EMT Model Intake and Quality Assurance

ESIG Webinar

May 18, 2023

Presented by Andrew L. Isaacs

ELECTRANIX
SPECIALISTS IN POWER SYSTEM STUDIES

Note about us…

- Electranix is a Canadian (Manitoba!) independent consulting company focused on power systems modelling and simulation

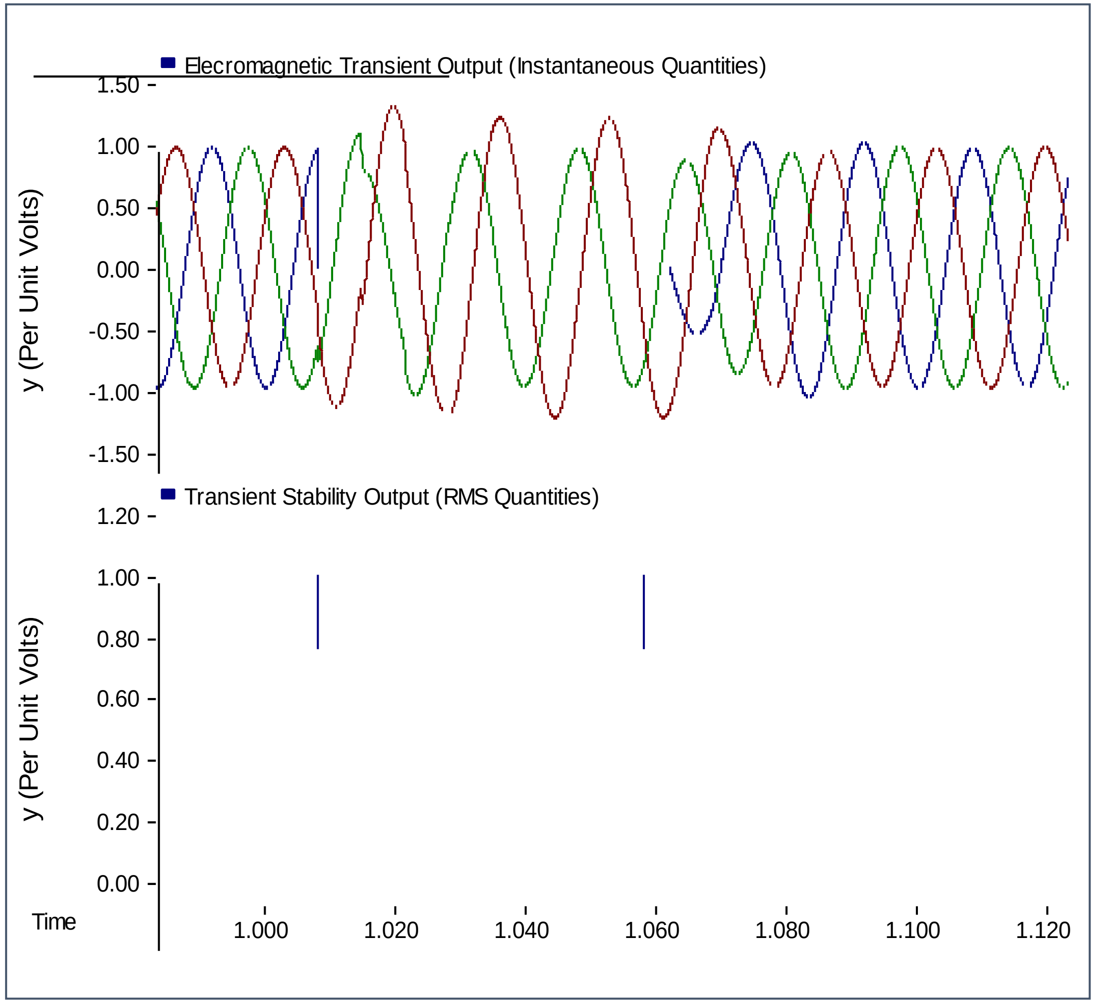
-40C to +40C

Bill Mason

EMT!!

Reminder: what is EMT exactly?

- Power-flow and transient stability programs iteratively solve systems of equations in the RMS 50/60 Hz phasor domain
- Electromagnetic Transient (EMT) software solves systems of differential equations which describe the three-phase electrical network in the time domain.
- This allows EMT simulations to represent the power system behavior at all frequencies, limited only by the period of time between solutions (simulation time-step). Every individual instantaneous phase quantity is represented, allowing unbalanced faults, harmonics, transients and other effects to be modeled.



