INTERCONNECTION INNOVATION e-XCHANGE
U.S. DEPARTMENT OF ENERGY

EMT Bootcamp for BES IBR Studies
Part 2: System Impact Assessment
| 9/14/23

An initiative spearheaded by the Solar Energy Technologies Office and the Wind Energy Technologies Office

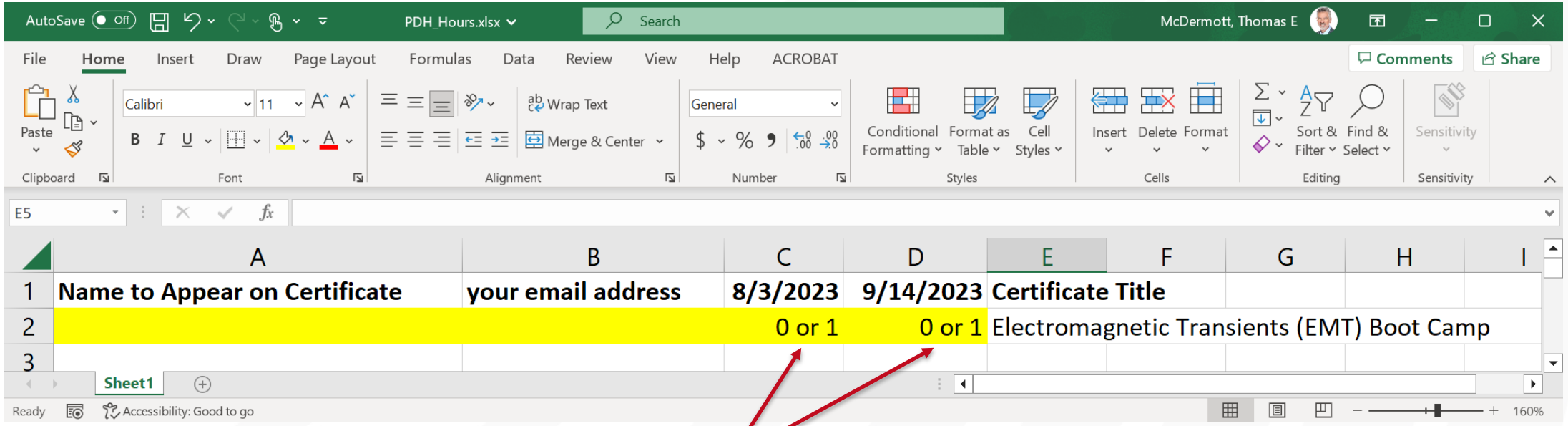
Thomas.McDermott@pnnl.gov

System-Level Session Agenda

- Course Completion Certificates from NERC
- Downloading Example Files
- NERC Guidelines for Use of EMT Models
  - Link: https://www.nerc.com/comm/RSTC/Pages/EMTTF.aspx and https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Reliability_Guideline-EMT_Modeling_and_Simulations.pdf
  - Comparison to IEEE P2800.2 Subgroup 3 Tests under Development
- Workflow Management for System Impact Studies
  - PSSE File Inputs
  - Common Information Model, IEC 61970-301 (network) and -302 (dynamics)
  - Dynamic Link Library (DLL) Models
- Technical Discussion: average, switching, and DC bus modeling
- Hands-on Sessions:
  - This meeting ends for all at 2:30 Eastern time; please join your tool-specific meeting then
  - Running IBR study cases in the IEEE 39-bus system
  - Tool-specific automation examples
  - Repository of Materials: https://github.com/pnnl/i2x/tree/develop/emt-bootcamp

Course Completion Certificates for 4-8 Hours.

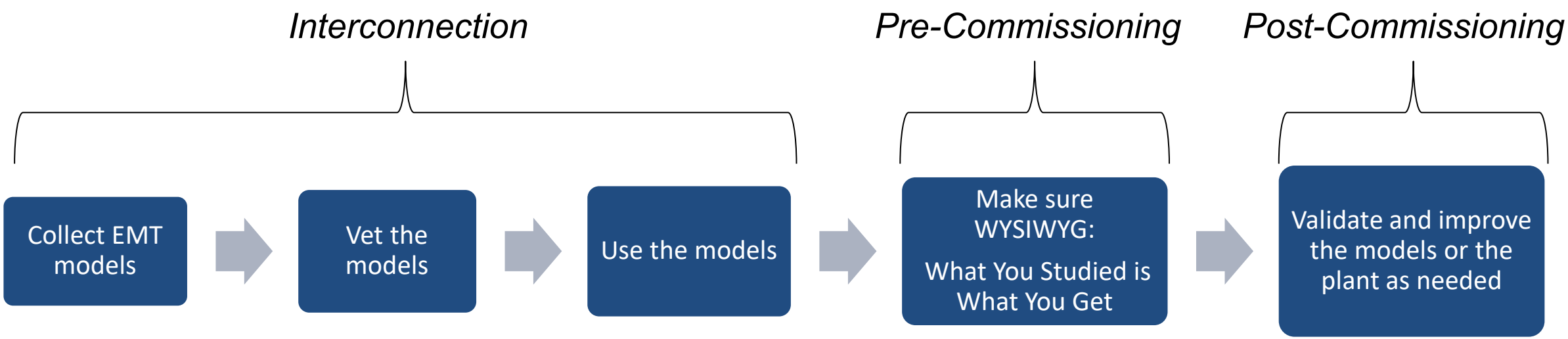
1. Download: https://github.com/pnnl/i2x/blob/develop/emt-bootcamp/PDH_Hours.xlsx
2. Complete the highlighted cells:



Enter a **1** for each session you attended

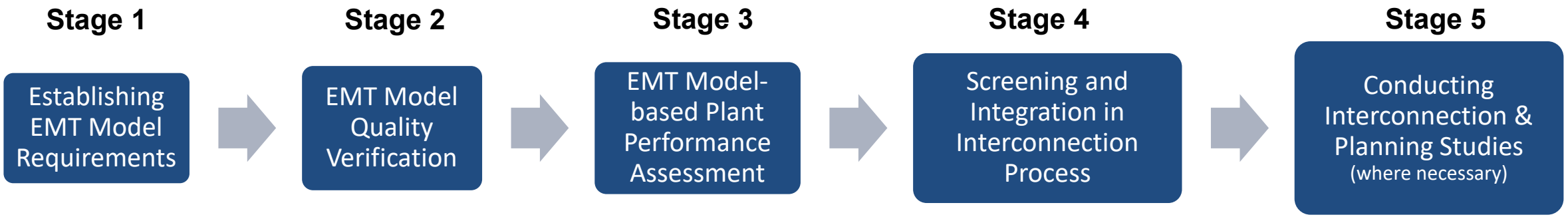
3. Email the xlsx file to Thomas.McDermott@pnnl.gov by 9/22/2023
4. You will receive an e-signed certificate from Ryan Quint of NERC
5. It's your responsibility to determine suitability for any state PE licensing requirements

EMT Model Life Cycle



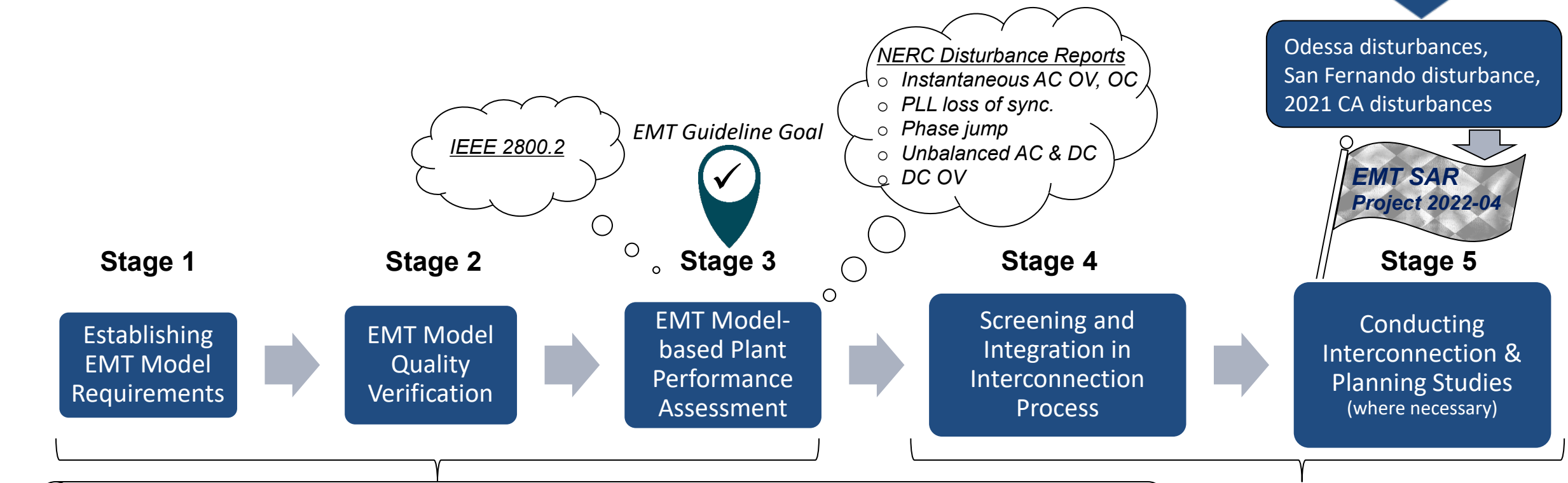
Source: Aung Thant, NERC Webinar, 6/27/2023

EMT Modeling Adoption Visualized in Stages



Source: Aung Thant, NERC Webinar, 6/27/2023

EMT Modeling Adoption Visualized in Stages



Published EMT Guideline Scope

Chapter 1
- Recommended EMT Model Requirements
- Sample Checklist

Chapter 2
- Principles of Model Quality
- Verification Processes
- Attestations – unit models & plant model
- Unit Model Validation

