Electromagnetic Transient Modeling Requirements

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Background

- Due to a shift in resource mix and increasing prevalence of HVDC and FACTS devices, operating characteristics and constraints of the bulk power system are changing
- Electromagnetic Transient (EMT) studies must be incorporated into planning to assure continued reliability
- Unlike traditional dynamic models, EMT models can represent the power system at all frequencies as well as individual phase quantities
- Examples of EMT applications include:
  - Unbalanced fault analysis
  - High frequency transient analysis
  - Sub-Synchronous Oscillation (SSO) analysis
  - Fast control interaction with nearby devices and/or generation

EMT Model Submission Criteria

- Generation facilities which meet the following criteria are required to submit EMT models
  a. Connected to facilities 60 kV or greater, and
  b. Individual resource with nameplate capacity > 10 MVA or Aggregate resource with nameplate capacity > 20 MVA, and
  c. Meet any of the following interconnection criteria:
     i. Any synchronous generation interconnected electrically close to series compensated line(s), and/or
     ii. All asynchronous generation (i.e. inverter-based resources)
- Facilities which utilize legacy Type 1 and Type 2 wind turbines are exempt from the EMT model requirement

EMT Model Submission Timeline

- The CAISO has been requesting EMT models since the inception of the program in 2018.
- Many generators have already submitted their EMT models, and as a result new issues have been identified, which has helped evolve the CAISO EMT modeling requirements.
- The CAISO has provided submission deadlines to individual generators, including “catch-up” submission deadlines for Phases 1-4 in 2021.

EMT Model Requirements

- The remainder of the presentation will highlight certain EMT model requirements. For complete CAISO EMT Modeling Requirements, refer to the link below:

  http://www.caiso.com/Documents/CaliforniaISOElectromagneticTransientModelingRequirements.pdf

- All EMT model submissions must comply with the CAISO EMT Modeling Requirements document

What to submit

- Documents
- A complete test case with PSCAD models for all devices in the plant, from generating facility to the Point of Interconnection
  - All PSCAD workspace and project files (*.pswx, *.pscx, *.pslx)
  - All library files (*.lib, *.dll)
  - All configuration files (*.txt,…)
- For inverter based resources, complete the IBR EMT Checklist

Checklist for Model Submission

Model Submission		
Choose	Are the complete model files submitted? GO, please list the files below.	Choose
File Name	Description	
Insert Notes Here:		
Choose	Is the model supplied with a sample test case including site specific plant representation?	Choose
Insert Notes Here:		
Choose	Does the model schematic align with the single line diagram and include all devices from the inverters to the Point of Interconnection?	Choose
Insert Notes Here:		

Documentation Requirement

- The documentation shall include
  - Vendor name and the version of the model
  - List and description of the files being submitted
  - Instruction for setup and running the model
  - Model limitations, including the lowest grid strength the model is designed for
  - Indication whether the model is real-code or not
  - List and description of all the control functions and associated parameters accessible to the user
  - List and description of all the protections (both AC and DC protections) and associated settings accessible to the user

Documentation Requirement (cont.)

- The documentation shall include
  - Description of the test case that should be configured according to the site-specific real equipment configuration up to the point of interconnection
  - Balanced and un-balanced fault tests using the test case
  - Voltage/reactive power reference step change test using the test case
  - Frequency/active power reference step change test using the test case
  - Model validation and benchmarking against field test data, if the model does not use real-code

Checklist for Documentation Requirement

Supporting Documentation		
Choose	Are the supporting documentation submitted? GO, please list the files below.	Choose
File Name		Description
Choose	Does the documentation include instruction for setup and running the model?	Choose
Insert Notes Here:		
Choose	Doesthe documentation provides a clear way to identify site-specific settings and equipment configuration?	Choose
Insert Notes Here:		

EMT Model

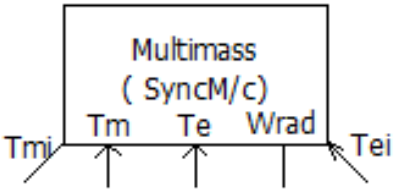
MODELING REQUIREMENT

Synchronous & Induction Generators

- The following EMT modeling details should be met for synchronous and induction generators, such as:
  - Combustion Turbine Generators
  - Steam Turbine Generators
  - Hydro Generators
  - Type 1 and 2 Wind Turbines (though not required to submit EMT models)

Synchronous & Induction Generators (cont.)

