NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Large Loads Task Force Meeting

Chair: Matthew Veith, AEP
Vice Chair: Agee Springer, ERCOT
August LLTF Meeting
August 28, 2025

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

NERC Antitrust Compliance Guidelines, Public Meeting Notice, and Participant Conduct Policy

Agenda

Time	Topic	Point of Contact
2:05 p.m.	NERC Antitrust Compliance Guidelines, Public Meeting Notice, Participant Conduct Policy	All
2:10 p.m.	**Review Agenda**	Jack Gibfried, NERC
2:10 p.m.	**Chair Opening Remarks**	Matthew Veith, AEP
2:15 p.m.	**Review and Approve Previous Meeting Minutes**	Evan Mickelson, NERC
2:20 p.m.	**Level 2 NERC Alert – Large Loads Interconnection, Study, Commissioning, and Operations**	Latrice Harkness, NERC JP Skeath, NERC
2:30 p.m.	**White Paper #2 Update: Assessment of Gaps in Existing Practices, Requirements, and Reliability Standards for Emerging Large Loads**	Tyler Springer, AEP Patrick Gravois, ERCOT Jack Gibfried, NERC
2:45 p.m.	**Reliability Guideline Update: Risk Mitigation for Emerging Large Loads**	Evan Mickelson, NERC Jack Gibfried, NERC
2:50 p.m.	**Presentation: Evaluating the wide area impact of large-load induced oscillations at the planning stage**	Shuchi Biswas, PNNL
3:20 p.m.	**Presentation: Developer's Experience - Navigating the Interconnection Process**	Evan Pierce, EdgeConneX
3:55 p.m.	**Next Step & Closing Remarks**	Agee Springer, ERCOT

Background

Key Dates

- White Paper #2, *Conclusions and Recommendations Chapter* out for final RSTC comments (October)
- White Paper #2 out for final RSTC approval (December)
- Reliability Guideline out for LLTF approval for release for comments (September 18)
- Reliability Guideline out for Industry Comment (November and December)

Key Actions

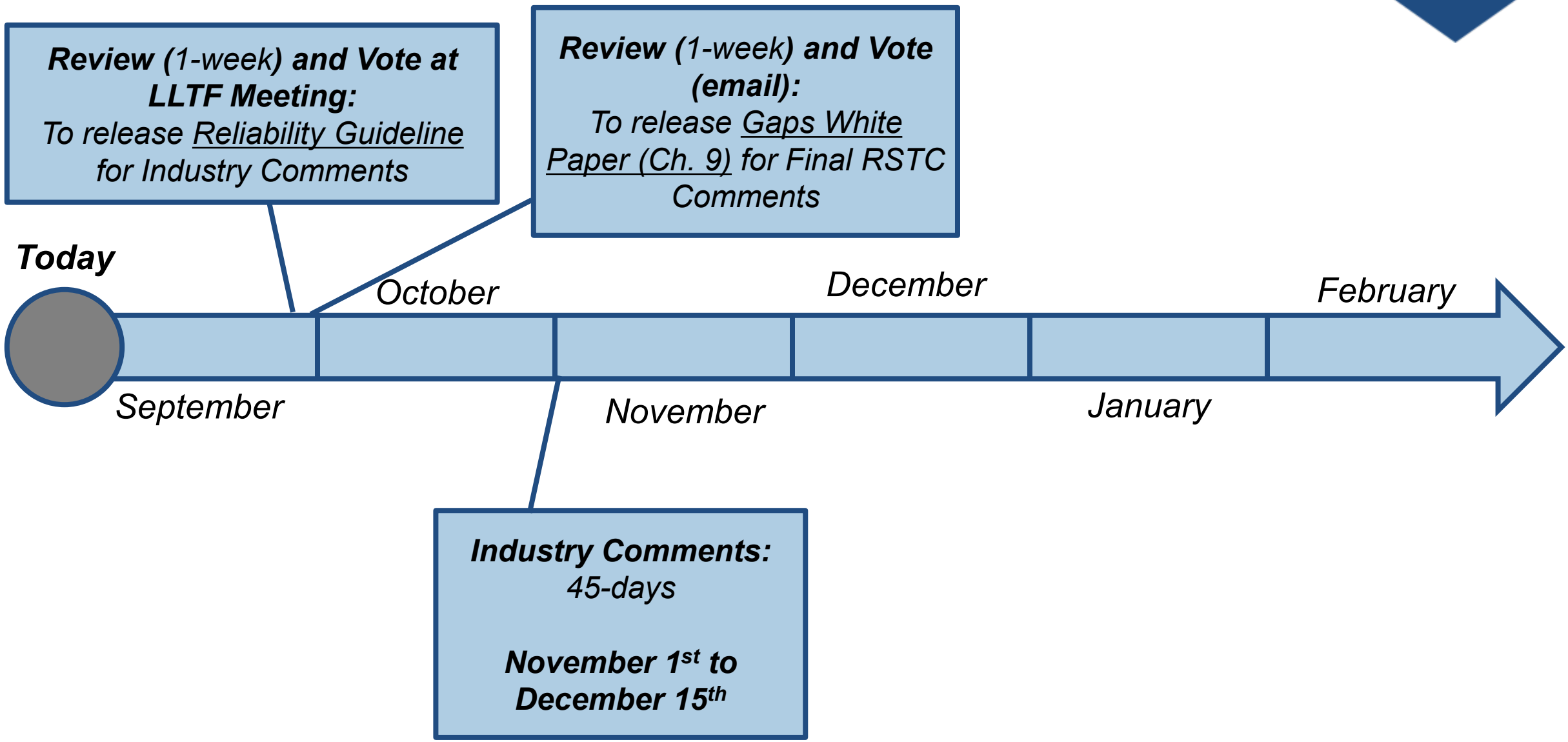
Email Vote on White Paper #2 (Ch. 9) to go out for final RSTC comments (October)

White Paper #2 **vote for final LLTF approval** (December)

Vote on Reliability Guideline to be released for Industry Comment (September 25 at LLTF Meeting)

Provide comments on Reliability Guideline (November/December)

Near-Term Timeline



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Level 2 Large Load Alert

JP Skeath, Manager of Engineering and Security Integration
August 27th, 2025

NERC Large Loads Action Plan

Reliability and Security Technical Committee's Large Loads Task Force (LLTF)

Q2 2026

NERC-Led Collaborative Industry Sessions

Q4 2025

Registration Analysis

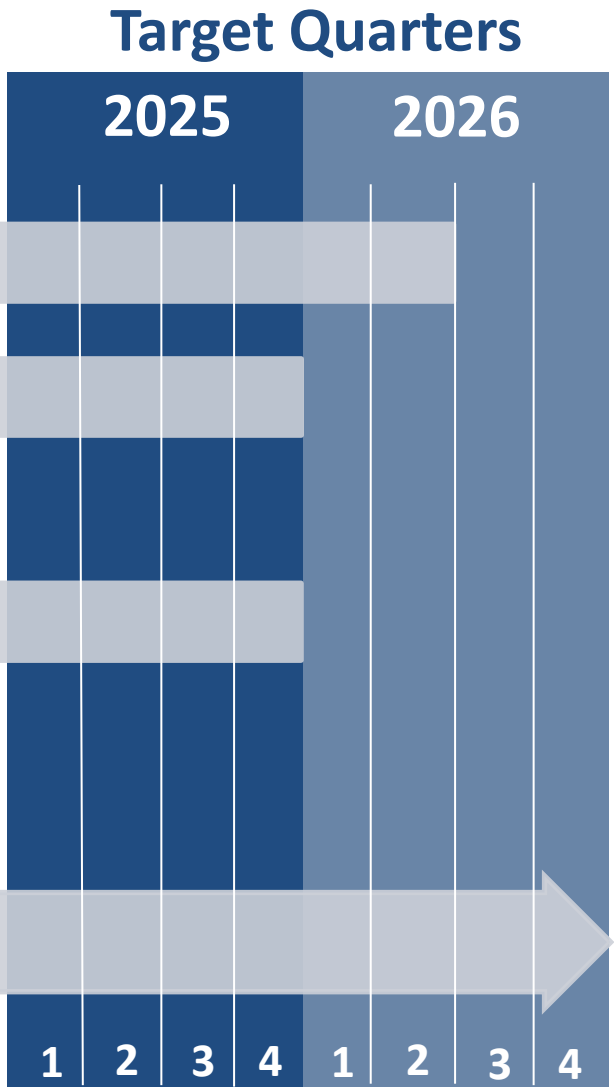
- *Legal basis for registration of large users of the bulk power system*
- *Consider if Load-Serving Entities (LSE) are accountable for large load performance*
- *Ability to write Reliability Standards that Large Loads or LSEs would follow*

Q4 2025

Complementary Activities

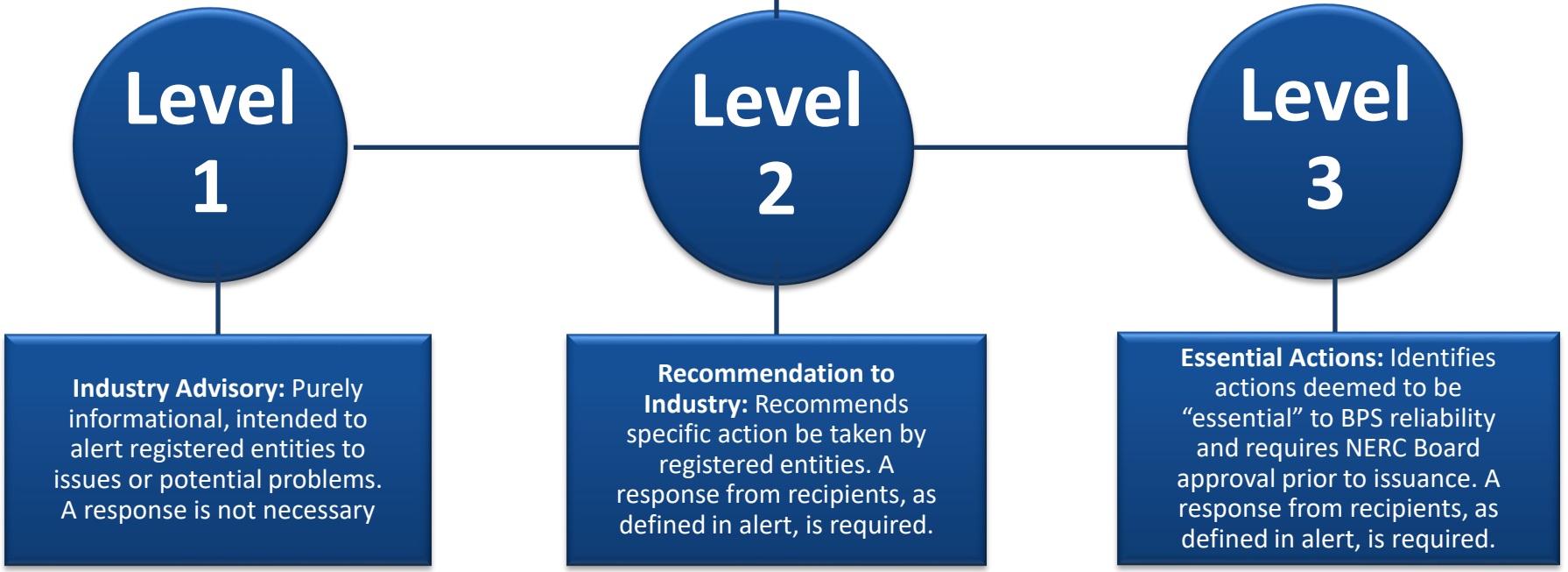
- *Load Modeling Working Group*
- *Coordination with other large loads efforts (e.g., ERCOT, ESIG)*
- *Industry Communications & Outreach*
- *Incident Analysis & Lessons Learned*

Ongoing



About NERC Alerts

As part of its normal course of business, NERC often discovers, identifies, or is provided with information that is critical to ensuring the reliability of the bulk power system (BPS) in North America. To effectively disseminate this information, NERC utilizes email-based "alerts" designed to provide concise, actionable information to the industry, as defined in its Rules of Procedure, there are three levels of alerts.



