

PSCAD Model Requirements Rev. 10

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Prepared By: Andrew L. Isaacs
Lukas Unruh
Garth Irwin

This document includes the following attachments:

Attachment #1: PSCAD Model Test Checklist

Attachment #2: PSCAD Model Requirements Supplier Checklist

Revision 10 notes (Changes from rev. 9):

Introduction	Clarification and comment about validation
Footnote 2	Clarification on average source models
Item B	Clarification
Item D	Clarification
Entire Document	Clarification on using representative SCR levels for testing
Item F	Clarification
Item M	Clarification on model initialization
Item R	Update to PSCAD v.4.6.3
Checklists	Minor updates to reflect above changes, changed test checklist from pass/fail to yes/no

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12-75 Scurfield Blvd.
Winnipeg, MB, Canada, R3Y 1P6
www.electranix.com



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Introduction

Specific model requirements for a PSCAD study depend on the type of study being done. A study with a scope covering weak system interconnections, ride-through evaluation, Sub-Synchronous Control Interactions (SSCI), short term¹ event response, and fast control interaction with nearby devices (for example) would require a model which has the following characteristics. Some specialty studies may require other features. Refer to “Attachment #1: PSCAD Model Test Checklist” and “Attachment #2: PSCAD Model Requirements Supplier Checklist”, appended to this document, for additional information on how these requirements may applied.

Validation of models against recorded equipment behaviour and benchmarking against other models are important tools for assuring accuracy. This document does not address how this validation or benchmarking should be done, but it is recommended that inverter and plant level validation be done to the extent practical and possible.

Model Accuracy Features

For the model to be sufficiently accurate, it must:

- A. *Represent the full detailed inner control loops of the power electronics.* The model cannot use the same approximations classically used in transient stability modeling, and should fully represent all fast inner controls, as implemented in the real equipment. Models which embed the actual hardware code into a PSCAD component are currently wide-spread, and this is the recommended type of model.²
- B. *Represent all control features pertinent to the type of study being done.* Examples include external voltage controllers, plant level controllers, customized PLLs, ride-through controllers, SSCI damping controllers and others. As in point A, actual hardware code is recommended to be used for most control and protection features. Operating modes that require system specific adjustment should be user accessible. 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

¹ Example analysis periods could be 2 to 10 seconds from fault inception. Some studies could require longer periods.

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.

It is not recommended to assemble the model using standard blocks available in the PSCAD master library, as approximations are usually introduced, and specific implementation details for important control blocks such as PLLs may be lost. In addition, there is a significant risk that errors will be introduced in the process of manually assembling the model. For this type of manually assembled model, (not using a direct “real code” embedding process), extra care is required, and validation is required.

- multiple types of IBRs (eg. Hybrid BESS/PV) this functionality should be included in the plant control model.
- C. *Represent all pertinent electrical and mechanical configurations.* This includes any filters and specialized transformers. There may be other mechanical features such as gearboxes, pitch controllers, or others which should be modelled if they impact electrical performance within the timeframe of the study. Any control or dynamic features of the actual equipment which may influence behaviour in the simulation period which are not represented or which are approximated should be clearly identified.
 - D. *Have all pertinent protections modeled in detail for both balanced and unbalanced fault conditions.* Typically this includes various OV and UV protections (individual phase and RMS), frequency protections, DC bus voltage protections, converter overcurrent protections, and often other inverter specific protections. Any protections which can influence dynamic behaviour or plant ride-through in the simulation period should be included. As in point A, actual hardware code is recommended to be used for these protection features.
 - E. *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.

Model Usability Features

In order to allow study engineers to perform system analysis using the model, the PSCAD model must:

- F. *Have control or hardware options which are pertinent to the study accessible to the user.* Although plant should be configured to match site specific settings as far as they are known (see point E above), parameters pertinent to the study should be accessible for use by the model user. Examples of this could include protection thresholds, real power recovery ramp rates, frequency or voltage droop settings, voltage control response times, or SSCI damping controllers.³ Diagnostic flags (eg. flags to show control mode changes or which protection has been activated) should be visible to aid in analysis.
- G. *Be accurate when running at a simulation time step of 10 μ s or higher.* Often, 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 larger simulation time-steps. In cases where the IGBT switching frequency is so high that even interpolation does not allow accurate switching representation at 10 μ s (eg. 40 kHz), an average source approximation of the inverter switching may be used to allow a larger simulation time step².
- H. *Operate at a range of simulation time steps.* The model should not be restricted to operating at a single time step, but should be able to operate within a range (eg. 10 μ s – 20 μ s)

³ Care should be taken to ensure that any user-settable options are not changed in a way that is not implementable in the real hardware, and that any selectable options are actually available at the specific site being considered. Discussion is recommended with the manufacturer prior to any changes being made in model configuration.