What has EMT been used for?

- Lightning evaluation
- TOV/TRV/Insulation coordination
- Switching/line energization
- Transformer energization
- Harmonic analysis
- Sub-Synchronous Resonance (SSR)
- HVDC/FACTS control design and analysis

What is EMT now also used for?

- Weak system interconnections
- Very high renewable penetration
- Regions with high chance of power electronic device interactions (eg. dynamic performance, FRT tests, etc)
- SSO phenomena (SSR, SSCI, SSTI)
- Fault ride-through evaluation
- Black start analysis
- Detailed fault current / protection analysis.

What is inside an EMT IBR model?

- Detailed protection algorithms
- Software matching specific equipment firmware code (DLL standard has been successful)
- Representation of energy source (may include machine, PV panel, DC-DC converters, etc)
- Detailed representation of electrical system (switching bridge, breakers, transformers, filters, etc.)
- For plant model, may include aggregation of collector system and GSUs, and generators, station transformers, capacitors, other devices, etc.

Why do we need EMT?

- Simply… to obtain the accuracy needed in our studies to design our power grid reliably.
  - Some phenomenon are difficult or impossible to predict using PD tools
  - Inverter based resources are challenging our ability to predict outcomes
- Notes:
  - We don’t always need it!! But when we do need it, we need to have the tools, models, and expertise ready.
  - EMT supplements and adds to our existing tools and processes. It generally doesn’t replace them.
- Events are reinforcing the need!!
- We are catching issues before projects go in service every day!

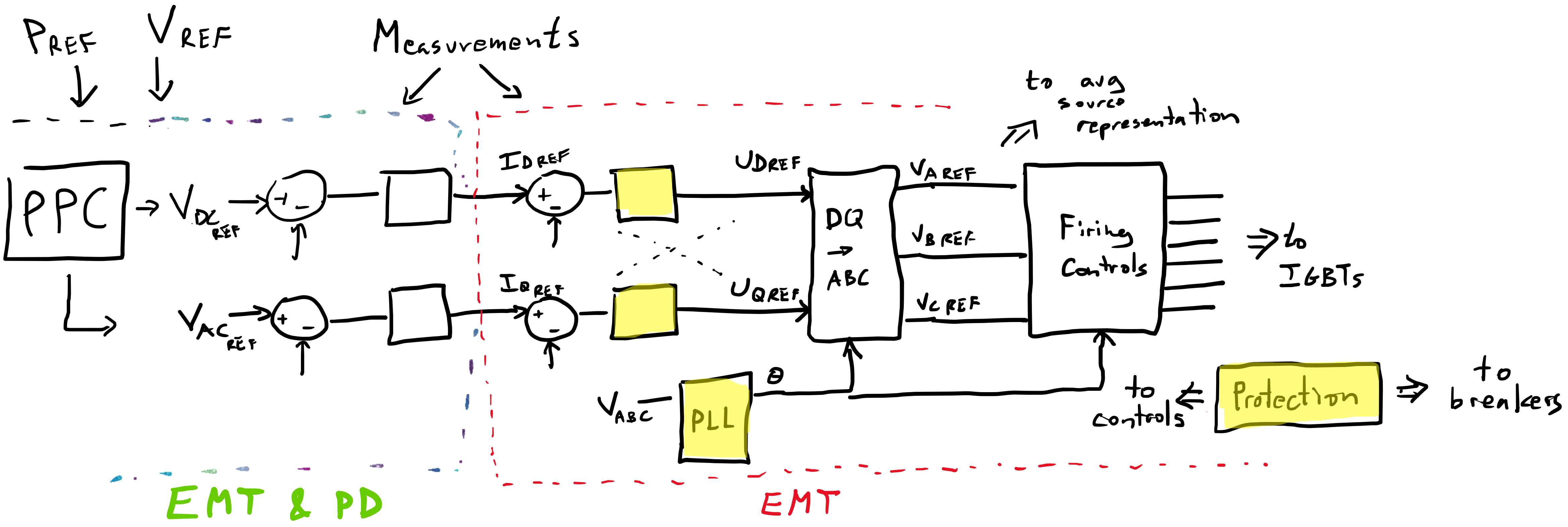
NERC and IEEE are in agreement…

- *"…NERC further recommends that **EMT models be required for all newly connecting BPS-connected inverter-based resources**"* - NERC EMT Reliability Guideline – March 2023