NERC Alert

- Gives guidance on ensuring reliable integration of **Large Loads**
  - **Large Loads** as defined in the LLTF *White Paper Characteristics and Risks of Emerging Large Loads*
  - **Interconnection Requirements and Process**
  - **Planning Studies and Models**
  - **Operations**
- Aligned with LLTF Initial White Paper and LLAP

- To collect data and analyze conditions
  - Registered Entities are required to respond
  - Large Load owners and operators are encouraged to collaborate with their Transmission Owners

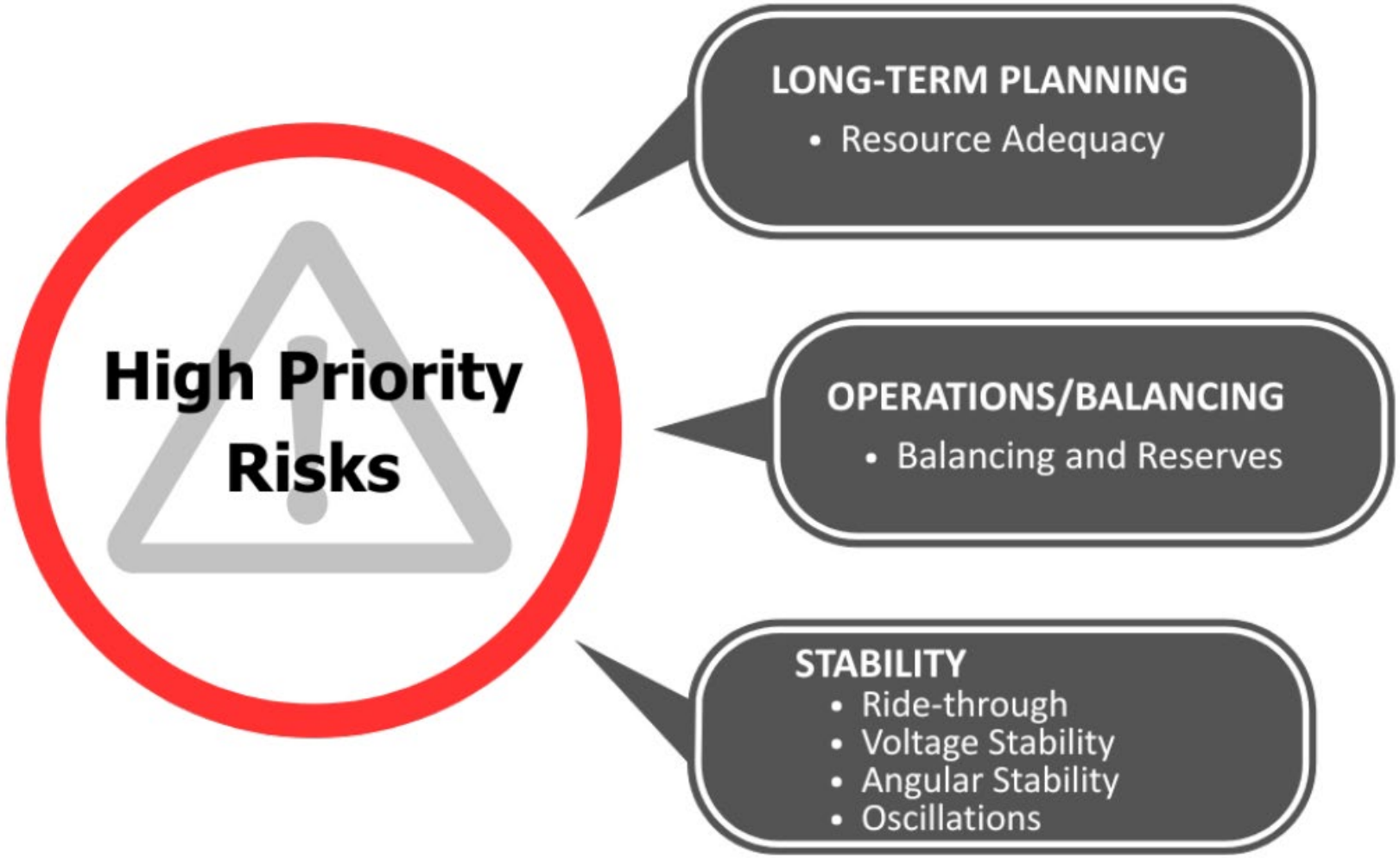
NERC LLTF "Large Load" Definition

Large Load Definition

*"Any **commercial or industrial individual load facility** or aggregation of load facilities **at a single site** behind one or more point(s) of interconnection **that can pose reliability risks to the BPS** due to its **demand, operational characteristics, or other factors**"*

- **No set demand threshold**
  - May be needed for Reliability Standards, Registration, state or federal regulation
  - Not appropriate for this set of papers
- **Risk is based on demand and operational characteristics**

High Priority Risks to the Bulk Power System



Questions and Answers

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Update on LLTF White Paper 2

Tyler Springer, Realtime Reliability Engineering Manager, AEP
Patrick Gravois, Lead Operations Engineer, ERCOT
Jack Gibfried, Engineer – Power Systems Modeling and Analysis, NERC
August LLTF Meeting
August 28, 2025

Comment Period Results

- Received ~350 comments
  - ~20 comments left to address.
  - Additional # of comments: we have made plans to address them.

New Recommendations Chapter

2. White Papers

Documents that explore technical facets of topics, making recommendations for further action. They may be written by subcommittees, working groups, or task forces of their own volition, or at the request of the RSTC. Where feasible, a white paper recommending potential development of a standard authorization request (SAR) shall be posted for comment on the RSTC website. White papers will be posted on the RSTC webpage, after RSTC approval.

Source: RSTC Charter: *https://www.nerc.com/comm/RSTC/RelatedFiles/RSTC_Charter_Oct2024.pdf*

New Recommendations Chapter

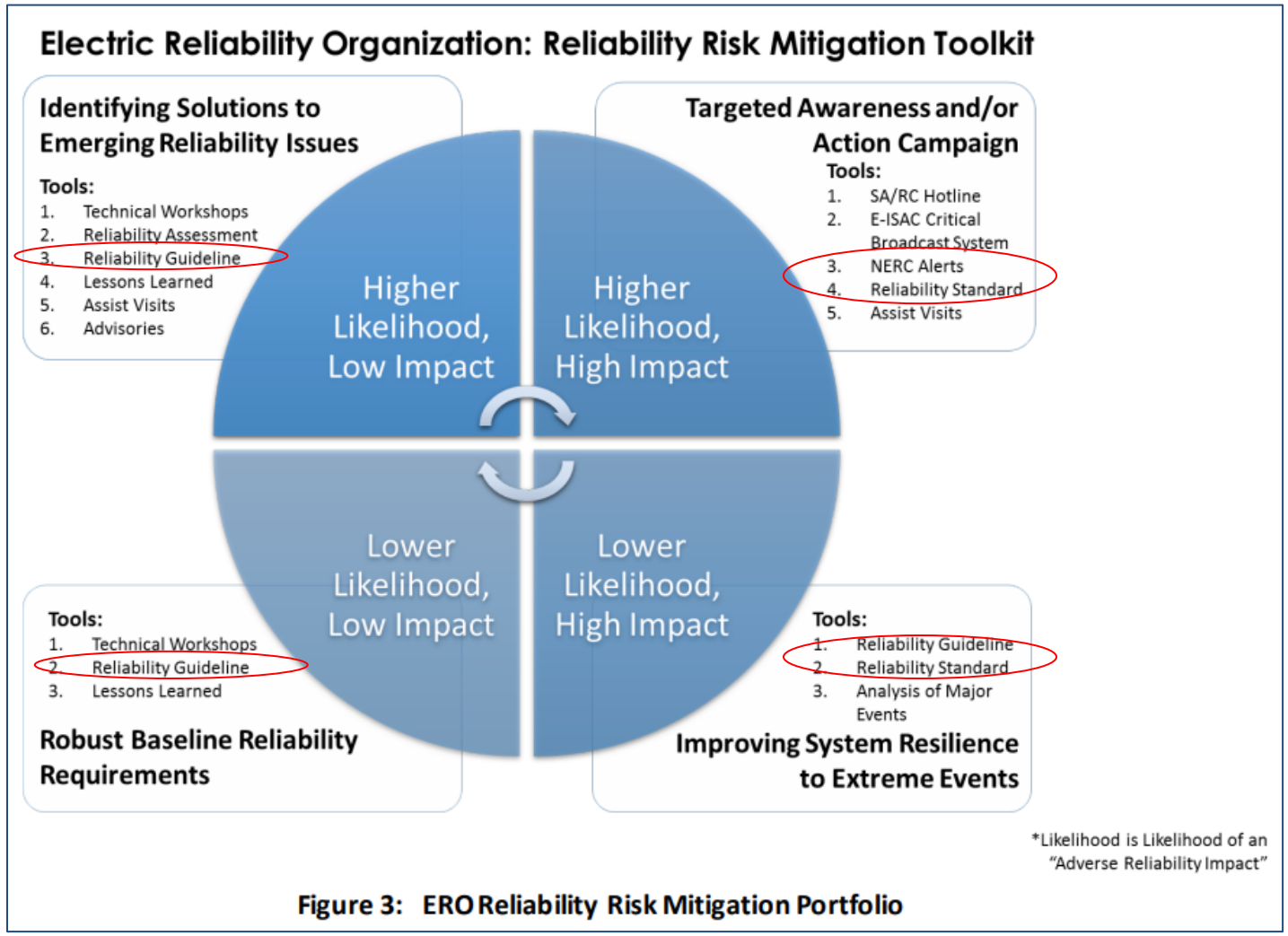


Figure 3: ERO Reliability Risk Mitigation Portfolio

Source: Framework to Address Known and Emerging Reliability and Security Risks
https://www.nerc.com/comm/RISC/Related%20Files%20DL/Framework-Address%20Known-Emerging%20Reliabilit-Securit%20%20Risks_ERRATTA_V1.pdf