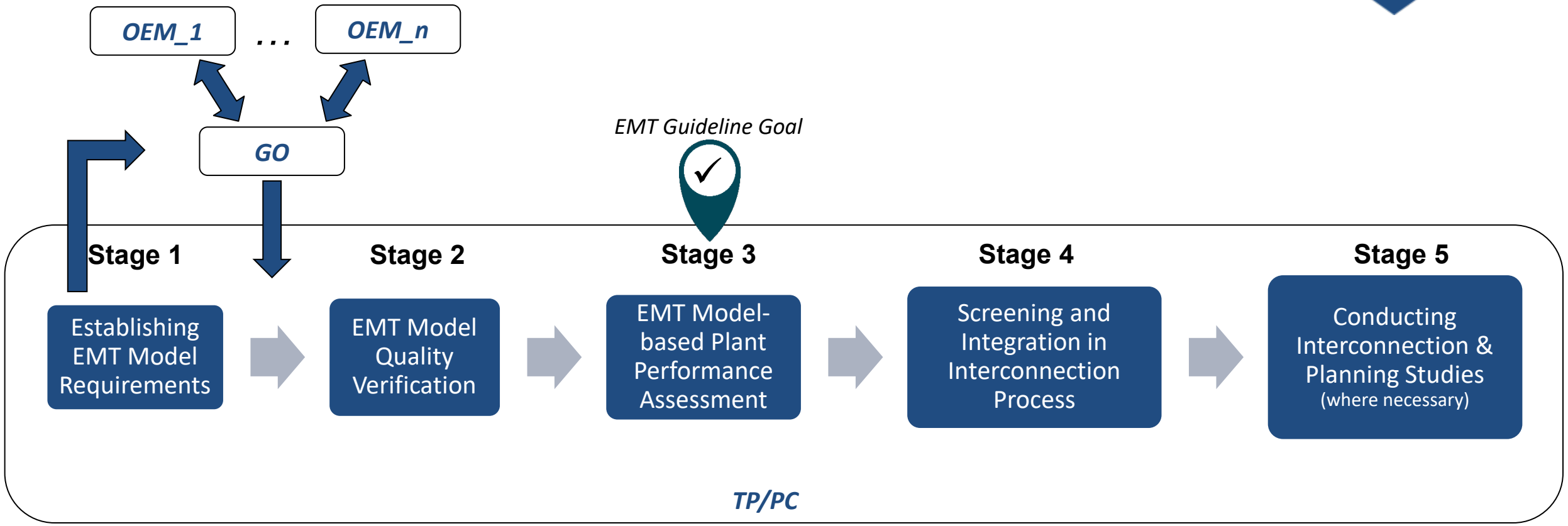
Chapter 3
- Model Adequacy Tests
- Functional Tests
- Disturbance Ride-through Performance Tests

Chapter 4
- EMT Study Use Cases
- Common situations needing an EMT study

New EMT Guideline Scope
(Work item 2 of NERC EMTTF)

Source: Aung Thant, NERC Webinar, 6/27/2023

EMT Modeling Visualized by Functional Entities



Source: Aung Thant, NERC Webinar, 6/27/2023

Recommended EMT Model Requirements

- Establish EMT modeling requirements per FAC-002 for all new IBR resources
- Create a “checklist” of EMT model requirements for GO and equipment manufacturers
- Require high quality EMT models as a prerequisite of interconnection
- Require the EMT models accurately represents all pertinent controls, and protections that could affect the electrical output of the facility during and after grid disturbances
- Require all submitted EMT models include
  - Attestations by the equipment manufacturers and
  - Attestations by GO that aggregate model represents the entire plant and includes site-specific models, settings, protections, and controls
- Include change management requirements and protocols regarding how changes should be reflected in EMT models by the GO
- Clearly define the purview and duration of EMT simulations

Source: Aung Thant, NERC Webinar, 6/27/2023

Chapter 2: Principles of Model Quality

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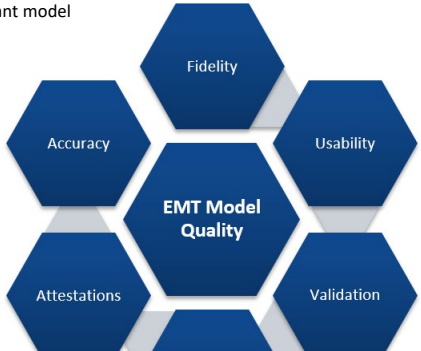

