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|  | <b>Procedure</b> | Department:    | System Planning |
|  |                  | Document No:   | PLG-PRD-0017    |
| <b>Title:</b><br><b>PSCAD PLANT MODEL VERIFICATION PROCEDURE</b>                 |                  | Revision No:   | 01              |
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### Table of Contents

|       |  |    |
|-------|--|----|
| 1.0   | Purpose .....  | 1  |
| 1.1   | Objective .....  | 1  |
| 1.2   | Applicability .....  | 1  |
| 2.0   | Scope .....  | 1  |
| 3.0   | PROCEDURE .....  | 1  |
| 3.1.1 | Steps for the Usability Portion of the Checklist .....                         | 1  |
| 3.1.2 | Steps for the PSSE vs PSCAD Parameter Comparison Portion of the Checklist..... | 5  |
| 3.1.3 | Steps for the Test Portion of the Checklist.....                               | 7  |
| 4.0   | Document Review .....  | 12 |
| 5.0   | Revision Information.....  | 12 |

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## 1.0 PURPOSE

This procedure document explains the steps to be taken to verify that PSCAD plant models meet ATC Planning Criteria and are acceptable to use in ATC System Planning studies. These procedures must be completed by the reconnection Customers (IC) with every PSCAD plant model submission to ATC. This procedure is necessary to ensure that ATC can complete accurate PSCAD studies in a timely manner.

### 1.1 Objective

The objective of this procedure is for ATC to receive PSCAD models that contain the up-to-date settings and parameters for all the equipment in the model and meet ATC Planning Criteria.

### 1.2 Applicability

This procedure applies to ICs/GOs when submitting PSCAD plant models to ATC.

## 2.0 SCOPE

This procedure applies to PSCAD plant model submissions to ATC for MISO DPP studies, Material Modifications, and As-built studies or updates.

## 3.0 PROCEDURE

This section details the steps required to complete this procedure and document compliance with ATC Planning Criteria in the ATC IBR PSCAD Model Verification Checklist.

### 3.1.1 Steps for the Usability Portion of the Checklist

#### 1. Manufacturer Name and Model Number

The manufacturer's name and the specific version of the inverter model must be clearly observable in the .pscx model file. Sometimes the inverter model is included in the parameters. To view the parameters right click on the inverter model GUI and select Edit Parameters.

In the ATC IBR PSCAD Model Verification Checklist the IC must either include a comment describing where the manufacturer's name and specific model number can be found or a screen shot can be pasted into the checklist clearly showing where in the PSCAD plant model the manufacturer's name and model number are located.

#### 2. PSCAD Model Instructions

PSCAD model instructional documentation must be provided and must match the model version in the .pscx model file and include instructions for setup and running of the model. If there is separate documentation for the PPC that must also be submitted.

In the ATC IBR PSCAD Model Verification Checklist the IC must include the file names of all instruction manuals provided with the PSCAD plant model.

### 3. Simulation Time Step

To limit the amount of time to run simulations ATC requires that the PSCAD model be able to run with a time step or 10 us or larger. PSCAD cases in which models are supplied typically have the recommended timestep implemented. Check by right-clicking on case canvas and selecting project settings. Click on the Runtime tab of the Project Settings window and the solution time step will be shown. Otherwise, this value can usually be found in model documentation.

In the ATC IBR PSCAD Model Verification Checklist the IC must include the recommended time step in us.

### 4. Fortran Version

Model documentation may specify which FORTRAN compiler version is required. Verify that model is compatible with Intel Visual Fortran (IVF) compiler version 2015 and higher. Test that the model initializes with the specified FORTRAN compiler version. Note that model .lib files may be supplied for several different FORTRAN compilers. In PSCAD go to file – options – dependencies and make sure Intel Fortran compiler is selected.

In the ATC IBR PSCAD Model Verification Checklist the IC must list the IVF compiler used for the PSCAD plant model being submitted.

