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

Forum for the Implementation of Reliability Standards for Transmission (i2X FIRST) | 09/23/25

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

BERKELEY LAB

EPRI

ESIG

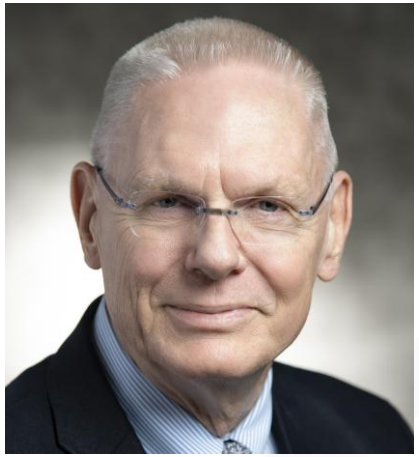
The first half of this meeting call is being recorded and may be posted on ESIG's website. If you do not wish to have your voice recorded, please do not speak during the call. If you do not wish to have your image recorded, please turn off your camera or participate by phone. If you speak during the call or use a video connection, you are presumed consent to recording and use of your voice or image.

Key Goals and Outcomes from i2X FIRST

- To facilitate understanding and adoption of new and recently updated standards relevant for existing and newly interconnecting wind, solar and battery storage plants
- The Forum will convene the industry stakeholders to enable practical and more harmonized implementation of these interconnection standards.
- The presentation portion of the meeting will be recorded and posted, and presentation slides will be shared.
- Additionally, the leadership team will produce **a summary of each meeting** capturing:
  - Recommended best practices
  - Challenges
  - Gaps that require future work

Leadership Team

Cynthia Bothwell, Boston Government Services, contractor to DOE's Wind Energy Technologies Office



Robert Reedy, Lindahl Reed, contractor to DOE's Solar Energy Technologies Office

Will Gorman, Lawrence Berkley National Laboratory

Jens Boemer, Electric Power Research Institute

Julia Matevosyan, Energy Systems Integration Group

Ryan Quint, Elevate Energy Consulting

Summary of the last meeting: IBR Plant Design Evaluation Part II

- **IBR Plant Design Evaluation – ISO Perspective:** Alan Urban, MISO
- **IBR Plant Design Evaluation Leaning on Documentation Review:** Jens Boemer, EPRI
- **IBR Plant Design Evaluation – Utility Perspective:** Anthony Williams, Duke Energy
- **Putting IEEE P2800.2 Concepts to Action: IBR Performance and Modeling Requirements:** Ryan Quint, Elevate Energy Consulting
- **Q&A and Structured Discussion**, led by Julia Matevosyan, ESIG
  - Is IBR plant design evaluation being carried out today? Is it sufficient?
  - How can IBR plant design evaluation be improved to ensure future grid reliability?

Meeting summary, recording & presentations are posted here

Key Themes from the Last Meeting

- **Balanced, risk-informed modeling:** MISO requires four model types (PSS®E Std Lib, PSCAD, TSAT UDM, PSS®E UDM) with tests mapped to IEEE 2800-2022/P2800.2. Draft requirements expected Q4 2025; effective 2026. Focus on automation, benchmarking, and cross-model consistency at POI.
- **Conformity assessment:** Mix of simulation + documentation (e.g., VRT, TOV via docs). Verification must cover full plant with traceability.
- **Interconnection studies:** Delayed model submittals complicate transmission studies. Benchmarking UDMs early preserves fidelity, avoids late-stage errors.
- **Execution risks:** Tooling, processes, and staffing need scaling to support IEEE P2800.2 conformity assessments.
- **Post-COD change management:** Use change-control matrix, delta reports, and scoped re-tests to reduce burden while ensuring confidence.
- **Operationalization:** Utilities adopting staged design evaluation and clearer artifacts. Standardized repositories + automation enable “trust-but-verify” and align with international best practice ahead of 2026 rollout.

Upcoming i2X FIRST Meetings – Season 2

1. May 27, 2025, 11 a.m. - 1 p.m. ET – **Season 2 Kick-Off**
2. June 24, 2025, 11 a.m.- 1 p.m. ET – **NERC Milestone 3 Standards**
3. July 22, 2025, 11 a.m.- 1 p.m. ET – **IBR Plant Design Evaluation with Applicable Requirements I**
4. August 26, 2025, 11 a.m.- 1 p.m. ET – **IBR Plant Design Evaluation with Applicable Requirements II**
5. **September 23, 2025, 11 a.m.- 1 p.m. ET – IBR Plant Modeling Requirements and Best Practices**
6. October 21, 2025, 11 a.m.- 1 p.m. ET – Challenges with IEEE2800-2022, Planned Revisions
7. November 25, 2025, 11 a.m.- 1 p.m. ET – Change of Management during IBR Plant Interconnection Process and Commissioning, How to Maintain Conformity
8. December 16, 2025, 11 a.m.- 1 p.m. ET – IBR Plant Commissioning Best Practices I
9. January 27, 2026, 11 a.m.- 1 p.m. ET – IBR Plant Commissioning Best Practices II
10. February 24, 2026, 11 a.m. - 1 p.m. ET – Grid Forming IBR Specifications and Testing Requirements I
11. March 16, 2026 hybrid event during ESIG Spring Workshop: Grid Forming IBR Specifications, Testing Requirements, Lessons Learned

Sign up for all future i2X FIRST Season 2 Meetings here

Follow ESIG i2X FIRST website https://www.esig.energy/i2x-first-forum/ for meeting materials & recordings and for future meeting details & agendas

IBR Plant Modeling Requirements and Best Practices – Agenda

- **Meeting Introduction:** Julia Matevosyan, ESIG
- **IBR Plant Modeling Requirements – NYISO Perspective:** Bruno Leonardi, NYISO
- **IBR Plant Modeling Requirements – Developer/Consultant Perspective:** Kasun Samarasekera, Elevate Energy Consulting
- **IBR Modeling: Where Do We Go From Here?:** Andrew Isaacs and Lukas Unruh, Electranix
- **Q&A and Structured Discussion**, led by Julia Matevosyan, ESIG
  - How can IBR Plant Modeling Requirements be Improved?
  - Requirements for Continuous IBR Plant Model Maintenance?

Virtual Meetings Code of Conduct

1. *Assume good faith and respect differences*
2. *Listen actively and respectfully*
3. *Use "Yes and" to build on others' ideas*
4. *Please self-edit and encourage others to speak up*
5. *Seek to learn from others*

Mutual Respect . Collaboration . Openness

Stakeholder Presentations

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Mutual Respect . Collaboration . Openness

Q & A Session

Interactive Group Discussion Topics

Topic #1: How can IBR Plant Modeling Requirements be Improved?

- Please go to slido to make comments and add questions of your own: **slido.com** and enter event code **FIRST5**
- For verbal commentary, please use the raise hand feature and we will call on you
- Additional related / associated questions:
  - How to assess IBR plant model accuracy during interconnection process? What criteria to use?
  - Qualitative vs quantitative IBR plant model pass/fail criteria pros and cons
  - PDT models are required earlier in the process, but EMT models are more detailed and required later in the process. Which model should serve as ground truth in benchmarking?
  - How to avoid “checking boxes” of modeling requirements during interconnection process rather than making sure the model is accurate representation of an actual plant?
  - How to incentivize/require updating of IBR plant models, as IBR plant design changes? How to ensure that “as built plant” is reflected in the IBR plant models that have been provided?

Topic #2: Applicability of IBR Plant Models and Reasonability of Modeling Requirements

- Please go to slido to make comments and add questions of your own: **slido.com** and enter event code **FIRST5**
- For verbal commentary, please use the raise hand feature and we will call on you
- Additional related / associated questions:
  - Applicability of models: not all models can be used for weak grids. What is the minimum set of information (e.g. ranges of SCR) a utility/ISO shall publish to set expectations for which grid conditions the model shall meet the specified performance requirements/criteria?
  - What is a reasonable amount of plant model performance tests and criteria, and why? IEEE P2800.2 has much more tests than what some utilities or ISOs have published to date. Are all these .2 tests necessary? What tests do utilities/ISOs require that may not be justified, and why? What tests are important but still missing?

Topic #3: Requirements for Continuous IBR Plant Model Maintenance?

- Please go to slido to make comments and add questions of your own: **slido.com** and enter event code **FIRST5**
- For verbal commentary, please use the raise hand feature and we will call on you
- Additional related / associated questions:
  - How to ensure that IBR plant models submitted during interconnection process remain usable and accurate through the lifetime of the plant?
  - How to encourage reporting of IBR plant design updates / IBR plant model updates. Do current or upcoming NERC requirements already address this?
  - How to ensure automatic firmware updates do not result in inadvertent changes in the plant rendering models inaccurate? What are the triggers and frequency for revalidation?
  - What kind of monitoring/maintenance practices should be integrated into plant's asset management lifecycle?