- Synchronous and induction generator models should:
  - Include the Multi-Mass Torsional Shaft Interface model. The approximate representation of one stiff shaft used in transient stability modeling is not allowed.



Model should include:
- Inertia constants
- Shaft spring constants
- Torque share between different masses
- Damping

  - Include representation of the machine saturation or magnetizing curve, and the transformer magnetizing curves

Synchronous & Induction Generators (cont.)

- Synchronous and induction generator models should:
  - Represent the following as a user-written PSCAD model or as standard PSCAD block models with the model type and data specified:
    - Excitation system
    - Governor
    - Power System Stabilizer
  - Include model parameters which reflect the actual installed settings in the field and not the manufacturer default parameters
  - Represent the generator grounding system
  - Represent all installed protections in detail for both balanced and unbalanced fault conditions
  - Represent dynamic reactive devices including automatically controlled capacitor and reactor banks, if applicable

Inverter-Based Generators

- The following EMT modeling details should be met for inverter-based generators, such as:
  - Solar Photovoltaic
  - Battery Energy Storage Systems (BESS)
  - Type 3 and 4 Wind Turbines

Inverter-Based Generators (cont.)

- Inverter-based generator models should:
  - Include the full detailed inner control loops of the power electronics. This representation should include all fast inner controls, as implemented in the installed equipment.
    - Full IGBT representation is preferred
    - Average source that approximates the IBGT switching but maintains full detail in the inner controls and DC side protection features is acceptable
    - Firmware code may be directly used (real code)
  - Represent all plant level controllers. This should include:
    - External voltage controllers
    - Plant level controllers
    - Customized phase locked loop (PLL) systems
    - Ride-through controllers
    - Sub-synchronous control interaction damping controllers
  - If multiple plants are controlled by a common controller, this functionality should be included.
  - The model parameters provided should reflect the actual installed settings in the field and **not the manufacturer default parameters**.

Inverter-Based Generators (cont.)

- Inverter-based generator models should:
  - Represent all installed protections in detail for both balanced and unbalanced fault conditions
  - Represent dynamic reactive devices including automatically controlled capacitor and reactor banks, if applicable
  - Include representation of the transformer magnetizing curves
  - Be configured to match expected site-specific equipment settings. Any user-tunable parameters or options should be set in the model to match the equipment at the specific site being evaluated, as far as they are known.

Checklist for Model Accuracy

Model Accuracy		
Choose	Does the model use the actual firmware code from the inverter for power electronic controls ("real code")?	
Insert Notes Here:		
Choose	If not using real code, is a model validation report included?	Choose
Insert Notes Here:		
Choose	Does the model include the plant level controller? List all the plant level controller below, e.g. power plant controller, customized phase locked loop systems, ride-through controllers, sub-synchronous control interaction damping controllers, etc.	Choose
Insert Notes Here:		
Choose	Does the plant level controller control generating resources other than the subject resource in this model submission?	
Insert Notes Here:		
Choose	Are the operating modes which require system specific adjustment accessible? Please describe how to access mode settings below.	Choose
Insert Notes Here:		