- *"Upon request from the TS operator and TS owner, the IBR owner shall provide: a) Verified IBR plant–level models, including a steady-state power-flow model, positive-sequence (fundamental-frequency) stability dynamic model (user written and/or generic), **an EMT model**, short-circuit and harmonics models, to perform IBR plant design evaluation and system studies. If necessary, the TS operator and TS owner may request additional types of models from the IBR owner with proper justification."* – IEEE 2800-2022 (Chapter 10)

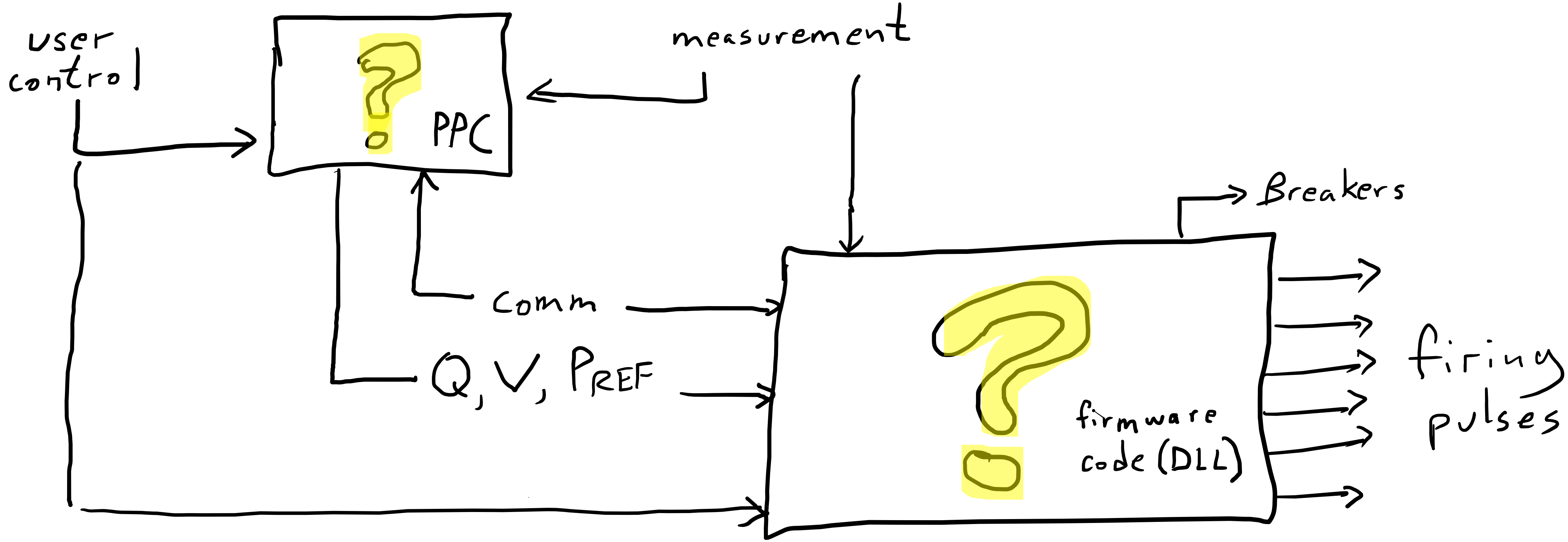
- *"TS operator/TS owner **should specify requirements for inverter based resources to provide EMT models** in situations where an EMT-type study may be needed now or in the foreseeable future."* – IEEE 2800-2022 (Annex G)

What is in an EMT inverter control model?



