISO may request the submission of non-aggregate IBR plant models, where each individual VSC/inverter unit and collector system cables are explicitly represented. All transformers included in the EMT model must model saturation. Transformer saturation may have an impact in certain types of studies, such as energization studies, or transient overvoltage performance upon fault clearing, especially in weak grids.

5.2 Have Control or Hardware Options Which Are Pertinent to the Study Accessible to the User

All parameters that may need to be adjusted to evaluate a range of possible operating modes or performance requirements, such as control flags, must be accessible for use by the model user. Examples of this could include control modes (e.g., voltage control mode, constant Q control mode, etc.), FFR and PFR enable/disable flags, protection thresholds, real power recovery ramp rates, frequency or voltage droop settings, reference setpoints for active power, reactive power, power factor, voltage, etc. Diagnostic flags (e.g. flags to show control mode changes or which protection has been activated) should be visible and active to aid in analysis.

5.3 Able to Operate at a Range of Time Steps

Often, requiring a smaller time step means that the model control implementation has not used the interpolation features of PSCAD, or is using inappropriate interfacing between the model and the larger network. Lack of interpolation support introduces inaccuracies into the model at larger simulation time-steps. In cases where the power transistor (e.g. IGBT) switching frequency is so high that even interpolation does not allow accurate switching representation at 10 µs (e.g. switching frequency greater than 40 kHz), an average source approximation of the inverter switching is preferred.

5.4 Include a Model User Guide and a Sample Case

The sample case must be configured according to the site-specific real equipment configuration up to the Point of Interconnection. This would include (for example): aggregated generator model, aggregated generator transformer, equivalent collector branch, main plant transformers, plant tie line, power plant controller, and any other static or dynamic reactive resources. Test case must use a single machine equivalent (SME) to represent the rest of the system. The equivalent machine must be configured with an appropriate SCMVA that is in a reasonable range that is observed at the interconnection point. More details about the testbed configuration are provided in Section 7.2.

Access to technical support engineers is desirable. The model documentation must also provide an obvious way to identify the specific settings and equipment configuration, proper labeling of model parameters and an explanation of their functions, etc.

5.5 Accept/Expose Reference Setpoints

This includes real and reactive power reference setpoints values for active/reactive power control modes, or voltage reference setpoints for voltage control modes. The model must accept these setpoint variables for initialization and be capable of changing the setpoint variables mid-simulation, i.e. dynamic signal references. It is recommended that models expose inputs to certain control functionalities to enable testing of performance requirements, such as the ability to inject a frequency perturbation to test PFR, FFR, etc. Additionally, this capability is critical when attempting to replicate staged field tests in EMT models.

5.6 Be Capable of Initializing Itself As Quickly As Possible

Once provided with initial condition variables, the model must initialize and ramp to the ordered output as quickly as possible, without external input from simulation engineers. The model should preferably initialize in less than 5 seconds but not take longer than 10 seconds to reach steady state. Any slower control functions which are included (such as switched shunt controllers or power plant controllers) must also accept initial condition variables if required. Note that during the first few seconds of simulation (e.g. 0-2 seconds) the system voltage and corresponding terminal conditions may deviate from nominal values due to other system devices initializing and the model must be able to tolerate these deviations or provide a variable initialization time.

5.7 Have the Ability to Scale Plant Capacity

The active power capacity of the model must be scalable in some way, either internally or through an external scaling component. This is distinct from a dispatchable power order and is used for modeling different capacities of plant or breaking a lumped equivalent plant into smaller composite models.

5.8 Have the Ability to Set Plant Active Power Reference Setpoint (Pref) Between Pmax and Pmin

This is distinct from scaling a plant from one unit to more than one and is used for testing plant behavior at various operating points.

6. PSCAD Model Test Checklist

6.1 Definitions

IBR – Inverter Based Resource

ICR – IBR continuous Rating (as defined in IEEE 2800)

ICAR – IBR continuous Absorption Rating (as defined in IEEE 2800)

POI – Point of Interconnection (as specified in the generator/device interconnection agreement)

6.2 Model Functionality Checklist

Project Name:	
Project Developer:	
Model Test date:	
Interconnection Location:	
Rated Capacity at POI:	
Equipment type: (e.g. PV, Wind, BESS or Hybrid)	
Manufacturers:	
Equipment version/lines:	
Documentation files (OEM):	
Documentation files (site specific):	
Model Files supplied:	

Item number		**Compliant? (Yes/No)**	**If No in previous column, provide additional details/comments.**
Model Accuracy Features			
1	Is the model based on an identical replica of firmware code (i.e., "real code")?		
2	Operating modes which require system specific adjustment are accessible.		
3	Plant level controller is included as specified in this document and is properly documented.		
4	Model can respond to frequency deviations.		
5	Includes pertinent electrical and mechanical features, such as gearboxes, pitch controllers, or other features which impact the plant performance in the simulation period.		
6	All protections which could impact ride-through performance are modeled in detail		
7	Model is configured for the specific site being evaluated.		
8	Is a full-switching representation used?		
Model and Project Documentation			

8	Model includes documentation.		
9	Documentation includes instruction for setup and running the model. The Vendor's name and the specific version of the model must be clearly observable in the .pscx PSCAD case. Documentation and supporting model filenames must not conflict with model version shown in the .pscx case file.		
10	Model is supplied with a sample test case including site specific plant representation.		
11	Plant single line diagram is provided and matches the PSCAD model diagram.		
12	Model documentation provides an obvious way to identify site-specific settings and equipment configuration.		
Model Usability Features			
13	Total active and reactive power, voltage (RMS and instantaneous) and current (RMS and instantaneous) **at the POI** are available for plotting. All values must be in pu on the plant/device ICR or ICAR rating (as defined in IEEE 2800).		
14	Total active and reactive power, voltage (RMS and instantaneous) and current (RMS and instantaneous) **at the aggregate inverter terminals** are available for plotting. All values must be in pu on the plant/device ICR or ICAR rating(as defined in IEEE 2800).		
15	Control or hardware options are accessible to the user as applicable.		
16	Diagnostic flags are visible to the user.		
17	Model uses a timestep greater than 10 µs. Model allows a range of simulation timesteps (i.e. not restricted to a single timestep).		
18	Model accepts external reference variables for active and reactive power and voltage setpoint, and these may be changed dynamically during the simulation.		
19	Model can initialize itself.		
20	Active power capacity is scalable.		
21	Active power is dispatchable.		
22	Model reaches setpoint P, Q, and V in less than 5 seconds.		
23	Model compatible with Intel FORTRAN oneAPI version 2021 and newer.		
24	Model compiles using PSCAD version 5.0.2 or newer.		
25	Model supports multiple instances of its own definition in a single PSCAD case.		
26	Model supports PSCAD "snapshot" feature.		
27	Model supports the PSCAD "multiple run" feature.		
28	Model does not use PSCAD global variables.		