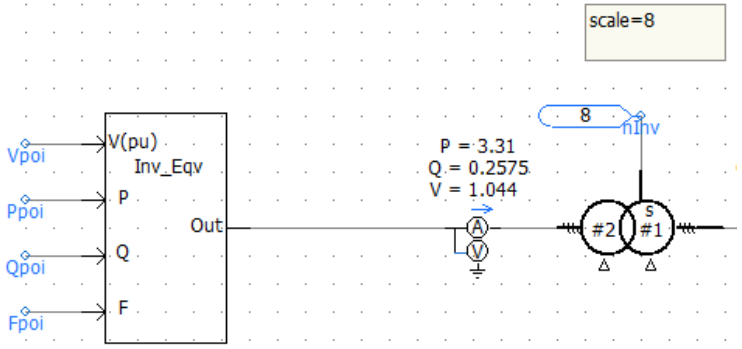
Choose	Does the model include automatically controlled capacitor and reactor banks?	Choose
Insert Notes Here:		
Choose	Are the transformer magnetizing curves included?	Choose
Insert Notes Here:		
Choose	Does the model include pertinent electrical and mechanical features, such as gearboxes, pitch controllers, or other features which impact the plant performance in the simulation period?	Choose
Insert Notes Here:		
Choose	Are all protections which could impact ride-through performance modeled in detail? Please list the protections included in the model below.	Choose
Insert Notes Here:		
Choose	Has the model being validated at different operating conditions ranging from minimum power through maximum power?	Choose
Insert Notes Here:		
Choose	Is the model configured for the specific site being evaluated, as far as they are known?	Choose
Insert Notes Here:		

EMT Model

USABILITY REQUIREMENT

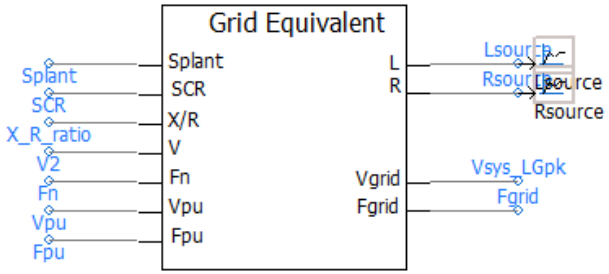
Model Usability Features

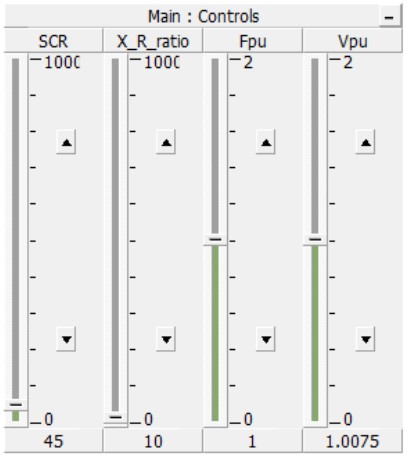
- All EMT models should:
  - Be capable of running at time steps anywhere in the range from 10 µs to 20 µs
  - Be capable of initializing itself. Models should initialize and ramp to full output without external input
  - Allow the active power capacity of the model to be scaled if using same inverter, collector and/or padmount transformer models
  - Have the ability to dispatch its output to values less than nameplate



Model Usability Features (cont.)

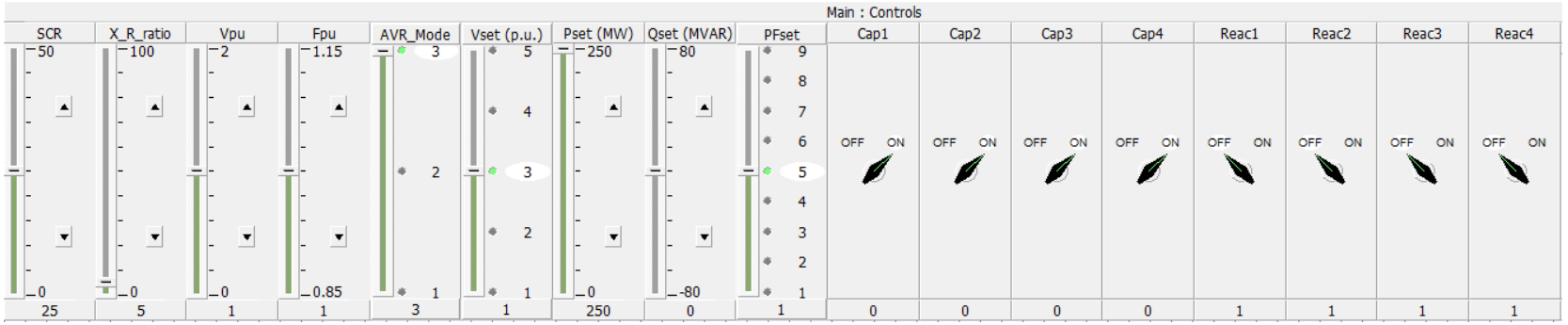
- All EMT models should:
  - Setup the test case with a single machine infinite bus representation of the system, configured with an appropriate representative Short Circuit Ratio (SCR)





