Power Sector Transmission & Distribution Data and Information

WEBINAR SERIES

Welcome

Our webinar will start soon

U.S. DEPARTMENT OF ENERGY
OFFICE OF ELECTRICITY

Los Alamos NATIONAL LABORATORY

OAK RIDGE National Laboratory

Pacific Northwest NATIONAL LABORATORY

Power Sector Transmission & Distribution Data and Information

WEBINAR SERIES

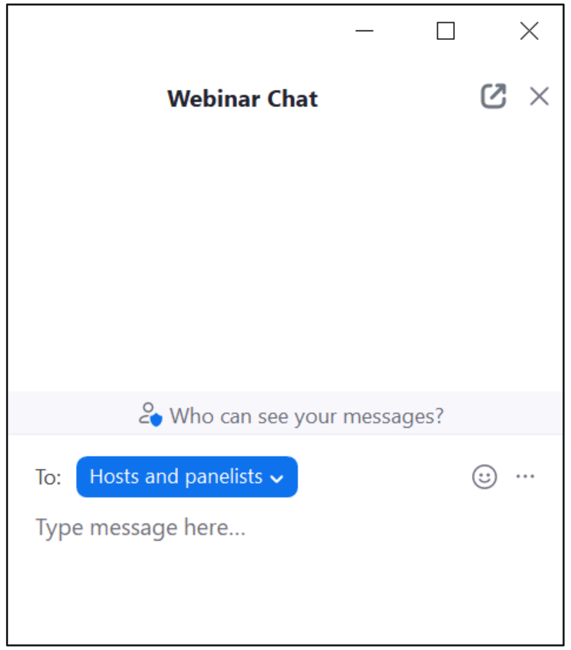
Topic 1. Transmission and Distribution Information Sharing

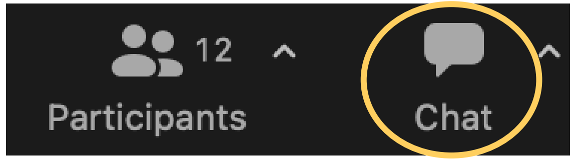
Supriya Chinthavali, ORNL - Topic 1 Host
Srijib Mukherjee, ORNL - Topic 1 Co-Moderator

U.S. DEPARTMENT OF ENERGY OFFICE OF ELECTRICITY
Los Alamos NATIONAL LABORATORY
OAK RIDGE National Laboratory
Pacific Northwest NATIONAL LABORATORY

Housekeeping items

- Recording the session (For internal purposes)
  - Slides will be made available through the event page
- Please type your questions in the chat box (2 options)
  - Use “Host and panelists” option for posing questions only to presenters
  - Post questions for all attendees
- Handling internet connection issues
  - PNNL team will be taking over and sharing the slide deck to continue the webinar
- 5 Q&A Discussions
  - GRIDS Overview and Data Standards Landscape
  - MAPLE-LEAF/MAPLE-BRANCH
  - COMMANDER
  - Discovery through Situational Awareness
- Handling unaddressed questions during the webinar





POWER SECTOR TRANSMISSION & DISTRIBUTION DATA AND INFORMATION WEBINAR SERIES

TOPIC 1: T&D Information Sharing
Wednesday, October 11 | 10:00 a.m. to 12:30 p.m. PDT

TOPIC 2: Cross-sector & Open Data Sharing and Risks
Wednesday, October 18 | 10:00 a.m. to 12:00 p.m. PDT

TOPIC 3: Sensor Systems and Platforms
Wednesday, October 25 | 10:00 a.m. to 12:00 p.m. PDT

TOPIC 4: Sensor Data and Device Research
Wednesday, November 1 | 10:00 a.m. to 12:00 p.m. PDT

REGISTER TODAY!