29	Model does not use PSCAD layer functionality.		
30	Model is compiled using Microsoft® Visual Studio v.2022 or newer.		

7. Model Tests

7.1 Description

The intent of these tests is to verify if EMT models meet minimum levels of functional capabilities and can be effectively used in studies. Test results will not be used as a proxy to determine if an IBR plant meets performance requirements, such as NYSRC Reliability Rule B5 (RR.B5) or IEEE 2800. A summary of all tests to be applied is provided below. All model documentation and test results will be reviewed by the NYISO upon receipt, at which point the NYISO may choose to re-run some (or all) tests for verification.

7.2 Testbed Setup

If the model being tested is a generation or energy storage plant, the test case shall include the representation of the aggregate plant model up to the point of interconnection. As mentioned previously, this should include an aggregate VSC/generator model, aggregate converter unit transformer, collector equivalent, main station transformer and a generator tie line, if existent. A pictorial representation of this topology was provided in Figure 1. Variations from this aggregate representation are allowed and must be based on the equipment included in the plant and whether multiple types of inverter technology exist in the plant. A single AC voltage source equivalent (Thevenin Equivalent) shall be connected at the POI to represent the rest of the system and must reflect typical SCMVA at the POI.

If the model being tested is an HVDC line (or other two terminal device that connects in series with the transmission system), the tests must be performed on both terminals of the model (e.g., on both HVDC stations). Two Thevenin equivalent must be created, each representing typical system SCMVA at each end. The NYISO may run additional tests depending on whether the project in consideration is expected to provide specific services. For instance, if the HVDC line/station is expected to provide Black Start Services, the NYISO may test its ability to "black start" and energize a portion of the system.

7.3 Measured Signals and Deliverables

The following signals/channels must be made available in the EMT model for access as needed. Only a subset of these signals are required to be submitted as described in the *deliverables* section of each test.

Signals at the Aggregate Inverter terminals:

Total active (P) and reactive power (Q), voltage (RMS and instantaneous) and current (RMS and instantaneous) must be made available for plotting in the EMT model. All values must be in put on the plant/device ICR or ICAR rating (as defined in IEEE 2800), except for instantaneous quantities which must be in kV or Ampere.

Signals at the Point of Interconnection:

Total active (P) and reactive power (Q), voltage (RMS and instantaneous) and current (RMS and instantaneous) must be made available for plotting in the EMT model. All values must be in put on the plant/device ICR or ICAR rating (as defined in IEEE 2800), except for instantaneous quantities, which must be in kV or Ampere.

7.4 Test Description

Tests	Baseline Performance
Test 1: Initialization Test	Specified in Table 1
Test 2: Balanced Fault Ride-through Tests	Specified in Table 2
Test 3: Unbalanced Fault Ride-through	Specified in Table 3
Test 4: Over-Voltage Ride-through	Specified in Table 4
Test 5: Voltage Reference Step Change	Specified in Table 5
Test 6: Active Power Reference Step Change	Specified in Table 6
Test 7: Grid Frequency Response and Ride-Through	Specified in Table 7
Test 8: PFR and FFR tests	Specified in Table 8
Test 9: Grid Voltage Phase Angle Change Ride-Through	Specified in Table 9
Test 10: POI SCR Change Tests (informational)	Specified in Table 10 – this test is informational and no baseline response is defined
Test 11: Voltage Protection Inclusion	Specified in Table 11

Test 1 Initialization Test

Test Description

The goal of Test 1 is to verify that the model initializes properly and can reach steady state within reasonable time. A description of each event is provided in Table 1.

Models Tested

This test must be applied to both the EMT and the PSPD model of the plant/device.

Deliverables

Plots of the following quantities versus time (in seconds) must be submitted for each test, for both the EMT and PSPD model. EMT and PSPD signals must be overlayed in the same plot; a single signal type (e.g., active power, reactive power, etc.) must be included in each plot.

- Total active power at the POI
- Total reactive power at the POI
- Phase to ground voltages at the POI (RMS for each phase) and positive sequence voltage (for comparison with PSPD model)

Table 1: Initialization Test

Test #	Test Description			Baseline Response
	Test duration [s]	MW injection at POI	MVAr injection at POI	
1-1	20	Pmax	0	Reach steady state in less than 5s; remain in steady state for the remainder of the simulation period; POI MW, MVAr and voltage are all within ±1% of their reference setpoint values
1-2	20	Pmin	0	Reach steady state in less than 5s; remain in steady state for the remainder of the simulation period; POI MW, MVAr and voltage are all within ±1% of their reference setpoint values

Test 2 Balanced Fault Ride-through Tests

Test Description

The goal of this test is to verify that the model can ride through balanced three phase to ground faults without tripping. A description of each event considered is provided in Table 2. Zf represents the fault impedance and Zs represents the driving point impedance at the POI without the interconnecting plant.

Models Tested

This test must be applied to both the EMT and the PSPD model of the plant/device.

Deliverables

Plots of the following quantities versus time (in seconds) must be submitted for each test, for both the EMT and PSPD model. EMT and PSPD signals must be overlayed in the same plot; a single signal type (e.g., active power, reactive power, etc) must be included in each plot.

- Total active power at the POI
- Total reactive power at the POI
- Phase to ground voltages at the POI (RMS for each phase) and positive sequence voltage (for comparison with PSPD model)

Table 2: Balanced Fault Ride-through Tests

Test #	Test Description					Baseline Response
	Fault duration [s]	Fault type	Fault impedance Zf	Active Power at POI	Initial Approx. Reactive Power at POI	
2-1	0.16	3PHG	Zf=0	Pmax	0	Rides Through
2-2	2.50	3PHG	Zf=Zs	Pmax	0	Rides Through

Test 3 Unbalanced Fault Ride-through Tests

Test Description

The goal of this test is to verify that the model can ride through unbalanced faults without tripping. The faults considered include any single line to ground (SLG) fault, any two line-to-line (LL) fault and any two line to-line-to-ground (LLG) fault. A description of each event considered is provided in Table 3.

Models Tested

This test must be applied to the EMT model of the plant/device.

Deliverables

Plots of the following quantities versus time (in seconds) must be submitted for each test.

- Total active power at the POI
- Total reactive power at the POI
- Phase to ground voltages at the POI (RMS for each phase)

Table 3: Unbalanced Fault Ride-through Tests

Test #	Test Description					Baseline Response
	Fault duration [s]	Fault type	Fault impedance Zf	Active Power at POI	Initial Approx. Reactive Power at POI	
3-1	0.16	LLG	Zf=0	Pmax	0	Rides Through
3-2	0.16	SLG	Zf=0	Pmax	0	Rides Through
3-3	0.16	LL	--	Pmax	0	Rides Through
3-4	0.16	LLG	Zf=0	Pmin	0	Rides Through
3-5	0.16	SLG	Zf=0	Pmin	0	Rides Through
3-6	0.16	LL	--	Pmin	0	Rides Through

Test 4 Overvoltage Ride-through Tests

Test Description

The goal of this test is to verify that the model can ride through overvoltage events. Simulation time can be arbitrarily chosen, as long as the overvoltage event is applied after the plant reaches steady state and the plant returns to steady state after the event is cleared. A description of each event is provided in Table 4.