### 5. PSCAD Model Version

The model must use PSCAD version 4.6.3 or higher. Model documentation may mention which PSCAD version the plant model was made with. The PSCAD version can also be ascertained by opening the .pscx file in a text editor and the PSCAD version will be listed on the top. Otherwise, model will likely not run correctly (throw errors or fail to initialize) in PSCAD version 4.6.X or higher.

In the ATC IBR PSCAD Model Verification Checklist the IC must include PSCAD model version.

### 6. PSCAD Snapshot Feature

This feature is currently difficult to implement for “real code” models and isn’t widely unsupported.

Model documentation may specify whether snapshot feature is supported. To verify:

- a. Specify Timed Snapshot in project settings and choose snapshot time to be posit-initialization.
- b. Launch case and run past snapshot time.

- c. Choose 'From Snapshot' as startup method in project settings.
- d. Launch case. Model should start at initialized values.

In the ATC IBR PSCAD Model Verification Checklist the IC must state whether the plant model can use the snapshot feature or not.

## 7. PSCAD Multiple Run Feature

This feature is currently difficult to implement for "real code" models and isn't widely unsupported.

Model documentation may specify whether multiple runs is supported. To verify:

- a. Change run configuration from 'Standalone' to 'Master' in project settings
- b. Change '# runs' to 2
- c. Launch case and verify that the model behavior (startup, fault response) is identical between the two runs.

In the ATC IBR PSCAD Model Verification Checklist the IC must state whether the plant model can use the multiple run feature or not.

## 8. PSCAD Model Scaling

Model can be scaled to represent any number of inverters/turbines and has the ability to dispatch its output to values less than nameplate, either using a scaling transformer or internal scaling. Note that changing the number of inverters may require other changes to the case, such as PPC plant ratings, changing R, L, C values of filters, etc. ATC does not accept model scaling by current injection.

In the ATC IBR PSCAD Model Verification Checklist the IC must give a brief description of how the model can be scaled.

## 9. Power Plant Controller (PPC) Model

A PPC model is required for all PSCAD plant model submissions. The PPC is typically present as a stand-alone component in the PSCAD case, but sometimes will be contained within the inverter/turbine component. The power plant controller must have as inputs (at minimum) the measured and reference values of POI voltage, and POI power, POI frequency, and the measured POI Q. The PPC outputs the signals required for inverter/turbine level controls, usually as P, Q ordered signals. Plant controllers must be represented in sufficient detail to accurately represent short term performance, including specific measurement methods, communication time delays, transitions into and out of ride-through modes, settable control parameters or options, and any other specific implementation details which may impact plant behavior. Generic PPC representations are not acceptable unless the final PPC controls are designed to exactly match the generic PPC

model. If multiple plants are controlled by a common controller, or if the plant includes multiple types of IBRs (eg. Hybrid BESS/PV) this functionality must be included in the plant control model.

In the ATC IBR PSCAD Model Verification Checklist the IC must give the manufacturer and model name of the PPC being submitted.

#### 10. PPC Active Power Setpoint

The PPC model must accept an active power setpoint. This item can typically be tested by lowering the power reference of the PPC, which will in turn adjust the power order of the inverters/turbines. Note that this is distinctly different from reducing the total number of inverters/turbines.

In the ATC IBR PSCAD Model Verification Checklist the IC must give a brief description of how to set the PPC active power setpoint.

#### 11. PPC Voltage Setpoint

The PPC model must be set to control voltage at the POI to 1.02 p.u. This is an ATC interconnection requirement. The PPC must be configured to be in voltage control mode, which may not be the case in the model as-received from the manufacturer. Model documentation may have information regarding the various PPC active/reactive control modes.

In the ATC IBR PSCAD Model Verification Checklist the IC must give a brief description of how to set the PPC voltage setpoint to 1.02 p.u at the POI.

#### 12. PPC Settable Voltage Droop

The PPC must have a settable voltage droop parameter.

This value is typically in the range of 2-5% on the Q base of the generator. The Q base used in droop calculation must be available as a parameter, model documentation may have more information on this. Note that droops can be converted using this formula:  $\text{droop\_new} = \text{droop\_old} * \text{base\_new} / \text{base\_old}$ .