U.S. DEPARTMENT OF ENERGY OFFICE OF ELECTRICITY

Los Alamos NATIONAL LABORATORY

OAK RIDGE National Laboratory

Pacific Northwest NATIONAL LABORATORY

Power Sector Transmission & Distribution Data and Information

WEBINAR SERIES

DOE-Office of Electricity (OE) Introduction

Sandra Jenkins, DOE-OE

U.S. DEPARTMENT OF ENERGY OFFICE OF ELECTRICITY

Los Alamos NATIONAL LABORATORY

OAK RIDGE National Laboratory

Pacific Northwest NATIONAL LABORATORY

Webinar Topic 1 Agenda (PDT)

TIME	TOPIC	PRESENTERS
10:00 – 10:10 AM	Welcome, Introductions and Webinar Goals	DOE/Webinar Host
10:10 – 10:25 AM	GRIDS Overview (DER/Emergency/real-time telemetry data communication)	Supriya Chinthavali (ORNL)
10:25 – 10:45 AM	GRIDS - Data Standards Landscape	Scott Coe (GridOptimize)
10:45 – 11:15 AM	VELCO - MAPLE LEAF/MAPLE BRANCH	Alex Anderson (PNNL) Dan Kopin (VELCO)
11:15 – 11:25 AM	Short Break	
11:25 – 11:50 AM	COMMANDER - Network of Microgrids	Cameron Brooks (Think Microgrid)
11:50 – 12:10 PM	Discovery Through Situational Awareness	James Follum (PNNL)
12:10 – 12:15 PM	Wrap up and Closeout	DOE/Webinar Host

Power Sector Transmission & Distribution Data and Information

WEBINAR SERIES

Grid Reliability Initiative utilizing through Data Standardization (GRIDS) Overview

DER/Emergency/Real-Time Telemetry Data Communication

Supriya Chinthavali

Group Leader, Geospatial Sciences and Human Security Division (ORNL)