New York ISO
Independent System Operator

IBR Plant Modeling Requirements

NYISO Perspective

Bruno Leonardi

Principal - Grid Transition Special Studies

The Drivers: FERC order 901 & NYSRC Reliability Rule B5

NERC to develop new or modified Reliability Standard projects to address a wide spectrum of reliability risks to the bulk power system (BPS) from the application of inverter-based IBR technology

NYSRC RR B5 (IEEE 2800-ish implementation) has already been effective since February 9, 2024

Work Plan to Order 901

Performance Requirements and Post-Event Performance Validation

Data Sharing and Model Validation

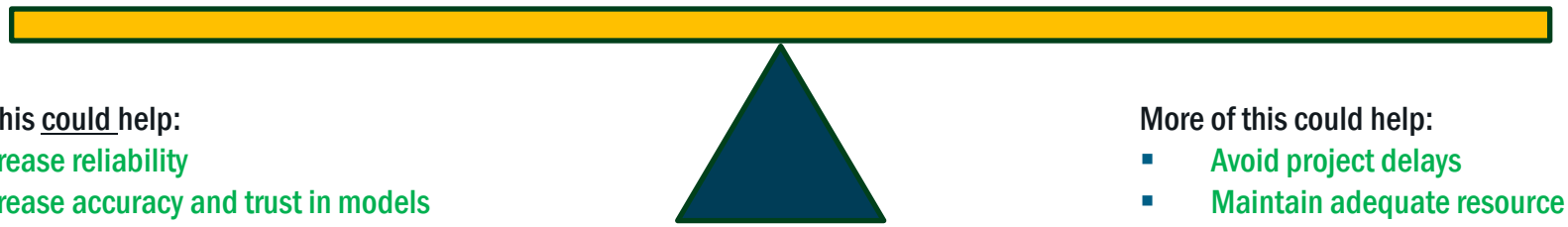
Planning and Operational Studies

New York ISO

NYISO Modeling Requirements are in alignment with NERC's vision

Modeling and Performance Validation Practices

Accelerated Interconnection & Construction Timelines



More of this could help:
- Increase reliability
- Increase accuracy and trust in models

More of this could hurt:
- Timely commercial operation dates
- Resource adequacy (LOLE), reductions in security margins
- Project timeline

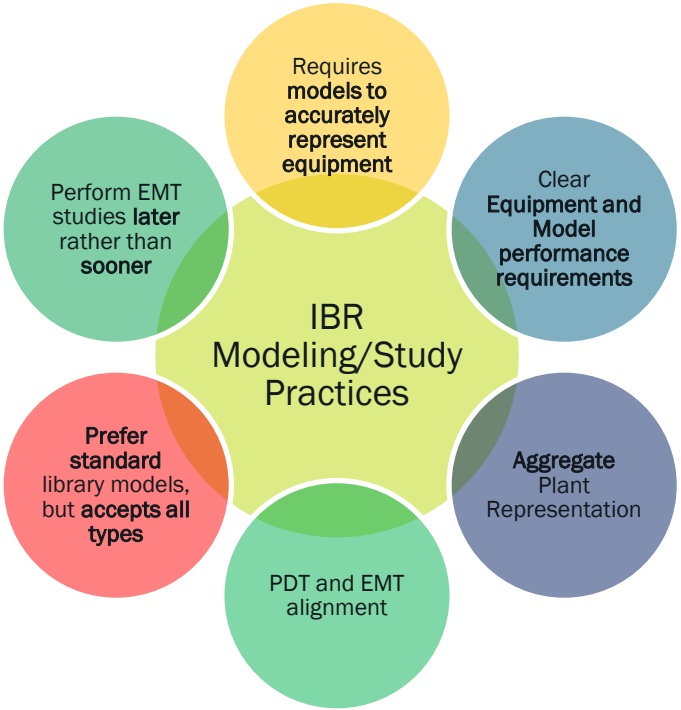
"Performance testing processes should include sufficient tests necessary to show conformity with published performance expectations without adding undue study burden"

More of this could help:
- Avoid project delays
- Maintain adequate resource adequacy

More of this *could* hurt
- Model verification and validation steps
- Resource adequacy and LOLE
- System reliability

New York ISO

NYISO's general IBR plant modeling practices



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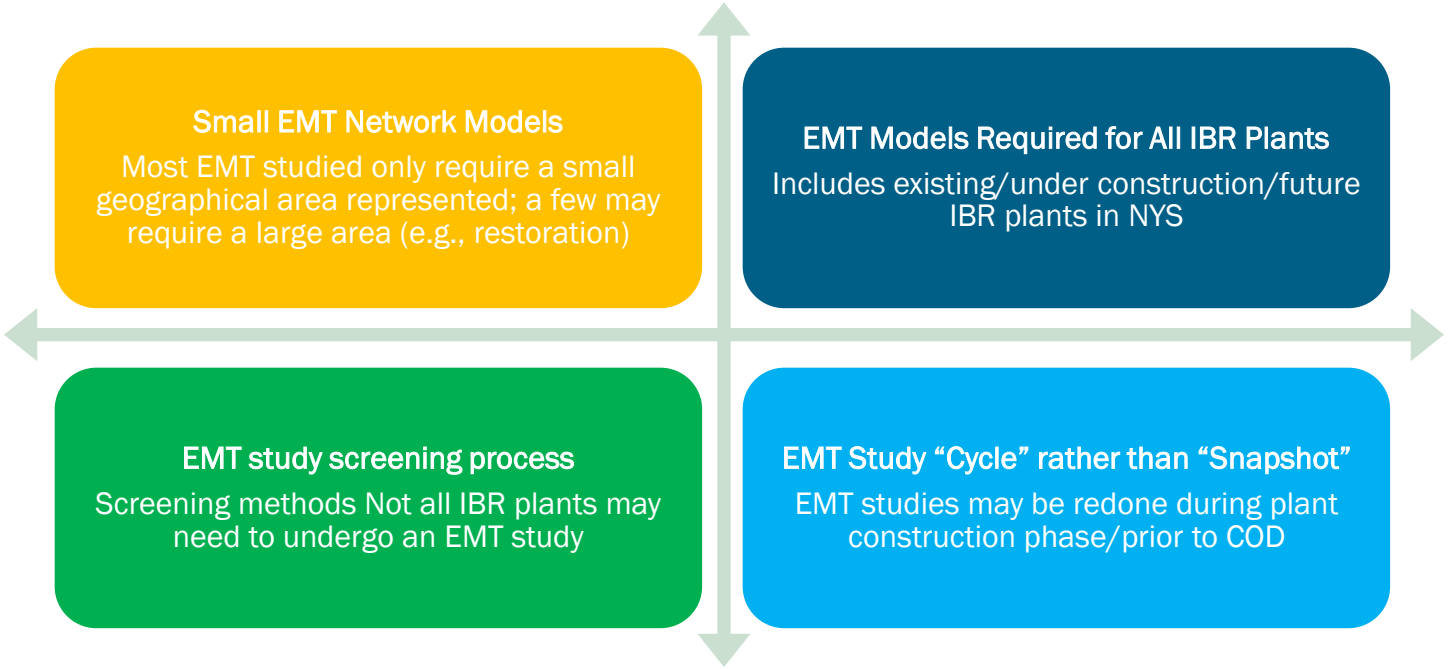
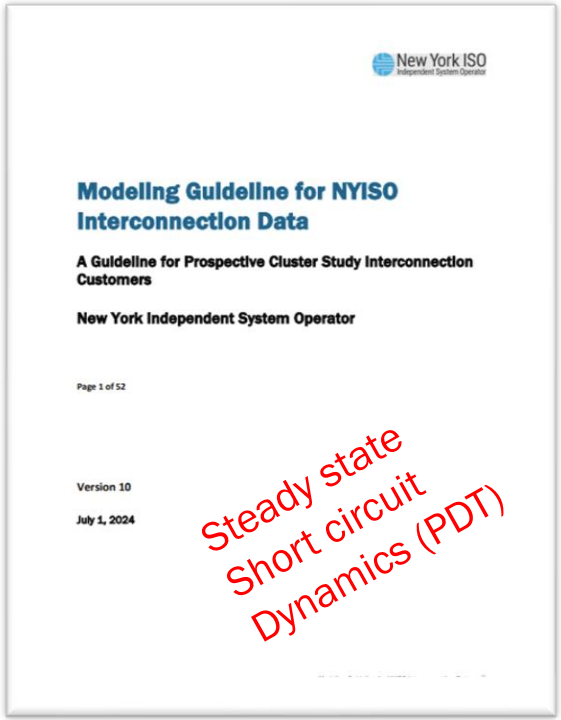
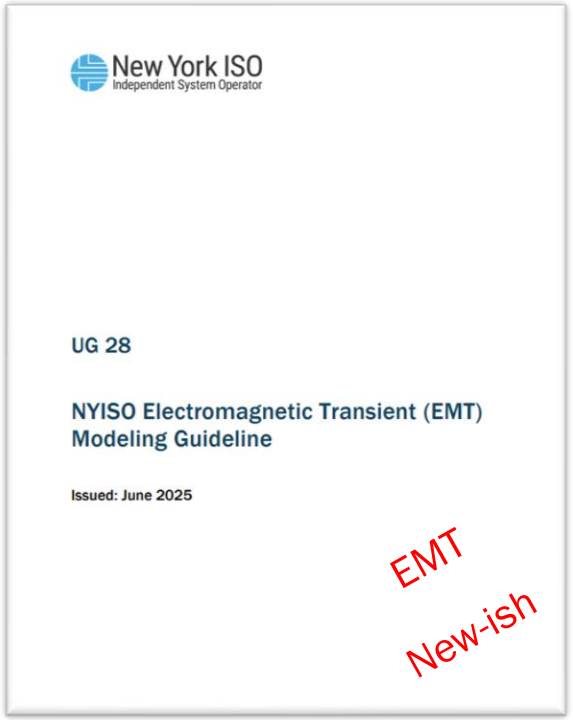
EMT Study/Modeling Practices



