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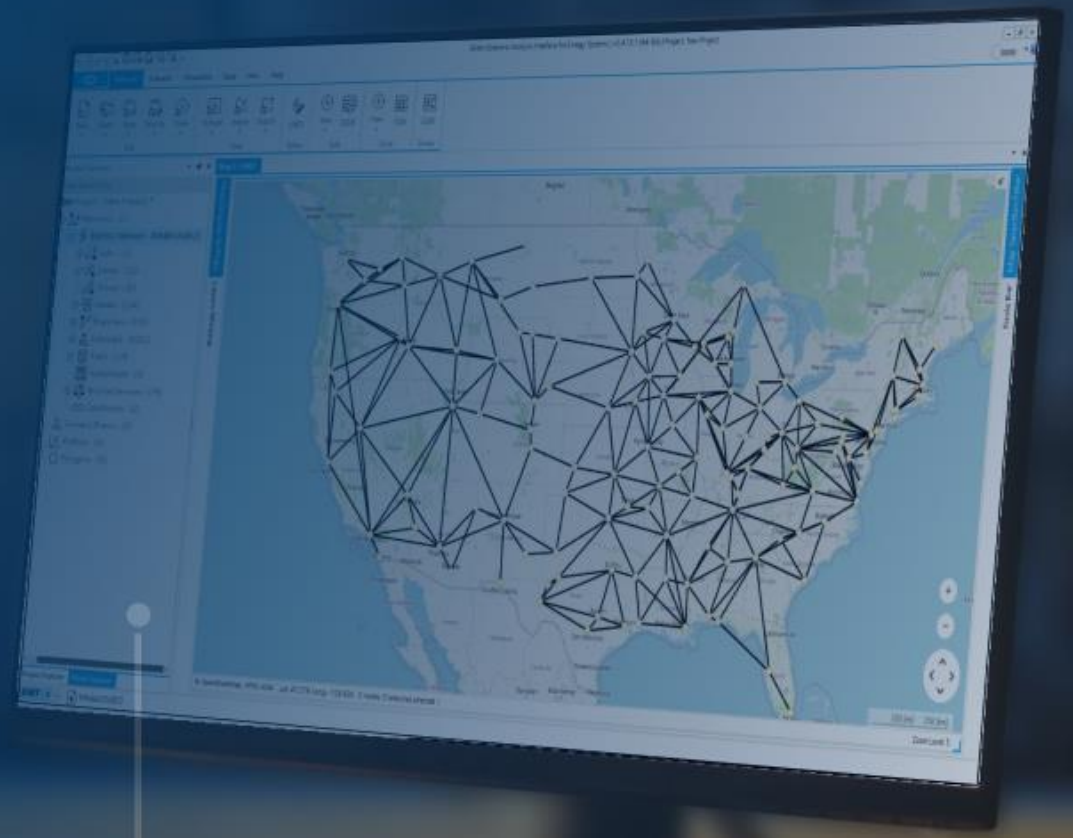
Plan the Energy Future



Insights, Consensus, and Disagreement in the Power Systems Community

About Dynamic Simulation Tools Necessary for Stability

Jacob Kravits, October 23, 2024

Estimate the Expertise at This Workshop

$$300 \text{ experts} * \frac{15 \text{ years}}{\text{expert}} * \frac{2000 \text{ hours}}{\text{year}} = \mathbf{9,000,000} \text{ expert hours}$$

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41 Interviewees From Diverse Roles and Backgrounds

As part of our ongoing NSF Small Business Innovation Research Grant, we interviewed 41 people:

- How are you assessing reliability *today?*
- How about *in 5-10 years*?