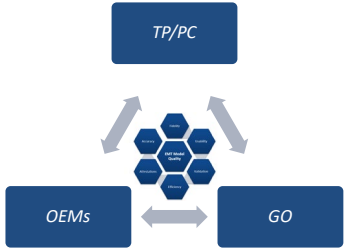

Chapter 2: Model Quality Verification

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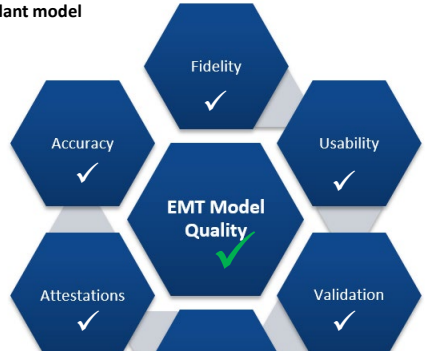
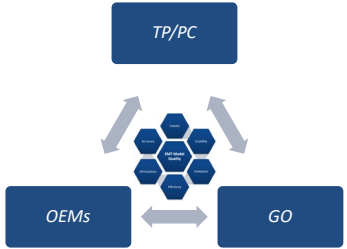
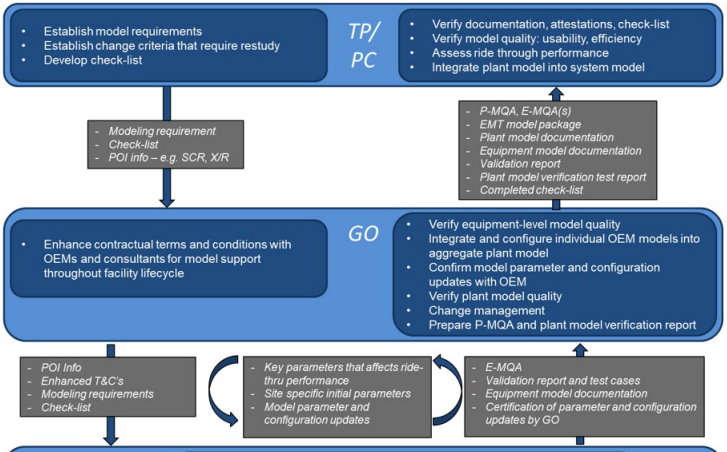
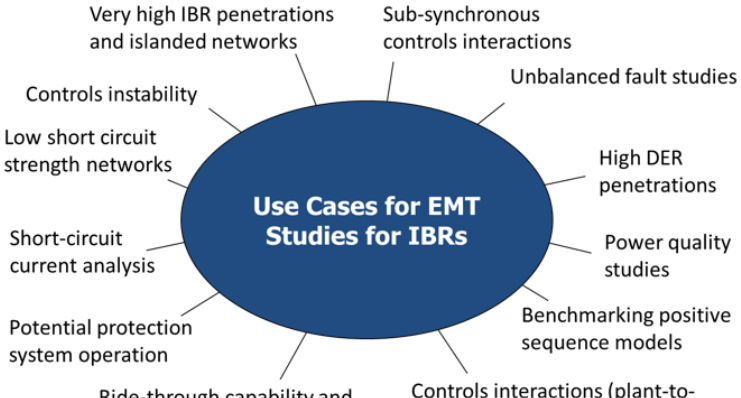




Chapter 2: Model Quality Verification Processes



Chapter 4: EMT Study Use Cases



Other Relevant Topics

ing Positive Sequence Dynamic Models against the EMT Model

for Future EMT Study Needs

y and Use of IEEE 2800 Guidance

: EMT Model Terminology

sus Equipment Specific Models

-Specific **Model Types**

nt EMT Models

" EMT Models

e" EMT Models

d Aggregate EMT Modeling

Key Takeaways

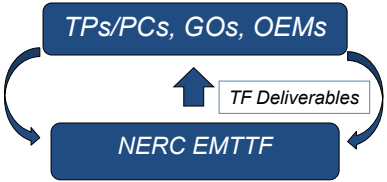
ry close EMT modeling knowledge gaps

oundation of knowledge for new modeling requirements and practices

o make quality-vetted EMT models available to TPs and PCs for the purposes
y studies – interconnection studies per FAC-002 and planning assessments

ry close current gaps between interconnection studies and installed

EMTTF Supporting EMT Adoption Across NA



TF Deliverables

Feedback & lessons learned from individual TP/PCs

Stage 2

EMT Model Quality Verification

Stage 3

EMT Model-based Plant Performance Assessment

Stage 4

Screening and Integration in Interconnection Process

Stage 5

Conducting Interconnection & Planning Studies

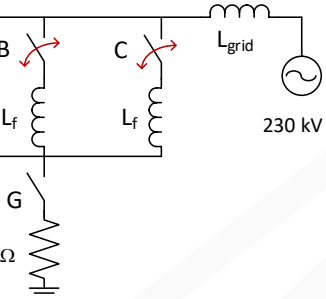
Upcoming Events

ing Boot Camps (Virtual)

y U.S. Department of Energy Interconnection Innovation e-Xchange (i2X) and NERC

	Time	Session
	1 – 3 pm Eastern	Pre-session
3	1 – 5 pm Eastern	Boot Camp 1: Individual IBR Plant Performance Assessment
, 2023	1 – 5 pm Eastern	Boot Camp 2: System Impact Assessment

tic fault simulations applied to a strong grid.