New York ISO

IBR plant modeling requirements





New York ISO

Current test list in EMT guideline

Tests	Baseline Performance
Test 1: Initialization Test	Specified in Table 1
Test 2: Balanced Fault Ride-through Tests	Specified in Table 2
Test 3: Unbalanced Fault Ride-through	Specified in Table 3
Test 4: Over-Voltage Ride-through	Specified in Table 4
Test 5: Voltage Reference Step Change	Specified in Table 5
Test 6: Active Power Reference Step Change	Specified in Table 6
Test 7: Grid Frequency Response and Ride-Through	Specified in Table 7
Test 8: PFR and FFR tests	Specified in Table 8
Test 9: Grid Voltage Phase Angle Change Ride-Through	Specified in Table 9
Test 10: POI SCR Change Tests (informational)	Specified in Table 10 – this test is informational and no baseline response is defined
Test 11: Voltage Protection Inclusion	Specified in Table 11

- NYISO opted for not specify a <u>quantitative criteria</u>
- Baseline criteria is not pass of fail
  - Obvious deviation from baseline performance will generate questions

New York ISO

Example: PFR/FFR tests

Test #	Test Description			Baseline Response
	Events	Active Power at POI	Reactive Power at POI	
8-1	With **FFR controls disabled** and **PFR controls enabled**, apply the frequency signal shown in Figure 7.	P_{POI} = 0.5*Pmax $P_{available}$=Pmax	0	IBR plant active power output varies by at least 0.321pu
8-2	With **FFR controls enabled** and **PFR controls disabled**, apply the frequency signal shown in Figure 8	P_{POI} = 0.5*Pmax $P_{available}$=Pmax	0	No significant response for the over frequency step; IBR plant active power shall reduce by at least 0.1pu
8-3	With **FFR controls disabled** and **PFR controls enabled**, apply the frequency signal shown in Figure 7.	P_{POI} = 0.5*Pmax $P_{available}$=Pmax	0	IBR plant active power output varies by at least 0.321pu, with response time in line with values in Table 8 of IEEE 2800
8-4	With **FFR controls enabled** and **PFR controls disabled**, apply the frequency signal shown in Figure 8.	P_{POI} = 0.5*Pmax $P_{available}$=Pmax	0	No significant response for the over frequency step; IBR plant active power shall reduce by at least 0.1pu, with response time in line with values described in section 6.2.2 of IEEE 2800

Figure 7: Grid Frequency Event Used to Test PFR

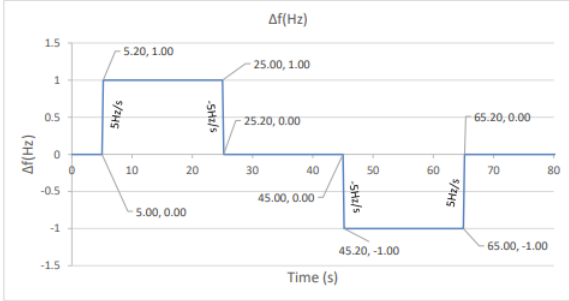
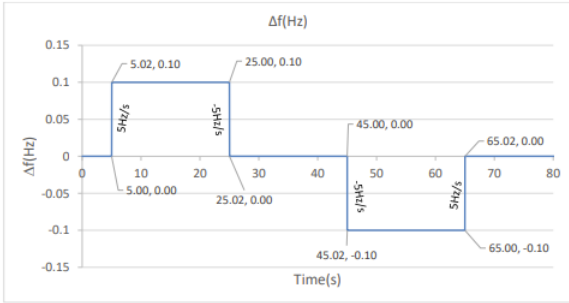


Figure 8: Grid Frequency Event Used to Test FFR



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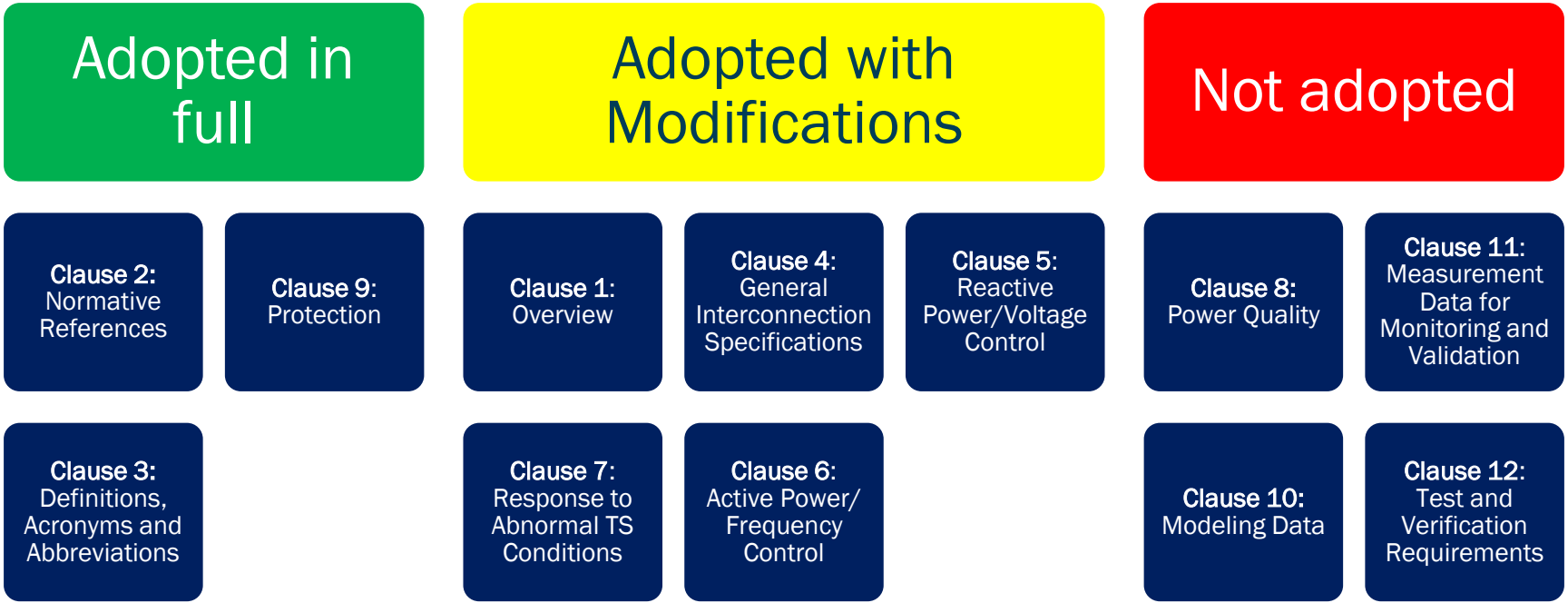
NYSRC Rule B5 adoption of IEEE-2800 requirements



More details here: https://www.nysrc.org/wp-content/uploads/2024/07/RRC-Manual-V47-final-7-2-24.pdf

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Example of an IEEE 2800 clause adopted with modifications: 7.2.2.3.5

IBR unit current response outside continuous operating range

Table 13—Voltage ride-through performance requirements

Parameter	Type III WTGs	All other IBR units
Step response time[b, c, d]	NA[a]	≤ 2.5 cycles
Settling time[b, c, d]	≤ 6 cycles	≤ 4 cycles
Settling band	–2.5%/+10% of *IBR unit maximum current*	–2.5%/+10% of *IBR unit maximum current*

7. Clause 7.2.2.3.5 – Performance Specifications (ride-through dynamic performance requirement applicability)

The dynamic performance requirements specified in Table 13 of the Standard, with the exception of the settling time and settling band requirements, shall be applicable to all contingencies within the Planning Design Criteria defined by the New York State Reliability Council. The settling time and settling band requirements of Table 13 are recommended goals for typical system conditions and ~~but~~ are not mandatory.