Diversity in roles and expertise

Methods of qualitative analysis

- 45 min. – 1 hr. interviews with each person
- Each interview followed a set of guiding topics/questions
- Detailed notes taken of points mentioned
- Notes were tagged for themes

Role	Titles	Interviews
End User	Researcher, Planner, Consultant	15
Decision Maker	Center Director, Manager of Transmission Planning, Senior Technical Leader	13
Non-purchase Decision Maker	Inverter-based Resource Specialist, Senior Technical Leader, Chief Engineer	4
Other	Professor, Founder, High Performance Computing Engineer	9

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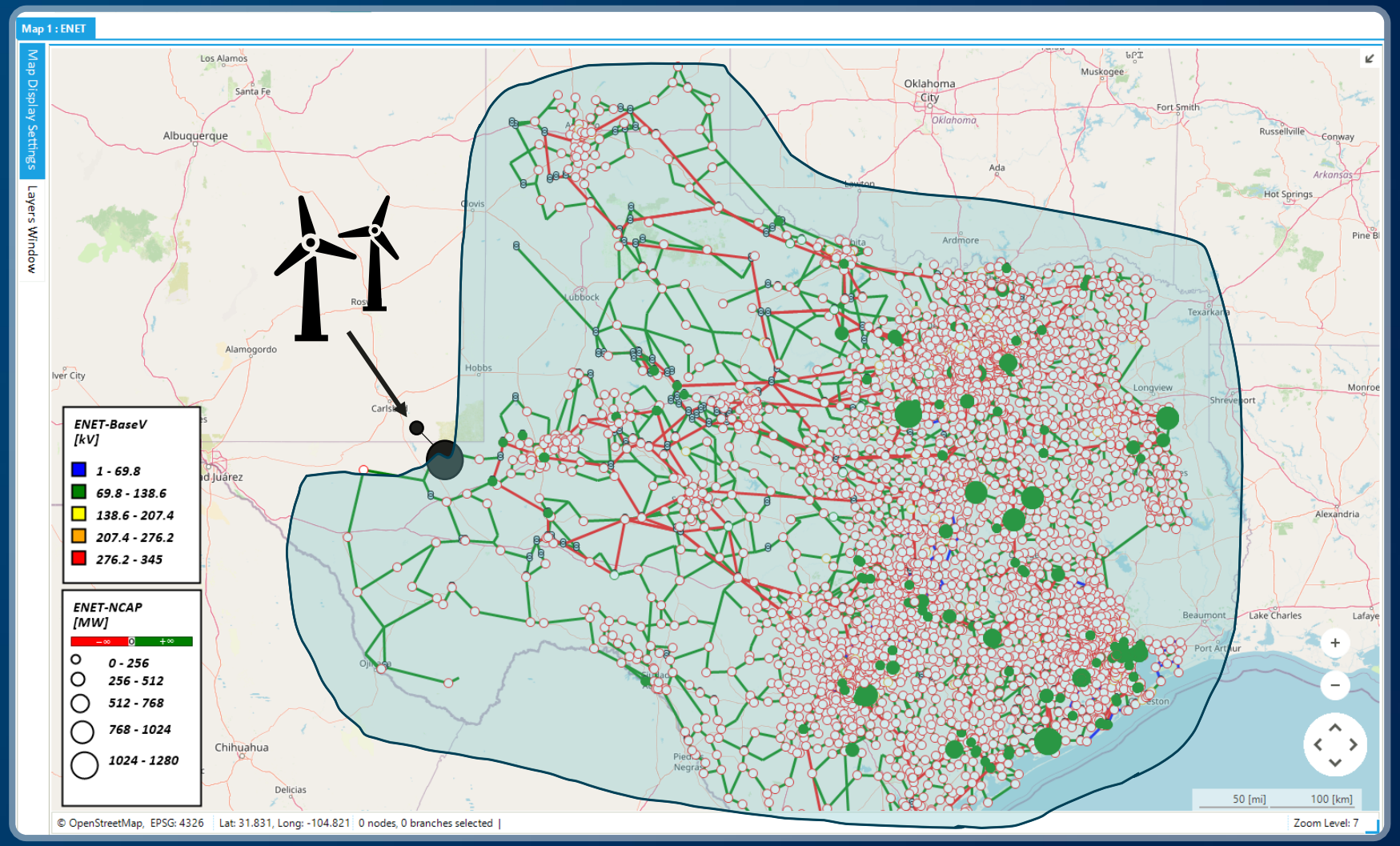
IBR Interconnection: A Key Challenge From Interviews