In the ATC IBR PSCAD Model Verification Checklist the IC must give a brief description of how to set the Voltage drop, indicate what the voltage droop was set to, and indicate what the voltage droop base is (S, P, or Q).

#### 13. Frequency

Base frequency of the grid and all other project components (generator mode, transformers, transmission lines, measurement blocks, capacitors, etc.) must be entered as 60 Hz.

In the ATC IBR PSCAD Model Verification Checklist the IC must indicate that the system and all components modeled were confirmed to be set for a 60 Hz system.

### 3.1.2 Steps for the PSSE vs PSCAD Parameter Comparison Portion of the Checklist

For all of the items in the PSSE vs PSCAD Comparison portion of the Checklist the IC must first review what modeling was submitted for the MISO DPP application, Material Modification, or As-built Settings and input those parameters in the “PSSE Model/MISO DPP Application” column. Then the IC must review all these parameters in the PSCAD plant model and input the parameters in the “PSCAD Plant Model” column. If any of the parameters differ between the two columns the IC needs to determine which parameter is correct and update the appropriate model.

The configuration of the PSCAD plant model must match the configuration of the PSSE steady state and .dvr models. All generator lead lines must be modeled to the POI. At the POI the latest posted version of the ATC test controller must be applied as an equivalent for the rest of the system. Each Main Power Transformer (MPT) must be modeled explicitly and multiple MPTs may not be modeled as one equivalent MPT. The PSCAD plant model must have the same number of equivalent collector circuits, equivalent Generator Step Up Transformers (GSUs), and equivalent Inverter-based Resource (IBR) machines as the PSSE steady state and .dvr models.

#### 1. Generator

Representation of generator controls and protection should be sufficiently accurate in the PSCAD model. This includes detailed and site-specific representation of the outer and inner control features of the inverters. 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 during external system events.

The MW level output at the POI must be equal to the requested or GIA ERIS MW amount. Machine MVA must match the individual MVA of each inverter times the number of inverters represented by each machine. The inverter voltage and the number of inverters in the PSSE and PSCAD models must match.

#### 2. Generator Step Up (GSU) Transformer

Equivalent pad mount transformer (from turbine/inverter terminals to medium voltage level, typically 34.5 kV) may be either a scaling transformer if the model scaling is performed externally via scaling transformer, or a lumped transformer if the model scaling is performed within the inverter model. ATC will not accept scaling via current injection due to the limitations with this type of scaling.



Check that the following pad mount transformer parameters match the application data: low voltage (kV), high voltage (kV), transformer MVA, # of transformers, positive sequence leakage reactance (X1), Copper losses (R1).

Positive sequence leakage reactance is the per unit positive sequence reactance (X1) based on the MVA of the transformer. The copper losses are the per unit positive sequence resistance (R1) based on the MVA of the transformer. If it's a three winding transformer then fill in the rest of the reactances and copper losses for each winding. Check that winding voltages match the application. Take care to consider scaling factor when determining MVA base for a scaling transformer.

### 3. Equivalent Collector Branch

Typically, a 34.5 kV line between equivalent pad mount transformer and main station step-up transformer. Equivalent collector system may be either a pi section transmission line model or a Bergeron transmission line model.

Compare line R, X, B to the corresponding line in loadflow. R, X, B entered in pi section models may need to be converted to per-unit for comparison to loadflow. For Bergeron line models, per-unit R, X, B parameters can be extracted by navigating into the line model page, right-clicking in the page and selecting solve constants (note that the 'Additional options' page must be added to the page as well, with the correct voltage base specified). R, X, B output can then be found in the 'Output' tab at the bottom of the window.

### 4. Main Power Transformer (MPT)

Check that the following main step-up transformer parameters match the application data: low voltage (kV), high voltage (kV), transformer MVA, positive sequence leakage reactance (X1), Copper losses (R1).

