Electromagnetic Transient Modeling Requirements

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I. Introduction

This document provides Generator Owners with modeling requirements, including guidelines for accuracy, usability, and efficiency, to be used for better planning, operation, and improved reliability of the bulk power system. Due to a shift in resource mix (e.g., higher penetrations of inverter-based generation), operating characteristics and constraints of the bulk power system are changing; therefore, Electromagnetic Transient (EMT) studies must be incorporated into planning to assure continued reliability. Specifically, EMT studies include Sub-Synchronous Oscillations (SSO) and fast control interaction with nearby devices or generation. For the EMT models to be usable, they should be in a format usable by the PSCAD™/EMTDC™ simulation tool, for e.g. *.pswx, *.pscx, *.pslx. The entirety of the project (only generator owner facilities) should be modeled up to the point of interconnection (to either the transmission grid or local utility distribution system) and tested in a working PSCAD™/EMTDC™ case. Finally, the working test case that contains the project should be submitted by the Generator Owner to its Planning Coordinator and/or Transmission Planner, as applicable. Moreover, if a single plant is split into multiple generating resources requiring individual submissions, it is acceptable and desirable to submit the PSCAD model for the entire plant as part of each individual submission.

II. Documentation Requirements

Supporting documentation is required when submitting the model. The following information should be included in the documentation:

1. Vendor name and the version of the model
2. List and description of the files being submitted
3. Instruction for setup and running the model and any limitation of the models, including the lowest grid strength the model is designed for
4. Indication whether the model is real-code[1] or not
5. List and description of all the control functions and associated parameters, and identifying those accessible to the user
6. List and description of all the protections (both AC and DC protections), and identifying those associated settings accessible to the user
7. Description of the test case that should be configured according to the site-specific real equipment configuration up to the point of interconnection
8. Balanced and un-balanced fault tests using the test case
9. Voltage/reactive power reference step change test using the test case
10. Frequency/active power reference step change test using the test case
11. Model validation and benchmarking against field test data, if the model does not use real-code.

[1] Actual code implemented in the inverter and plant controller firmware

III. Modeling Requirements

a) Synchronous and Induction Generators

The modeling details described in this section should be met for synchronous generators and induction generators, such as combustion turbine generators, steam turbine generators, hydro generators, and Type 1 and Type 2 wind turbines. Synchronous and induction generator models should:

1. Include the Multi-Mass Torsional Shaft Interface model configured for a Synchronous Machine or Induction Machine as appropriate. The model should include the inertia constants, shaft spring constants, torque share between the different masses, and damping. The approximate representation of one stiff shaft used in transient stability modeling is not allowed.
2. Include representation of the machine saturation or magnetizing curve, and the transformer magnetizing curves.
3. Represent the generator excitation system as a user-written PSCAD model or as standard PSCAD block models with the model type and data specified. If standard PSCAD block models are used, a statement from the manufacturer or plant operator confirming that the models can represent the accurate excitation system performance in transient simulations (50 micro-second time step) must be included.
4. Represent the generator governor model as a user-written PSCAD model or as standard PSCAD block models with the model type and data specified. If standard PSCAD block models are used, a statement from the manufacturer or plant operator confirming that the models can represent the accurate excitation system performance in transient simulations (50 micro-second time step) must be included.
5. Represent the generator power system stabilizer (PSS) as a user-written PSCAD model or as standard PSCAD block models with the model type and data specified. If standard PSCAD block models are used, a statement from the manufacturer or plant operator confirming that the models can represent the accurate excitation system performance in transient simulations (50 micro-second time step) must be included.
6. Include model parameters which reflect the actual installed settings in the field and not the manufacturer default parameters.
7. Represent the generator grounding system. The generator grounding will impact the generator fault contribution and represent the imbalance in the three phase system.
8. Represent all installed protections in detail for both balanced and unbalanced fault conditions. Typically, this includes overcurrent protection, various over-voltage and under-voltage protection (individual phase and RMS), frequency protection, loss of field protection, under/over-excitation protection, reverse power protection, out of step protection, and any other special protection including the ability to enable and disable.

This list of protection schemes is not intended to be exhaustive, as there may be other pertinent types of protection.

9. Represent the Sub-Synchronous Oscillation (SSO) mitigation and/or protection including the ability to enable and disable SSO mitigation/protection, if applicable.
10. Represent dynamic reactive devices including automatically controlled capacitor and reactor banks, if applicable.
11. Represent all pertinent electrical and mechanical configurations, such as filters and specialized transformers. Mechanical features (such as gearboxes, pitch controllers, etc.) should be included in the model if they impact electrical performance. Any control or dynamic features of the actual equipment which may influence simulation behavior but are not represented or are approximated should be documented.
12. Accurately reflect behavior throughout the MW and MVAr output range, from minimum power through maximum installed capacity.
13. Including detailed representation of any hardware or software filters for the wind turbine controllers is necessary as they may act to block the sub-synchronous frequencies.
14. 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. Default parameters may not be appropriate.

b) Inverter Based Generators

The modeling details described in this section should be met for inverter based generators. Inverter based generator models should:

1. 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. The approximate representation used in transient stability modeling is not allowed. It is possible to create models by embedding the actual hardware code into a PSCAD™ component; and this is the recommended type of model.[2] If the model is assembled using standard blocks available in the PSCAD™ master library, a validation against actual hardware performance is required.
2. Represent all control features pertinent to the type of study being done. This should include external voltage controllers, plant level controllers, customized phase locked

[2]The model must be a full IGBT representation (preferred), or may use an average source representation that approximates the IGBT switching but maintains full detail in the inner controls, and maintains DC side protection features. Models manually translated block-by-block from MATLAB or control block diagrams may be unacceptable because the method used to model the electrical network and interface to the controls may not be accurate, or portions of the controls such as PLL circuits or protection circuits may be approximated or omitted. Note that firmware code may be directly used to create an extremely accurate PSCAD model of the controls. The controller source code may be compiled into DLLs or binaries if the source code is unavailable due to confidentiality restrictions.

loop (PLL) systems, ride-through controllers, sub-synchronous control interaction damping controllers, and others. Operating modes that require system specific adjustment should be user accessible. In most cases, plant level voltage control should be represented along with adjustable droop characteristics. 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 should be included in the plant control model. The model parameters provided should reflect the actual installed settings in the field and not the manufacturer default parameters.

3. Represent the Sub-Synchronous Oscillation (SSO) mitigation and/or protection including the ability to enable and disable SSO mitigation/protection, if applicable.
4. Represent dynamic reactive devices including automatically controlled capacitor and reactor banks, if applicable.
5. Include the transformer magnetizing curves.
6. Represent all pertinent electrical and mechanical configurations, such as filters and specialized transformers. Mechanical features (such as gearboxes, pitch controllers, etc.) should be included in the model if they impact electrical performance. Any control or dynamic features of the actual equipment which may influence simulation behavior but are not represented or are approximated should be documented.
7. Represent all installed protection systems in detail for both balanced and unbalanced fault conditions. Typically, this includes various over-voltage and under-voltage protection (individual phase and RMS), frequency protection, DC bus voltage protection, and overcurrent protection. This list of protection schemes is not intended to be exhaustive, as there may be other pertinent types of protection. Any protections which can influence dynamic behavior or plant ride-through in the simulation period should be included.
8. Accurately reflect behavior throughout the MW and MVAr output range from minimum power through maximum power.
9. Including detailed representation of any hardware or software filters for the wind turbine controllers if necessary.
10. 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. Default parameters may not be appropriate.

IV. Model Usability Features

The model usability features described in this section should be met. All models should:

1. Have pertinent control or hardware options accessible to the user (e.g., adjustable protection thresholds, real power recovery ramp rates, frequency or voltage droop settings, voltage control response times, or Sub-Synchronous Control Interaction damping controllers). Diagnostic flags (e.g., flags to show control mode changes or

which protection has been activated) should be reasonably accessible to facilitate analysis and should clearly identify why a model trips during simulations.

2. Be capable of running at time steps anywhere in the range from 10 µs to 20 µs. Most of the time, requiring a smaller time step means that the 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 longer time steps.
3. Include a sample implementation test case. Test case models should be configured according to the site-specific real equipment configuration up to the point of interconnection. This includes, but is not limited to: aggregated generation model, aggregated generator transformer, equivalent collector branch, main step-up transformers, generator tie line, and any static/dynamic reactive resources. Test case should use a single machine infinite bus representation of the system, configured with an appropriate representative Short Circuit Ratio (SCR), such as 3. Access to technical support engineers is desirable.
4. Be capable of initializing itself. Models should initialize and ramp to full output without external input from simulation engineers.
5. Have an identification mechanism for configuration. The model documentation should provide a clear way to identify the specific settings and equipment configuration which will be used in any study, such that during commissioning the settings used in the studies can be checked. This may include control revision codes, settings files, or a combination of these and other identification measures.
6. Accept external reference values. This includes real power reference (for active power control mode) or frequency reference (for frequency control), and reactive power reference values (for Q control modes) or voltage reference values (for V control modes). Model should accept these reference variables for initialization and be capable of changing these reference variables mid-simulation, i.e. dynamic signal references.
7. Allow protection models to be disabled. Many studies result in inadvertent tripping of converter equipment, and the ability to disable protection functions temporarily provides study engineers with valuable system diagnostic information.
8. Allow the active power capacity of the model to be scaled if using same inverter, collector and/or padmount transformer models. The active power capacity of the model should be scalable in some way, either internally or through an external scaling transformer. This is distinct from a dispatchable power order described below, and is used for modeling different plant capacities or breaking a lumped equivalent plant into smaller composite models.
9. Have the ability to dispatch its output to values less than nameplate. 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.

V. Model Efficiency Features

The model efficiency features described in this section should be met. All models should:

1. Be compiled using Intel Fortran compiler version 12 and higher.
2. Be compatible with PSCAD™ version 4.6.3 or higher. The model should not be dependent on a specific PSCAD™ version to run.
3. Initialize as quickly as possible (for example < 5 seconds) to user supplied terminal conditions.
4. Support multiple instances of its own definition in the same simulation case.
5. Support the PSCAD™ "timed snapshot" and "multiple run" features.
6. Does not use global variables. Allow replication in different PSCAD™ cases or libraries through the "copy" or "copy transfer" features.
7. Model should not utilize multiple layers in the PSCAD environment, including 'disabled' layers.