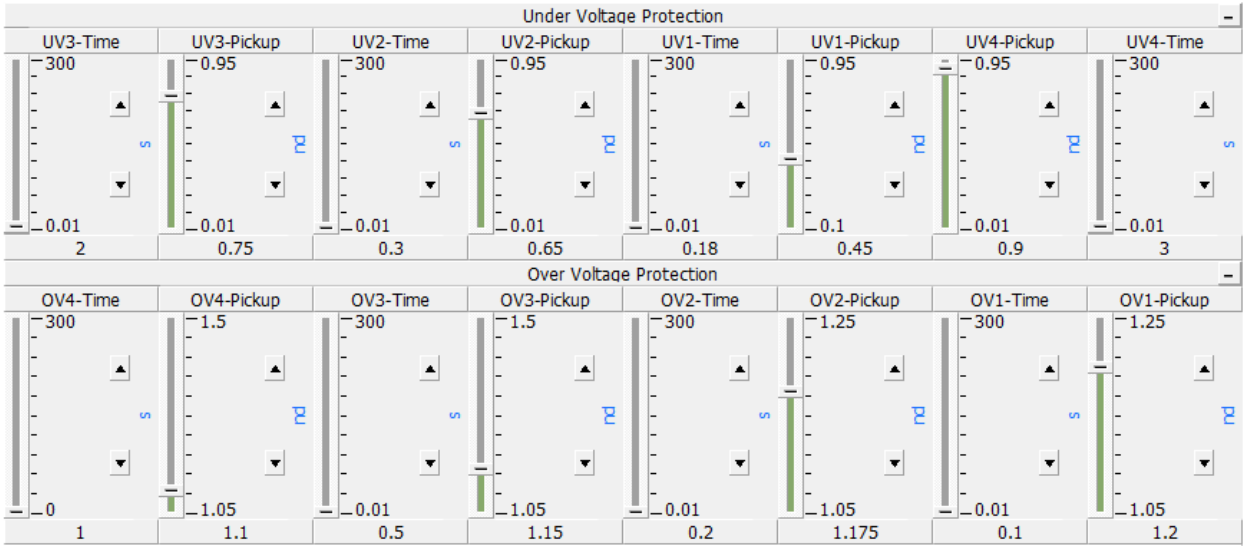
Model Usability Features (cont.)

- All EMT models should:
  - Accept external reference values, such as real power reference or frequency reference, and reactive power reference values or voltage reference values. Model should accept these reference variables for initialization and be capable of changing these reference variables mid-simulation, i.e. dynamic signal references.



Model Usability Features (cont.)

- All EMT models should:
  - Allow protection models to be disabled
  - Have pertinent control or hardware options accessible to the user (e.g., adjustable protection thresholds, real power recovery ramp rates, or Sub-Synchronous Control Interaction damping controllers)



Model Efficiency Features

- All EMT models should:
  - Be compiled using Intel Fortran compiler version 12 and higher
  - Be compatible with PSCAD version 4.6.3 or higher. The model should not be dependent on a specific PSCAD version to run.
  - Initialize as quickly as possible (for example < 5 seconds) to user supplied terminal conditions
  - Support multiple instances of its own definition in the same simulation case
  - Support the PSCAD “timed snapshot” and “multiple run” features
  - Allow replication in different PSCAD cases or libraries through the “copy” or “copy transfer” features
  - Not utilize multiple layers in the PSCAD environment, including “disabled” layers