- **Infinite Bus Method**
- **Phasor Domain Model**
- **Electro-Magnetic Transient (EMT) Domain Model**



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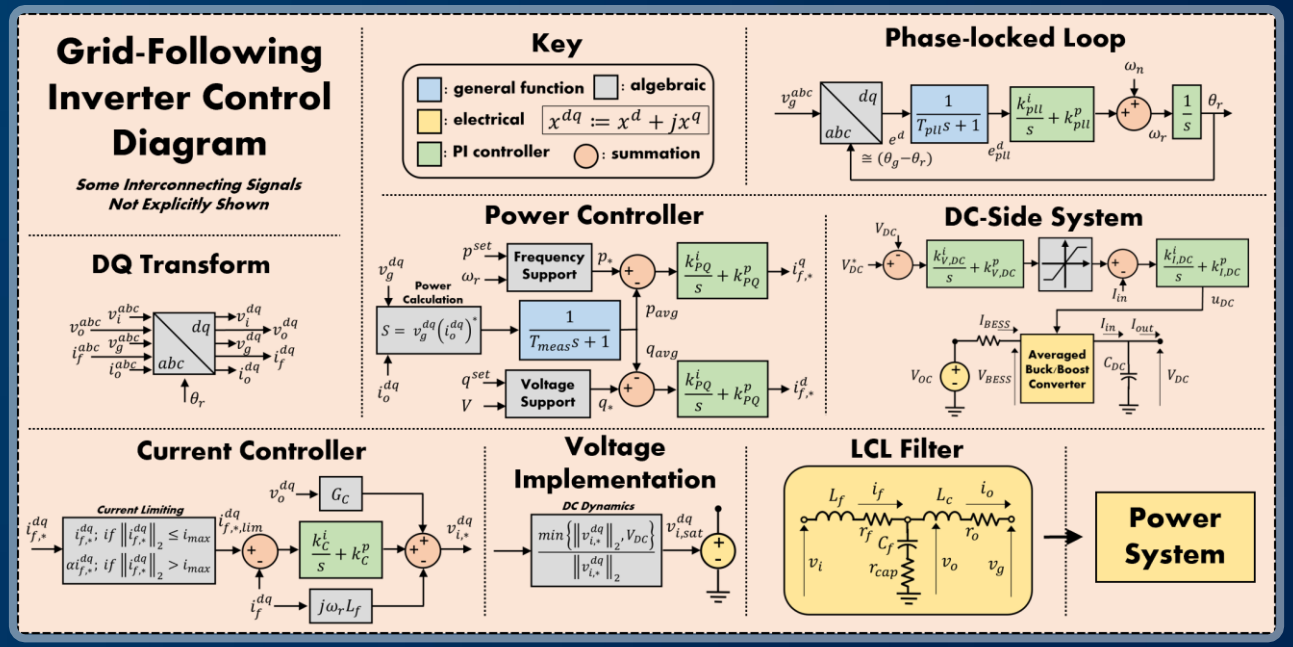
70% of participants - Input Data Barriers

Network Information:

- Amount of high-quality data required to run meaningful simulations
- Validation of these high-fidelity simulations is particularly onerous

Dynamic Models:

- The physics of inverter-based resources permit a wide range of design
- Proprietary nature of devices



R. W. Kenyon, A. Sajadi, A. Hoke, and B.-M. Hodge, "Open-Source PSCAD Grid-Following and Grid-Forming Inverters and A Benchmark for Zero-Inertia Power System Simulations," in *2021 IEEE Kansas Power and Energy Conference (KPEC)*, Apr. 2021, pp. 1–6. doi: 10.1109/KPEC51835.2021.9446243