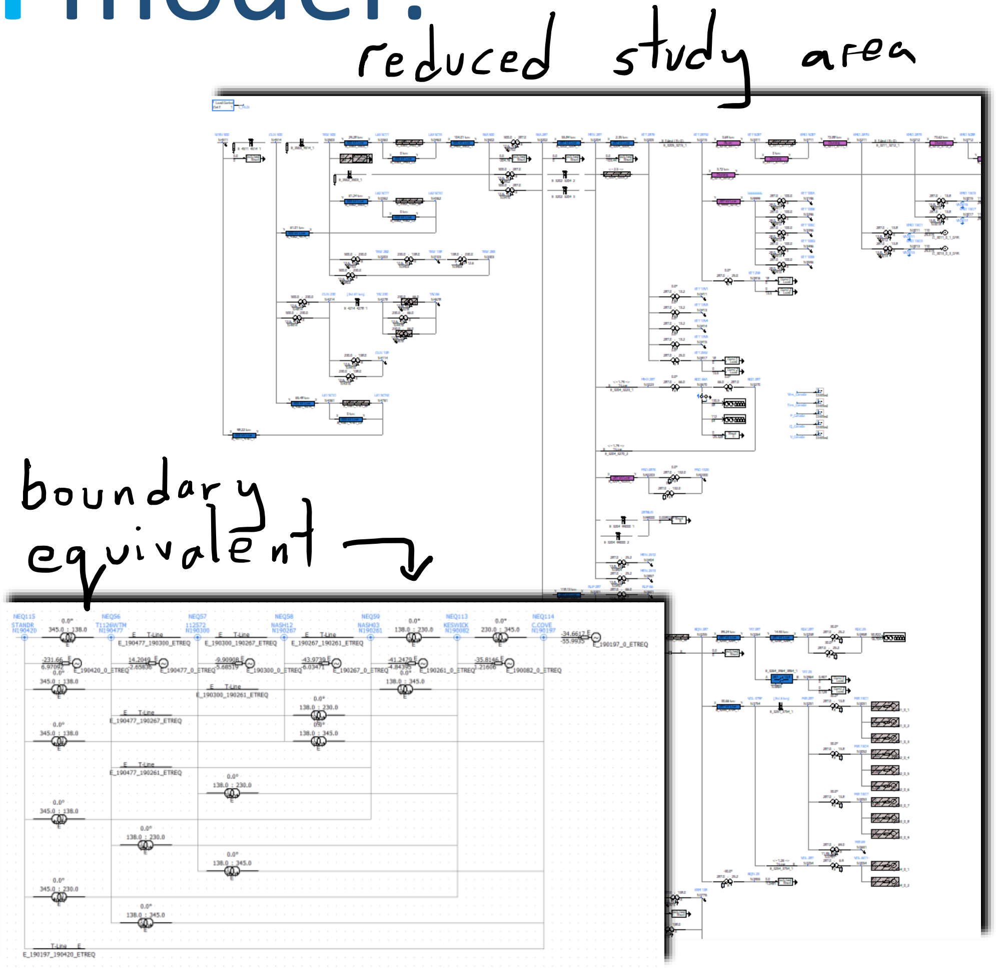
Disclaimer: Highly simplified control representation!!

What do **you** see in an EMT control model?



What is in an EMT system model?

- Transmission lines and cables (can be travelling wave, frequency dependent models)
- Detailed series capacitor models, shunt capacitors
- Equivalent boundary representation (can be multi-port, frequency dependent, or even co-simulation/hybrid dynamic)
- Transformers (can include details on windings/cores, saturation, remanence effects, arresters, etc)
- Detailed dynamic models for generators, HVDC and FACTs
- Faults, events, monitoring, automation, etc.



NOTE: System modeling and studies are a topic for another webinar!!

What do the requirements look like?

- Range from basic frameworks, to checklists, to detailed testbench models!
- Most include requirements for:
  - **Accuracy**: Is it detailed and correct?
  - **Usability**: Does it function within a study context?
  - **Site-specific**: Does it represent the equipment being used?

It is useful to also have requirements for…

- **Performance**: Is the plant likely to conform with basic performance needs for the system? (Note that usually a full study is the final arbiter of "acceptable performance")

Example requirements:

HECO, SPP, CAISO, AESO, TVA all have requirements, with many others in effect or in development.

Regional entities within ISOs have their own requirements. NERC guides, Consultant or research entity guides are also available.

IEEE 2800-2022

(public) models, with a brief description of the limitations of the generic models, so that the utility is able to share the generic models with neighboring entities and/or reliability entities that may require them for system-wide studies.

G.4 Electromagnetic transient (EMT) dynamic modeling data requirements

Along with positive-sequence stability models, EMT models may be needed to study certain issues involving inverter-based resources that cannot be studied in positive-sequence stability programs. These types of studies are particularly useful in areas where inverter-based resources may interact with other power electronic controls, such as existing HVDC, STATCOMs, SVCs, or other inverter-based resources. They are also useful where inverter-based resources are connected in low short-circuit strength networks, or in close proximity to series capacitors. Therefore, *TS operator*/*TS owner* should specify i based resources to provide EMT models in situations where an EMT-type study the foreseeable future. All OEMs are encouraged to develop such EMT models fo such models are available when requested.