New Recommendations Chapter

Prioritized risks from White Paper 1

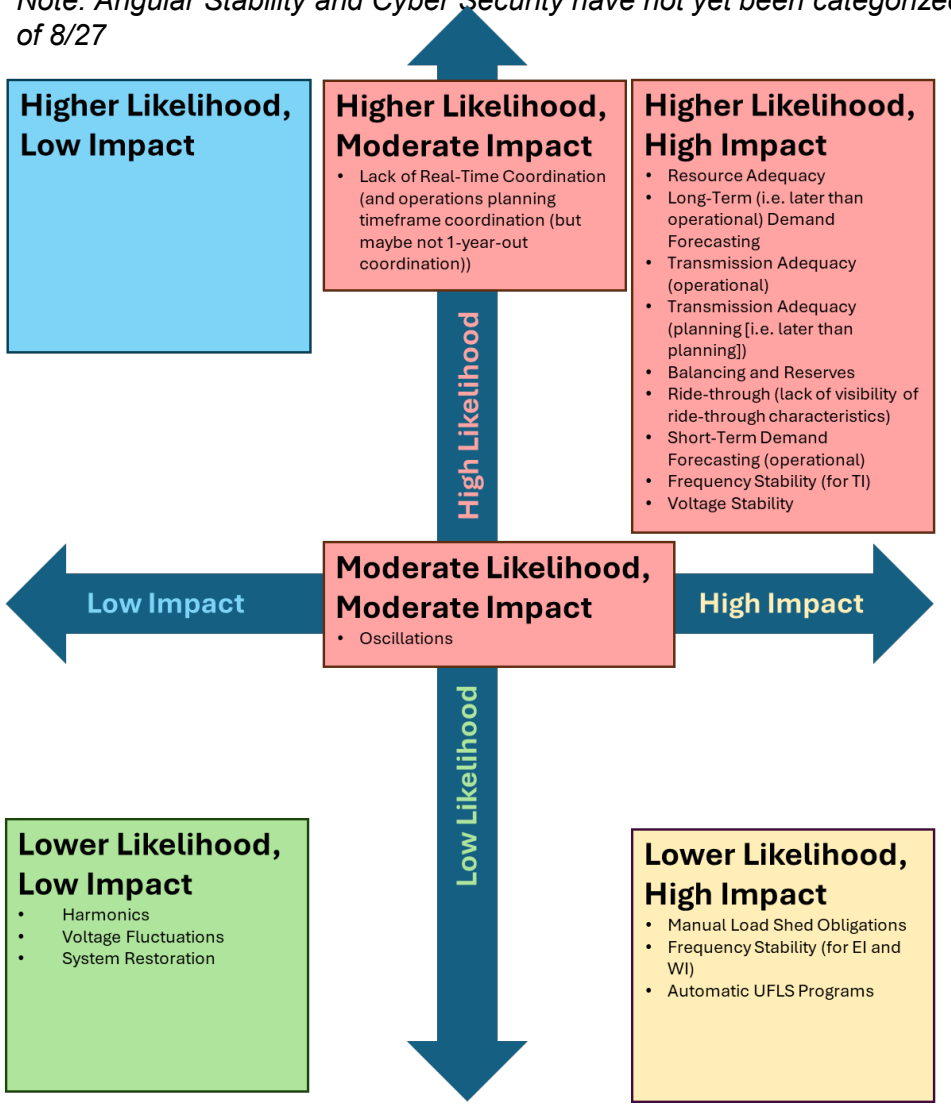
High-Priority Risks	
Long-Term Planning	Resource Adequacy
Operations/Balancing	Balancing and Reserves
Stability	Ride-through
	Voltage Stability
	Angular Stability
	Oscillations

Medium-Priority Risks	
Operations/Balancing	Short-Term Demand Forecasting
	Lack of Real-Time Coordination
Long-Term Planning	Demand Forecasting
	Transmission Adequacy
Stability	Frequency Stability
Security Risks	Cyber Security
Load Shedding Programs & System Restoration	Manual Load-Shed Obligations
	Automatic UFLS Programs

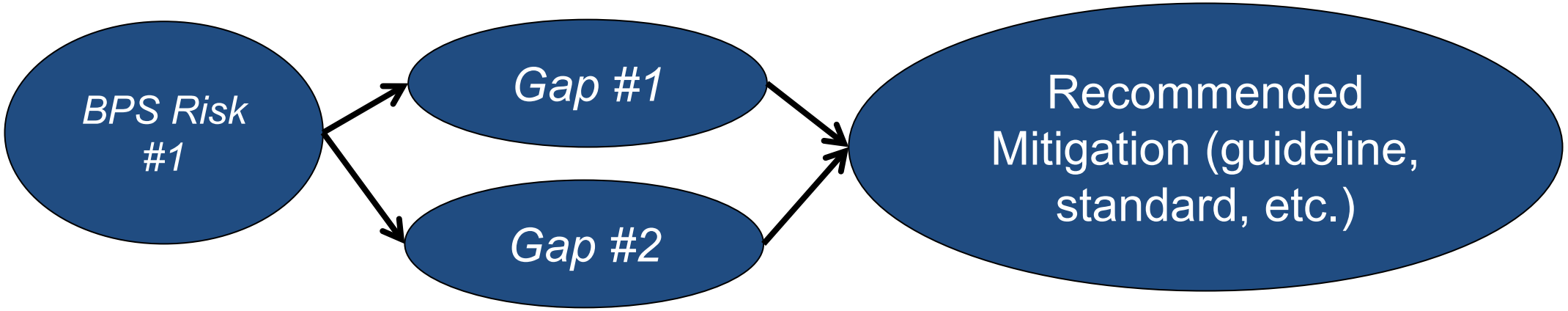
Low-Priority Risks	
Power Quality	Harmonics
	Voltage Fluctuations
Load Shedding Programs & System Restoration	System Restoration

Current Draft categorization of risks for White Paper 2

Note: Angular Stability and Cyber Security have not yet been categorized as of 8/27



New Recommendations Chapter



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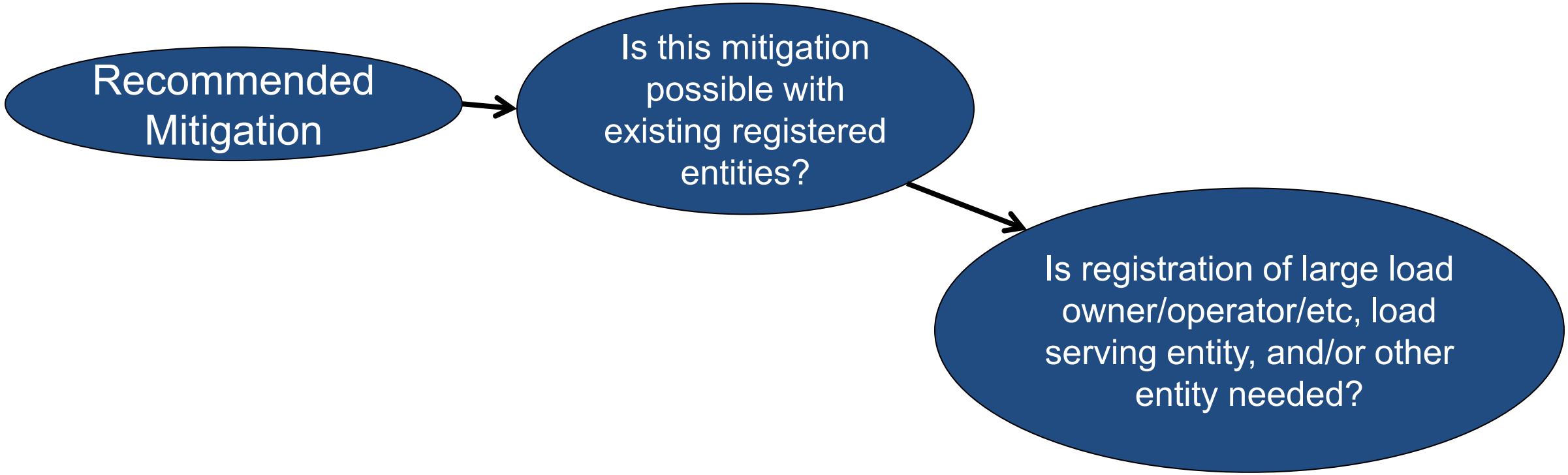

RSTC Standard Authorization Request Process

RSTC Group SAR Development Steps (first two steps):
(*Reliability and Security Technical Committee Standard Authorization Request (SAR) Process)*
https://www.nerc.com/comm/RSTC/Documents/RSTC%20SAR%20Development%20Process%20clean%20Sept%2020%202023.pdf

1. Identify Risk Reliability Gap (problem statement) and clearly articulate risk to Reliability, Resilience or Security through any of the following:
   a. White Paper
   b. Event Analysis or Disturbance Report
   c. RISC Report
   d. Assessment
   e. Other documents or reports

Next Steps and Upcoming Meetings

Next Steps:

- **Draft recommendations chapter**
- **LLTF comment period on new recommendations chapter**
- **Updates based on comments**
- NERC Legal, admin, and publications review
- **LLTF review and approval to send to RSTC for comments**
  - This would not be a comment period; it would just be the LLTF deciding we are ready for RSTC to review/comment
- **Updates based on comments**
- NERC legal review
- NERC admin and publications review
- **LLTF review and vote**
- December 10th/11th RSTC Meeting: RSTC vote

Upcoming Meetings:

- *Recommendations chapter drafting meetings:*
  - *Daily until the chapter is drafted*

Questions and Answers

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NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Reliability Guideline: Risk Mitigations for Emerging Large Loads

Final Steps to Completion of First Draft

Evan Mickelson
Jack Gibfried
LLTF – Monthly Meeting
August 28, 2025

NERC Large Loads Action Plan

Reliability and Security Technical Committee's Large Loads Task Force (LLTF) — Q2 2026

NERC-Led Collaborative Industry Sessions — Q4 2025

Registration Analysis — Q4 2025

- *Legal basis for registration of large users of the bulk power system*
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Complementary Activities — Ongoing

- *Load Modeling Working Group*
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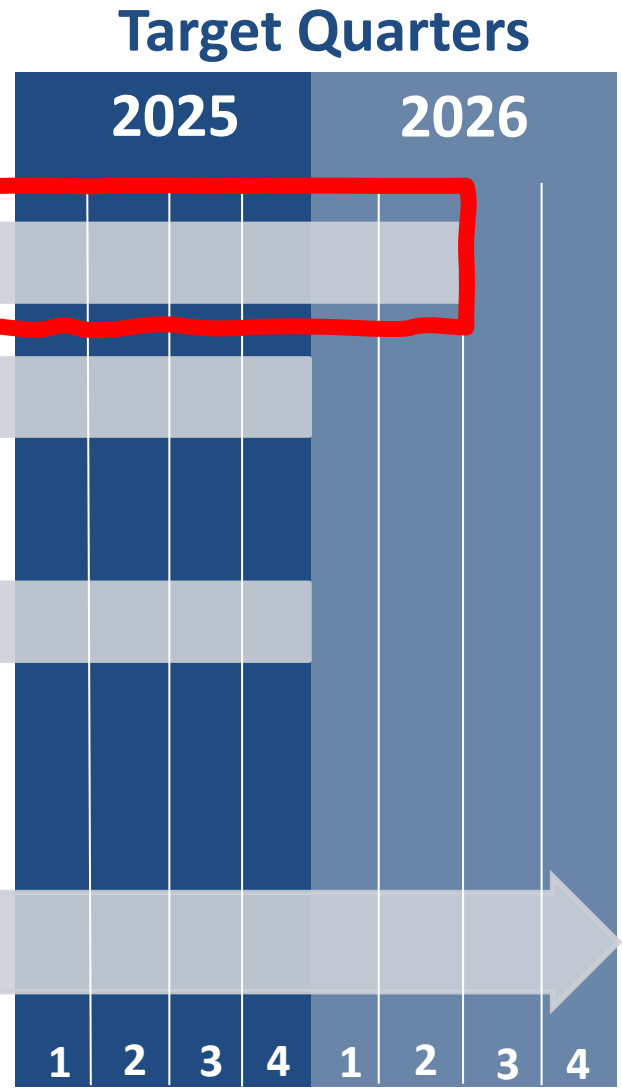


What's Been Done so Far?