Checklist for Model Usability

Model Usability		
Choose	Are pertinent control or hardware options accessible to the user (e.g., adjustable protection thresholds, real power recovery ramp rates, or Sub-Synchronous Control Interaction damping controllers)	Choose
Insert Notes Here:		
Choose	Are there diagnostic flags accessible? Please provide the description of the diagnostic flags below.	Choose
Insert Notes Here:		
	Please provide the grid strength in terms of simple short circuit ratio at POI that the model is designed for.	
Insert Notes Here:		
Choose	Does the model run at a time step between 10 µs to 20 µs? Please specify the time step required by the model below.	Choose
Insert Notes Here:		
Choose	Is the model restricted to the time step provided above?	Choose
Insert Notes Here:		
Choose	Does the model initialize itself?	Choose
Insert Notes Here:		
Choose	Does the model initialize to P, Q, V setpoints in 5 seconds or less?	Choose
Insert Notes Here:		
Choose	Does the model accept external reference variables for active and reactive power?	Choose
Insert Notes Here:		
Choose	Could the external references be changed dynamically during the simulation?	Choose
Insert Notes Here:		
Choose	Could the protection models be disabled for troubleshooting?	Choose
Insert Notes Here:		
Choose	Is the active power capacity scalable?	Choose
Insert Notes Here:		
Choose	Is the active power dispatchable?	Choose
Insert Notes Here:		

Checklist for Model Usability (Cont.)

Choose	Is the model compatible with Intel FORTRAN version 12 and higher? Please specify Intel FORTRAN version required below.	Choose
Insert Notes Here:		
Choose	Does the model compile using PSCAD version 4.6.3 or higher?	Choose
Insert Notes Here:		
Choose	Does the model support multiple instances of its own definition in a single PSCAD case?	Choose
Insert Notes Here:		

Choose	Does the model support the PSCAD "snapshot" feature?	Choose
Insert Notes Here:		
Choose	Does the model support the PSCAD "multiple run" feature?	
Insert Notes Here:		
Choose	Does the model support "copy transfer" feature to replicate the components in a different PSCAD case?	
Insert Notes Here:		
Choose	Is it true that the model does not use PSCAD layer functionality?	
Insert Notes Here:		

EMT Model

MODEL PERFORMANCE TESTS

Model Basic Performance Tests

- CAISO and PTOs perform model review tests to verify acceptable performance
- Flat run
  - Verify initialization
  - Verify clean voltage and current waveforms with minimal distortion
- Bump test: three phase fault at POI with typical fault clearing time at SCR = 3
  - Verify stability at the specified grid strength
  - Benchmark with simulation in positive sequence model

Model Basic Performance Tests (cont.)

- Voltage or reactive power reference step change
  - Verify volt/var control performance
  - Verify performance against MOD-026 test report
- Frequency or active power reference step change
  - Verify freq/mw control performance
  - Verify performance against MOD-027 test report
- Voltage ride-through
  - Verify protection settings
  - Verify protection diagnostic signals

Checklist for Model Performance by CAISO and PTO

Model Basic Performance		
4.a	Instantaneous voltage and current waveforms have minimal distortion, and no oscillations are observed.	Choose
Insert Notes Here:		
4.b	Model is able to ride-through and recover from a temporary (no line outage or drop in SCR), 6-cycle, zero-impedance, three-phase fault at the high side of the station transformer, with a POI level SCR of 3.	Choose
Insert Notes Here:		
4.c	Model responds to a step change in PPC voltage setpoint, reaching 90% of the new value between 1 and 10 seconds in a test system with POI level SCR of 3.	Choose
Insert Notes Here:		
4.d	Model responds to a step change in PPC active power setpoint, reaching 90% of the new value between 1 and 10 seconds in a test system with POI level SCR of 3.	Choose
Insert Notes Here:		

4.e	Model trips or blocks when terminal voltage rises above 1.3 pu for 1.5 second.	Choose
Insert Notes Here:		
4.f	Model trips or blocks when terminal voltage falls below the protection setting for specified time period.	Choose
Insert Notes Here:		
4.g	Model clearly displays trip / diagnostic signals indicating the status of all pertinent protection elements.	Choose
Insert Notes Here:		

Contact Information

- Comments to be sent to CAISO at GridModelingData@caiso.com. If discussing a specific resource, please use following subject line:

[Resource ID] [Generating unit name] BPM Model Submission

- Please cc your interconnecting PTO in your email to CAISO; using the contacts provided below:

SCE basecase@sce.com

PG&E GenModel@pge.com

SDG&E basecase@semprautilities.com

VEA veaengineering@vea.coop

Gridliance GLW-planning@gridliance.com

QUESTIONS?