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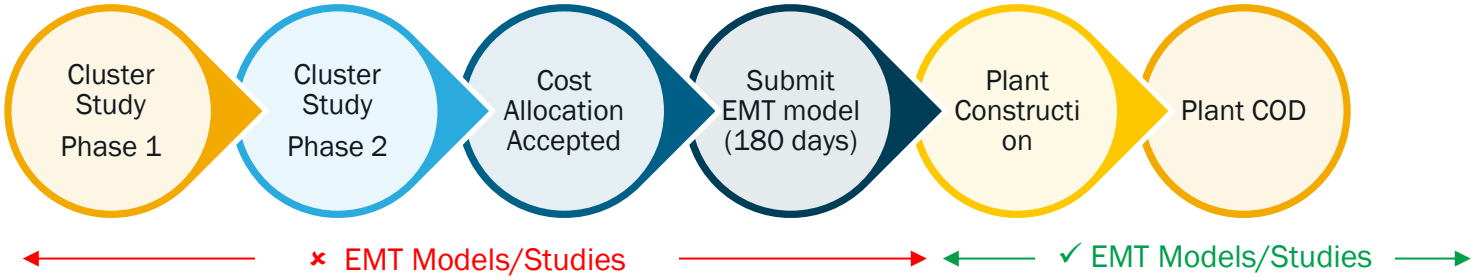
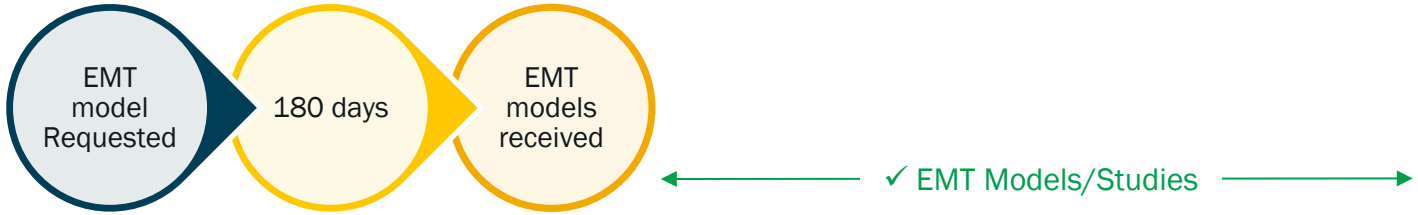
EMT Model Collection and Study Periods

New Plants



Existing Plants



New York ISO

An endless state of flux

NYISO has well established IBR plant modeling requirements and practices

- Covers PDT and EMT models, as wells short circuit and steady state
- Attempts to strike a balance (regulatory requirements vs avoid adding delays to projects)
- Practices are evolving (and will continue) for a while

Plant performance (& model) conformity verification

- Encompasses both new and existing plants (to a different degree)
- NERC Alert on IBR Performance -> NYISO practices currently address some essential actions, so…
- Efforts should help increase trust in models, studies, actions
- Increases assurance that plants behave as they should

New York ISO

Our Mission and Vision

Mission

Ensure power system reliability and competitive markets for New York in a clean energy future

Vision

Working together with stakeholders to build the cleanest, most reliable electric system in the nation

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The Importance of IBR Modeling & Validation

Exploring Three Compelling Case Studies

Kasun Samarasekera, *Head of Power System Studies and Modeling, Elevate GridStrong*

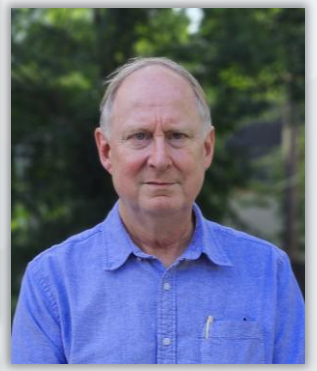
September 23, 2025

Today's Presenter and The Elevate Team

Kasun Samarasekera, MSc, PEng
Head of Power System Studies and Modeling, Elevate











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Disclaimers

- These views reflect the insights and learning of power system studies of various sites
- These views do not necessarily reflect the views of Elevate's industry partners and clients.
- These views should not be interpreted as compliance advice or guidance; they are solely for the purpose of discussion and *elevating* industry understanding of practical and pragmatic issues.
- Plots are shared with permissions from applicable Resource Entities.

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Study Cases

1. Recent PSCAD model validation revealed discrepancies between the "verified" model and actual on-site behavior.
2. A PPC OEM's "generic" model may not meet new ERCOT requirements, with ongoing confusion over what qualifies as "generic" versus true Controller-Hardware-in-the-Loop (CHIL) modeling.
3. Clients working with OEM PSCAD models encountered inconsistent test results; updated models would pass some tests but fail others, requiring a comprehensive testing approach.

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Study Case #1: PSCAD Validation to Field Disturbance

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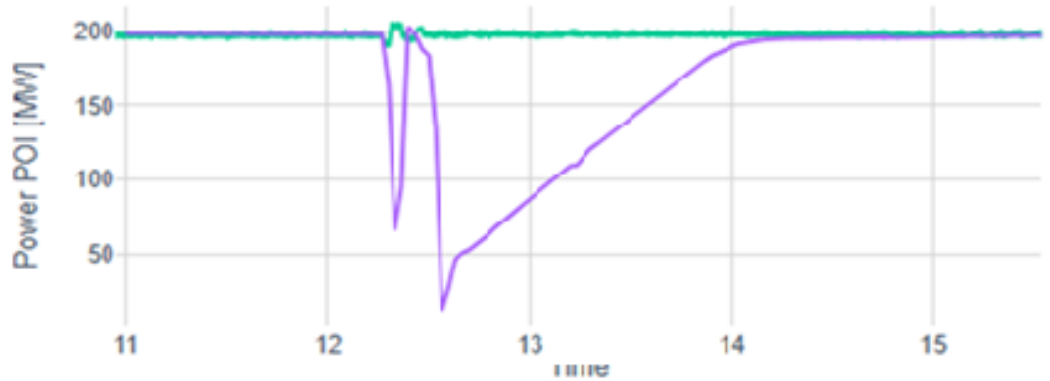
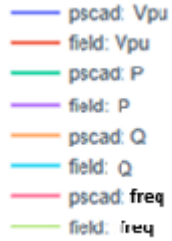
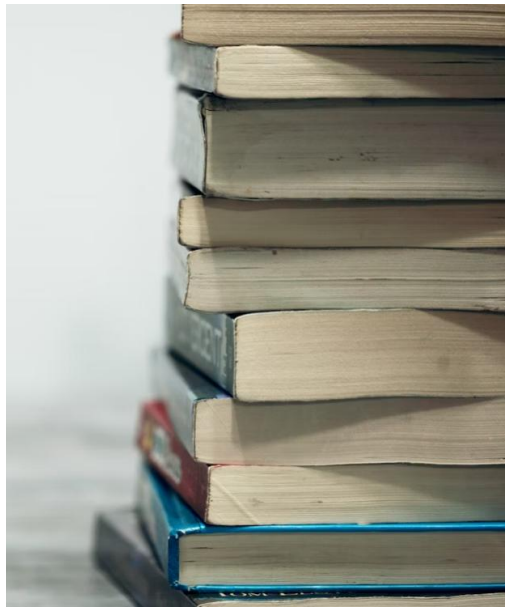
Study Case #1: PSCAD Validation





Study Case #1: PSCAD Validation

PSCAD Model



PSCAD Model Documentation

Inverter As-left Setting

Mode 1: LVRT α $\neq$ Mode 1: LVRT β $\neq$ Mode 1: LVRT π

Model Versus As-Left Equipment

- After performing the MQT Tests and system studies
- As-left settings should **REFLECT** the model parameters that were tuned to ensure stability
- Otherwise, what is the point?

Model Parameters in Simulation

MATCH?