- Review of All Risk Areas (Long-Term Planning, Operations and Balancing, Stability, etc.)
  - ✓ Risk mitigation matrices
    - ✓ Risk mitigations in each category (data collection, analysis, etc.)
    - ✓ Risk mitigation at various stages (interconnection, operations, planning)
  - ✓ **Writing section for each mitigation at each stage**

Mitigation Category	Planning Domain	Interconnection Domain	Operations Domain
1. Data Collection	- Collect expected ride-through behavior from similar load classes. - Historical LL disconnection events. **- Identify largest credible load loss (MW) for each BA (similar to RLPC in BAL-003-2)**	- Require ride-through curves and equipment specs as part of LL interconnection request. - Collect settings for protection relays, UPS logic, and auto-transfer schemes.	**- Load owners SHALL provide high accuracy values of instantaneous load loss for BAL-003-2 analysis**
2. Modeling	- Include representative ride-through assumptions for large loads in stability base cases.	- Require submission of dynamic models for LLs (e.g., low-voltage behavior of power electronics or UPS). - Model how protection triggers backup transition.	
3. Coordination	- Align with TO/TP on LL behavior during faults. - Plan for overlapping impacts from clustered LLs. **- Identify largest credible load loss (MW) for**	**- Load owner, TP, BA, and RC shall coordinate regarding updates to largest credible load loss and the amount of frequency response they provide in the event of loss of large load(s)** **'Utilities need to define ride-through criteria for the facilities and the facility will need to ensure that their protection and switch-over settings**	**- BAs should coordinate with resource owners (loads and/or gens) to implement frequency response to loss of large loads, especially IBRs**

Short-Term Forecasting

Large Loads pose new challenges for short-term operational forecasting by RC, BA, and TOs. These loads can be highly variable and exhibit both second to second and minute to minute power oscillations along with fast ramping capabilities. If Large Loads are not considered in short-term forecasting the BA could under procure generation in real time potentially leading to reliability issues and load shedding.

Data Collection for Forecasting

Load forecasting information from Large Loads is critically important for Balancing Authorities (BAs) to assess risks to energy adequacy under BAL-007 and to ensure appropriate unit commitment and dispatch. Therefore, TOs in consultation with BAs,

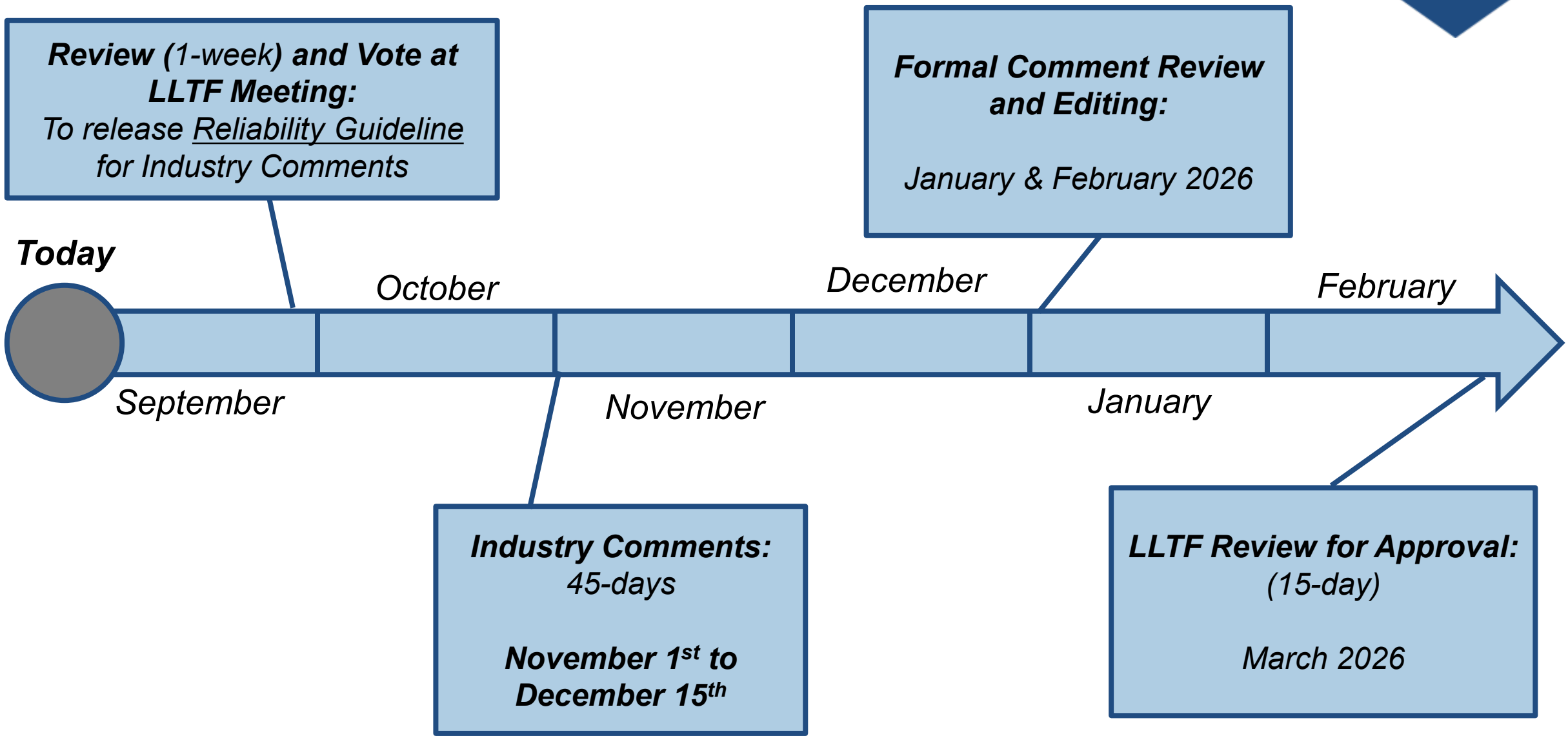
1. Should establish operating protocols with Large Loads to establish required load forecasting information needs and timing of updates, and
2. Should prior to energization of new Large Loads to ensure the loads are properly accounted for in load forecasting and other operational modeling.

As Large Loads seek to interconnect to the grid, the TO, RC, and BA should obtain information on the loads including the planned in-service dates and projected load growth over time. Additionally the TO, RC, and BA should have the Large Load Owner and Operator attest if the load will be price responsive and to identify what kind of triggers they will respond to - energy prices, emissions, commodity prices, cryptocurrency prices, etc.

What's Left to Finalize?

- Executive Summary
  - **Plan:** Collaborate with NERC Communications team to write ES
- Introduction Chapter – Vocabulary Terms
  - **Plan:** Get volunteers to submit terms, work with small group to define
- Data Collection Chapter
  - **Plan**
    1. Take data collection mitigations from each chapter
    2. Summarize for "Interconnection/Evaluation" stage
    3. Summarize for "Commissioning/Operations" stage
- Overall "homogenization"
  - **Plan:** Get volunteers, work with small group to finalize

Near-Term Timeline



Questions and Answers

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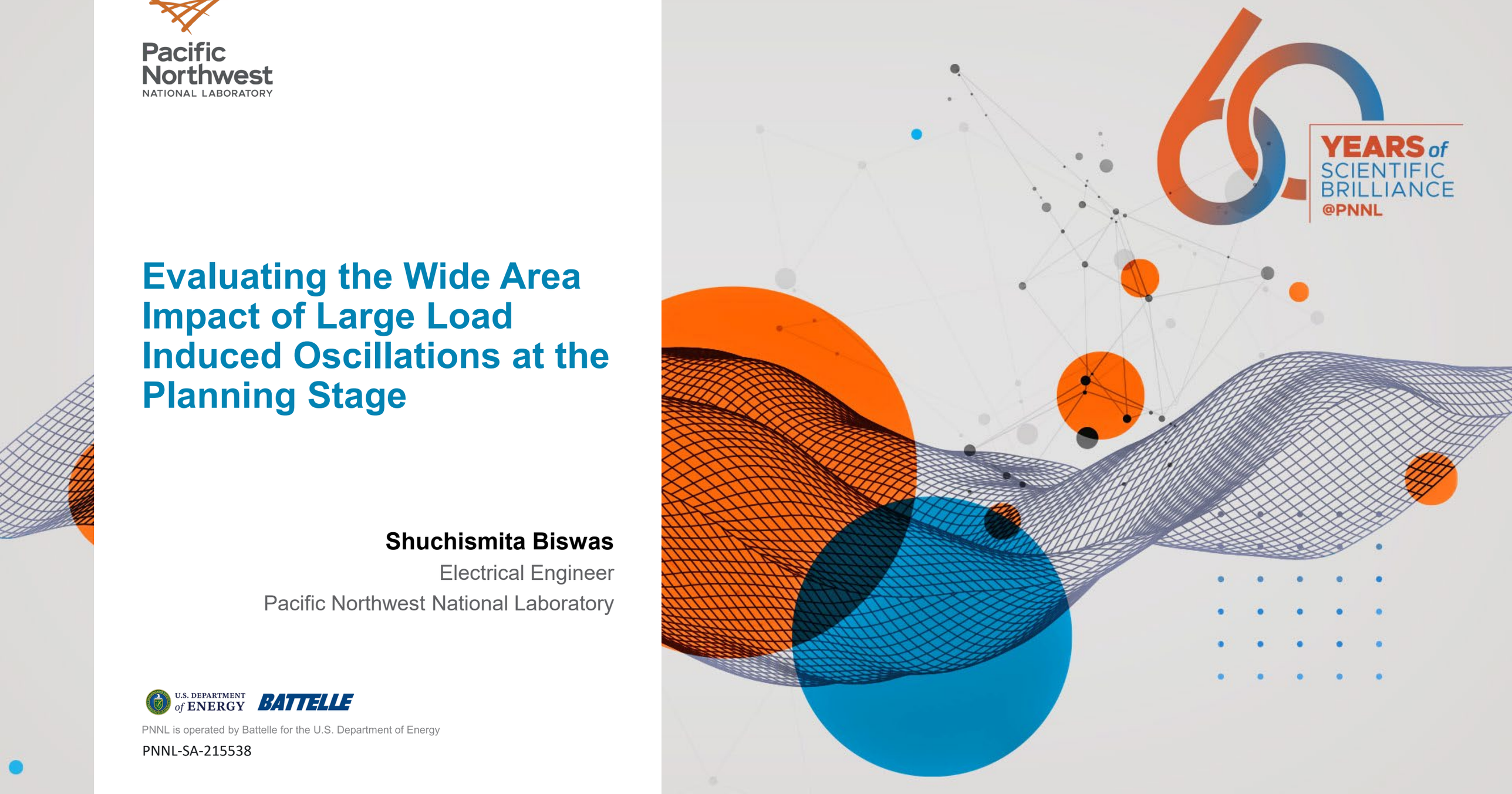
Evaluating the Wide Area Impact of Large Load Induced Oscillations at the Planning Stage