The *TS operator*/*TS owner* may either require EMT models for all newly interc resources or may require these models on a case-by-case basis. Situations wher required may include, but are not limited to, the following:

— Areas of low (or decreasing) short-circuit strength (NERC Reliability Guic

— Areas near existing (or planned future) series-compensated transmission ci subsynchronous resonance phenomena (e.g., subsynchronous oscillation *control interaction [SSCI]*, self-excitation, etc.), as well as other resonanc transient overvoltages

[194] OEMs may consider block diagrams for user-written dynamic models as proprietary informatio disclosure agreement before sharing proprietary block diagrams. The end user should not use block d some cases, block diagram for user-written dynamic models may not be available.

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AEMO

Dynamic Model Acceptance Test Guideline

Version 2: November 2021

Electranix

PSCAD Model Requirements Rev. 12

Date: September 19, 2022

Prepared By: Andrew L. Isaacs
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This document includes the following attachments:
Attachment #1: PSCAD Model Test Checklist for Reviewing Model Submissions
Attachment #2: PSCAD Model Requirements Supplier Checklist

Revision 12 notes (Changes from rev. 11):

Entire document	Editorial changes for clarity
PMR sections A,B	Model Accuracy Requirement: "Real Code" model now required, not recommended

ISONE

ISO New England Planning Procedure PP5-6: Interconnection Planning Procedure for Generation and ETUs

ISO NEW ENGLAND PLANNING PROCEDURE NO. 5-6

INTERCONNECTION PLANNING PROCEDURE FOR GENERATION AND ELECTIVE TRANSMISSION UPGRADES

EFFECTIVE DATE: April 12, 2023

ERCOT

ercot

Model Quality Tests (MQT) and Voltage Ride-Through (VRT) Tests

John Schmall
ERCOT Transmission Planning

Resource Integration Working Group Meeting
June 28, 2022

Who should check the models?

- The more checking along the way, the better!! At least:
  - **OEMs** should provide good unit level models (Validate and use best practice!).
  - **GO** or GO consultants should prepare and check the plant models before submitting.
  - **TO** should check the models prior to use in an expensive and time-consuming study.
- TOs are likely to check the models, but may require "pre-checking" by GOs to avoid iterating.

How do you check the models?

- Example from ATC (MISO footprint)
- https://www.atcllc.com/customer-engagement/connecting-to-the-grid/

ATC	Procedure	Department:	System Planning
		Document No:	PLG-PRD-0017
Title: PSCAD PLANT MODEL VERIFICATION PROCEDURE		Revision No:	01
		Issue Date:	03-29-2023
		Previous Date:	03-15-2023

Table of Contents

Approved By:	Author: Damien Sommer, P.E., Xiangyang Zhou
Enterprise Information Management (EIM) Classification: ☒ Public (Green) ☐ Non-Public (Yellow) ☐ Confidential (Red)	

Provide requirements for Accuracy, usability, etc…

Generation Interconnection
Business Practices Manual
BPM-015-r25
Effective Date: MAR-01-2023

MISO

Manual No. 015

Business Practices Manual

Generator Interconnection

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 must 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 required type of model.[2,3]

B. *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. As in point A, actual hardware code is required to be used for most control and protection features. Operating modes that require system specific adjustment must be user accessible.

C. *Represent plant level control.* Power Plant Control (PPC) representation must be included which represents the specific controllers used in the plant. 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 behaviour. 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. If supplementary or multiple voltage control devices (eg. STATCOM) are included in the plant, these should be coordinated with the PPC.

D. *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 must be modelled if they impact electrical performance within the timeframe and electrical purview 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 must be clearly identified.

E. *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 must be included. Actual hardware code is recommended to be used for these protection features.

F. *Be configured to match expected site-specific equipment settings.* Any user-tunable parameters or options must be set in the model to match the equipment at the specific site being evaluated, as far as they are known. Default parameters are not appropriate unless these will match the configuration in the installed equipment.