- I. *Have the ability to disable protection models.* 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.
- J. *Include documentation and 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 would include (for example): aggregated generator model, aggregated generator transformer, equivalent collector branch, main step up transformers, gen tie line, and any other static or dynamic reactive resources. Test case should use a single machine infinite bus representation of the system, configured with an appropriate representative SCR⁴. Access to technical support engineers is desirable.
- K. *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 be control revision codes, settings files, or a combination of these and other identification measures.
- L. *Accept external reference variables.* This includes real and reactive power ordered values for Q control modes, or voltage reference values for voltage control modes. Model should accept these reference variables for initialization, and be capable of changing these reference variables mid-simulation, ie. dynamic signal references.
- M. *Be capable of initializing itself.* Once provided with initial condition variables, the model must initialize and ramp to the ordered output without external input from simulation engineers. Any slower control functions which are included (such as switched shunt controllers or power plant controllers) should also accept initial condition variables if required. Note that during the first few seconds of simulation (eg. 0-2 seconds), the system voltage and corresponding terminal conditions may deviate from nominal values due to other system devices initializing, and the model should be able to tolerate these deviations or provide a variable initialization time.
- N. *Have the ability to scale plant capacity.* The active power capacity of the model should be scalable in some way, either internally or through an external scaling transformer⁵. 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.
- O. *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 behaviour at various operating points.
- P. *Initialize quickly.* Model must reach its ordered initial conditions as quickly as possible (for example <5 seconds) to user supplied terminal conditions.

⁴ Representative SCR should reflect approximate N-1 interconnection SCR where possible, especially if the system is expected to be weak. If the system strength is not known, using a relatively low SCR in the test system, such as 2.5, may help to avoid issues during study phases.

⁵ A free publicly available scaling transformer suitable for this purpose is available in the E-Tran library.

Study Efficiency Features

In addition, the following elements are required to improve study efficiency, model compatibility, and enable other studies which include the model to be run as efficiently as possible. If these features are not supported, additional discussion is required⁶:

- Q. Model should be compatible with Intel Fortran compiler versions 12 and higher.
- R. Model should be compatible with PSCAD version 4.6.3 and higher.
- S. Model supports multiple instances of its own definition in the same simulation case.
- T. Model supports the PSCAD “timed snapshot” feature accessible through project settings.
- U. Model supports the PSCAD “multiple run” feature.
- V. Model does not use or rely upon global variables in the PSCAD environment.
- W. Model should not utilize multiple layers in the PSCAD environment, including ‘disabled’ layers.

⁶ Electrenix has parallelization tools available (E-Tran Plus for PSCAD) which can circumvent compatibility concerns in some cases.

Attachment #1: PSCAD Model Test Checklist

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Purpose

This document is a test checklist meant to accompany “PSCAD model requirements” provided above and “Attachment #2: PSCAD Model Requirements Supplier Checklist”. The procedures provided in this document are intended to provide an indication of the core model accuracy, performance, and usability features specified in the model requirements. These procedures cannot ultimately prove that the model is compliant with all requirements, as black box models usually hide the details of the equipment controls and protection. It is recommended that the equipment manufacturer supply additional confirmation that the model meets each individual requirement. The requirements in this document do not necessarily represent interconnection criteria for specific individual systems, and may be supplemented or adjusted based on interconnection region.

The tests outlined here are considered “basic”, and may be supplemented by more rigorous testing, including various fault types, depths, and durations, as well as more extensive protection testing and benchmarking against phasor models. This document is not intended to be a guide for thorough benchmarking between PSCAD, PSS/E, and actual equipment, and is subject to revision as the state of the art in EMT modeling evolves.

<i>Model test Summary</i>	
Model Test date:	
Project Name:	
Manufacturer:	
Equipment type: (eg. PV or Wind)	
Equipment version:	
Documentation file:	
Model Files supplied:	

Verification Procedure and Checklist

		Yes/No	Comments
<i>Vendor and site specific model verification</i>			
1a	The Vendor's name and the specific version of the model should be clearly observable in the .pscx PSCAD case.		
1b	Documentation and supporting model filenames should not conflict with model version shown in the .pscx case file.		
1c	Model is supplied with a test circuit which is configured for the site specific application. ⁷		
<i>"Real Code" model verification</i>			
2a	Controls are black-boxed, and no PSCAD master library control blocks are visible within control circuits. ⁸ If the model is not based on "real code", a separate validation report is required showing model comparison against hardware tests. ⁹		
<i>Model usability verification</i>			
3a	Model uses a timestep greater than 10 μ s ¹⁰		
3b	Model allows a variation in simulation timestep		
3c	Model compiles using Intel FORTRAN version 12		
3d	Model initializes in 5 seconds or less with a POI level SCR of 2.5 ¹¹ . Real power, reactive power, and RMS voltage should reach steady state by this time.		
3e	Model allows multiple instances of itself to be run together in the same case ¹²		
<i>Model electrical configuration verification</i>			
4a	Plant level electrical single line diagram (SLD) is included.		