U.S. DEPARTMENT OF ENERGY OFFICE OF ELECTRICITY

Los Alamos NATIONAL LABORATORY

OAK RIDGE National Laboratory

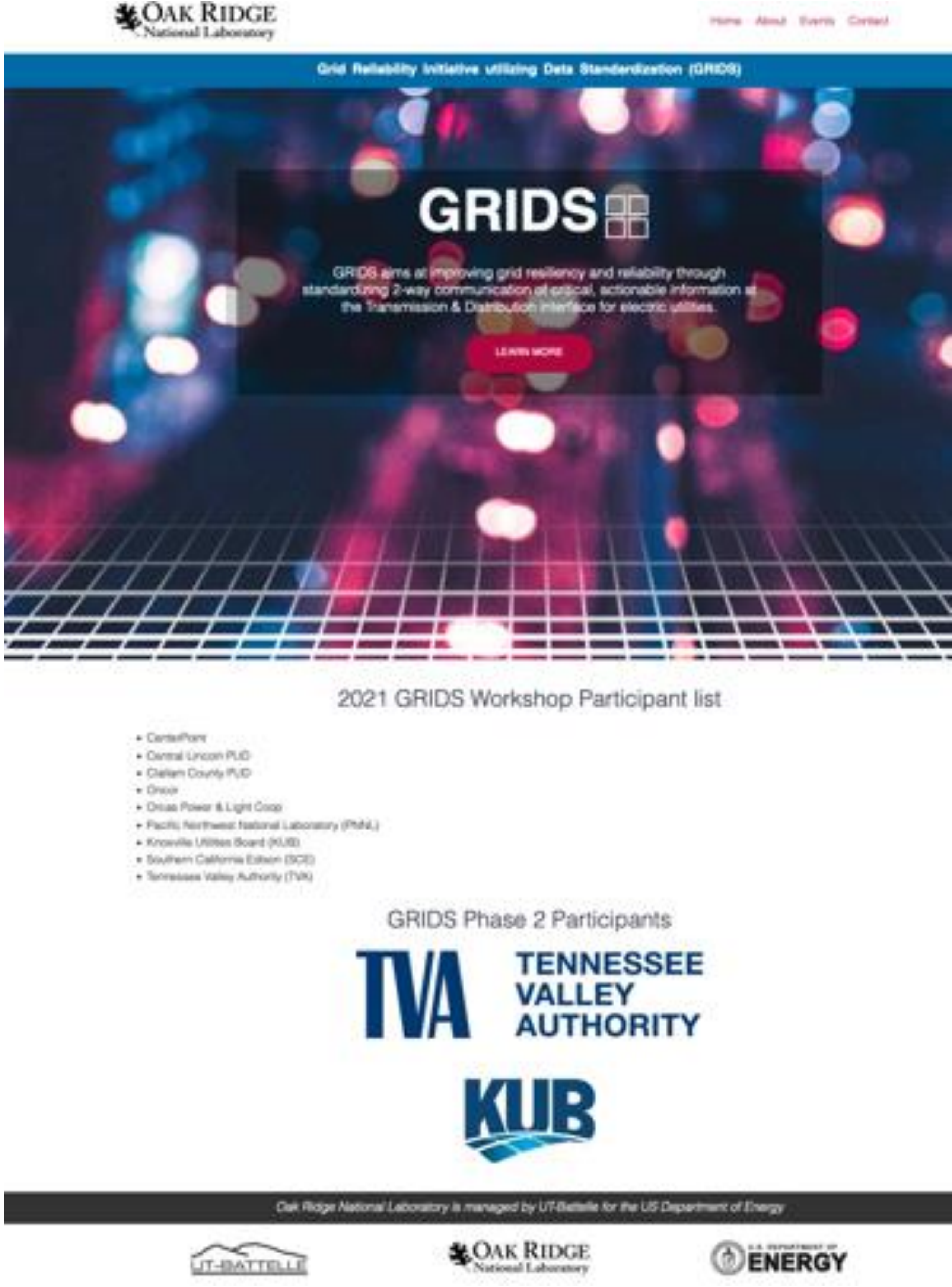
Pacific Northwest NATIONAL LABORATORY

GRIDS - Grid Reliability Initiative utilizing Data Standardization

https://grids.ornl.gov

Improving interoperability between transmission and distribution for better coordination between them thereby improving reliability and resilience

- **Transition to bidirectional Grid**
  - Outage Planning and restoration: Frequent extreme events
  - **Proliferation of DER and FERC2222:** Needs efficient DER data communication between Transmission Operators (TOs), Distribution Operators (DOs) and ISOs.
- **Electrification** (Meet NetZero goals)



Sources:
tva.com/
https://www.kub.org//

GRIDS Motivation: NERC Proposed Reliability Guideline (2020) for Transmission Planners (TP) to collect DER model data from Distribution Planners (DP), referenced IEEE 1547-2018