As-Lefts in the Field

Study Case #2: PPC generic models

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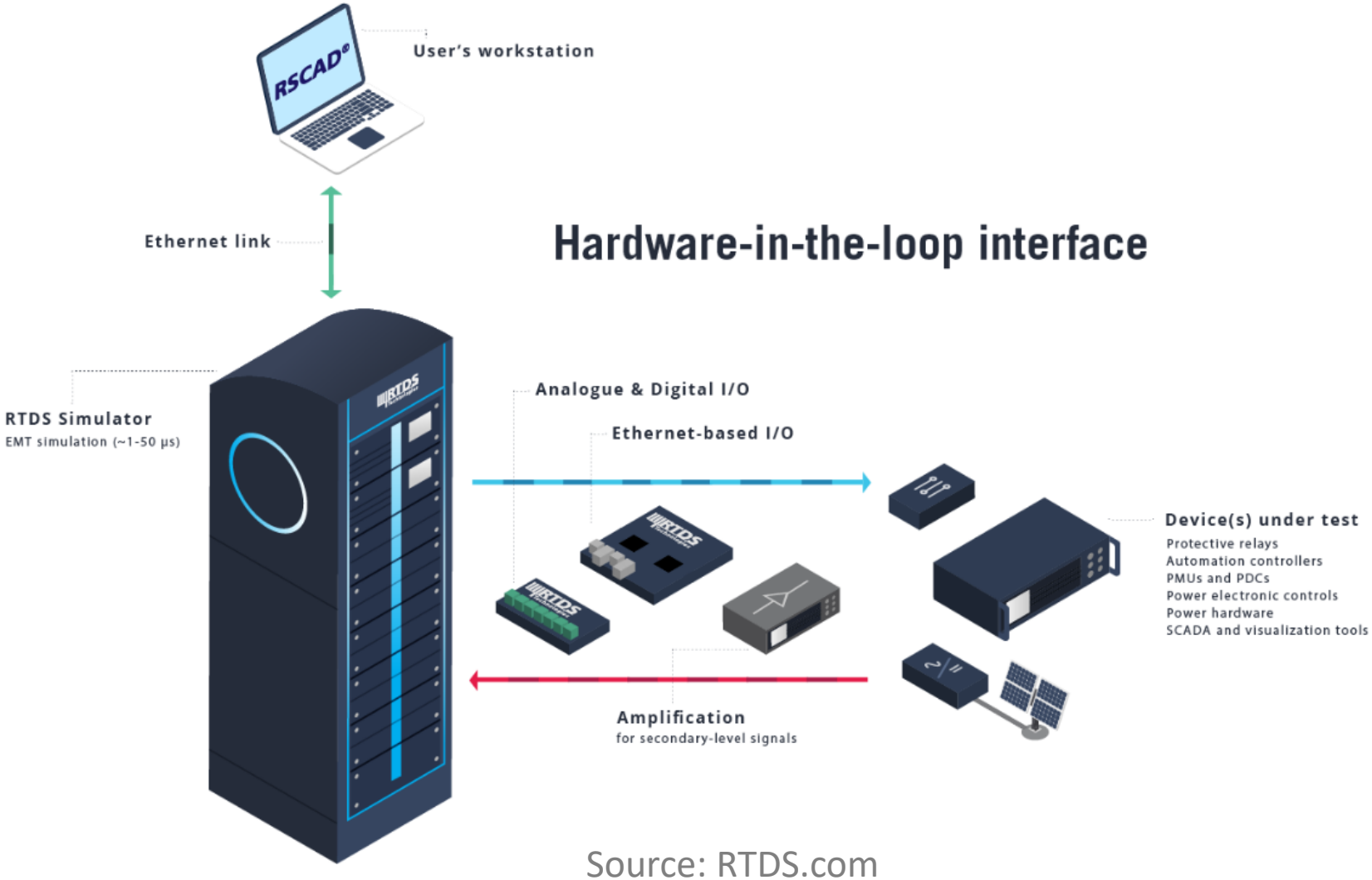
Generic PPC Models

Generic PPCs ie REPCAU EMT model no longer allowed

CHIL Validation is a requirement for inverters but not PPC?

Unrealistic PPC models ie high gains, and no communication delay.

Control-Hardware-in the-Loop Validation



Source: RTDS.com

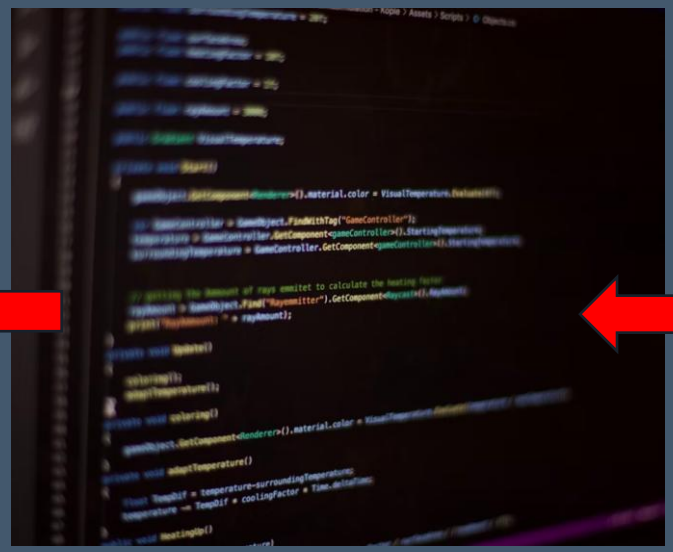
Importance of Accurate Model Validation

- Two Options:
  - .dll “real code” wrapper
  - PSCAD “Block” Model

  With CHIL Validation

PSCAD

[PSCAD-Model-Requirements-Rev.-13-Feb-2025-1.pdf]



.dll real code wrapper

[Guidelines for use of real-code in EMT models for HVDC, FACTs and inverter based generators in power systems analysis - Technical Brochures | eCIGRE]

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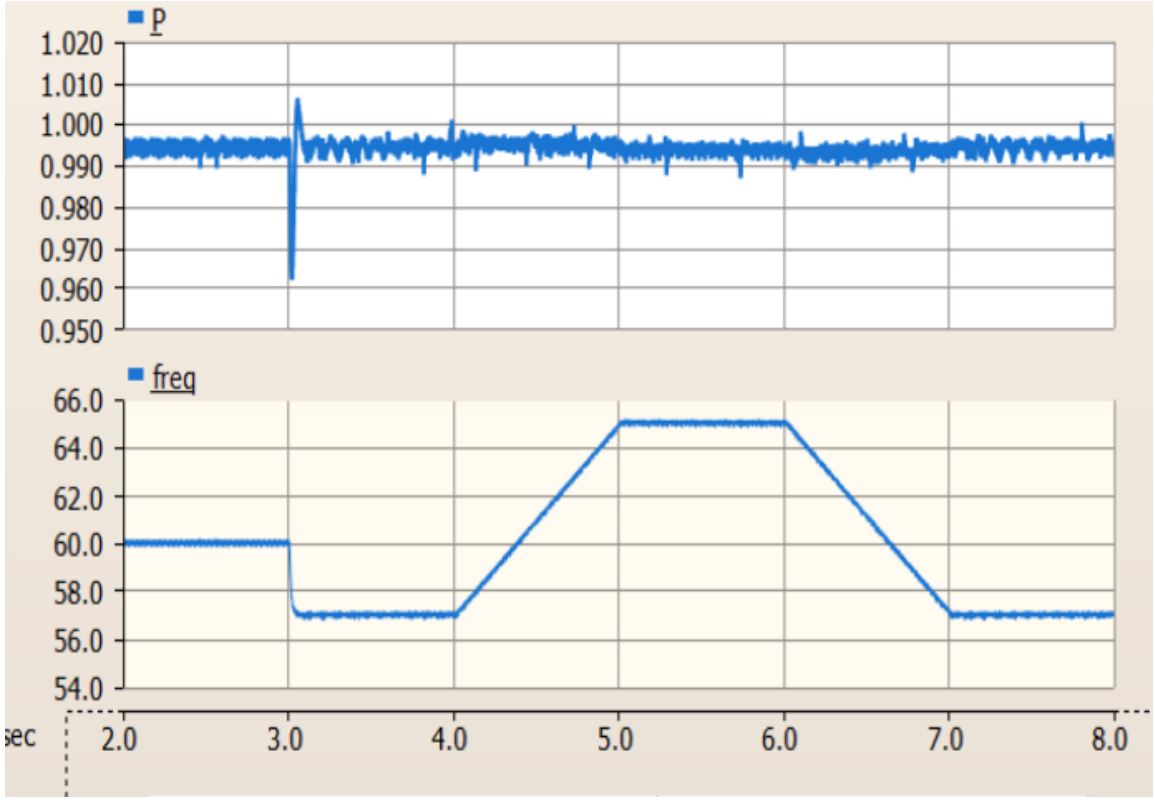
Example IBR Plant Model versus As Lefts

- IBR tripped due to ROCOF protection in the field
- Isolated and tested the inverter model by applying ROCOF at inverter terminal
- Inverter model did not trip – why?
- OEM stated that the inverter EMT model did not include ROCOF protection…
- Model inherently not matching actual equipment settings



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Study Case #3: HECO GFM Model Tuning

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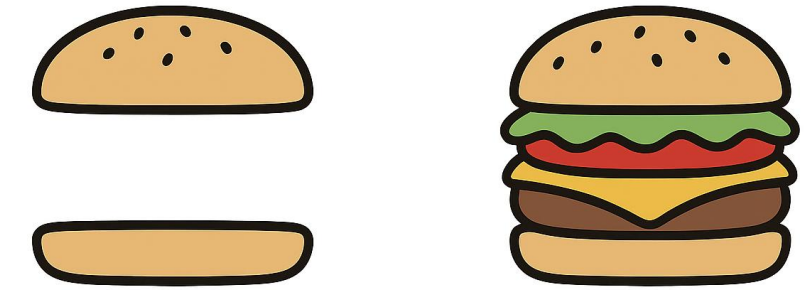
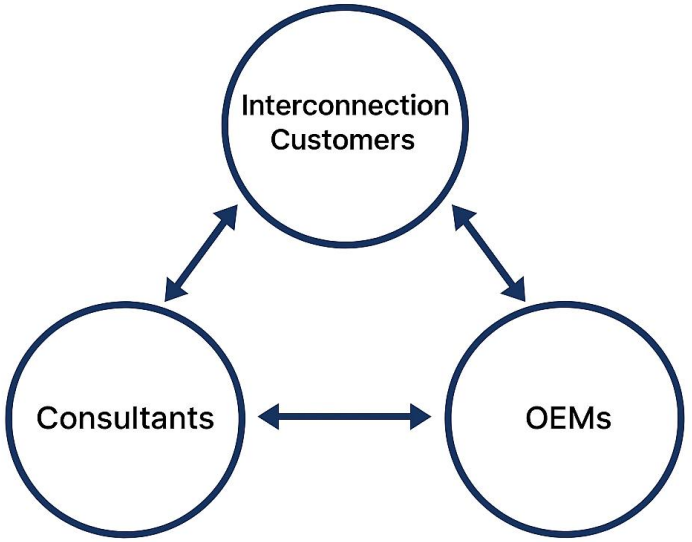
Study Case #3: HECO GFM Model Tuning

- OEM-provided model with default settings may not meet all grid requirements under all system conditions; hence, model tuning is necessary to ensure compliance.