⁷ The test circuit should model all relevant electrical components of the plant and contain a system equivalent. Parameters will be assumed to be site-specific, unless there are obvious indications otherwise, such as an incorrect grid base frequency.

⁸ Black-boxing of controls to a high level does not guarantee that real-code is embedded into the model, however the visibility of PSCAD master-library control blocks in the inner control loops (PLL, inner current controllers, etc.) suggest that the model is generic in nature. Model documentation may contain information on use of real-code in the model.

⁹ All aspects of the controller operation are required to be validated by utilizing a "hardware in loop" platform or other hardware test systems. Model should not be validated against other software models. Validations should include control responses to various types of faults, changes in power and voltage references, changes in system frequency, testing frequency response in sub and super-synchronous ranges, and testing of protection operation. Tests should also be performed under a variety of system strengths, including very weak systems. Other tests may also be required. The validation report is required along with any model updates that result from the more rigorous validation tests.

¹⁰ Models with timesteps less than 10 μ s may be acceptable in situations where a small timestep does not significantly increase the runtime of the total simulation

¹¹ For all tests where an SCR of 2.5 is specified, this may be replaced with an SCR equal to that of the POI under contingency conditions if this is known.

¹² Depending on specific application and whether E-Tran Plus for PSCAD is allowed to be used to overcome the limitation, this requirement may be waived.

4b	Generator step-up transformer(s) included, with impedance between 5 and 10% on generator base, and matches SLD. ¹³		
4c	Lumped collector equivalent(s) included, with total charging equal to between 0.5 and 5% of plant rating, and matches SLD. ¹³		
4d	Substation transformer(s) included, rated appropriately for plant size, and impedance between 6 and 12% on transformer base, and matches SLD. ¹³		
4e	Model can be scaled to represent any number inverters/turbines, either using a scaling transformer or internal scaling.		
4f	All external devices included in the plant (such as STATCOMs) include appropriate models.		
<i>Plant controller verification</i>			
5a	Model includes power plant controller (PPC)		
5b	PPC accepts an external active power setpoint.		
5c	PPC accepts a voltage setpoint.		
5d	PPC has a mechanism to implement a settable voltage droop.		
5e	Overall plant responds to frequency changes by increasing or decreasing its active power as appropriate. This may be accomplished either at an inverter level or via the PPC. ¹⁴		
5f	Model initializes to the setpoints specified in the PPC. If droops or deadbands are utilized, the initial values may differ from the setpoints. ¹⁵		
5g	If external voltage control devices (STATCOM/DVAR, SVC, MSCs) are included in the plant, ensure that the voltage control of these devices is coordinated with the PPC, with no potential for VAR looping or oscillations.		
<i>Basic performance verification¹⁶</i>			
6a	Instantaneous voltage and current waveforms have minimal distortion, and no oscillations are observed.		

¹³ Impedance range is for sanity checking only. Impedances outside this range may be allowed.

¹⁴ Non-compliance with this item may not require model revision as frequency response may not be required in PSCAD models by some utilities. In this case, a description of the under/over frequency response capabilities of the actual equipment should be provided by the manufacturer.

¹⁵ If voltage control with droop is implemented, it is preferred that the PPC model requests an initial Q value to match the voltage setpoint. If no initial Q is requested, the voltage setpoint can be biased by the initial Q before it is sent to the PPC. If a non-zero deadband is included in the voltage controller, the deadband can also be considered in the voltage setpoint sent to the PPC.

¹⁶ Performance testing is recommended with a POI level SCR of 2.5 as this is a representative system condition seen during weak system studies. Testing may be performed at higher SCRs if the stable operating SCR of a model is known to be above 2.5.

6b	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 2.5. ¹¹		
6c	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 2.5. ¹¹ (Various systems may have specific speed requirements, which should be met)		
6d	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 2.5. ^{11,17}		
<i>Basic protection verification</i> ¹⁸			
7a	Protection settings are implemented. These could be available as inputs in the model, or hard-coded in the black-boxed controls. ¹⁹		
7b	Option to disable protection models is present. ²⁰		
7c	Model trips or blocks when terminal voltage rises above 1.3 pu for 1.5 second. ²¹		
7d	Model trips or blocks when terminal voltage falls below 0.2 pu for 1.5 second. ²¹		
7e	Model clearly displays trip / diagnostic signals indicating the status of all pertinent protection elements		
<i>Documentation</i>			
8a	Model documentation states compliance with “Recommended PSCAD model requirements Rev. 10” ²² , or is supplied with a completed PSCAD Model Requirements Supplier Checklist.		
8b	Model documentation includes instructions for setup and running of the model, including the recommended range of simulation timesteps. Documentation should give a clear description of trip / operation code signals produced by model.		