Presented to DOE in June 2021

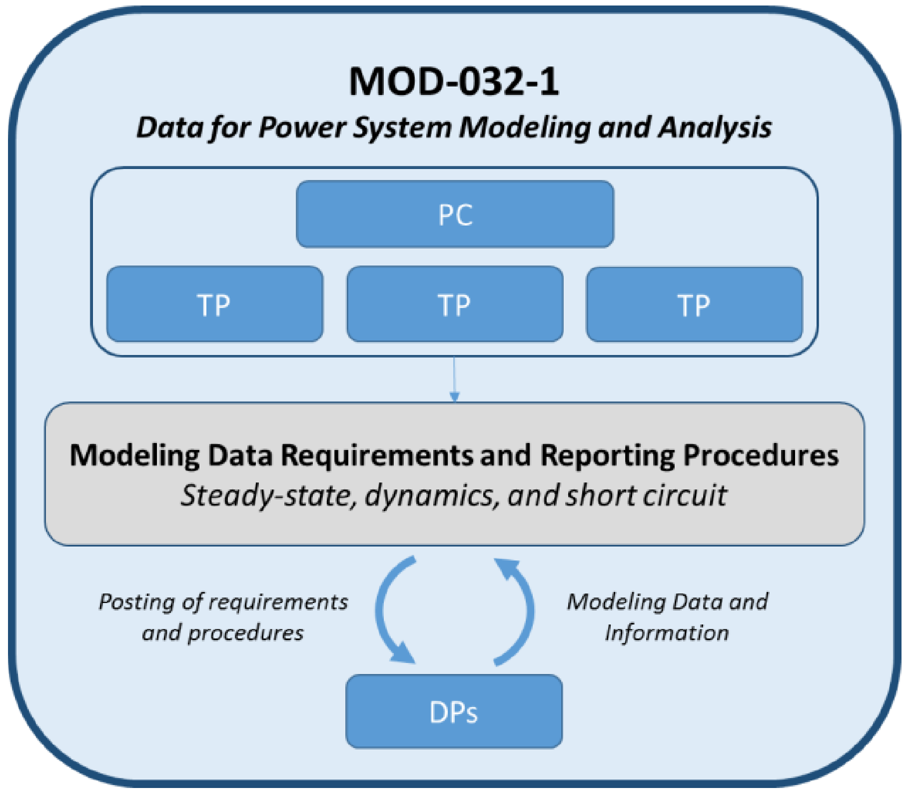


Figure 1.1: MOD-032-1 Flowchart for DER Data

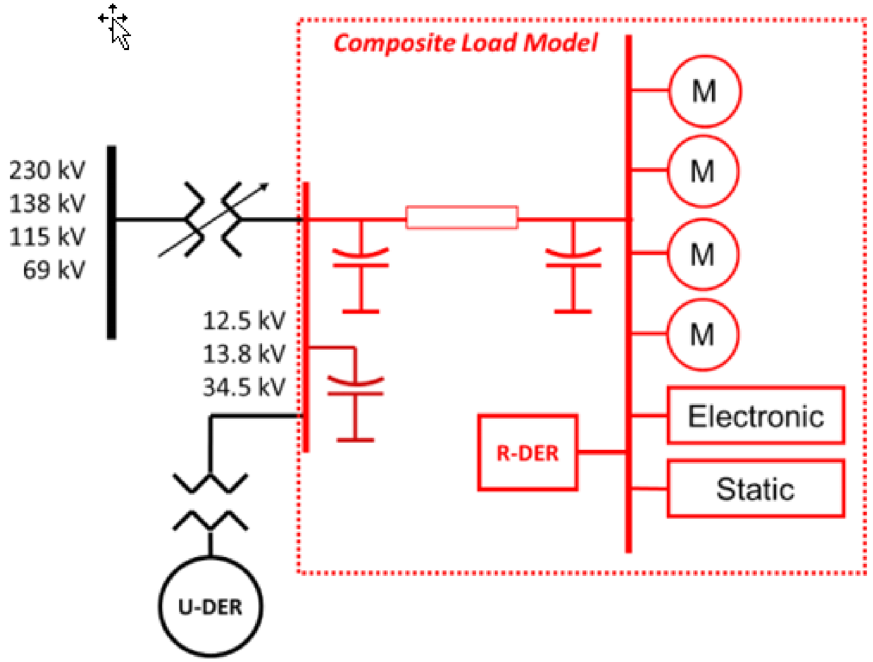


Figure I.1: DER Modeling Framework

Table 2.1: Steady-State Power Flow Modeling Data Collection

Aggregate DER Modeling Information Needed[51]	Information Necessary for Suitable Modeling of Aggregate DERs
Location	The DER interconnection location will need to be assigned to a specific T-D transformer or associated BPS or distribution bus based on the TP and PC modeling practices. Geographic location should also be given so that proper DER (e.g., solar) profiles and estimated impedance can be applied.
Type of DER (or aggregate type)	Specify the percentage of DERs considered U-DER and R-DER.[52] Provide an aggregate breakdown (percentage) of the types of DERs per T-D transformer. Preferably, this is specified as a percentage of aggregate DERs that are solar PV, synchronous generation, energy storage, hybrid[53] power plants, and any other types of DERs.
Historical or expected DER output profiles	For each type of aggregate DER (e.g., solar PV, combined heat and power, energy storage, etc.), specify a general historical DER output profile occurring during the studied conditions. What output are these resources dispatched to during peak and off-peak conditions? The TP and PC should define peak and off-peak conditions.
Status	Based on the DER output profile provided, TPs and PCs will know whether to set the aggregate DER model to in-service or out-of-service based on assumed normal operating conditions for the case.
Maximum DER active power capacity (Pmax)	Maximum active power capacity of aggregate DERs should be provided to the TP and PC. This, again, should be aggregated to the T-D transformer (i.e., each T-D transformer should generally have an amount of aggregated U-DER and R-DER, as necessary), depending on the TP and PC requirements.