Models Tested

This test must be applied to both the EMT and the PSPD model of the plant/device.

Deliverables

Plots of the following quantities versus time (in seconds) must be submitted for each test, for both the EMT and PSPD model. EMT and PSPD signals must be overlayed in the same plot; a single signal type (e.g., active power, reactive power, etc.) must be included in each plot.

- Total active power at the POI
- Total reactive power at the POI
- Phase to ground voltages at the POI (RMS for each phase) and positive sequence voltage (for comparison with PSPD model)

Table 4: Overvoltage Ride-through Tests

Test #	Test Description				Baseline Response
	Overvoltage Event Duration [s]	Grid Voltage at POI (see notes below)	Active Power at POI	Initial Approx. Reactive Power at POI	
4-1	1.0	1.2 pu	Pmax	0	Rides Through
4-2	1.0	1.2 pu	Pmax	Qmax	Rides Through
4-3	1.0	1.2 pu	Pmin	0	Rides Through
4-4	1.0	1.2 pu	Pmin	Qmax	Rides Through

Note 1: This test must be performed by varying the voltage reference setpoint at the Thevenin equivalent voltage source.

Note 2: If the Thevenin equivalent voltage source is not able to hold voltage at 1.2pu during the test, an infinite strength source may be used in this test (e.g., a voltage source with extremely high SCMVA).

Test 5 Voltage, Reactive Power and Power Factor Reference Step Tests

Test Description

The goal of this test is to verify that the model can regulate voltage, reactive power or power factor at the POI. A description of each event is provided in Table 5. It is possible that small plants in strong areas of the system may not be able to change the regulated voltage to the voltage setpoint value. In those situations, equipment limits (e.g., maximum Q range) may be limiting accurate voltage regulation and additional explanation may be needed.

Models Tested

This test must be applied to both the EMT and the PSPD model of the plant/device.

Deliverables

Plots of the following quantities versus time (in seconds) must be submitted for each test, for both the EMT and PSPD model. EMT and PSPD signals must be overlayed in the same plot; a single signal type (e.g., active power, reactive power, etc.) must be included in each plot.

- Total active power at the POI
- Total reactive power at the POI
- Phase to ground voltages at the POI (RMS for each phase) and positive sequence voltage (for comparison with PSPD model)

Table 5: Voltage, Reactive Power and Power Factor Reference Step Tests

Test #	Test Description			Baseline Response
	Event	Active Power at POI	Reactive Power at POI	
5-1	Incremental V reference setpoint change as per Figure 2	Pmax	0	Stable response
5-2	Incremental V reference setpoint change as per Figure 2	Pmin	0	Stable response
5-3	Incremental Q reference setpoint change as per Figure 3	Pmax	0	Stable response
5-4	Incremental Q reference setpoint change as per Figure 3	Pmin	0	Stable response
5-5	PF reference setpoint change as per Figure 4	Pmax	0	Stable response
5-6	PF reference setpoint change as per Figure 4	Pmin	0	Stable response
5-7	With the plant in voltage control mode, apply the incremental voltage reference change shown in Figure 2. ** see note 1 below.*	Pmax	0	15 second response time

Note 1: Test 5-7 must be performed by varying the voltage reference setpoint of the Thevenin equivalent voltage source