Shuchismita Biswas
Electrical Engineer
Pacific Northwest National Laboratory



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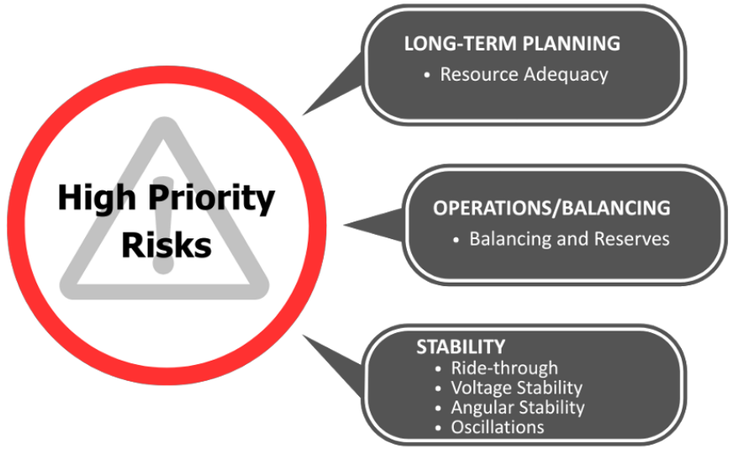
PNNL-SA-215538

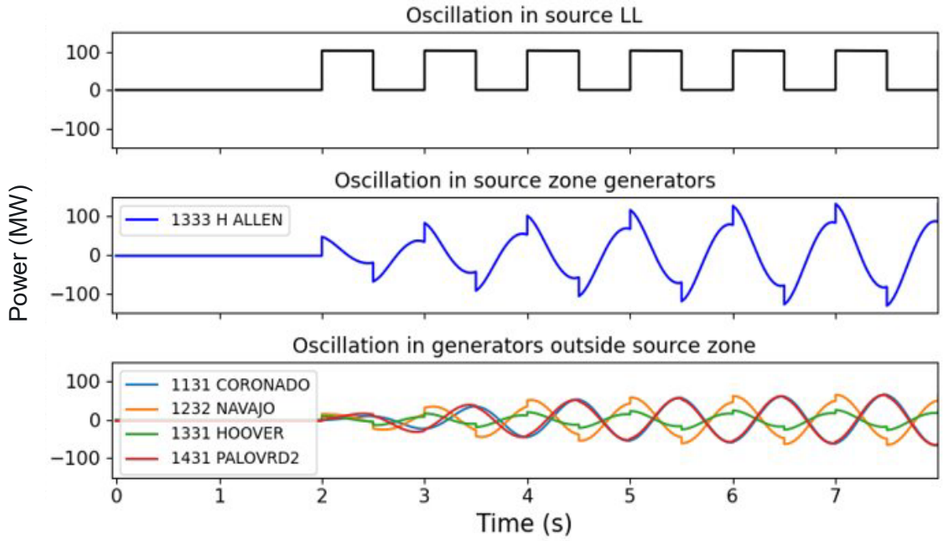
Pacific Northwest
NATIONAL LABORATORY

Outline

- The Challenge
- Oscillations 101
- Proposed Approach
- Some Results
- Key Takeaways

The Challenge





- Data center load can fluctuate periodically, introducing forced oscillations in the grid.
- If these oscillation frequencies are near inter-area modes, wide-area propagation and oscillation amplification is possible. Risks vary with grid location where the oscillation source is located.
- How to evaluate oscillation susceptibility at the planning stage?
- What are permissible oscillation limits that will not lead to protection/control misoperations?

NERC, “Characteristics and Risks of Emerging Large Loads: Large Loads Task Force White Paper”, July 2025.
Biswas S., A. Varghese, K. Chatterjee, S. Nekkalapu, B.A. Ross, and J.D. Follum. 2025. "Evaluating the Risk to Bulk Power System Reliability from Large Load Induced Oscillations." PNNL-SA-214877.

Power System Oscillations

Associated with system's modes

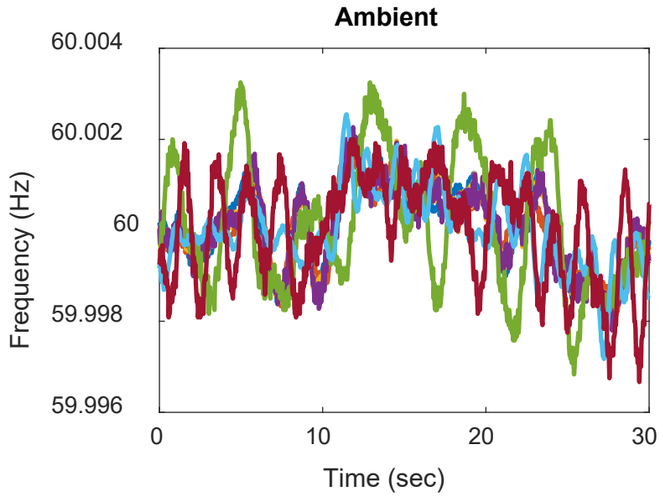
Associated with a periodic external input

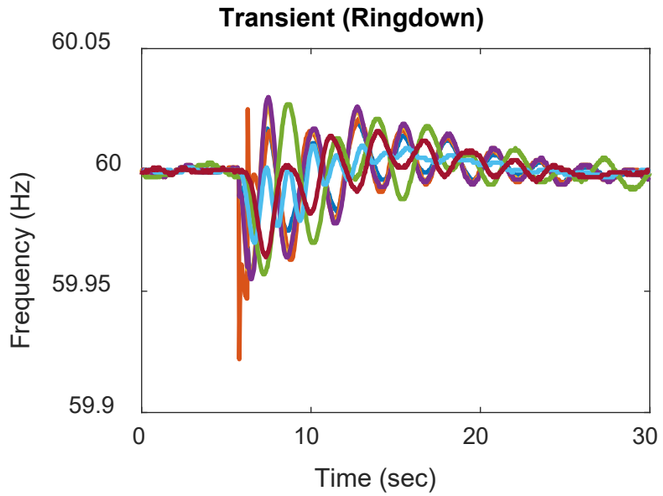
Natural

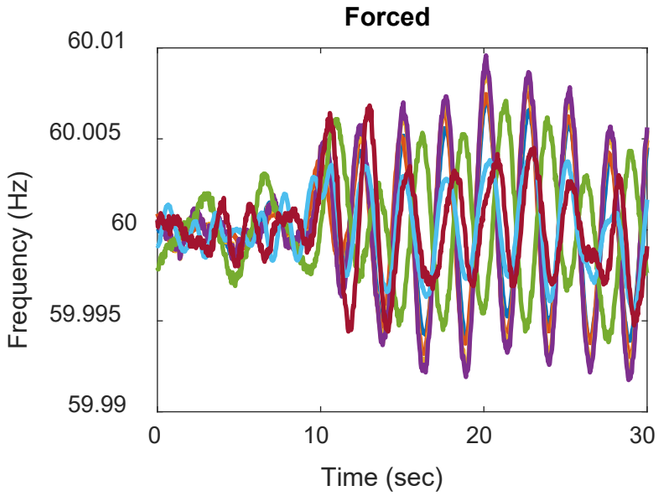
Forced

Response to small random changes

Response to a sudden disturbance



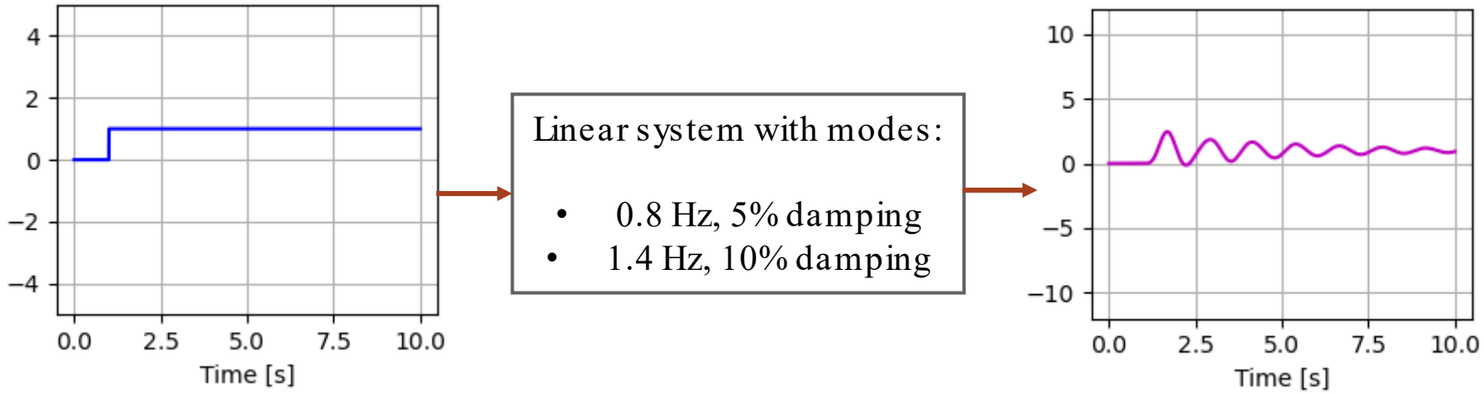




Slide graphics: Jim Follum

Power System ‘Modes’

- Power system dynamics can be described by its modes.
- Modes are parametrized by *frequency*, *damping ratio*, and *shape*.
- As operating conditions change, modes may move around.
- A power system has thousands of modes, but only a few become dominant, or of concern to operations.



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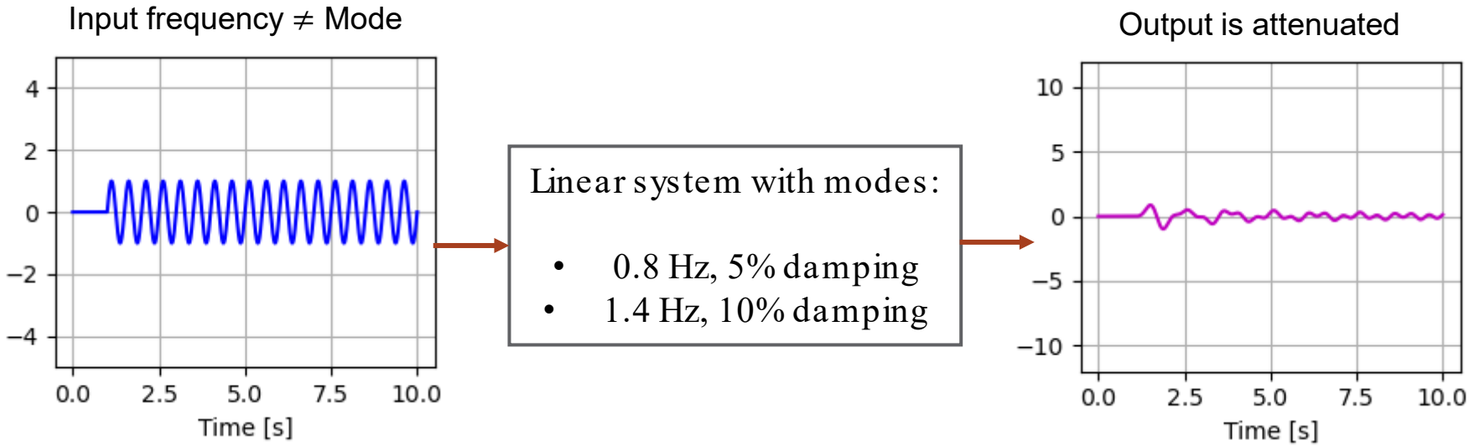