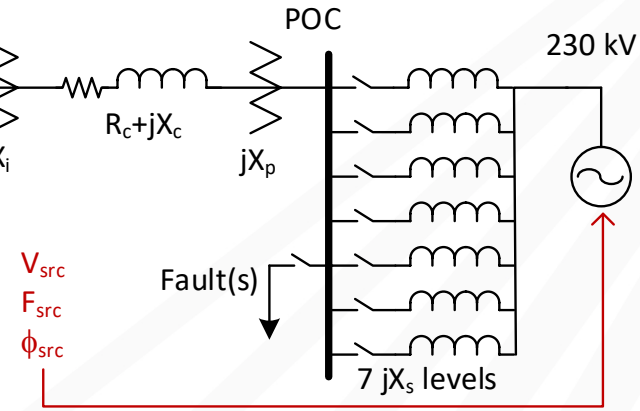


onditions don’t change
ities removed from service

$$Z_{grid} = 10\angle 85° = 0.8716 + j9.9619$$
$$L_{grid} = 9.9619 / 377 = 0.0264$$

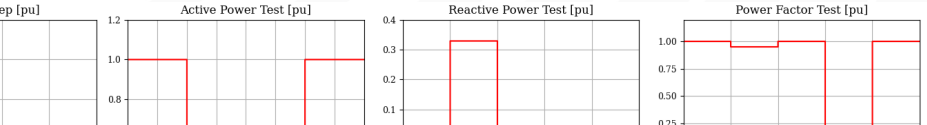
Phases	Retained Voltage	Lf [H]
ABCG	80%	0.1057
ABCG	50%	0.0264
ABCG	25%	0.0088
ABCG	1%	0.0001
AG	80%	0.1057
AG	50%	0.0264
AG	25%	0.0088
AG	1%	0.0001

odel testing framework on a weak grid; IEEE P2800.2 templates testing at SCR = 2.5, details in D0.5, clause 7.



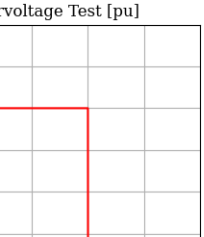
itialization, undervoltage, and control step tests are ed with IBR control references and fault parameters.

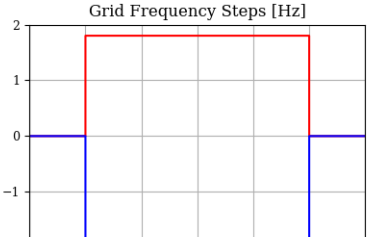
at-start tests to initialize *from zero* in 10s, remain stable for 10s
inverter continuous rating (ICR) and P_{min}, 7 variations each:
V_{ref}=1; Q_{ref}=[0.3287, 0, -0.3287]; pf_{ref}=[0.95, 1.0, -0.95]
ndervoltage ride-through tests, fault duration=0.16s, all at P=ICR
xed Q values of 0.3287, 0, -0.3287 pu
ault types [3ϕ sag to 50% voltage, 3ϕg, 1ϕg, 2ϕg, 2ϕ]
ntrol reference change tests plotted below

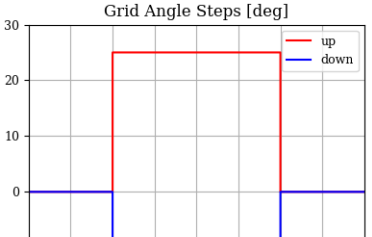


grid overvoltage, frequency change, and angle jump
implemented with controlled grid sources.

- ervoltage ride-through tests at P=ICR and 3 fixed Q values:
  = 0, +0.3287, -0.3287
- quency ride-through tests, over/under at P=ICR and P_{min}, fixed Q=0
- gle ride-through tests, positive/negative at P=ICR and P_{min}, fixed Q=0



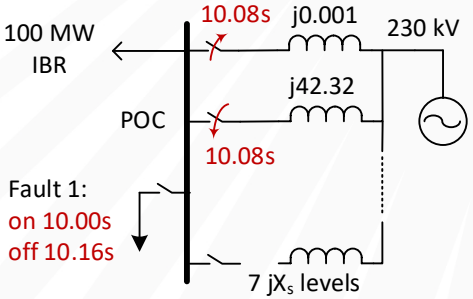




cuit ratio (SCR) ramp-down tests transition between ces during faults at 5-second intervals.