Figure 2: Incremental Voltage Reference Setpoint Change

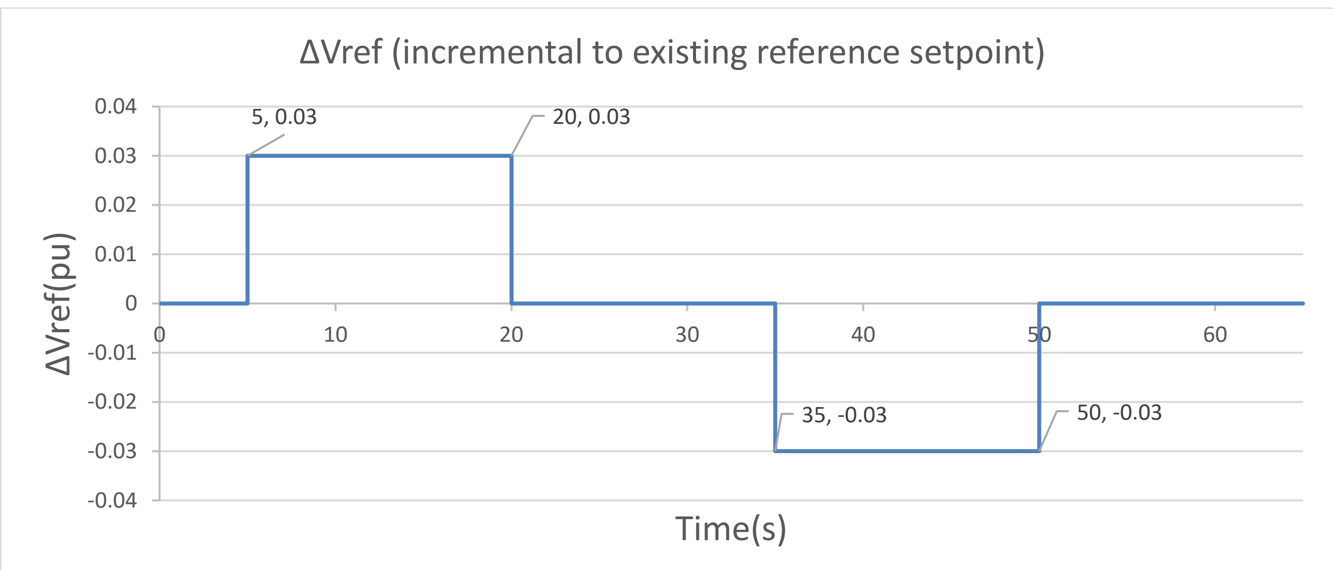


Figure 3: Incremental Reactive Power Reference Setpoint Change

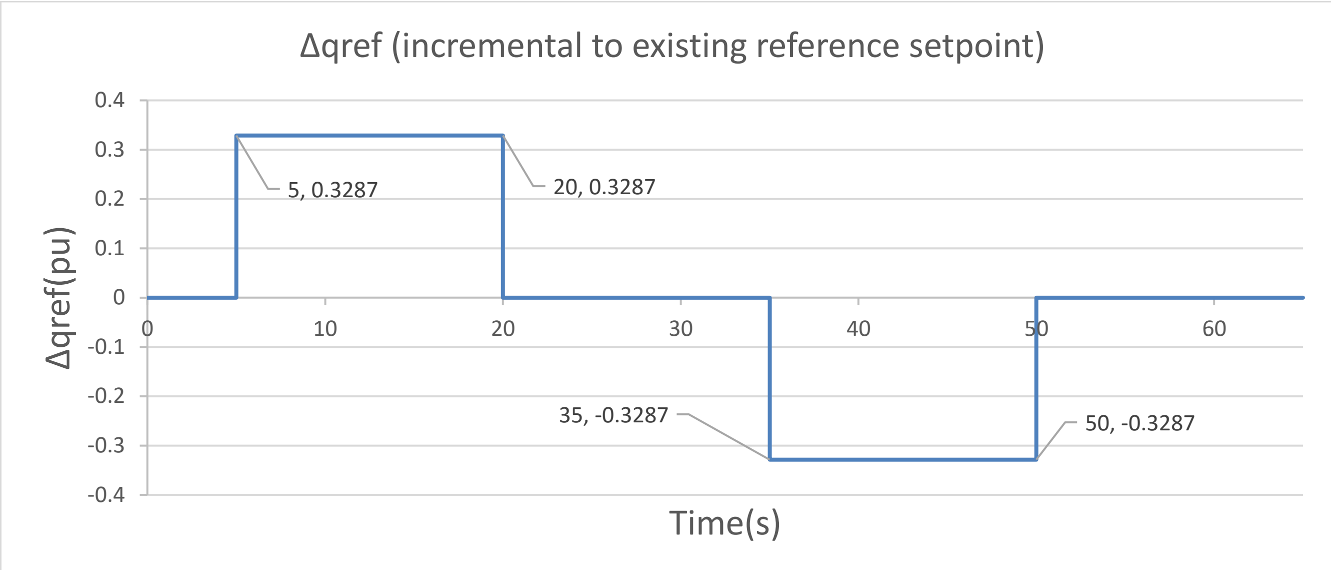
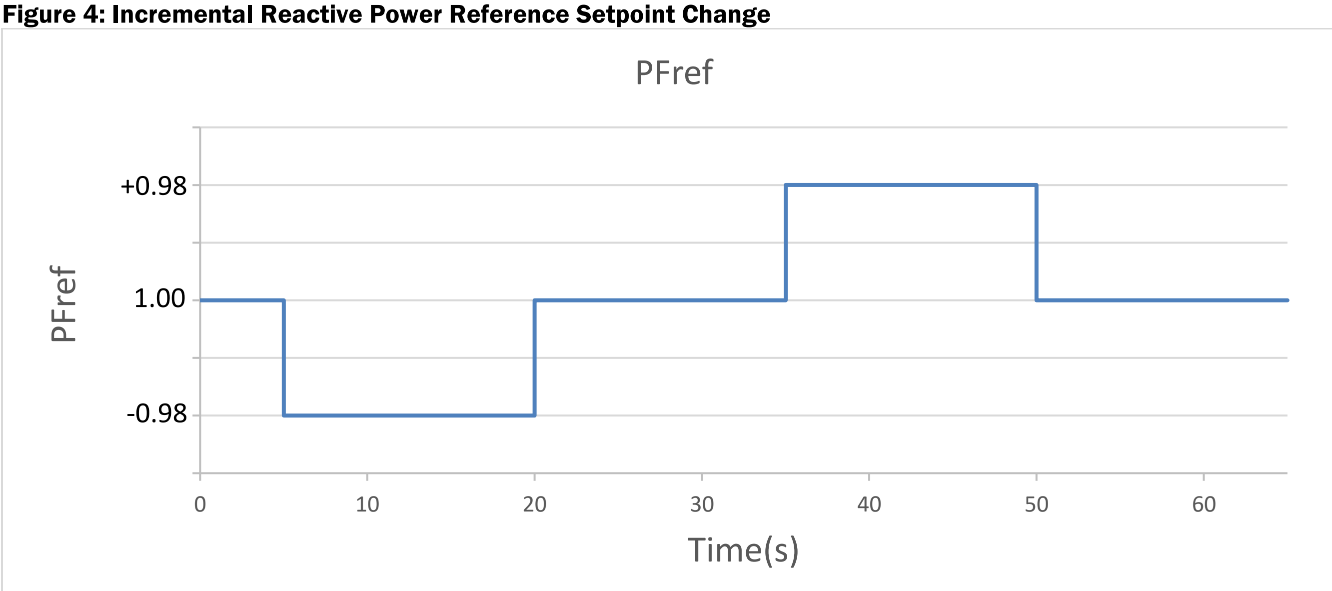


Figure 4: Incremental Reactive Power Reference Setpoint Change



Test 6 Active Power Reference Ramp Tests

Test Description

The goal of this test is to verify that model active power output at the POI can follow the active power reference setpoint. If the model output is limited by Pmin during the test, that should be mentioned in the test report. A description of each test event is provided in Table 6.

Models Tested

This test must be applied to both the EMT and the PSPD model of the plant/device.

Deliverables

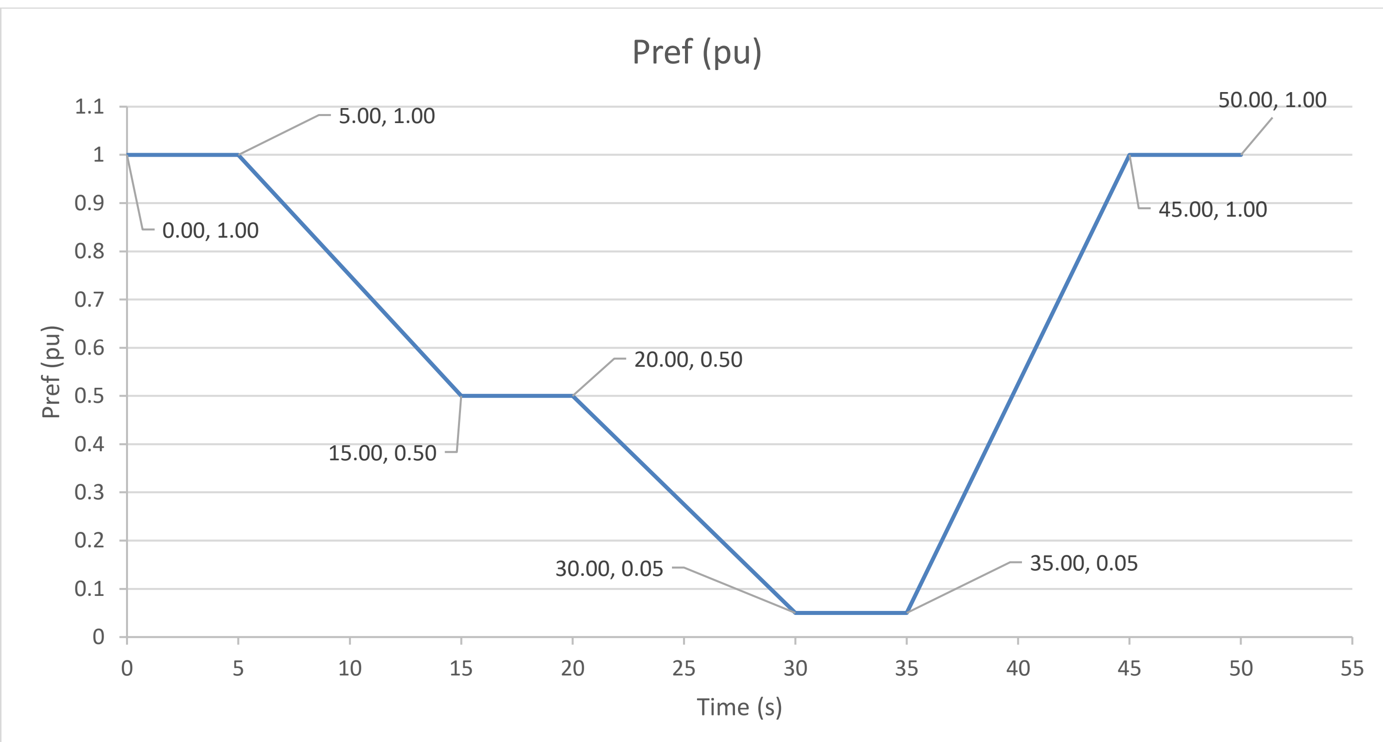
Plots of the following quantities versus time (in seconds) must be submitted for each test, for both the EMT and PSPD model. EMT and PSPD signals must be overlayed in the same plot; a single signal type (e.g., active power, reactive power, etc.) must be included in each plot.