Positive sequence leakage reactance is the per unit positive sequence reactance (X1) based on the MVA of the transformer. The copper losses are the per unit positive sequence resistance (R1) based on the MVA of the transformer. If it's a three winding transformer then fill in the rest of the reactances and copper losses for each winding. Check that winding voltages match the application. ATC requires a grounded high side wye on this transformer. Ensure that this is modeled.

### 5. Generator Tie Line

Gen-tie line may be either a pi section transmission line model or a Bergeron transmission line model.

Compare line R, X, B to the corresponding line in loadflow. See item 3 for instructions on extracting R, X, B parameters.

### 6. Cap Banks



The connection point and MVAR capability of the cap banks must match the load flow.

#### 7. Dynamic Voltage Control Devices

The connection point and capability of the dynamic voltage control devices must match the load flow.

#### 8. Aux Load

Any auxiliary loads above 1 MW must be modeled in both the PSSE and PSCAD models. The connection point, MW, and MVAR of the load must match.

#### 9. Protection Settings

Make sure that all protection settings (voltage protections, frequency protections, DC bus voltage protections, converter overcurrent protections, and often other inverter specific protections) are implemented in the PSCAD model. These could be available as inputs in the model, or hard-coded in the black-boxed controls.

Model protection settings may be observable as model parameters (right click on model, edit parameters) or as sliders visible within the model itself. Flags for enabling various protection settings must be enabled.

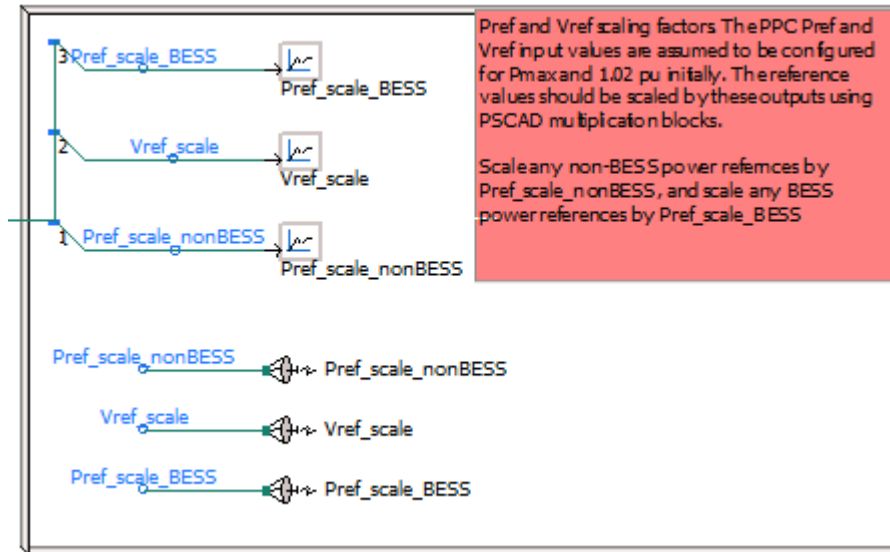
For all voltage and frequency protection settings the .dyr model and PSCAD plant model must match.

### 3.1.3 Steps for the Test Portion of the Checklist

The latest posted version of the ATC test controller must be applied as an equivalent for the rest of the system in the PSCAD plant model. When adding the ATC test controller to the PSCAD plant model case the component will need to be copy transfer/paste transferred. For best results in moving all of the other components over they should all be selected together, copied, and pasted over into the PSCAD plant model at once. The PSCAD case which has the ATC test controller needs to include a link to the "TestController\_innerVX\_1.lib" file in the "Link" tab of the project settings.