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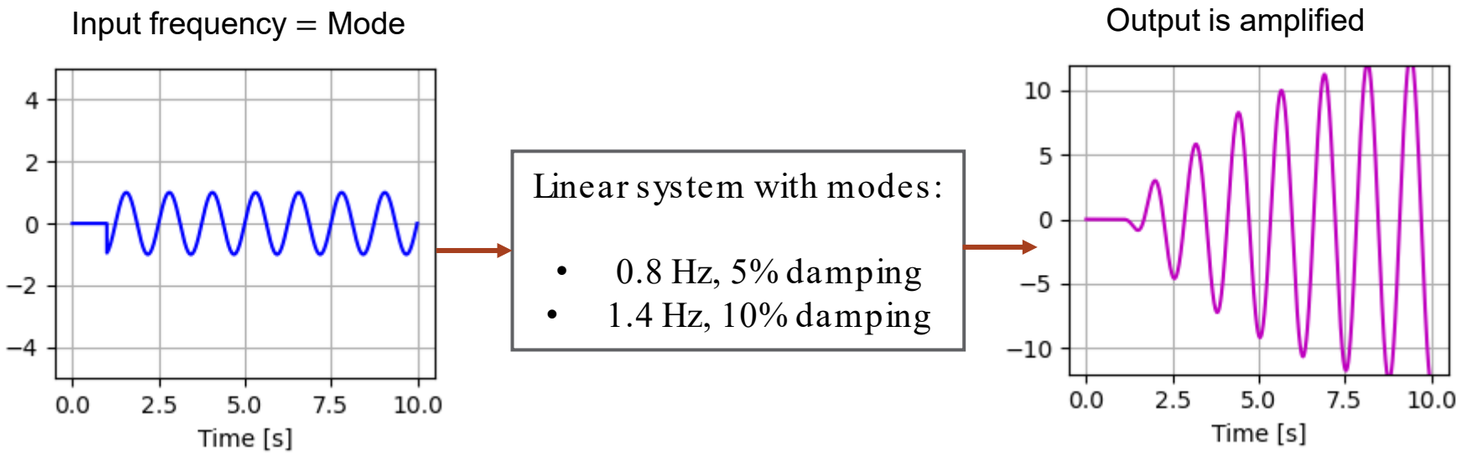
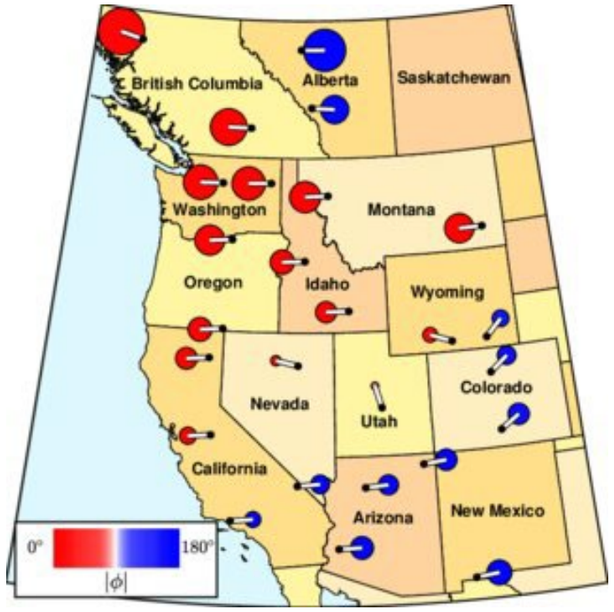
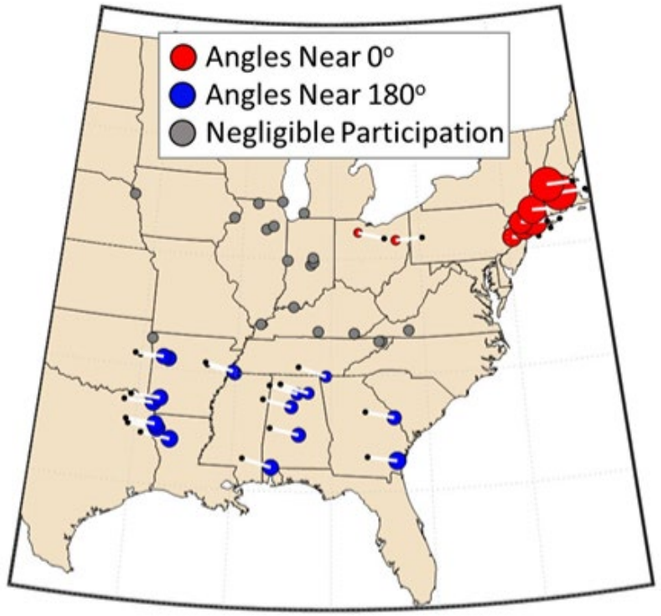


Mode Shape

- Parametrized by a *magnitude* and *angle*
- Magnitude describes observability
- Angle describes relative grouping of generators





R. T. Elliott and D. A. Schoenwald, "Visualizing the Inter-Area Modes of the Western Interconnection," *2022 IEEE Power & Energy Society General Meeting (PESGM)*, Denver, CO, USA, 2022.
Follum, James D., Neeraj Nayak, and Joseph H. Eto. *Online tracking of two dominant inter-area modes of oscillation in the Eastern Interconnection*. No. PNNL-SA-173702. Pacific Northwest National Lab.(PNNL), Richland, WA (United States), 2023.

Why do we Care?

- Large power/voltage swings can cause protection mis-operations leading to cascading failures.
- Oscillations in the 0.1-1.5 Hz frequency range tend to spread across large areas (**inter-area**).

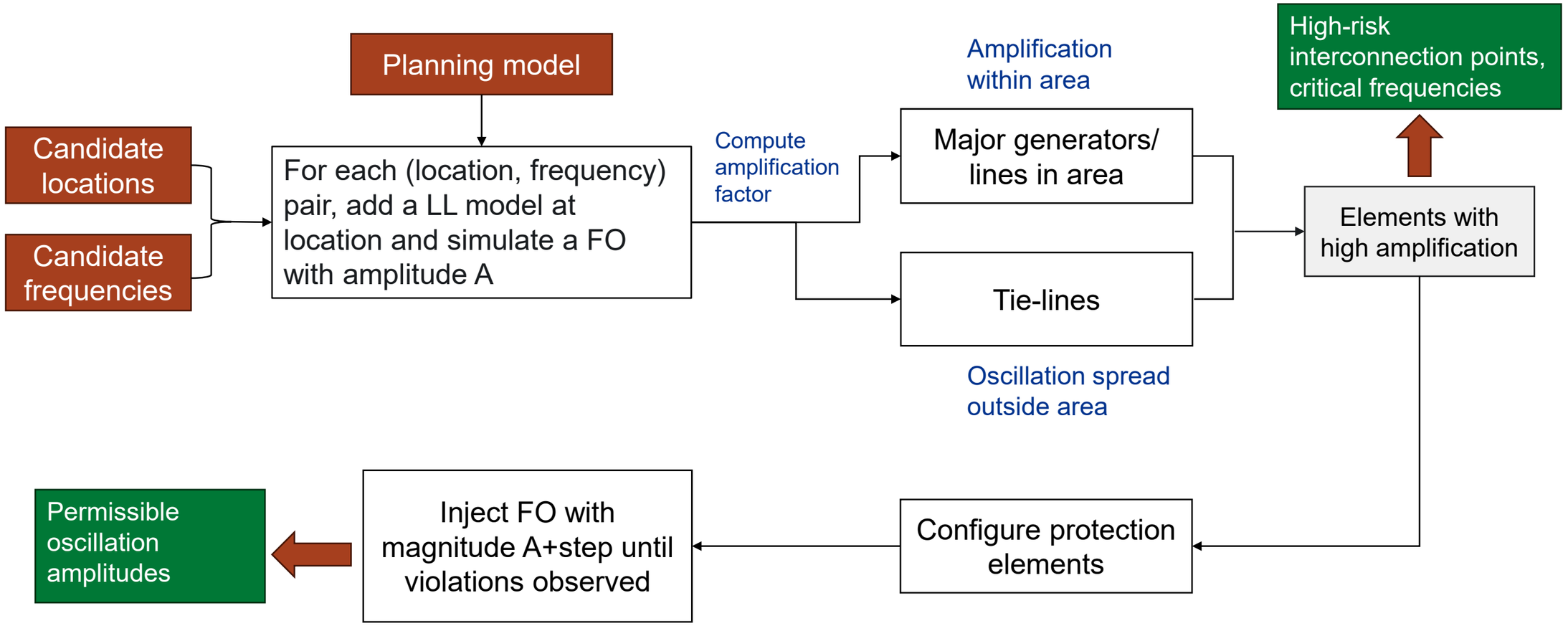
Frequency	Characteristics	Problems
0.1-1.5 Hz	May spread across large areas	Resonance with inter-area modes may cause amplification in distant locations
>1.5 Hz	Tend to be localized	Flicker, power quality problems, equipment fatigue
>10 Hz	Tend to be localized	Resonance with torsional modes, mechanical vibrations

Can be studied with positive sequence models

EMT models needed

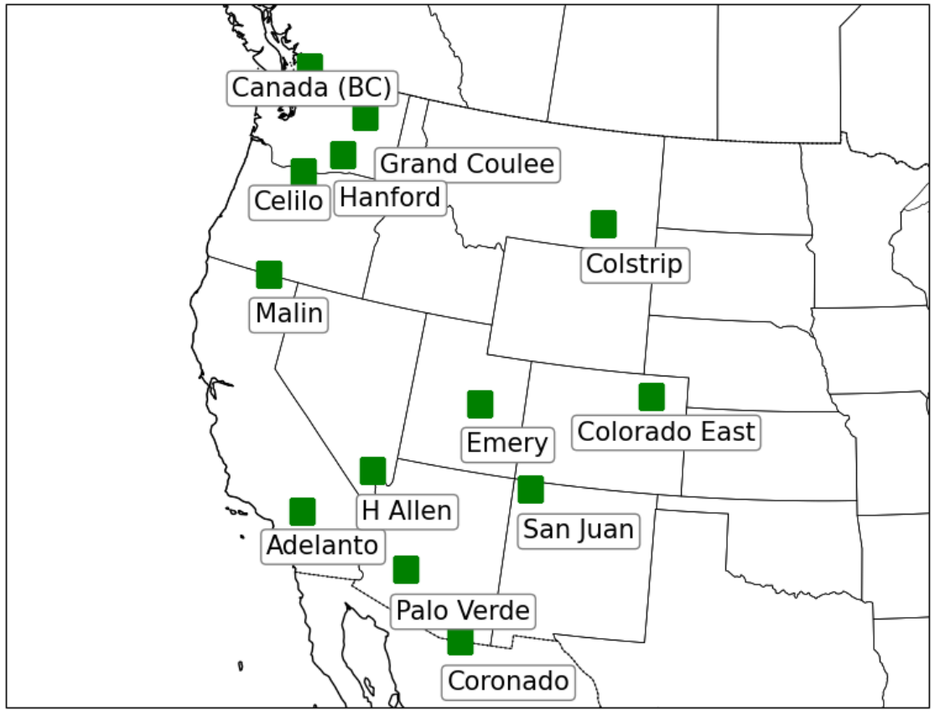
Proposed Approach

Readily automatable framework to evaluate oscillation-induced reliability risk during planning studies.