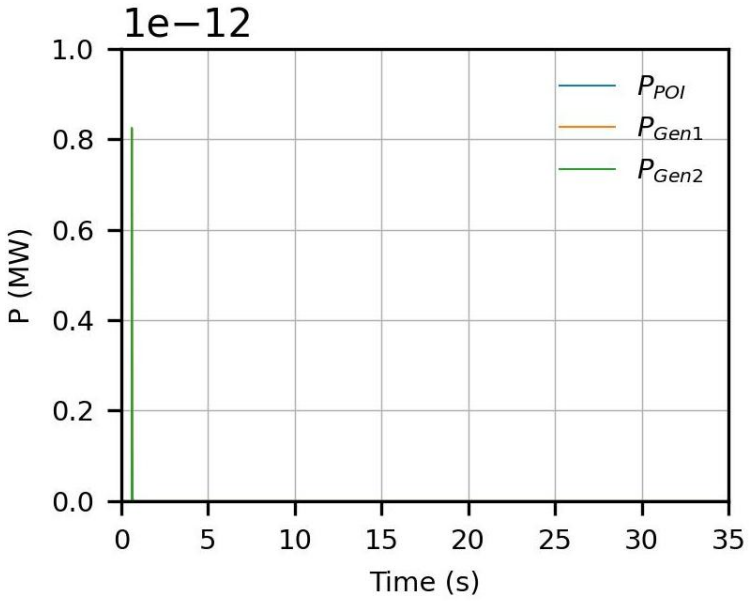
- Close collaboration among interconnection customers, consultants, and OEMs is essential to ensure inverter compliance with all applicable grid requirements.



Study Case #3: HECO GFM Model Tuning

- The underfrequency protection tripped the inverters during black start. Extending the frequency protection settings enabled the inverters to initialize properly, pick up the load, and ride through the fault.

Before



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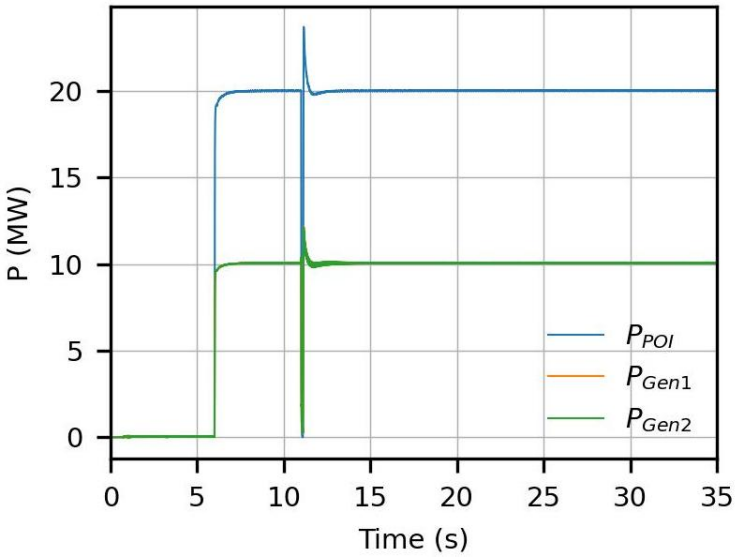
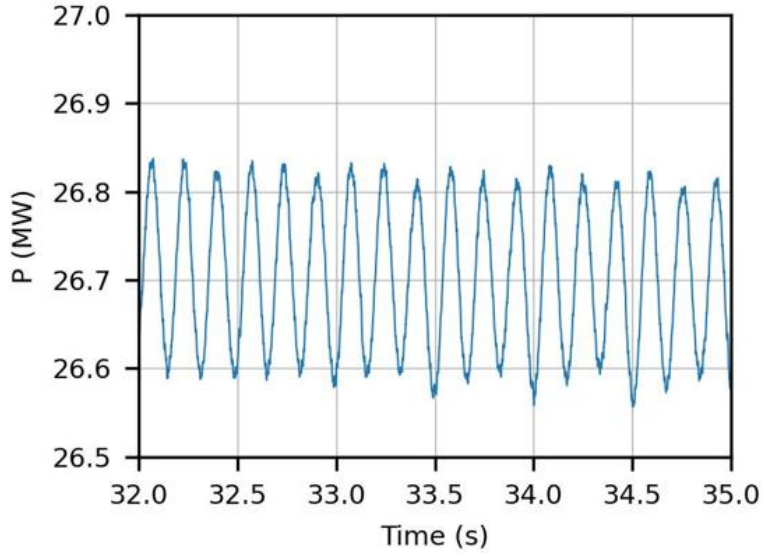


Study Case #3: HECO GFM Model Tuning

- Undamped oscillations in active power output of inverters following a disturbance was observed.
- Changing the frequency response of the inverters to a mode with a faster control loop and less filtering mitigated the oscillatory output.

Before



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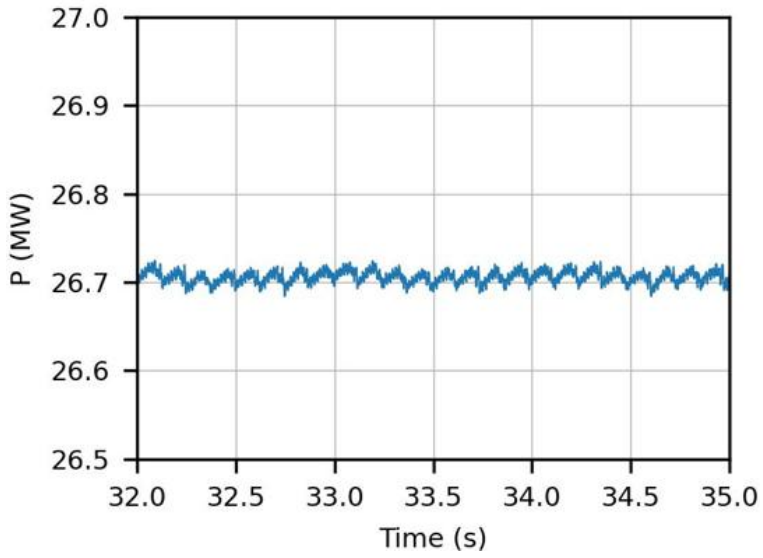


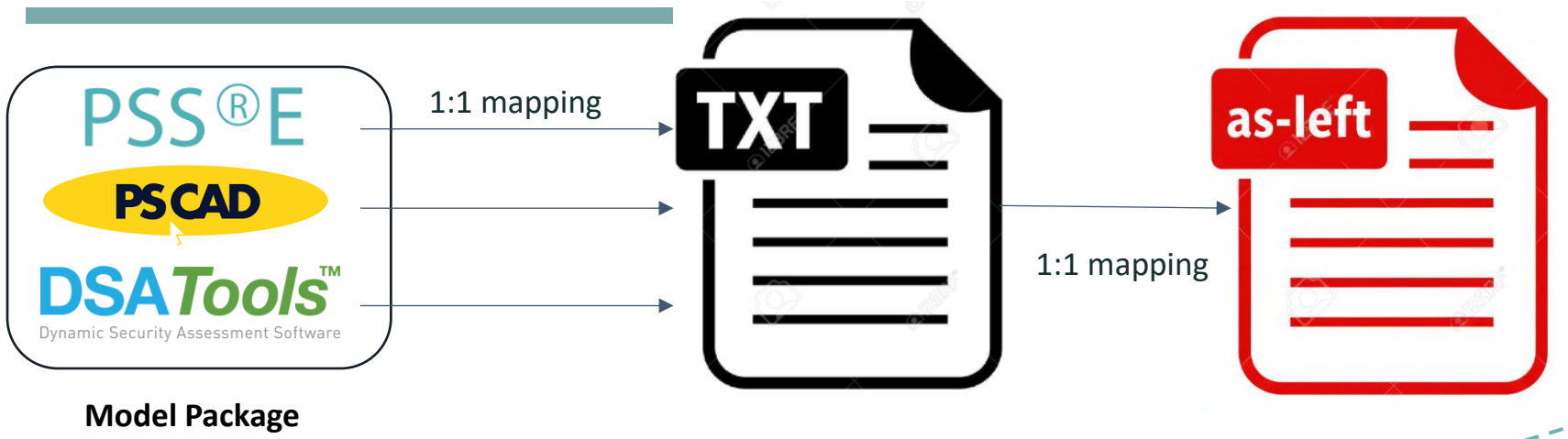
Study Case #3: HECO GFM Model Tuning

- Model tuning involved an iterative process with the OEM; resolving one issue sometimes introduced another. The full HECO test suite was executed at each step to ensure compliance with all requirements.