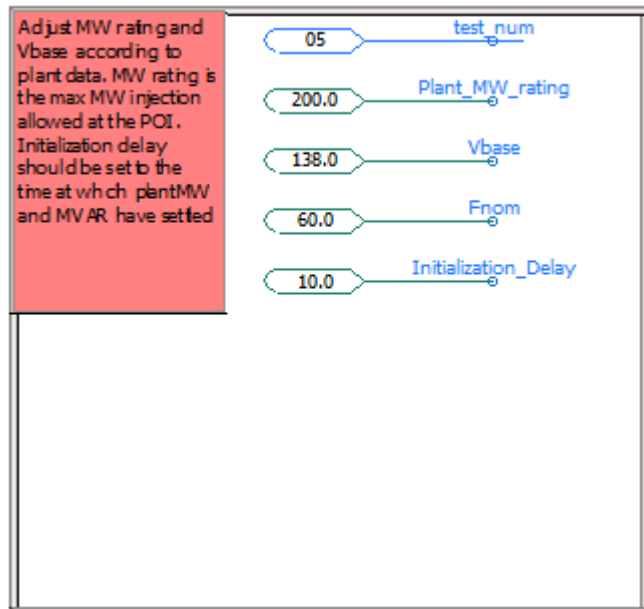
Some of the tests require the plant PPC active power references or voltage set point to be scaled. To get these tests to work correctly PSCAD gain blocks must be placed between the Pref and Vref signals and the Pref and Vref inputs to the PPC controller. The Vref gain multiplying constant must be set to "Vref\_scale". For BESS plants the Pref gain multiply constant must be set to "Pref\_scale\_BESS". For non-BESS plants the Pref gain multiply constant must be set to "Pref\_scale\_nonBESS". If the scaling blocks need to be put inside a different module from the module that the test controller is located in these signals need to be linked to the module where the scaling blocks are located. It is recommended to do this by placing Wireless Radio Link components in the module where the scaling blocks reside to receive the signals from the

Wireless Radio Link components that come with the test controller case as shown in Figure 1 below.



**Figure 1: Test Controller Scaling Parameters and Wireless Radio Link Transmitters**

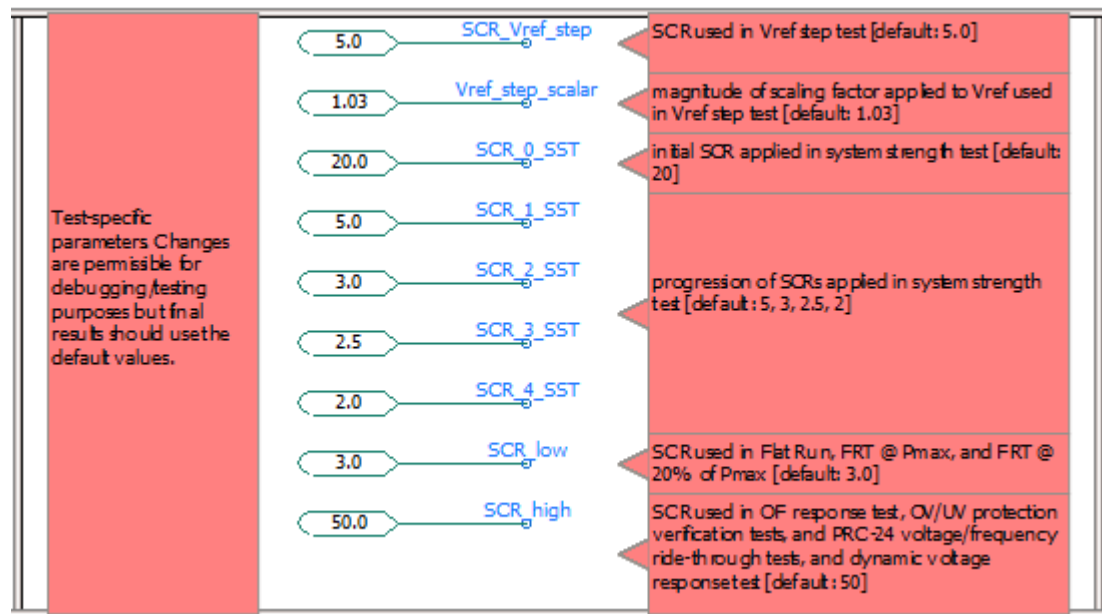
The plant must be set to control the POI voltage to 1.02 p.u. per ATC interconnection requirements. The test controller components shown in Figure 2 below must be set to match the plant being studied. “Initialization\_Delay” should be set to a time at which the plant active and reactive power output has settled to steady-state values. A good default value for “Initialization\_Delay” is 10 seconds. “Fnom” is system frequency and should remain at 60 Hz. “Vbase” should be set to match the POI voltage in kV. “Plant\_MW\_rating” should match the plant power at the POI in MW. “test\_num” should be set to match the test to be performed as described in the procedure steps further below in this section.