Check usability…

PSCAD Plant Model Usability Requirements			
Item #	Requirement	Interconnection Customer/Generator Owner Comment	ATC Comment
1	The manufacturer's name and the specific version of the inverter model should be clearly observable in the .psc model file.		
2	PSCAD model instructional documentation should be provided and should match the model version in the .psc model file and include instructions for setup and running of the model.		
3	Model uses a simulation timestep of 10 μs or larger.		
4	Model compiles using Intel FORTRAN version 15 or higher.		
5	Model uses PSCAD version 4.6 or higher.		
6	Model supports the PSCAD "snapshot" feature.		
7	Model supports the PSCAD "multiple run" feature.		
8	Model can be scaled to represent any number inverters/turbines, either using a scaling transformer or internal scaling. Model should not be using current injection to scale the plant.		
9	Model includes power plant controller (PPC)		
10	PPC accepts an external active power setpoint.		
11	PPC accepts a voltage setpoint of 1.02 p.u. at POI. PPC is in voltage control mode.		
12	PPC has a mechanism to implement a settable voltage droop.		
13	60 Hz grid frequency base		

Check site specific…

PSSE Plant Model parameters vs PSCAD Plant Model parameters Verification				
Item #	**Equipment**	**Parameter**	**PSSE Model/MISO DPP Application**	**PSCAD Plant Mode**
1	Generator	Energy Resource Interconnection Service (ERIS) MW level requested at the Point of Interconnection (POI)		
		Total Machine MVA (Mbase)		
		Inverter Voltage		
		# of inverters that make up the generator		
2	Generator Step Up Transformer (Inverter to Medium Voltage)	GSU Low voltage winding kV		
		GSU Low voltage winding configuration		
		GSU High voltage winding kV		
		GSU High voltage winding configuration		
		Transformer MVA		
		Copper losses (R based on the MVA of the transformer)		
		Positive Sequence Leakage Reactance (X based on the MVA of the transformer)		
3	Equivalent Collector Branch	R (p.u.)		
		X (p.u.)		
		B (p.u.)		
4	Main Power Transformer (Medium Voltage to POI Voltage)	MPT Low voltage winding kV		
		MPT Low voltage winding configuration		
		MPT High voltage winding kV		
		MPT High voltage winding configuration		
		Transformer MVA		
		Copper losses (R based on the MVA of the transformer)		
		Positive Sequence Leakage Reactance (X based on the MVA of the transformer)		
5	Gen Tie Line	R (p.u.)		
		X (p.u.)		
		B (p.u.)		
6	Cap Banks	# of banks		
		MVAR of banks		
		Connection bus		
7	Dynamic Voltage Control	MVAR rating		