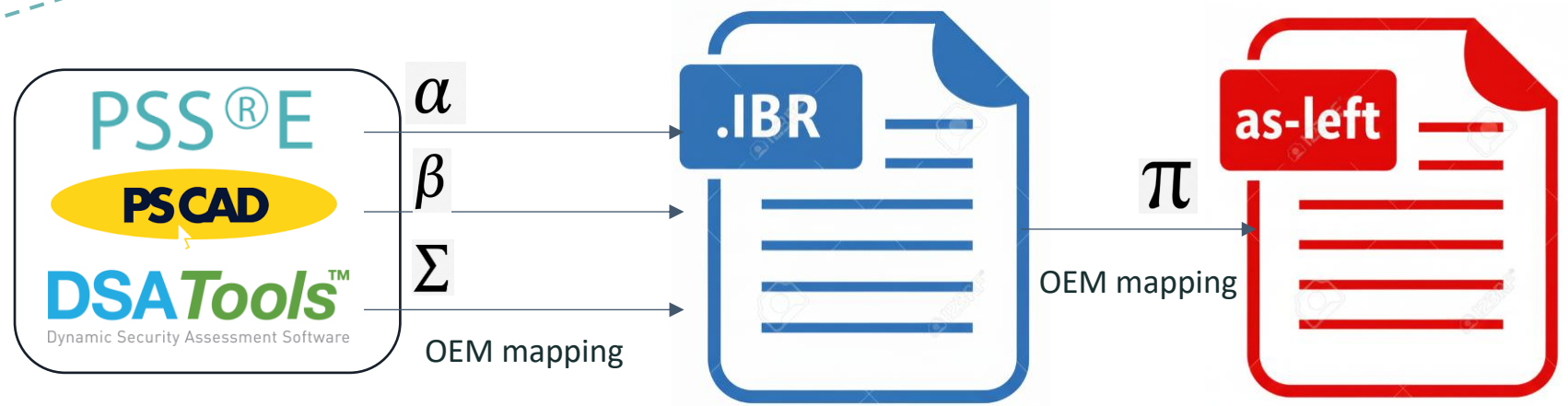
- Following proper tuning, the plant successfully passed all tests, demonstrating that the inverter was capable of meeting the requirements. However, the default settings were insufficient for the specific application.

- The simulation results also underscore the importance of using models that accurately reflect inverter performance.

Steps Forward: Standard Mapping



*Or .dll “real code” wrapper method



ELEVATE ENERGY CONSULTING

Steps Forward: Better CHIL Testing

- **Mandate yearly maintenance- incentivize or penalize?**
- **Understanding and finding the "potholes" in the models requires strenuous CHIL tests**
- **Good commissioning process**

CHIL

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i2X FIRST
IBR Modeling: Where Do We Go From Here?

September 23, 2025

Andrew L. Isaacs and Lukas Unruh

ELECTRANIX

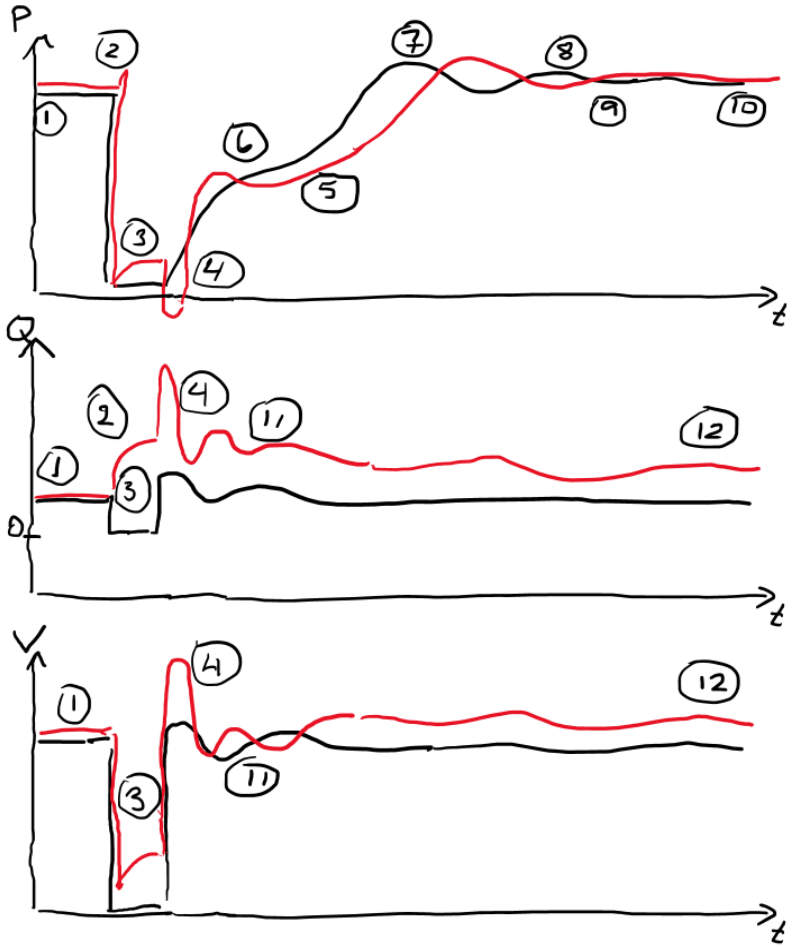
SPECIALISTS IN POWER SYSTEM STUDIES

What have we (as an industry) achieved?

- We have published an IEEE standard that significantly raises the bar for IBR interconnection performance and modeling
- We have widely increased the prevalence of EMT model intake requirements for IBRs, and deepened our understanding of PDT along the way
  - Many groups have made a good start on automation
  - Many transmission utilities routinely check basic performance and usability for all incoming IBRs.
- We have made good headway on understanding GFM and other enabling technologies
  - Requirements rolling out, projects in service, further research is looking good.
- Through modeling and performance testing, we have improved system performance and prevented issues from ever occurring
  - Some utilities have fully integrated EMT into their planning processes
  - **Hundreds (thousands?) of serious issues identified at the study level resulting in fundamental changes to design, or other mitigation.**

Work Ahead: Improvements to model Accuracy

- Validation
  - Validated plant model composed of validated unit models
    - "Type testing" in 2800.2
    - Clear guidance on validation accuracy is missing!
  - Commissioning, field events
- As-built confirmations
  - Control Firmware
  - Parameters (!!!)
- Adoption of .dll standards (i.e. "real code")
  - Important in absence of strong validation criteria!
- More key model features
  - PPCs ("delays", real code?)
  - DC-side (protection, DC-DC controllers, PV array, SOC)



Work Ahead:
Improvements to model Accuracy

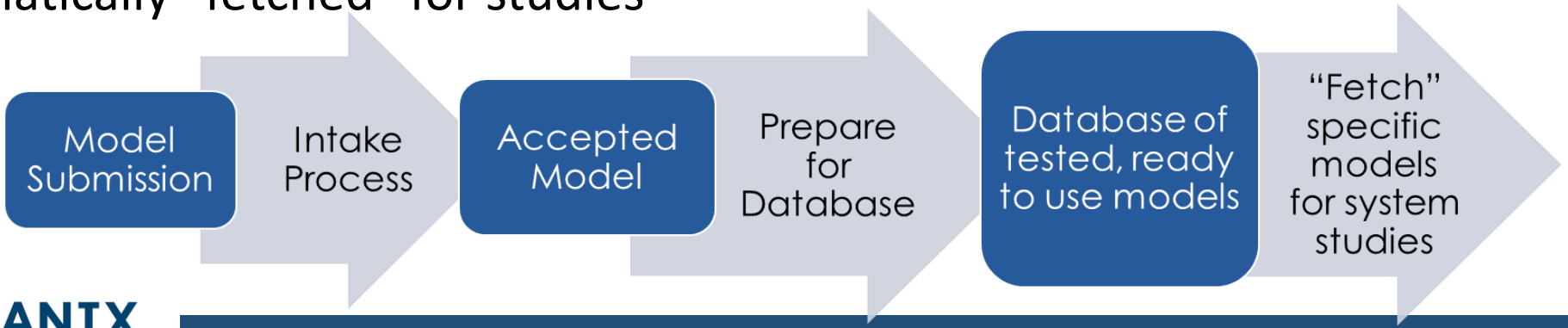
Memorable quotes from model development work:

- *"OEM provides general purpose models that must be parameterized for project specific conditions. OEM does not have the resources to create and maintain as-left models"*
- *"OEM models are compliant. Our challenge is your consultant is asking for information considered company propriety"*
- *"Protection "X" is only disabled by default in the model because depending on the market this protection is not tested in the models"*