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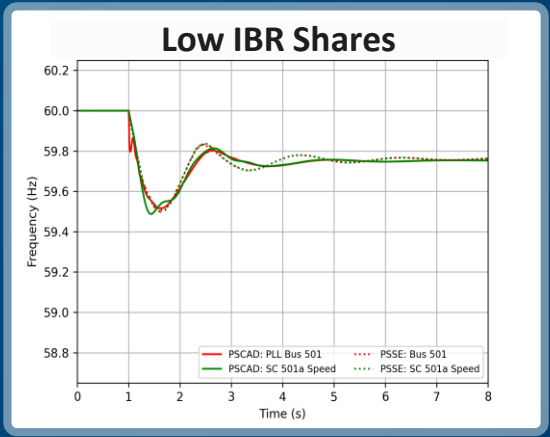
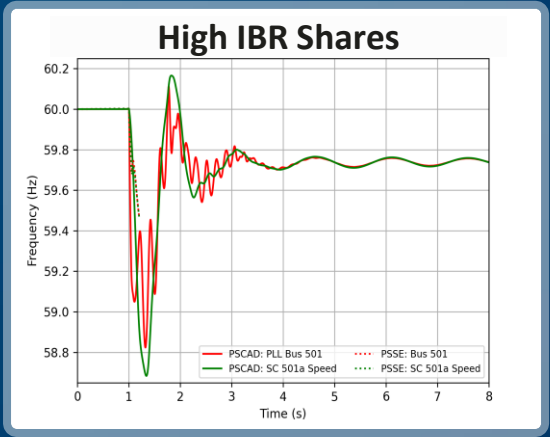
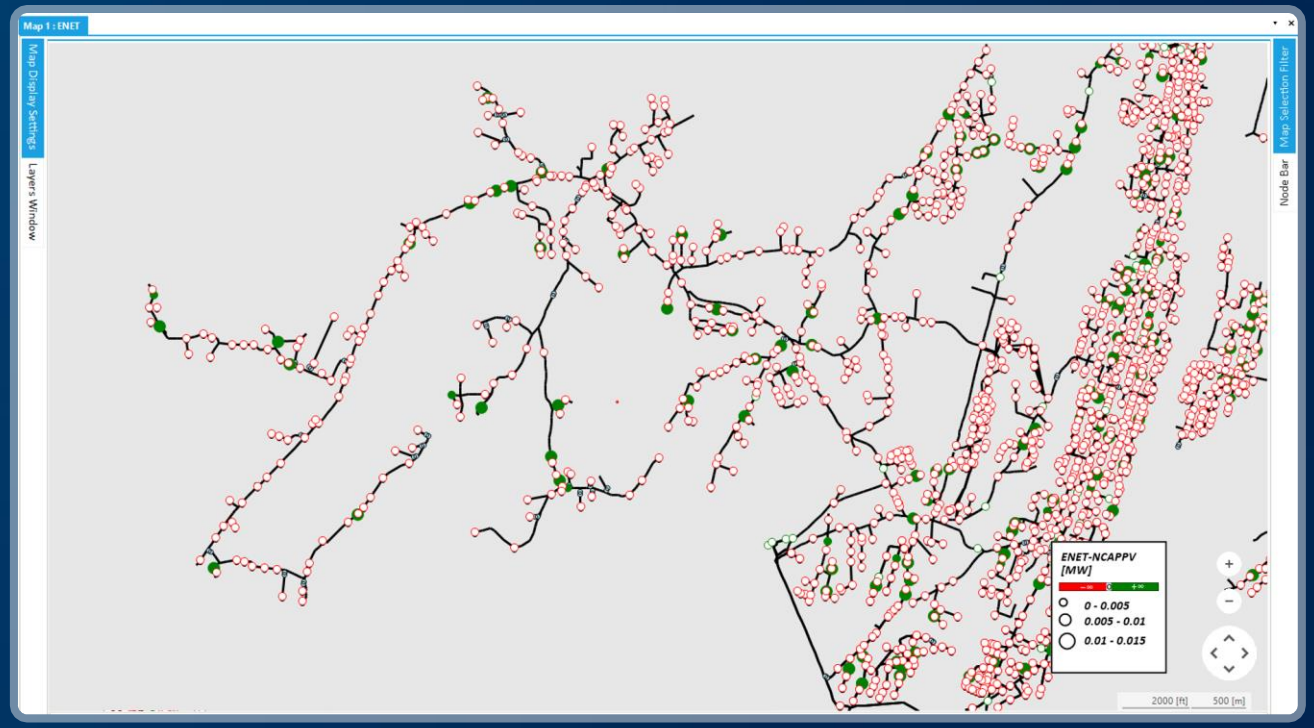
50% of Participants - More Detail Needed...
during certain conditions and space