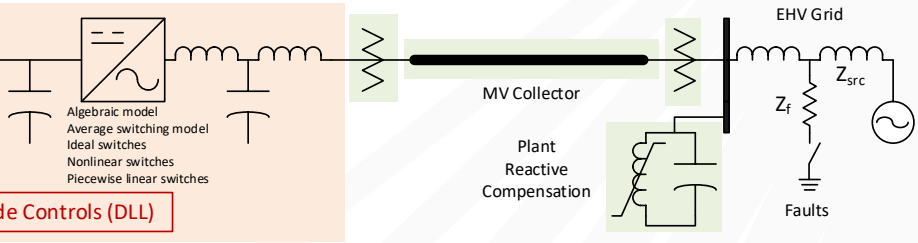
use 7.3.5.1.2
Informational Tests
expected until SCR=2.5

SCR	X @ 230 kV
20	26.45
10	52.90
5	105.80
4	132.25
3	176.33
2.5	211.60
2	264.50
1.5	352.67
1	529.00



This test is simulated manually,
with sequenced faults and

ng NERC EMT Task Force and IEEE P2800.2 emphases.



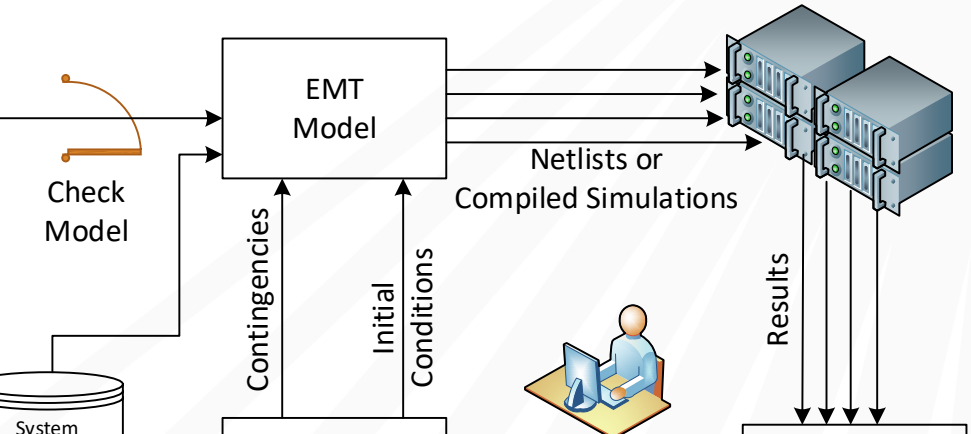
mphasis

mance of the hardware and controls to IEEE 2800-2022 requirements
to match unit and plant commission tests, use in design evaluations

T Task Force Emphasis includes P2800.2, plus

h EMT modeling and IBR performance criteria, including ride-through, for

gineers build and check models, organize simulations, yze the results.



s can help build the balance-of-system model for EMT.

st commercial EMT tools can import from PSSE files:

– positive sequence network bus and branch data for power flow

– zero-sequence and negative-sequence data for short circuit solution

– dynamics data (machines, exciters, governors, stabilizers, IBR)

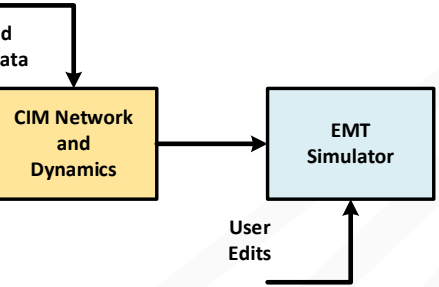
– bus locations for visualization

remember:

e may be some gaps in data for controls, non-linearities, etc.

ual edits to the EMT model files will be decoupled from the original

n Information Model (CIM) has been used to maintain ange bulk electric system models, including dynamics.



org/wiki/File:CIM_EMT_Article.pdf

(35 countries)

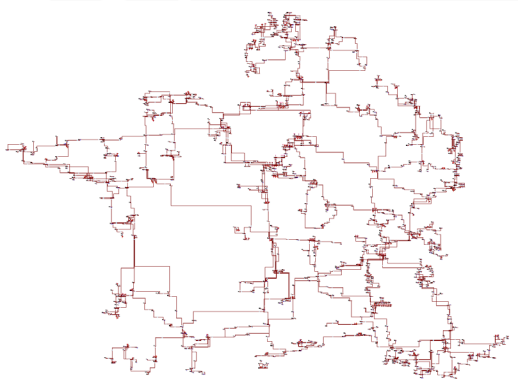
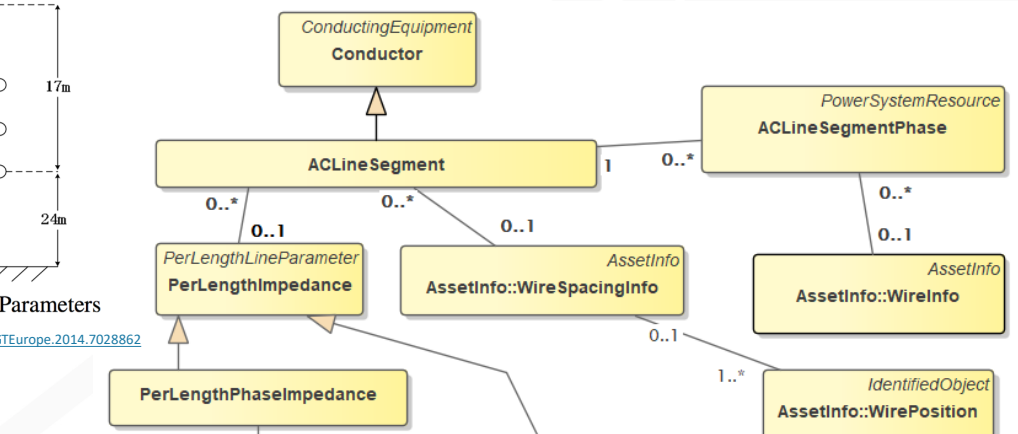


Fig. 5. French 225 kV grid after CIM import in EMTP

represent line impedances and coupling in detail;
ced distribution system models have been exchanged.