Work Ahead: Data Management

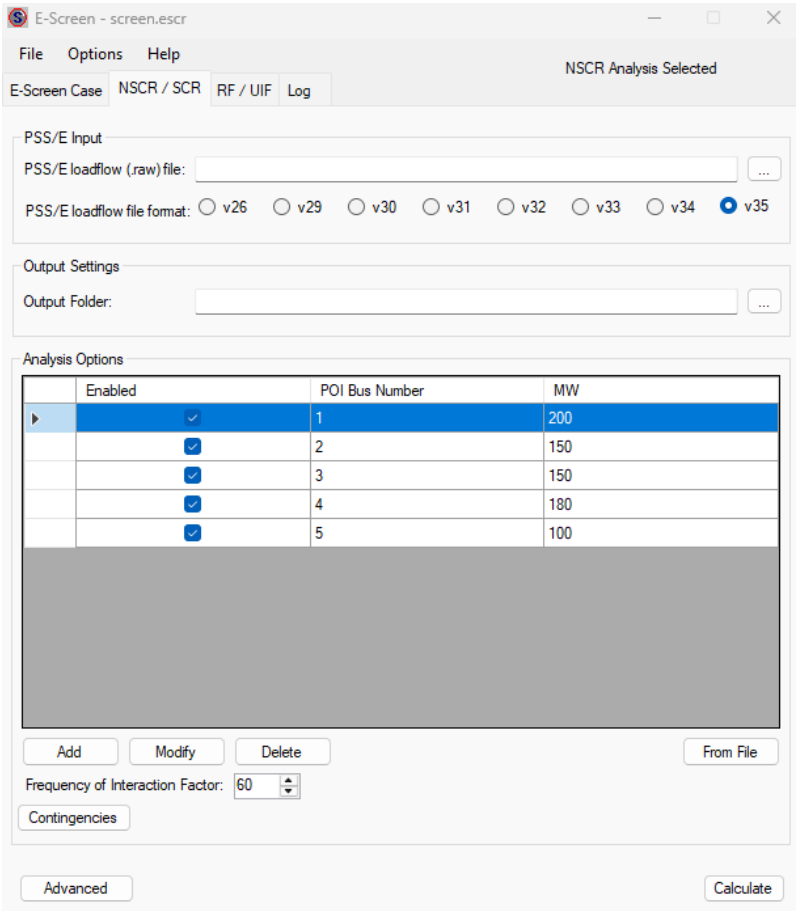
- 5+ iterations of a single plant model not uncommon from application to post-commissioning
- Documentation model updates (changes made, test reports, etc.) is important
- Code management and versioning tools (Github, SVN) may be leveraged
- Future: store models in data repositories, models automatically “fetched” for studies

Model test Summary	
Model Test date:	
Reviewer	
Project Name:	
Interconnection Location:	
Rated Capacity at POC:	
Manufacturer:	
Equipment type: (eg. PV, Wind, BESS or Hybrid)	
Equipment version:	
Documentation files (OEM):	
Documentation files (site specific):	
Model Files supplied:	



Work Ahead:
Maturity in EMT application

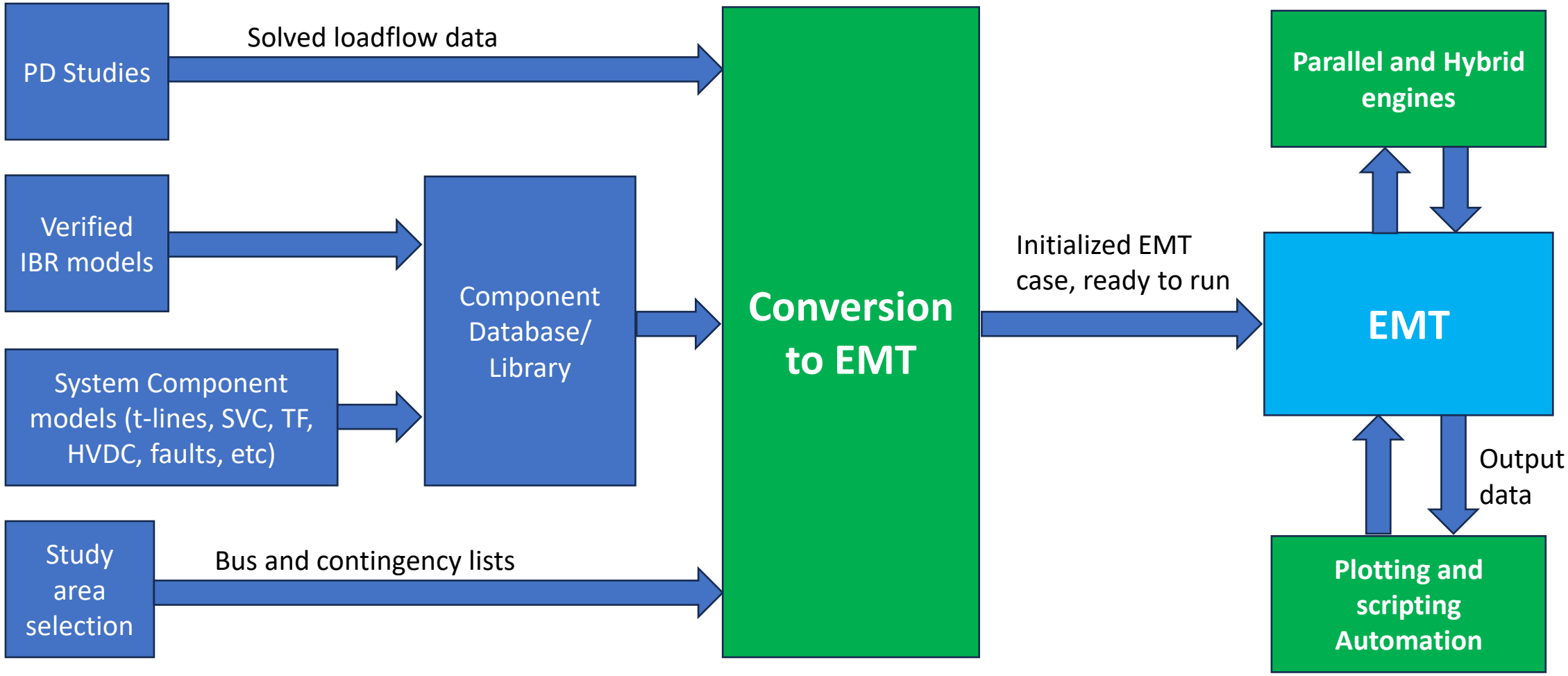
- Screening techniques to identify focus areas for analysis
  - Weak Systems:
    - Past: visual checks aided with simple SCR / WSCR based screening
    - Future: Commercial-grade software for automated interaction-factor based approaches applied at scale, considering some device characteristics
  - SSO:
    - Past: System impedance scans in EMT software
    - Future: Commercial-grade high-capacity dedicated scanning tools for screening and issue identification
  - The return of Eigenvalue/Small Signal tools!
    - Past: limited in use by computation and black box models
    - Future: Modern algorithms and impedance scan technology can be integrated into screening approaches



Work Ahead:
Maturity in EMT application

- Clean and effective automation of studies, including system modeling and analysis
  - At present:
    - System modelling is somewhat automated with a collection of commercial tools and ad-hoc scripts. Unifying tools needed to streamline the process
    - Analysis automation in a similar state
  - Ideal future: tools that abstract the modeling to a degree that the engineer can focus on asking questions and performing actionable analysis.
    - The tools would leverage data constructs to create models based on guidance from an engineer, and consolidate output in a useful way to prepare for an engineer to apply their brain to analysis and mitigation.

Notes on Commercial EMT system study process:

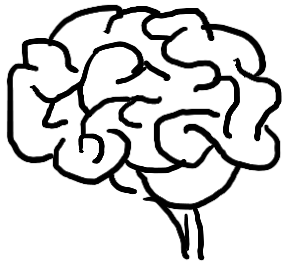


Work Ahead: Continuing Education

- Many groups now focused on training for basic EMT literacy.
- Future learning must continue in more advanced applications, including:
  - Appropriate selection of study boundaries and identification of scenarios
  - Prioritization of concerns
  - Adjusting model and study scales appropriately
  - Advanced analysis techniques and understanding of control driven phenomena
- Software tools must be further developed to offload some of the simulation nuts and bolts, freeing up the engineers to focus on need, analysis, and action.

What is our end goal?

- Work backwards from a reliable power grid...
- Unlock study capability for a wider group of engineering brain-trust.
- Provide a solid foundation for reliability grounded in engineering principles.



Reliable Power Grid with IBRs ⇒ and loads?

Act based on good information

We're falling behind!

Perform useful studies and analysis where needed to inform decisions

Need better tools, stronger foundations

Create Sufficiently accurate study models

Getting Better!!

Collect and organize accurate component models

Ask the right questions to scope studies

More work to do!

Develop requirements and standards based on need

Apply screens and judgement to focus effort

Doing well, but the world is changing!

Develop understanding about needs

Questions?

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