Operating Conditions May Be Indicators





Spatial Diversity



R. W. Kenyon, B. Wang, A. Hoke, J. Tan, and B.-M. Hodge, "Comparison of Electromagnetic Transient and Phasor Dynamic Simulations: Implications for Inverter Dominated Systems," in *2023 IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT)*, IEEE, 2023, pp. 1–5. Accessed: Oct. 02, 2023. [Online]. Available: https://ieeexplore.ieee.org/abstract/document/10066384/

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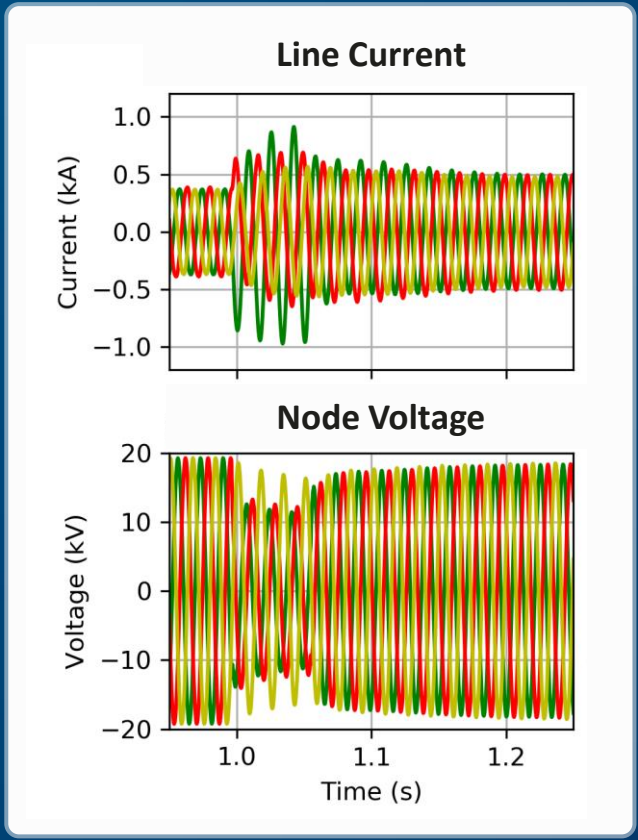
60% of participants - Cognitive Burden: Part 1

EMT Simulations Generate a Huge Amount of Data



R. W. Kenyon, B. Wang, A. Hoke, J. Tan, C. Antonio, and B.-M. Hodge, "Validation of Maui PSCAD Model: Motivation, Methodology, and Lessons Learned," in *2020 52nd North American Power Symposium (NAPS)*, Apr. 2021, pp. 1–6. doi: 10.1109/NAPS50074.2021.9449773

100 Node System x 1 second Simulation -> Gigabytes

100,000 Node System x 1 second Simulation -> Terabytes

For one simulation run (1 contingency)

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60% of participants - Cognitive Burden: Part 2

What Is the Analyst Looking For?