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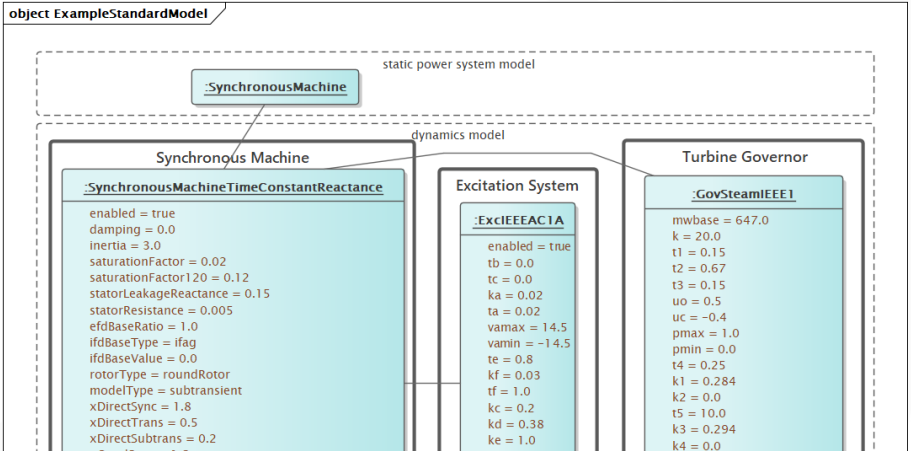
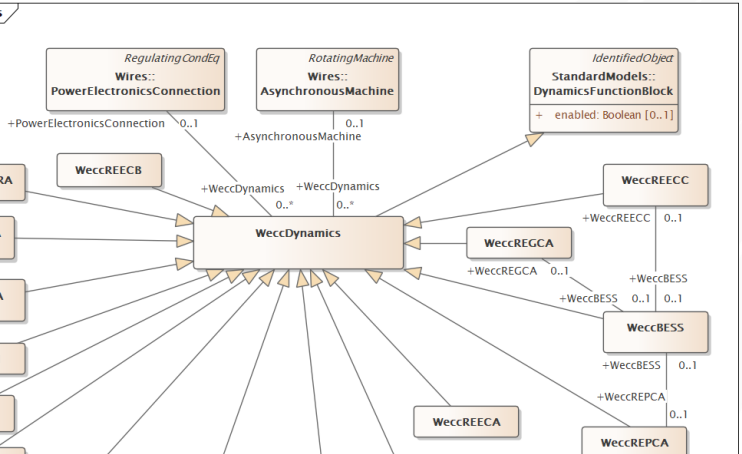
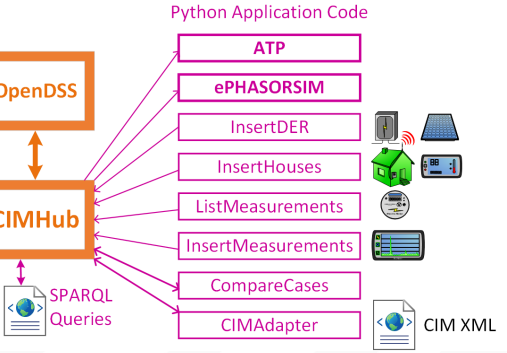
-302:2018 (CIM Dynamics) already supported machines.

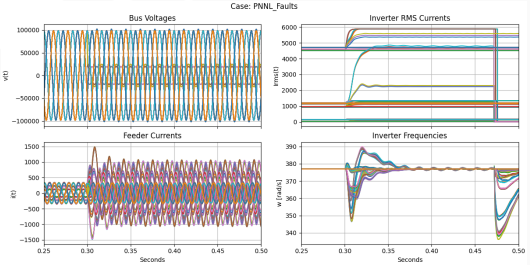


ewable models were added for 61970-302:2022



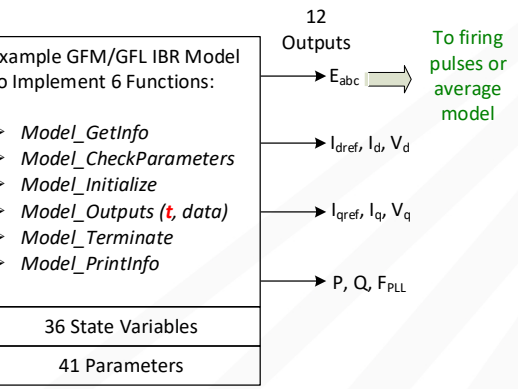
els were added to IEC 61970-302:2022 and IEEE 1547.2 (in olution). These models support EMT simulation of DER.