- Total active power at the POI
- Total reactive power at the POI
- Phase to ground voltages at the POI (RMS for each phase) and positive sequence voltage (for comparison with PSPD model)

Table 6: Active Power Reference Ramp Tests

Test	Test Description			Baseline Response
	Event	Active Power at POI	Initial Approx. Reactive Power at POI	
6-1	Active power reference setpoint change as per Figure 5	Pmax	0	Active power output at POI follows Pref command shown in Figure 5

Figure 5: Chart Showing Pref Variations with Time



> ***Note:*** For plants where Pmin is greater than 0.05pu, Pgen may not be able to follow Pref up to 0.05pu. That is an acceptable and expected outcome.

Test 7 Frequency Ride Through Tests

Test Description

The goal of this test is to verify that the model can ride-through frequency events and does not trip during the test. The test signal must be applied at the Thevenin equivalent voltage source.

Models Tested

This test must be applied to both the EMT and the PSPD model of the plant/device.

Deliverables

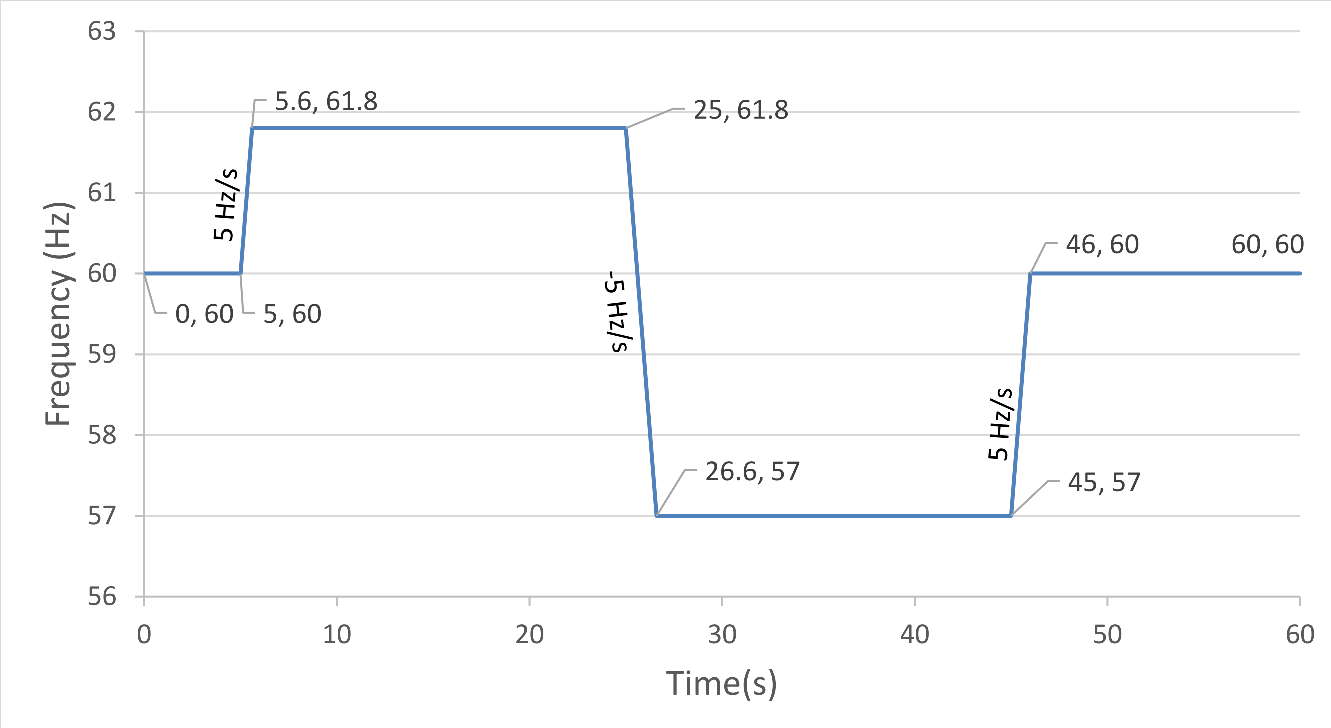
Plots of the following quantities versus time (in seconds) must be submitted for each test, for both the EMT and PSPD model. EMT and PSPD signals must be overlayed in the same plot; a single signal type (e.g., active power, reactive power, etc) must be included in each plot.

- Total active power at the POI
- Total reactive power at the POI
- Phase to ground voltages at the POI (RMS for each phase) and positive sequence voltage (for comparison with PSPD model)
- Frequency event applied and measured POI frequency

Table 7: Frequency Ride Through Tests

Test #	Test Description			Baseline Response
	Events	Active Power at POI	Initial Approx. Reactive Power at POI	
7-1	Grid Frequency Change as per Figure 6	Pmax	0	Rides Through
7-2	Grid Frequency Change as per Figure 6	Pmin	0	Rides Through

Figure 6: Grid Frequency Event to Test Frequency Ride Through



Test 8 PFR and FFR tests

Test Description

The goal of this test is to verify that the model PFR and FFR controls are included in the model and that they respond as expected. For all tests, ensure that the plant has enough headroom and footroom to provide PFR and/or FFR.