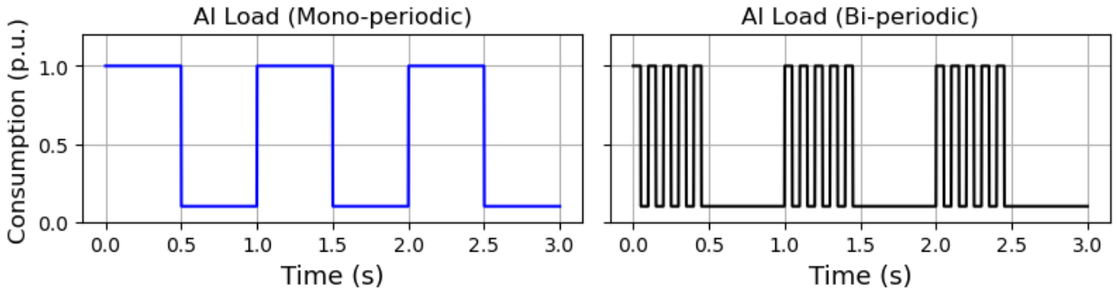


Some Results

- Simulation methodology developed and illustrated with the 240-bus reduced WECC model. High-risk large load interconnection points and critical oscillation frequencies can be identified.



Two types of load oscillatory behavior modeled.

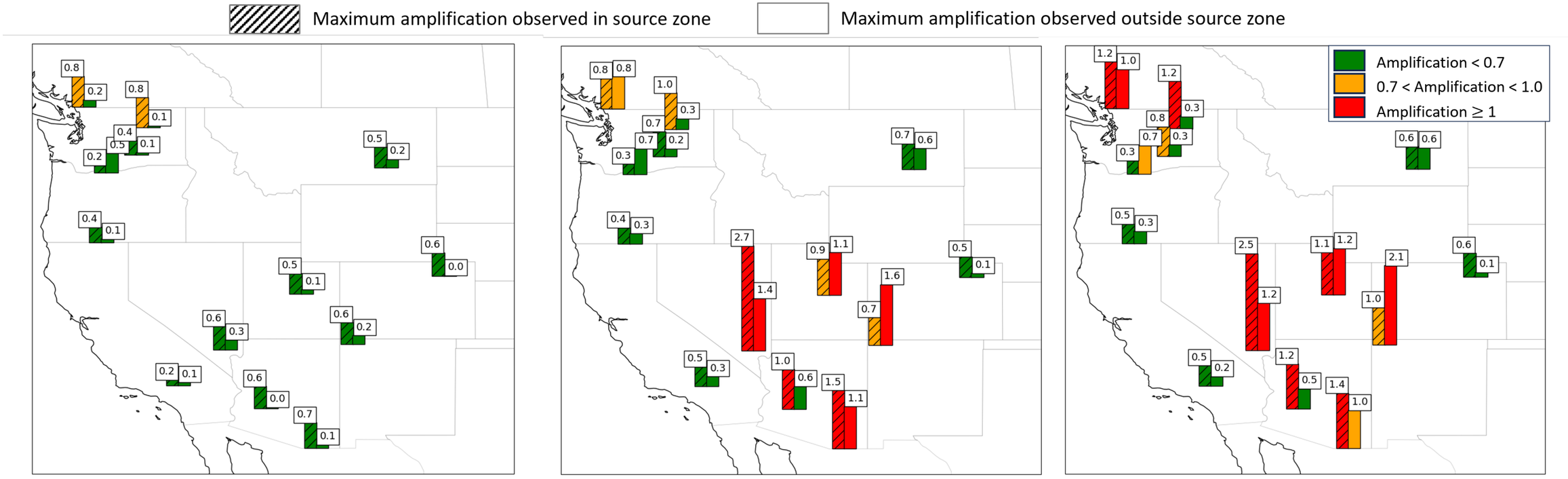


Disclaimer: Results from the reduced WECC model cannot be directly extrapolated to the Western Interconnection.

H. Yuan, R. S. Biswas, J. Tan and Y. Zhang, "Developing a Reduced 240-Bus WECC Dynamic Model for Frequency Response Study of High Renewable Integration," *2020 IEEE/PES Transmission and Distribution Conference and Exposition (T&D)*, Chicago, IL, USA, 2020, pp. 1-5, doi: 10.1109/TD39804.2020.9299666.

Some Results

The risk of oscillation propagation and amplification is a function of the source location and oscillation frequency.



(a) Oscillation frequency = 0.5 Hz
(Forcing function is a square wave)

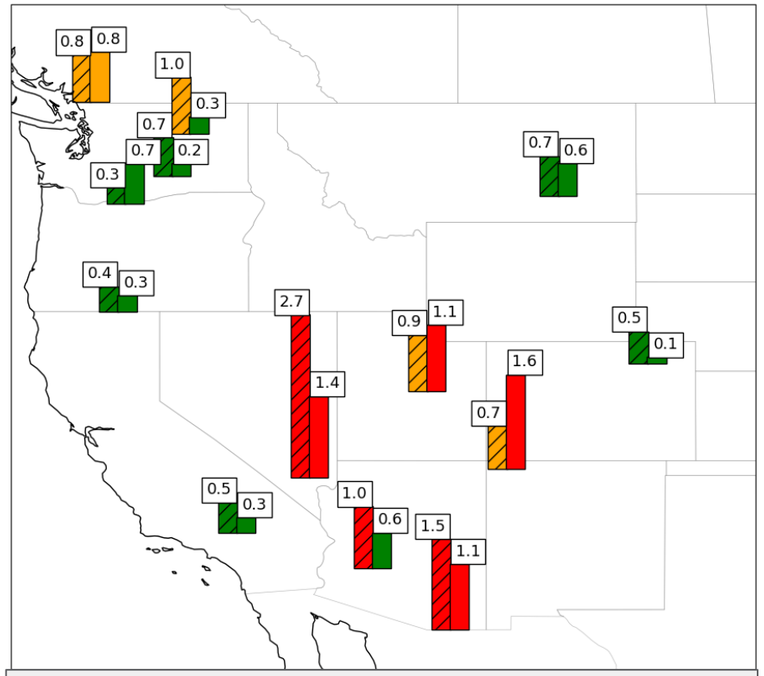
(b) Oscillation frequency = 1 Hz
(Forcing function is a square wave)

(c) Oscillation frequency = 0.1 Hz, 1 Hz
(Forcing function is bi-periodic)

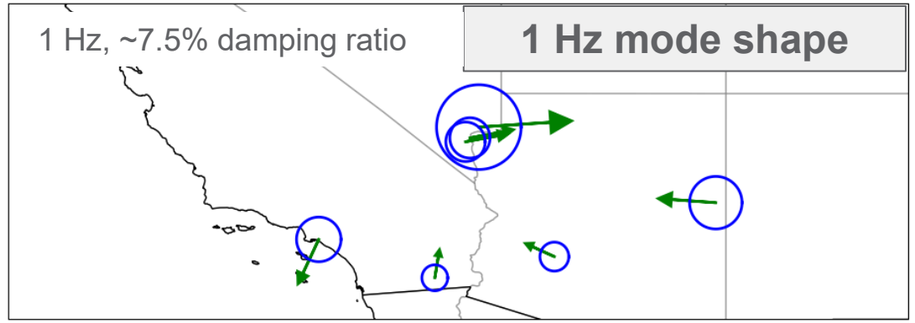
Closer Look at the 1 Hz Mode

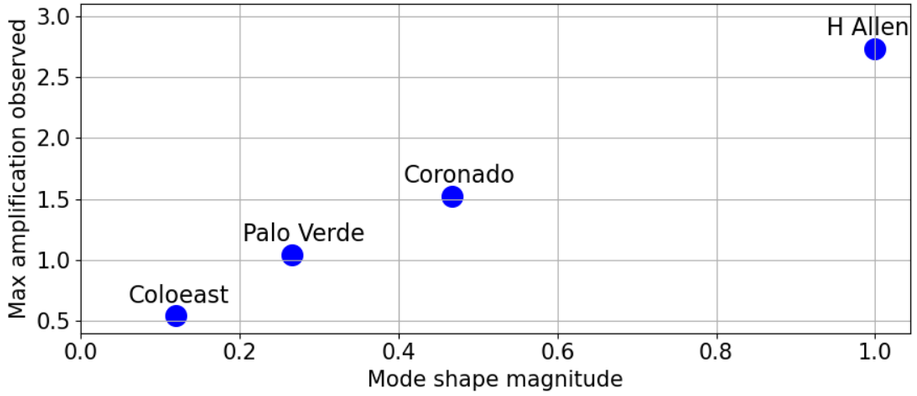
Highest amplification in 1 Hz oscillations observed when the source is located in the Southwestern region.

Insight: Reliability risk high if oscillatory LL is located close to generators with high participation in a system mode. Mitigation measures may be necessary.



Amplification when 1 Hz oscillations introduced from different locations

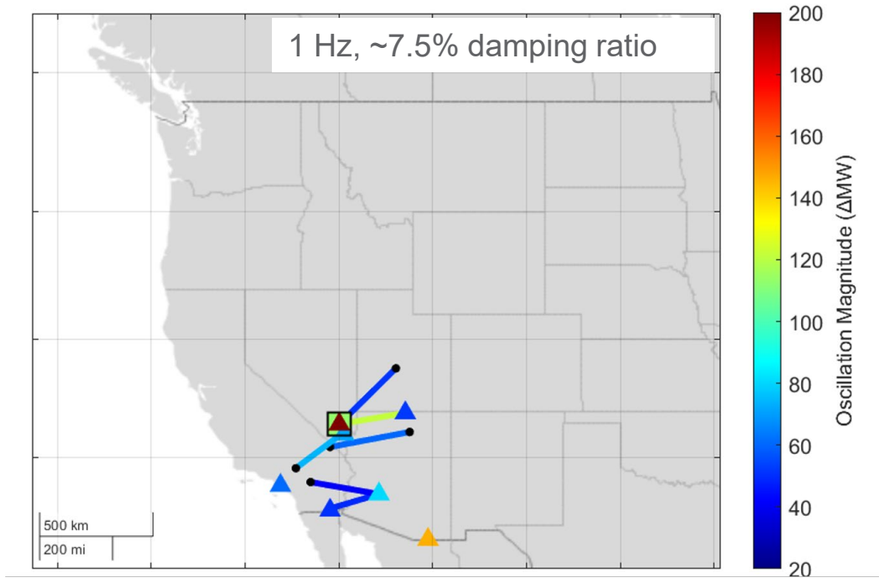




Some Results

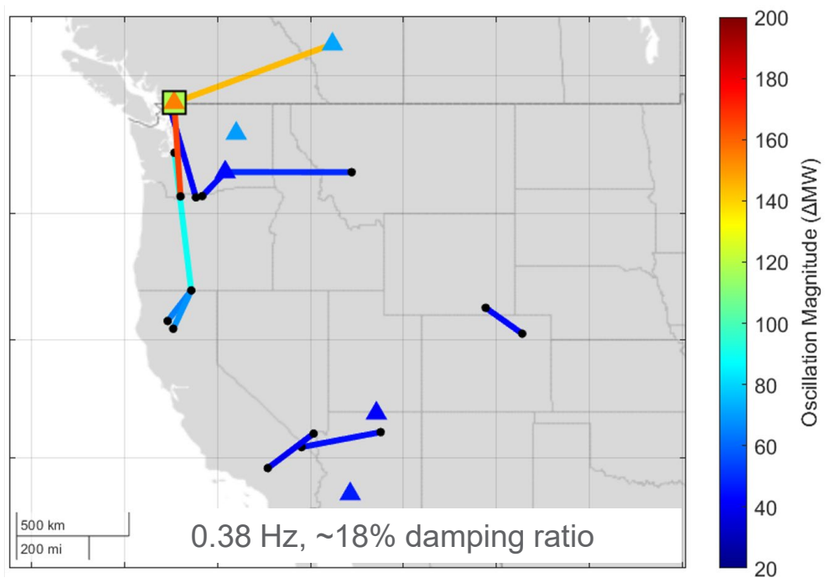
- Planning studies can identify locations where oscillation amplification factors are high.