Often some sort of anomalous behavior which can be hard because…

Numerical Noise vs Results

In certain cases, it can be difficult to distinguish numerical error from important response characteristics

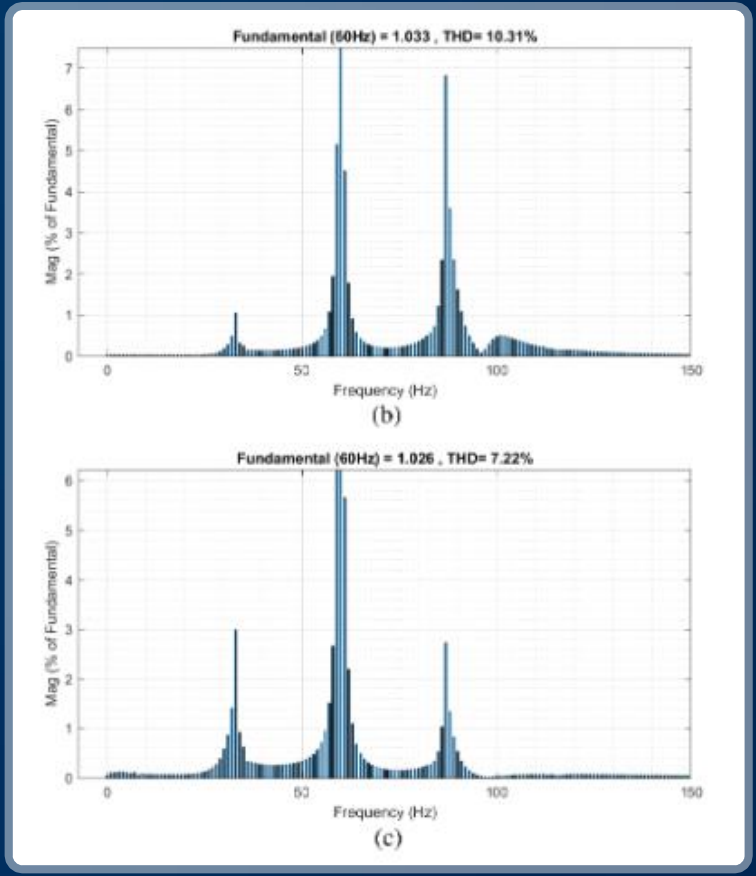

Fig 12 from - L. Fan *et al.*, "Real-World 20-Hz IBR Subsynchronous Oscillations: Signatures and Mechanism Analysis," *IEEE Transactions on Energy Conversion*, vol. 37, no. 4, pp. 2863–2873, Dec. 2022, doi: 10.1109/TEC.2022.3206795.

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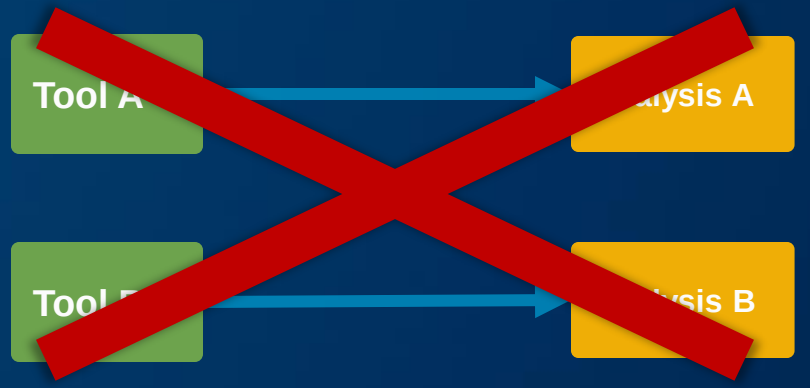
50% of participants - High "Inertia" Industry