For tests 8-1 and 8-2, ***the test signal must be applied to the FFR/PFR frequency signal summation junction of the controls. As such, an input port that allows signal injection must be available.***

For tests 8-3 and 8-4, ***the test signal must be applied at the Thevenin equivalent voltage source so that it is seen by the model as a variation of grid frequency rather than an injected frequency signal.***

> ***Note 1:*** Both PFR and FFR controls shall be parameterized using default settings in accordance with guidelines from NYSRC reliability Rule B5 (i.e., IEEE 2800 Tables 7 and 9).

> ***Note 2:*** If FFR controls are implemented at the individual converter/turbine units rather than at the plant level controller, the EMT model must allow the isolation of the individual converter unit from the plant level controller for testing purposes. This functionality would allow validation of FFR controls against field tests/measurements by allowing field tests at an individual unit to be replicated in the model. In other words, the EMT model should allow the same topological representation that would be used in a field test of the FFR functionality.

Models Tested

This test must be applied to both the EMT and the PSPD model of the plant/device.

Deliverables

Plots of the following quantities versus time (in seconds) must be submitted for each test, for both the EMT and PSPD model. EMT and PSPD signals must be overlayed in the same plot; a single signal type (e.g., active power, reactive power, etc.) must be included in each plot.

- Total active power at the POI
- Total reactive power at the POI
- Phase to ground voltages at the POI (RMS for each phase) and positive sequence voltage (for comparison with PSPD model)
- Frequency event applied and measured POI frequency

Table 8: PFR and FFR tests

Test #	Test Description			Baseline Response
	Events	Active Power at POI	Reactive Power at POI	
8-1	With FFR controls disabled and PFR controls enabled, apply the frequency signal shown in Figure 7.	P_{POI} = 0.5*Pmax $P_{available}$=Pmax	0	IBR plant active power output varies by at least 0.321pu
8-2	With FFR controls enabled and PFR controls disabled, apply the frequency signal shown in Figure 8	P_{POI} = 0.5*Pmax $P_{available}$=Pmax	0	No significant response for the over frequency step; IBR plant active power shall reduce by at least 0.1pu
8-3	With FFR controls disabled and PFR controls enabled, apply the frequency signal shown in Figure 7.	P_{POI} = 0.5*Pmax $P_{available}$=Pmax	0	IBR plant active power output varies by at least 0.321pu, with response time in line with values in Table 8 of IEEE 2800
8-4	With FFR controls enabled and PFR controls disabled, apply the frequency signal shown in Figure 8.	P_{POI} = 0.5*Pmax $P_{available}$=Pmax	0	No significant response for the over frequency step; IBR plant active power shall reduce by at least 0.1pu, with response time in line with values described in section 6.2.2 of IEEE 2800

Figure 7: Grid Frequency Event Used to Test PFR

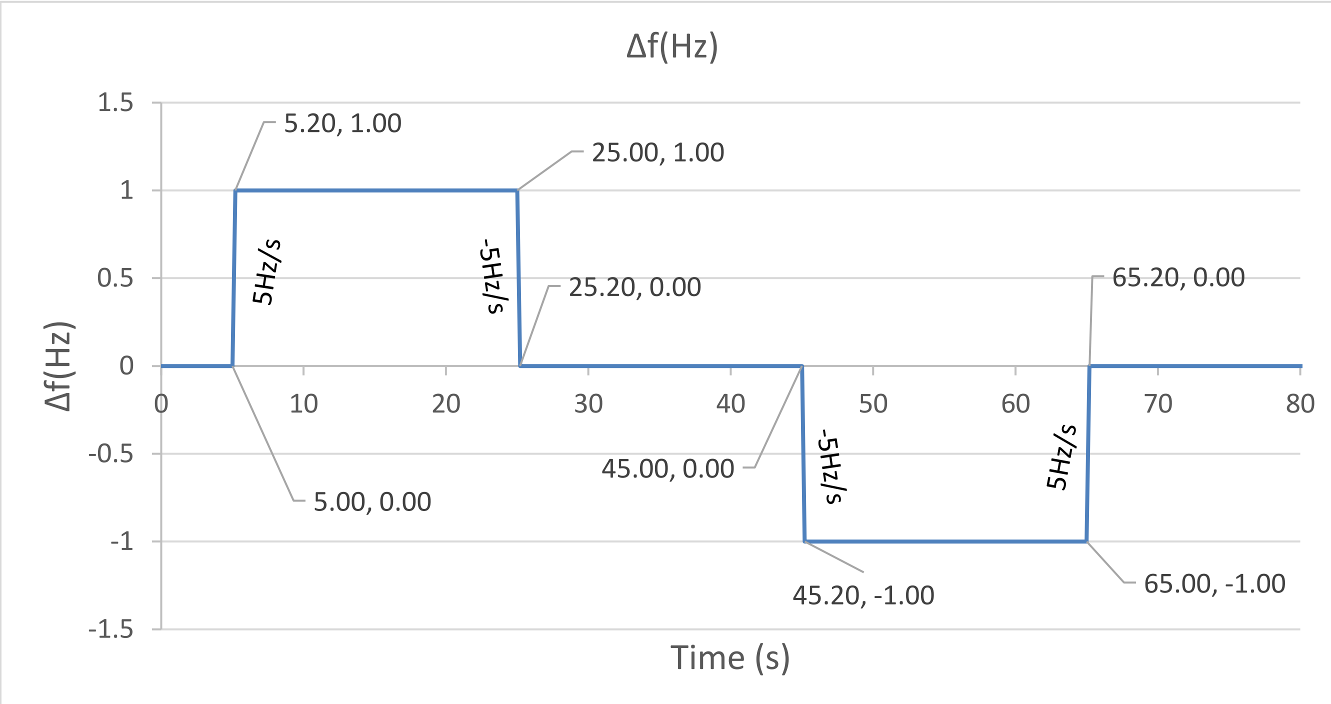
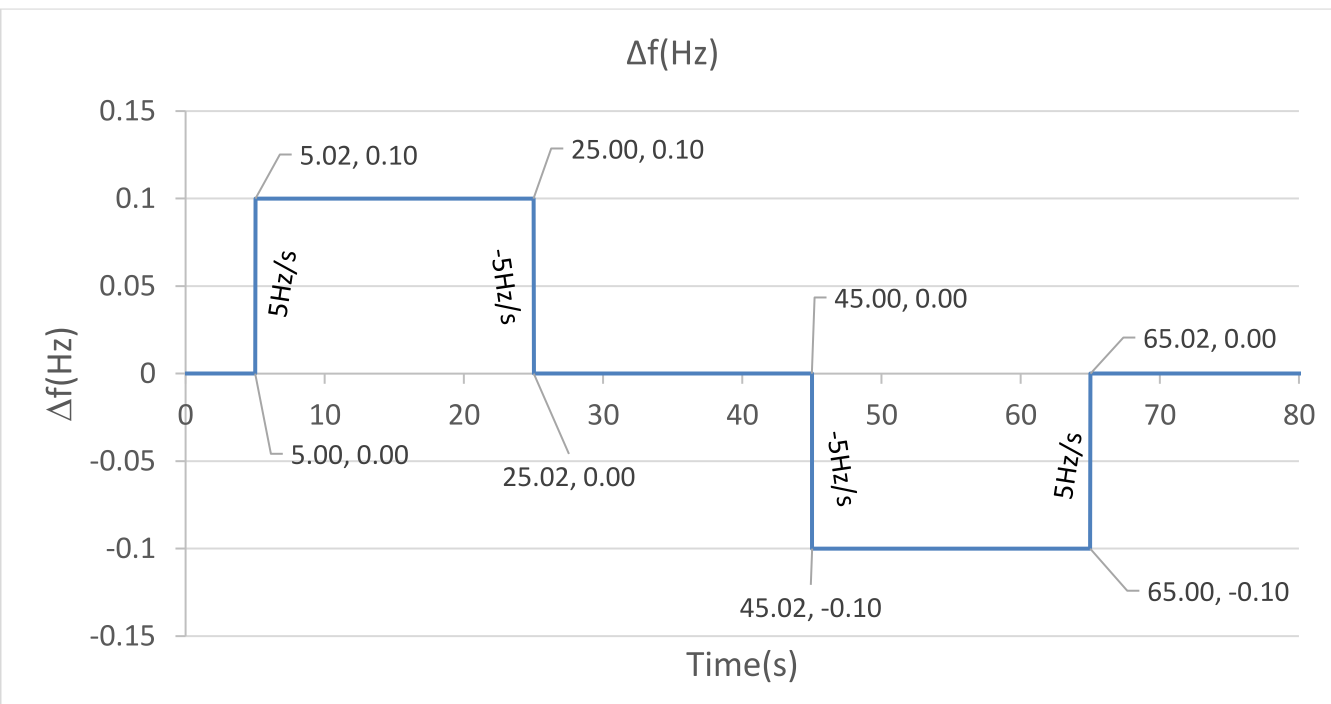