Source location: H Allen, Nevada



1 Hz, 100 MW square wave load perturbation

Source location: British Columbia



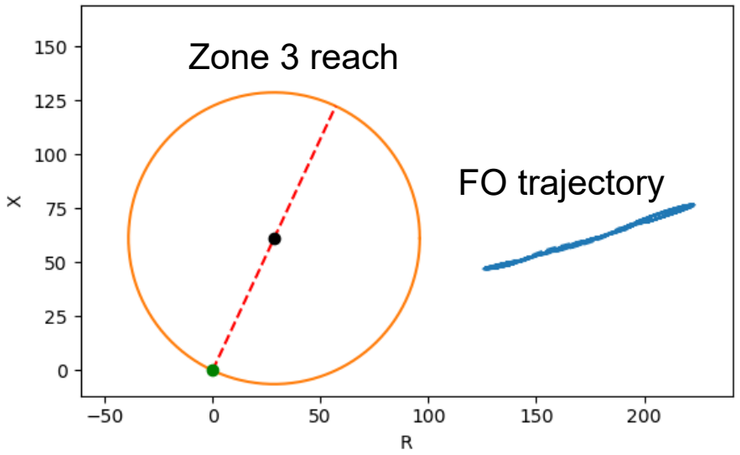
0.38 Hz, 100 MW square wave load perturbation

Takeaways

- A framework developed to identify high-risk locations where FO–natural mode resonance and wide-area propagation of induced oscillations are likely.
- Open-source scripts (PSSE+Python) will be made publicly available shortly. Looking for industry feedback.

Next Steps:

- Configuring protection elements to determine permissible oscillation magnitudes.
- Extending the framework to identify risks associated with load steps/ramps.
- Illustration with full interconnection models.



Preprint available: http://dx.doi.org/10.13140/RG.2.2.32970.43206

Pacific Northwest
NATIONAL LABORATORY

Thank you

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Developer’s Experience Navigating Processes

Evan A. Pierce – Vice President, Site Development, Americas

8/28/2025

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20+ Countries

1GW+MW

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- Strong local presence, know-how and relationships with key stakeholders across all major markets; excel in uniquely challenging environments
- Strategic alliances with the world's largest real estate firms

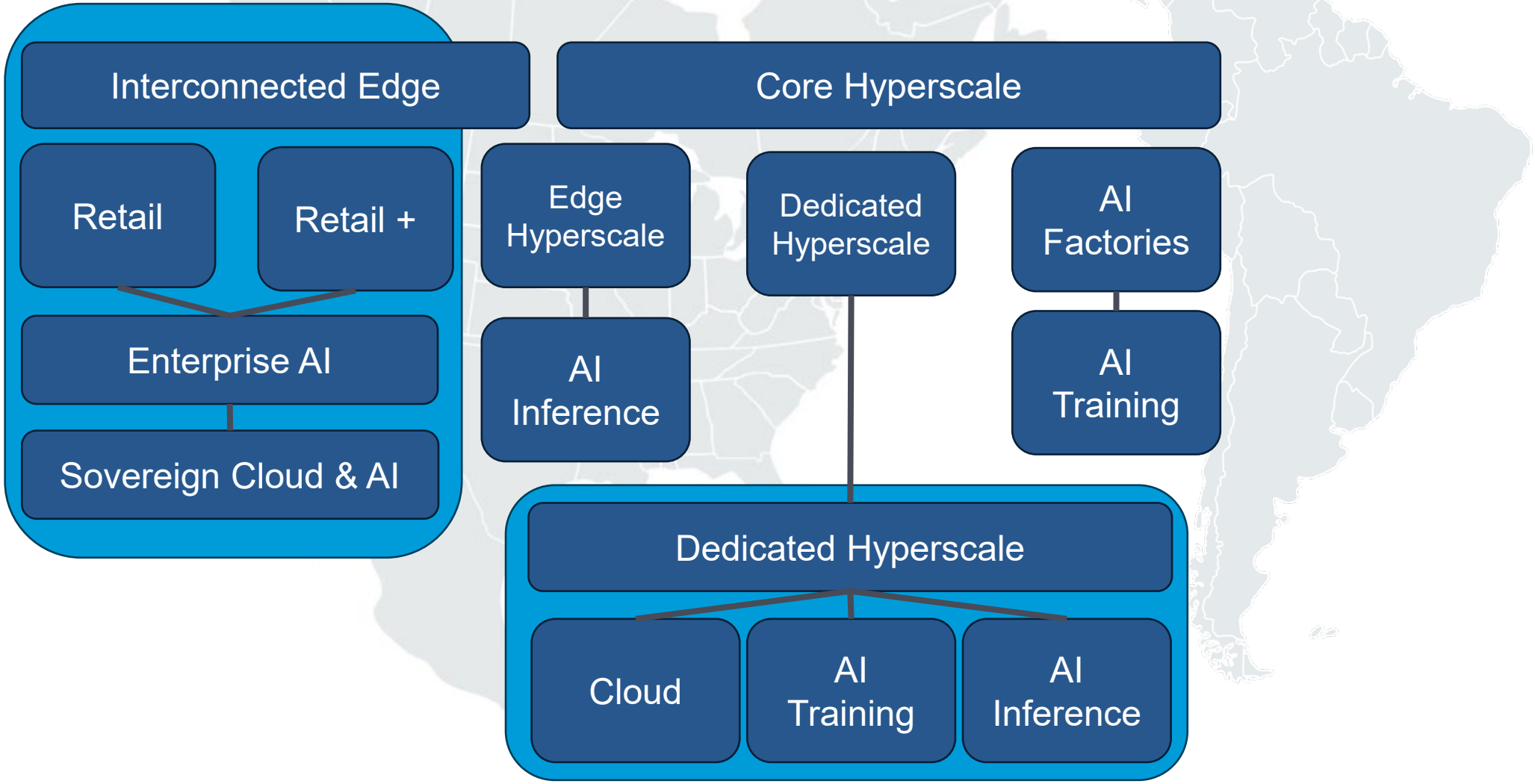
What we do now will become history.

This may be the last, great infrastructure buildout

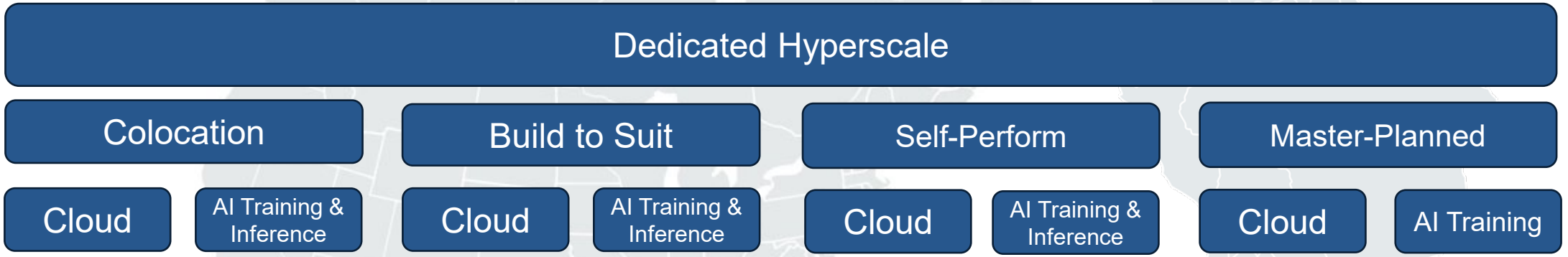
The datacenter industry is operating without a map

We are living through a once-in-a-lifetime opportunity

Data Center Taxonomy



Data Center Taxonomy



Indicative Capacity	2-20MW	20-400MW	30-500MW	> 1GW
Customization Level	Low-Moderate	High	Very High	High
Time to Market	3 - 9 months	10 - 30 months	2.5 - 4 years	3 -5 years

Customer Focus

Location

- Existing Market
- New Markets
- Customer Request
- Availability Zones
- Workload Requirements

Workload

- Hyperscale Cloud
- GPU, AI/ML
- LLM: Training vs. Inference
- Cooling:
  - Closed Loop
  - Air Cooled
  - Liquid to Chip

Timeframe

- Today
- Yesterday
- Constraints:
  - Power Availability
  - Long lead equipment

“Everyone has a GW, but no one has a GW”

Power Due Diligence

Technical

- Compliance with Utility Power Topology requirements.
- Reliable and Resilient Power: Ensure power infrastructure is designed and delivered to prevent customer impacts.

Project

- Schedule risk and alignment with data center delivery need-by-dates
- Power Capacity Delivery: Provide power infrastructure by coordinating with Utilities, Engineering, and Construction Teams.

Financial

- Energy rate options and contribution to total cost of ownership (TCO)
- Cost Optimization: Optimize energy costs through reporting, forecasting, utility tariff optimization, hedging, and energy management.

If you've met one utility, you've met one utility.

Working with Utilities – Pre-Application

“You have to be part of our regional study.”
“What are the requirements to enter?”
“We don’t know yet, but you will have to do them all.”
“Can you give me an example?”
“Yes, we will need a substation SLD to complete the application.”
“Can you provide specifications?”
“No, we don’t care what you do once the power enters your site.”
“Then why do you need a SLD?”
“To ensure your design meets our standards.”

Realistic Questions

- How does the Connection Application process work?
- Is there a different process above a certain amount of load?
- How does the Connection Agreement (ESA) process work?
- How much power do you have available?
- Do you have bridging power available?
- Can we have some power now and more power later?
- How fast can we ramp?
- What can we build?
- Can we make the substation pad-ready?
- Can we secure LLE now?
- How big are your substations?
- How do you feel about behind-the-meter?
- How do you feel about PUNs?
- How long do studies take?
- Can provide a study?
- How can we move up the queue?
- Can we get study status updates?

Future of Reliability & Resilience

"It's better to work together because this is happening."

- High Reliability
  - Five 9s or greater
  - UPS and backup power
  - Operations and training
- Operational Coordination
  - Utility outages
  - AI Training ramps and oscillations
  - System Restoration
- System Protection Coordination
  - Load shedding
  - Ride through requirements

Thank You

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