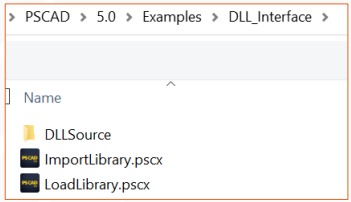


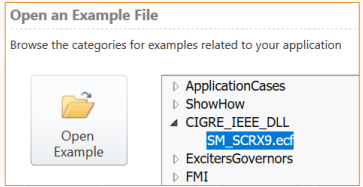


Name	Type	V_{LL} [kV]	#Loads	#DER	Load [MW]
IEEE 13x	Radial	4.16	9	4	3.4
IEEE 123x	Radial	4.16	114	14	3.8
EPRI DPV J1	Radial	12.47	1384	13	11.6
IEEE 9500	Variable	12.47	1275	12	12.3
IEEE LVN	LV Network	13.20	624	8	42.2
Smart DS	Radial	12.47	4173	928	42.2
Avista CEF2	2 Feeders	13.20	582	4	10.1

Link Library (DLL) real-code model interfaces were ed by a joint IEEE AMPS / Cigre B4.82 task force.







presentations: http://www.electranix.com/ieee-pes-tass-realcodewg/

models use energy-conserving, controlled sources to the reference phase voltages.

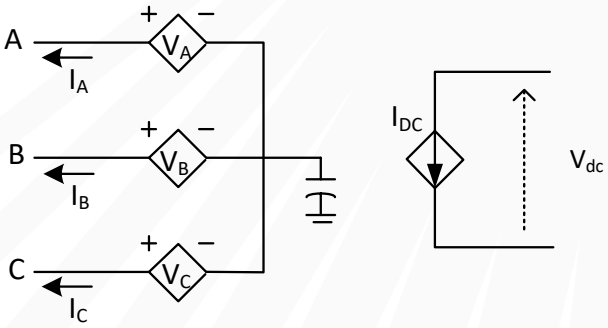
odulation indices:

$t)$

$t + 2\pi / 3)$

$t - 2\pi / 3)$

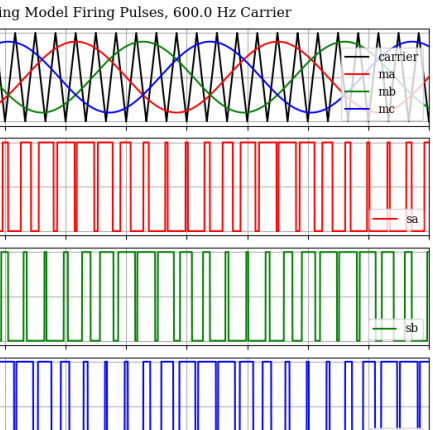
e sources:

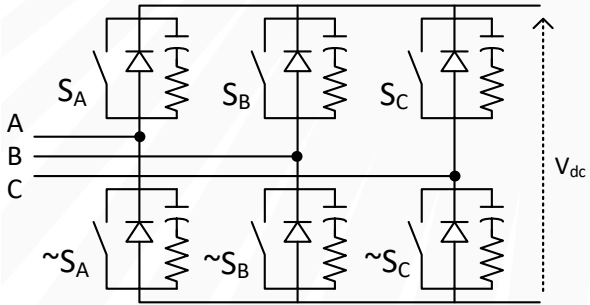


DC current source:

Check power balance:

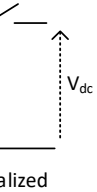
g (detailed) models are driven by the same reference , or modulation indices, as the average models.

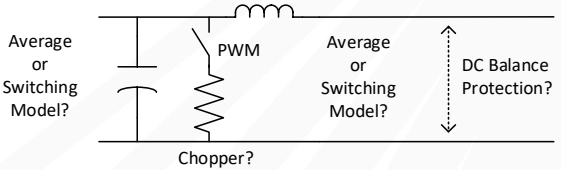


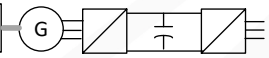


$S_A = m_A >$ carrier

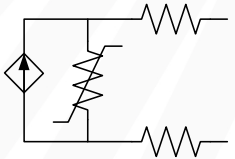
nodeling may be necessary to represent control system s and protective functions accurately.







Wind Type 4 Model



Nonlinear PV Model

nt Links and Instructions

eting now “ends for all”

oin your tool-specific meeting from 2:30 – 5:00 Eastern time

t meeting will be on a separate invitation that you should have received

ons, models, slides, videos, and other material:

github.com/pnnl/i2x/tree/develop/emt-bootcamp

uestions about software operation to your tool vendor

estions about the bootcamp materials here:

s://github.com/pnnl/i2x/issues/16

may benefit from the experience of others this way