Figure 8: Grid Frequency Event Used to Test FFR



Test 9 Phase Angle Jump Test

Test Description

The goal of this test is to verify that the model can ride through phase/angle jumps.

Models Tested

This test must be applied to the EMT model of the plant/device.

Deliverables

Plots of the following quantities versus time (in seconds) must be submitted for each test.

- Total active power at the POI
- Total reactive power at the POI
- Phase to ground voltages at the POI (RMS for each phase)
- Phase to ground voltage at the POI (instantaneous voltages for each phase such that it enables observation of the phase angle jump applied)

Table 9: Phase Angle Jump Test

Test#	Test Description			Baseline Response
	Events	Active Power at POI	Reactive Power at POI	
9-1	POI voltage angle change equal to +25°	Pmax	0	Rides Through
9-2	POI voltage angle change equal to -25°	Pmax	0	Rides Through
9-3	POI voltage angle change equal to +25°	Pmin	0	Rides Through
9-4	POI voltage angle change equal to -25°	Pmin	0	Rides Through

Test 10 SCR Test

Test Description

The goal of this test is to verify at which SCR the model becomes unstable to a three-phase to ground fault as system strength is reduced. During test, the SCR is gradually reduced at equal time intervals and a three-phase to ground fault is applied at the POI at each SCR transition. The fault must be cleared in 6 cycles (0.1 sec) without removing any element from service.

Figure 9 illustrates how SCR must change over time.

Models Tested

This test must be applied to both the EMT and the PSPD model of the plant/device.

Deliverables

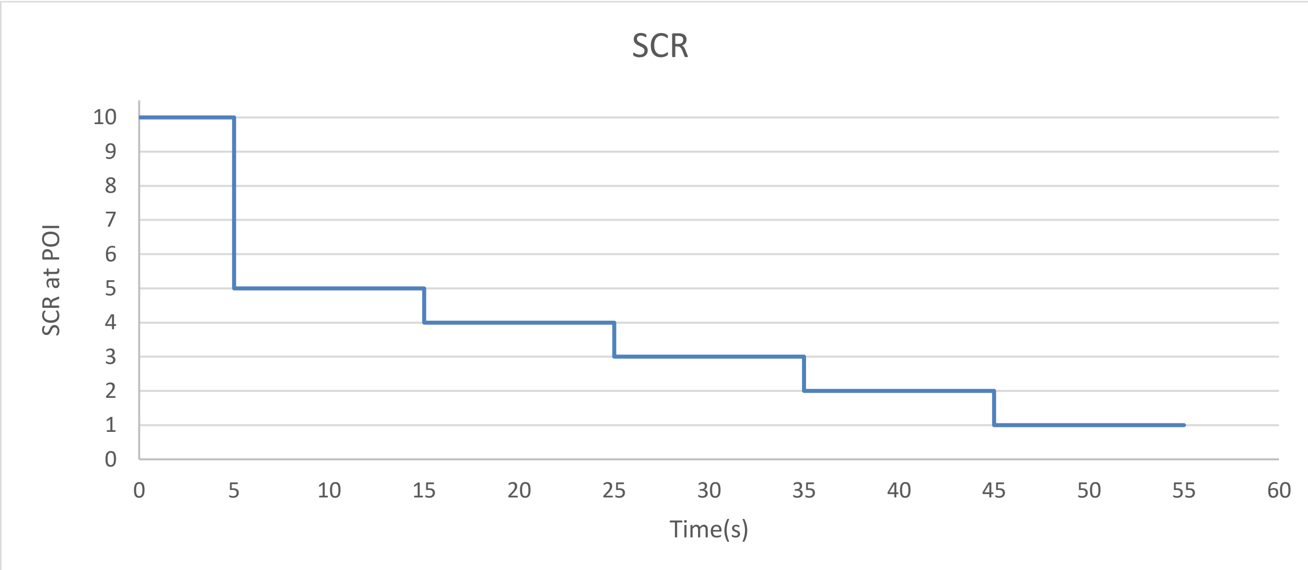
Plots of the following quantities versus time (in seconds) must be submitted for each test, for both the EMT and PSPD model. EMT and PSPD signals must be overlayed in the same plot; a single signal type (e.g., active power, reactive power, etc.) must be included in each plot.