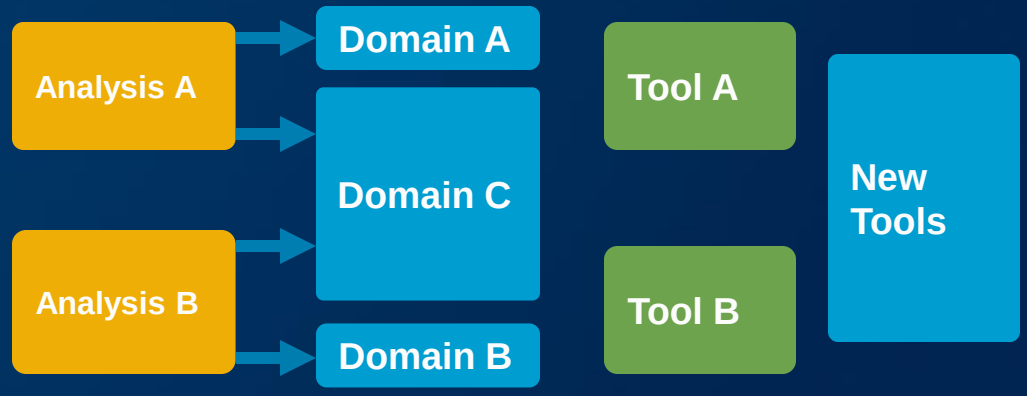
Expertise in Tools

9,000,000 expert-hours have been put into a handful of tools



Separate Domains from Tools:

Domains, not specific tools, should guide analysis



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Other Viewpoints

Device/Model Standardization:
Test-driven practices can standardize certain device behavior

Grid-Forming Inverters May Absolve Need for EMT-level Detail:
Assumptions may no be valid for all system stressors

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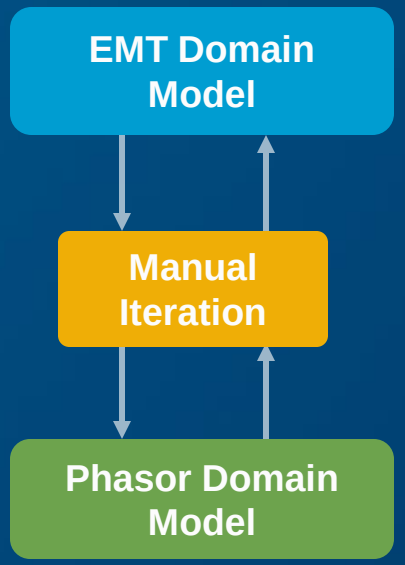
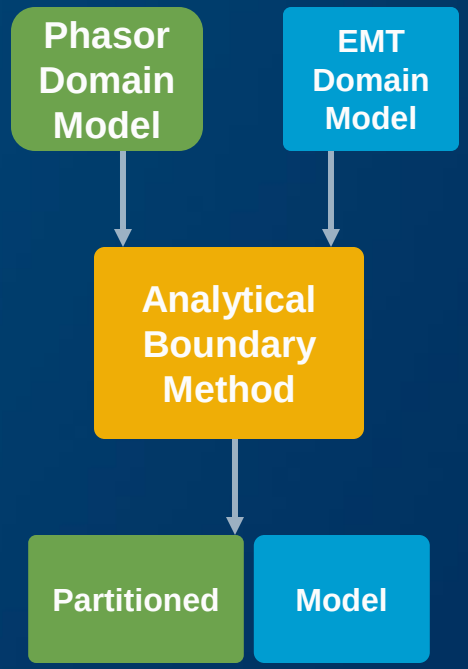
Approaches Mentioned To Speedup Stability Analysis

Iterate using Rules of Thumb



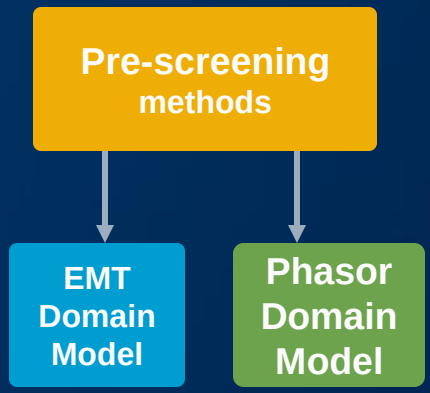
- Mentioned Pro: Engineers to use judgement
- Mentioned Con: Commercial tools weren't created for iteration

Analytical Boundary Tools



- Mentioned Pro: Get a single answer
- Mentioned Con: Are you confident in your analytical method?