¹⁷ Different response time criteria may apply depending on specific interconnection region.

¹⁸ There are many protection functions which should be modelled, per footnote 1, and these basic tests will not be proof that these are modelled.

¹⁹ If settings are not visible in model or documentation, verification that protection settings are implemented in the PSCAD model should be received from the manufacturer.

²⁰ Non-compliance may not require model revision as many studies do not require testing with protection settings disabled.

²¹ Non-compliance with this item should result in verification of protection settings implementation from the manufacturer, as some models may have capabilities beyond what is listed here.

²² Non-compliance may be waived in systems which do not require compliance with the model requirements document.

Attachment #2: PSCAD Model Requirements Supplier Checklist

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Purpose

This document is a model requirements checklist which should be completed by the supplier of the model and submitted alongside each PSCAD model. This document accompanies the “PSCAD model requirements Rev. 10” document above (PMR), which should be used for further reference to describe the requirements associated with each point. Generic testing of the model may be done using “Attachment #1: PSCAD Model Test Checklist”, which may be used as a reference.

Model supplier must review every item in the checklist and indicate compliance for each item. If the supplied model does not meet any of the requirements an explanation of the deficiency should be provided in the comments column.

<i>Model Submission Summary (to be completed by model supplier)</i>	
Submission date:	
Project Name:	
Primary contact information for model related questions:	
Secondary contact information for model related questions:	
Manufacturer:	
Equipment type: (eg. PV or Wind)	
Equipment version:	
Documentation file(s):	
Model Files supplied:	

Model Requirements Checklist		PMR Reference	Model Complies? (Yes/No)	Comments
1	<i>Model Accuracy Features</i>			
1.1	Power electronic controls are modelled by interfacing with actual firmware code from the inverter (“real code” model), or includes detailed validation report.	A, B		
1.2	Operating modes which require system specific adjustment are accessible.	B		
1.3	Plant level controller is included. ²³	B		
1.4	Model is capable of controlling frequency ²⁴	B		
1.5	Includes pertinent electrical and mechanical features, such as gearboxes, pitch controllers, or other features which impact the plant performance in the simulation period. ²⁵	C		
1.6	All protections which could impact ride-through performance are modelled in detail.	D		
1.7	Model is configured for the specific site being evaluated, as far as they are known.	E		
2	<i>Model and Project Documentation</i>			
2.1	Model includes documentation.	J		
2.2	Documentation includes instruction for setup and running the model.	J		

²³ If the plant is part of a multi-plant control scheme, a description of the overall scheme should be provided, and corresponding PPC models should be configured to control multiple plants accordingly.

²⁴ Frequency control model requirements may vary by region. Example response time may be less than 10 seconds.

²⁵ Simulation period may vary depending on the model use, but 10 seconds of simulation following an event such as a fault is a typical period.

2.3	Model is supplied with a sample test case including site specific plant representation.	J		
2.4	Plant single line diagram is provided, and aligns with model	J		
2.5	Model documentation provides a clear way to identify site-specific settings and equipment configuration.	K		
3	<i>Model Usability Features</i>			
3.01	Control or hardware options are accessible to the user as applicable.	F		
3.02	Diagnostic flags are visible to the user.	F		
3.03	Model uses a timestep greater than 10 μ s.	G		
3.04	Model allows a range of simulation timesteps (ie. not restricted to a single timestep).	H		
3.05	Protection model may be disabled for troubleshooting	I		
3.06	Model accepts external reference variables for active and reactive power and voltage setpoint, and these may be changed dynamically during the simulation.	L		
3.07	Model is capable of initializing itself.	M		
3.08	Active power capacity is scalable.	N		
3.09	Active power is dispatchable.	O		
3.10	Model reaches setpoint P, Q, and V in 5 seconds or less	P		
3.11	Model compatible with Intel FORTRAN version 12 and higher.	Q		
3.12	Model compiles using PSCAD version 4.5.3 or higher.	R		
3.13	Model supports multiple instances of its own definition in a single PSCAD case.	S		
3.14	Model supports PSCAD “snapshot” feature.	T		

3.15	Model supports the PSCAD “multiple run” feature.	U		
3.16	Model does not use PSCAD global variables.	V		
3.17	Model does not use PSCAD layer functionality	W		