### Figure 2: Test Controller Components to Set

Graphs must be made to show the POI RMS voltage in per-unit, MWs, MVARs, and frequency. For plants with multiple energy resources (e.g. PV / Wind plus BESS), MW and MVARs for each resource should be plotted in separate channels. The graph frame inside the Test Controller component is already configured to show these quantities and should be used to report test results whenever possible.

The parameters shown in Figure 3 below must be used in the final model verification runs to be submitted to ATC. However, the user is given the option to change these numbers for their own internal testing purposes.



**Figure 3: Required Test Controller Component Parameters for Model Verification**

The test controller must be used to complete all of the following tests. For all tests, the PSCAD plant model must be compliant with latest version of the ATC Planning Criteria for ATC to accept the model submission. In particular the IC should refer to the ATC Planning Criteria sections on Stability Assessments, Resource Facility Requirements, and PSCAD Inverter-Based Resource EMT Model Requirements.

1. Flat Run Test

To perform the Flat Run Test set the test\_num integer constant block to “01” and then hit the PSCAD run button. Plot the POI voltage, MWs, and MVARs out to 20 seconds and submit the plots with the PSCAD plant model as proof of model verification.

For the model to be accepted by ATC the model must reach all setpoints within 5 seconds of simulation time and meet the latest version of the ATC Planning Criteria requirements.

## 2. Three Phase to Ground (3PG) at 100% MW Test

To perform the 3PG at 100% MW Test set the test\_num integer constant block to "02" and then hit the PSCAD run button. Plot the POI voltage, MWs, and MVARs out to 30 seconds and submit the plots with the PSCAD plant model as proof of model verification.

For the model to be accepted by ATC the model must meet the latest version of the ATC Planning Criteria requirements.

## 3. Three Phase to Ground (3PG) at 20% MW Test

To perform the 3PG at 20% MW Test set the test\_num integer constant block to "03" and then hit the PSCAD run button. Plot the POI voltage, MWs, and MVARs out to 10 seconds post-fault and submit the plots with the PSCAD plant model as proof of model verification.

For the model to be accepted by ATC the model must meet the latest version of the ATC Planning Criteria requirements.

## 4. Three Phase to Ground (3PG) with BESS 100% charging dispatch, non-BESS at 100% MW output Test (only needed for projects which include a BESS)

To perform the 3PG with BESS 100% charging dispatch, non-BESS at 100% MW output Test set the test\_num integer constant block to "04" and then hit the PSCAD run button. Plot the POI voltage, MWs, and MVARs out to 10 seconds post-fault and submit the plots with the PSCAD plant model as proof of model verification.

For the model to be accepted by ATC the model must meet the latest version of the ATC Planning Criteria requirements.

## 5. System Strength Test

The System Strength Test applies a sequence of 4 6-cycle faults, separated by 5 second intervals. At each fault clearing time, the system strength is reduced. The default initial system strength is 20 and the default final system strength is 2.

To perform the System Strength Test set the test\_num integer constant block to "05" and then hit the PSCAD run button. Plot the POI voltage, MWs, and MVARs out to 30 seconds after the first fault and submit the plots with the PSCAD plant model as proof of model verification.

For the model to be accepted by ATC the model must meet the latest version of the ATC Planning Criteria requirements. Note that ride-through and stable operation is not necessarily required at an SCR of 2, but should be possible at

an SCR of 2.5. The results of this test may be interpreted according to the system strength characteristic at the project POI or known system characteristics.