Pre-screening Methods



- Mentioned Pro: Fast way to arrive as trusted-domains
- Mentioned Con: Mainly in-house tools

Other Domains

- Impedance Spectroscopy
- Frequency Analysis

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Other Viewpoints – Scalability

Contemporary Approaches Are Unsustainable:

Today's method of speeding up EMT, or create hybrid phasor/EMT models by linking existing software is exceedingly difficult (impossible?) to scale

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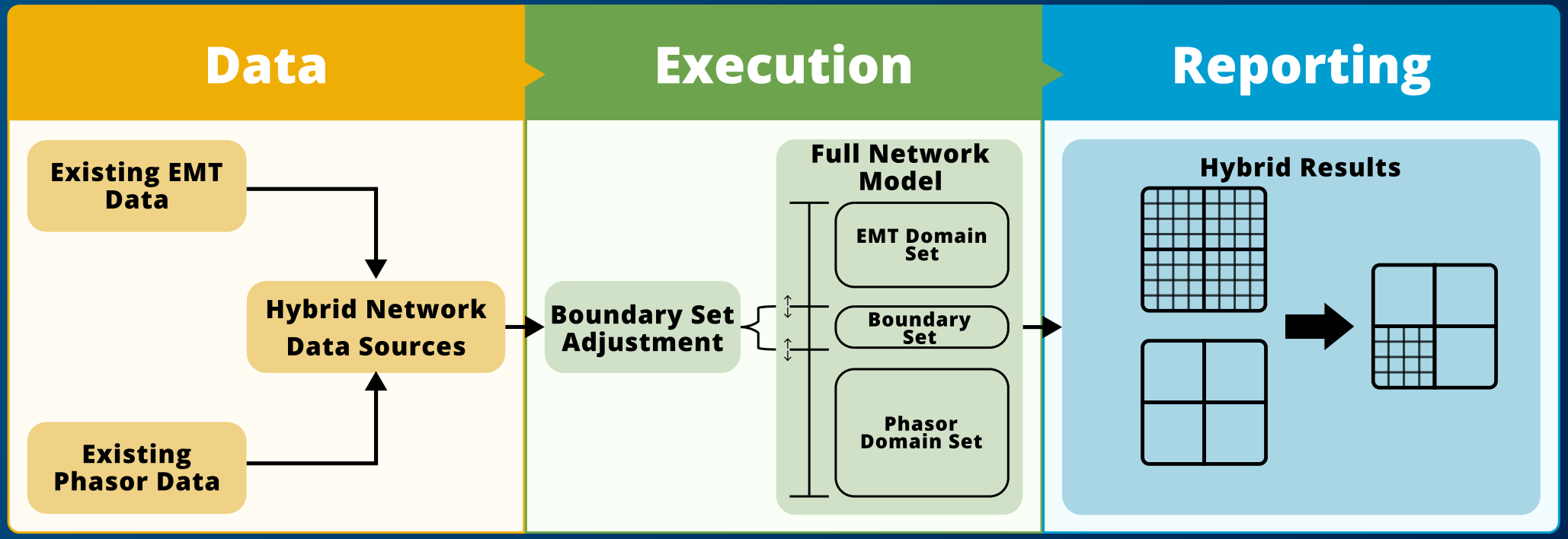
Our Perspective: Hybrid Phasor/EMT



Alleviates the need for system-wide high fidelity data

Autoadaptively **determines when phasor or EMT is needed**

Targeted insights reduces need to sift through big data

We are finalizing our proof of concept as part of our NSF SBIR Phase I initiative!

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Conclusion

Consensus:

- Input data is a barrier
- Difficult to know when more detail is needed
- Avoid cognitive overload
- Change is hard

Selected Views:

- Model standardization
- Role of grid-forming inverters
- Unsustainable contemporary approaches

“May you live in interesting times”

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