- Total active power at the POI
- Total reactive power at the POI
- Phase to ground voltages at the POI (RMS for each phase) and positive sequence voltage (for comparison with PSPD model)
- SCR at the POI

Table 10: SCR Test

Test#	Test Description			Reference Response
	Events	Active Power at POI	Reactive Power at POI	
10-1	Vary the short circuit ratio at the POI as shown in Figure 9. At each SCR transition, apply a 3PHG fault and clear in 0.1s without tripping any element.	Pmax	0	For informational purposes only
10-2	Vary the short circuit ratio at the POI as shown in Figure 9. At each SCR transition, apply a 3PHG fault and clear in 0.1s without tripping any element.	Pmin	0	For informational purposes only

Figure 9: Figure Illustrating SCR Variation to be Used in This Test



Test 11 Over and Under Voltage Protection Verification Test

Test Description

The goal of this test is to verify that protective functions are included in the model. This is achieved by applying abnormally high and low voltages for an extended period of time, as shown in

Figure 10 and

Figure 11. A detailed description of the tests to be performed is provided in Table 11.

Models Tested

This test must be applied to both the EMT and the PSPD model of the plant/device.

Deliverables

Plots of the following quantities versus time (in seconds) must be submitted for each test, for both the EMT and PSPD model. EMT and PSPD signals must be overlayed in the same plot; a single signal type (e.g., active power, reactive power, etc.) must be included in each plot.

- Total active power at the POI
- Total reactive power at the POI
- Phase to ground voltages at the POI (RMS for each phase) and positive sequence voltage (for comparison with PSPD model)

Table 11: Over and Under Voltage Protection Verification Test

Test#	Test Description			Baseline Response
	Events	Active Power at POI	Reactive Power at POI	
11-1	Apply the voltage step shown at Figure 10 to the POI.	Pmax	0	Model shall trip
11-2	Apply the voltage step shown in Figure 11 to the POI.	Pmax	0	Model shall trip

Figure 10: Overvoltage Event Used to Test Protection

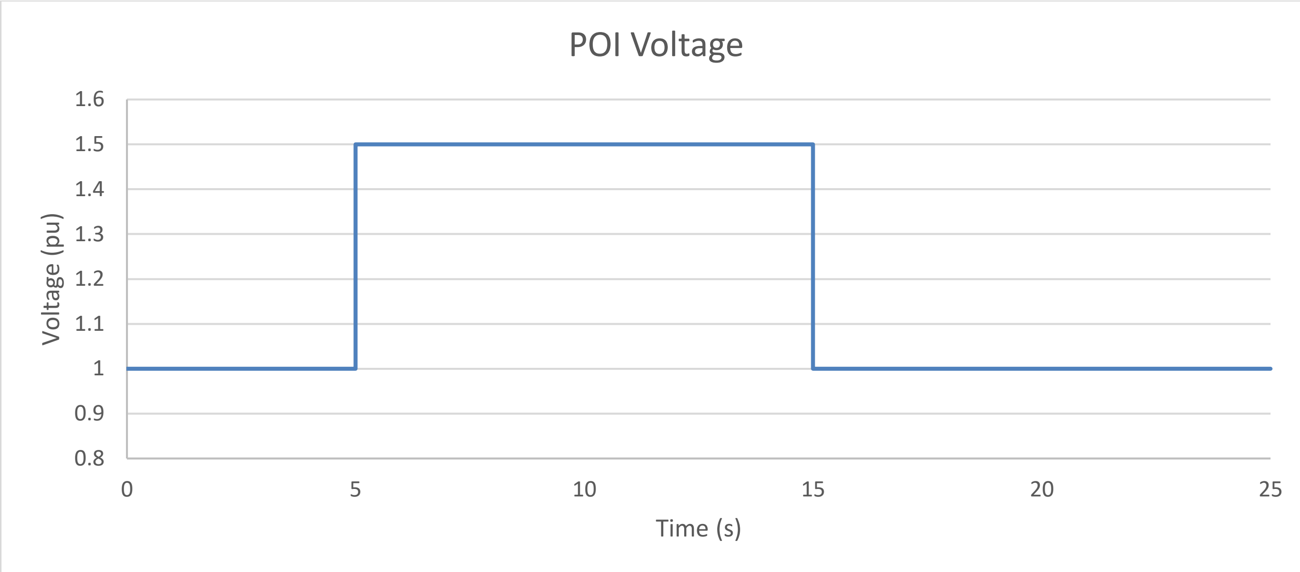
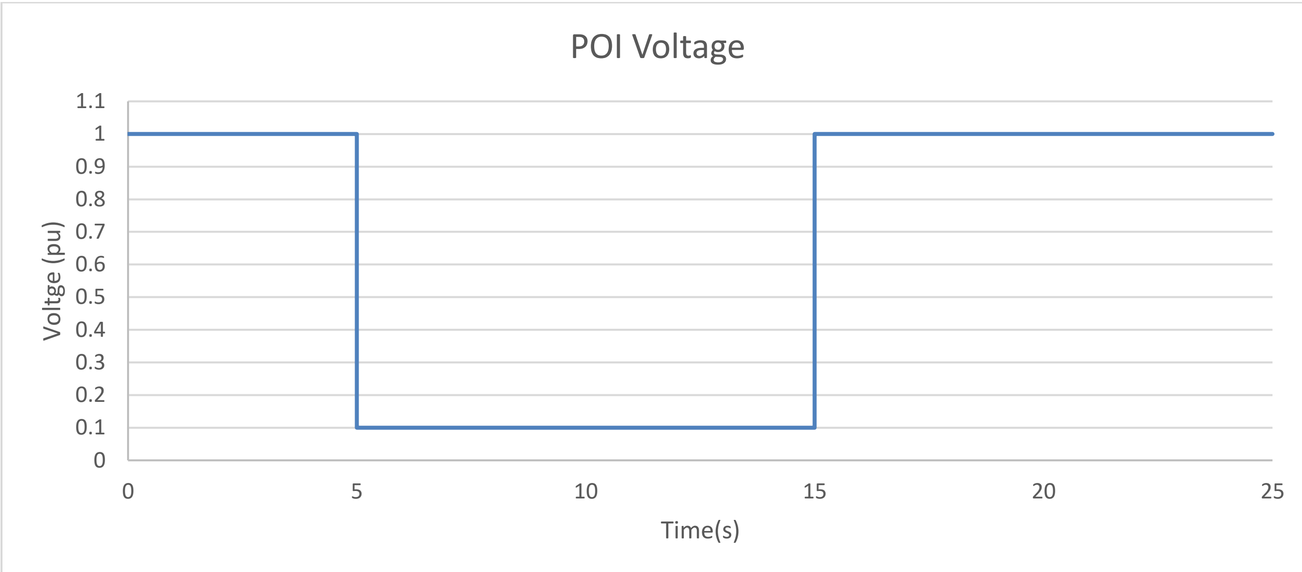

POI Voltage
Voltage (pu)
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0
5
10
15
20
25
Time (s)

Figure 11: Undervoltage Event Used to Test Protection



8. References

PSCAD Model Requirements Rev. 12, Electranix Corporation, September 19, 2022.

9. Results

Append all plots for all tests to this section and submit this document & test results along with all other EMT model files and documentation.