#### 6. Over Frequency Step Test

To perform the Over Frequency Step Test set the test\_num integer constant block to "06" and then hit the PSCAD run button. Plot the POI voltage, MWs, \ MVARs, and frequency out to 20 seconds post-event and submit the plots with the PSCAD plant model as proof of model verification.

For the model to be accepted by ATC the active power response must meet the latest version of the ATC Planning Criteria requirements.

#### 7. Voltage Step Test

The Voltage Step Test scales up the voltage reference by a factor of "Vref\_step\_scalar" in order to assess the plant voltage response time in the nominal operating voltage range.

To perform the Over Frequency Step Test set the test\_num integer constant block to "07" and then hit the PSCAD run button. Plot the POI voltage, MWs, and MVARs out to 20 seconds post-event and submit the plots with the PSCAD plant model as proof of model verification.

For the model to be accepted by ATC the reactive power response must meet the latest version of the ATC Planning Criteria requirements.

#### 8. Over Voltage Protection Test

To perform the Over Voltage Protection Test set the test\_num integer constant block to "08" and then hit the PSCAD run button. Plot the POI voltage, MWs, and MVARs out to 20 seconds post-event and submit the plots with the PSCAD plant model as proof of model verification.

This test is designed to make sure that the PSCAD plant model has over voltage protection settings enabled correctly in the model. For the model to be accepted the plant should trip.

#### 9. Under Voltage Protection Test

To perform the Under Voltage Protection Test set the test\_num integer constant block to "09" and then hit the PSCAD run button. Plot the POI voltage, MWs, and MVARs out to 20 seconds post-event and submit the plots with the PSCAD plant model as proof of model verification.

This test is designed to make sure that the PSCAD plant model has under voltage protection settings enabled correctly in the model. For the model to be accepted the plant should trip.

#### 10. Under Voltage Dynamic Response Test

The Under Voltage Dynamic Response Test sets the POI voltage to 0.5 pu permanently in order to assess the speed at which the plant can inject reactive power into a low voltage. Note that the plant will trip after some time due to undervoltage protection, which is permitted outside of the PRC-024-3 curve and is not the focus of this test.

To perform the Under Voltage Dynamic Response Test set the test\_num integer constant block to “10” and then hit the PSCAD run button. Plot the POI voltage, MWs, and MVARs from just before the test start time to 5 seconds after the test start time and submit the plots with the PSCAD plant model as proof of model verification.

For the model to be accepted by ATC the reactive power response must meet the latest version of the ATC Planning Criteria requirements.

### 11. NERC PRC-024-3 Test

The NERC PRC-024-03 Tests assess the plant for compliance with the PRC-024-03 over/under voltage/frequency. Each of the four ride-through curves are tested by altering the POI voltage/frequency over time to match the envelope of the ride-through curve.

To perform the NERC PRC-024-3 Test set the test\_num integer constant block to “111” and then hit the PSCAD run button. Plot the POI voltage, MWs, and MVARs out to 20 seconds after the start of the test and submit the plots with the PSCAD plant model as proof of model verification. This process will need to be repeated three more times with the test\_num integer constant block set to “112”, “113”, and “114”.

For the model to be accepted by ATC the plant must not trip or enter momentary cessation. The plant must also meet the latest version of the ATC Planning Criteria requirements.

## 4.0 DOCUMENT REVIEW

This document will be reviewed in accordance with ATC review requirements. The review will ensure this document remains current and meets all new or revised procedures and Standards. All reviews will be documented in the Revision Information section.

## 5.0 REVISION INFORMATION

| Revision | Author                              | Date       | Section | Description  |
|----------|-------------------------------------|------------|---------|--|
| 00       | Damien Sommer, P.E., Xiangyang Zhou | 03/15/2023 | All     | New document.  |
| 01       | Damien Sommer, P.E., Xiangyang Zhou | 3/29/2023  | 3.1.3   | Added more description of how to use the test controller component. Deleted an old reference to a test “021” that was changed to test “04” |