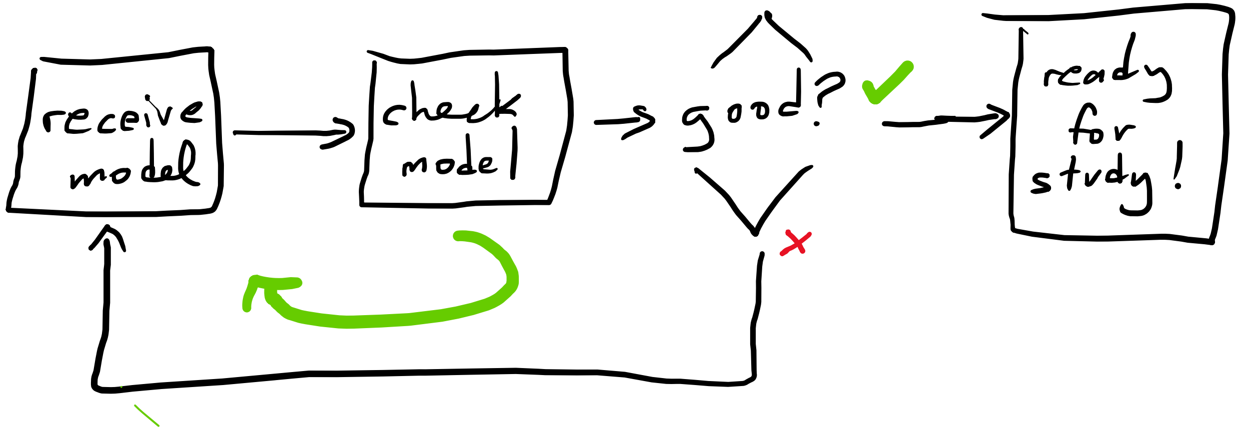
Check performance…

		PSCAD Plant Model Tests		
Item #	Test	Requirement	Interconnection Customer/Generator Owner Comment	ATC Comment
1	Flat Run Test	Model initializes to PPC setpoints in 5 seconds Meet ATC Planning Criteria		
2	3PG Fault at 100% of MW Test	Meet ATC Planning Criteria		
3	3PG Fault at 20% of MW Test	Meet ATC Planning Criteria		
4	3PG Fault test Charging	Meet ATC Planning Criteria		
5	System Strength Test	Meet ATC Planning Criteria for an appropriate SCR		
6	Over Frequency Step Test	Meet ATC Planning Criteria		
7	Voltage Step Test	Meet ATC Planning Criteria		
8	Over Voltage Protection Test	Plant should trip		
9	Under Voltage Protection Test	Plant should trip		
10	Under Voltage Dynamic Response Test	Meet ATC Planning Criteria		
11	NERC PRC-024-3 Test	Plant should not trip or enter momentary cessation Meet ATC Planning Criteria		

Demonstration…

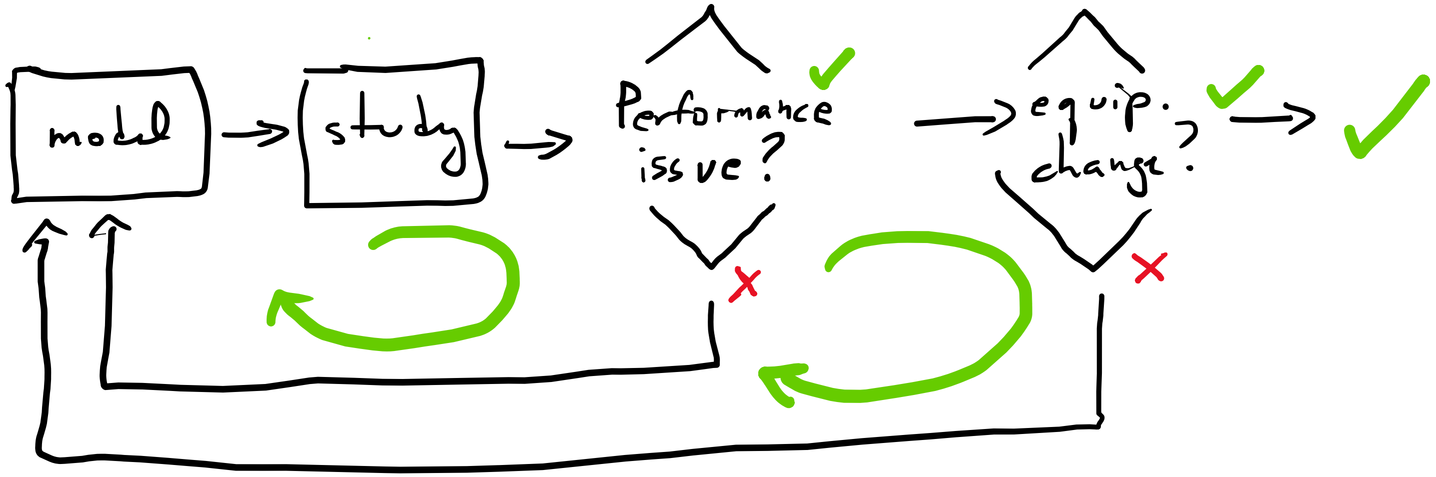
What challenges should you expect?

- **Delay**
  - Schedule impacts due to modelling
    - By the time you start a study, models need to be ready, otherwise you could be looking at a 1-6 month delay to collect and check models.
  - Delay due to HR constraints and up-skilling
    - You need to invest in people and software.
    - Once you have invested in people and software, there is a time lag to getting the people productive.



What challenges should you expect?

- **Study/model iterations**
  - Performance challenges
    - You may find yourself in an iterative loop of model changes to mitigate issues -> Study
  - Changing equipment and technology
    - Once the models are checked and the studies are completed, the equipment may change and the models (and therefore studies) may become invalid.



Take-aways!

- EMT models are a fact of life in our future!
  - Invest in people
  - Invest in knowledge
  - Get started on processes
  - Start collecting models if you haven't already
- EMT models need to be detailed and correct, or the studies become much less useful.
- There are now many examples and resources available for model requirements and checking!
- Once you have the requirements and processes in place, model intake and checking can be streamlined.
  - Software automation helps
  - Shared responsibility for QC between OEM, GO, and TO helps

Questions?

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