Table 3.1: Data Collection for Parameterizing the DER_A Dynamic Model

Param	Default	Information Necessary for Suitable Modeling of Aggregate DERs
trv	0.02	Parameter values do not generally change between vintages of IEEE 1547. For the purposes of modeling, these default parameters are appropriate. Any dynamic voltage support requirements set by the DP should be communicated to the TP and PC so they can determine an appropriate modeling practice. Note that these parameters can be used to represent either dynamic voltage support or steady-state volt-var functionality; TPs and PCs will need to determine which approach is being used and specify any data collection requirements accordingly.
dbd1	-99	
dbd2	99	
kqv	0	
vref0	0	
tp	0.02	
tiq	0.02	

Source: https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Reliability_Guideline_DER_Data_Collection_for_Modeling.pdf

GRIDS Motivation: MOD-032-2 - NERC Development of the standard SAR (May 2023) for Transmission Planners (TP) to collect specific DER model data from Distribution Planners (DP)

Table 1: Consider Standards Revisions		
Standard	**High-Level Description of Outcome**	**Priority**
MOD-031-2	Revise the standard to ensure that existing and forecasted DER data is provided by DPs or Transmission Planners (TPs) to the Planning Coordinator (PC) upon request[7] Allow TPs to be an intermediary to provide data from DPs to the PC	High

Anticipated Actions	Date
45-day formal or informal comment period with ballot	6/1/2023 – 7/17/2023
45-day formal or informal comment period with additional ballot	9/1/2023 – 10/15/2023
XX-day final ballot	
Board adoption	12/12/2023

Data Reporting Requirements

- *Information that is required to effectively **model the interconnected transmission system** for the Near-Term and Long-Term Transmission Planning Horizon*
- *Data must be **shareable on an interconnection-wide basis** to support use in the Interconnection-wide cases.*
- *A Planning Coordinator **may specify additional information** that for each item in the table. Each functional entity (DP,TO) responsible for reporting the respective data in the table is identified by brackets "[functional entity]" adjacent to and following each data item.*

steady-state *(Items marked with an asterisk indicate data that vary with system operating state or conditions. Those items may have different data provided for different modeling scenarios)*	dynamics *(If a user-written model(s) is submitted in place of a generic or library model, it must include the characteristics of the model, including block diagrams, values and names for all model parameters, and a list of all state variables)*	short circuit
1. Each bus [TO] a. nominal voltage b. area, zone and owner 2. Aggregate Demand[2] [DP, TO (when a Demand is not associated with a registered DP)] a. real and reactive power* b. in-service status* 3. Generating Units[3] [GO, RP (for future planned resources only)]	1. Generator [GO, RP (for future planned resources only)] 2. Excitation System [GO, RP (for future planned resources only)] 3. Governor [GO, RP (for future planned resources only)] 4. Power System Stabilizer [GO, RP (for future planned resources only)]	1. Provide for all applicable elements in column "steady-state" [GO, RP, TO] a. Positive Sequence
9. Distributed Energy Resource (DER) data[4] [DP, TO (when DER is not associated with a registered DP)] a. Location (bus from item 1) and if DER feeder is subject to UFLS and/or UVLS b. Real power capability (minimum and maximum) c. Reactive power capability (minimum and maximum) d. Generator type (solar, battery, etc.) e. In-service date or other information to be used to make assumptions about DER capabilities related to ride-through, voltage control and/or frequency control.	10. Distributed Energy Resource (DER) data [DP, TO (when DER is not associated with a registered DP)] 11. Other information requested by the Planning Coordinator or Transmission Planner necessary for modeling purposes. [BA, GO, DP, TO, TSP]	

Source: https://www.nerc.com/pa/Stand/Project202202ModificationstoTPL00151andMOD0321DL/2022-02%20MOD-032-2_Clean_May2023.pdf

GRIDS Phase 1

Significant gaps exist within the current communication processes at the Transmission and Distribution (T&D) interface

T&D Survey and Workshop

- Sent a survey to several T&D utilities
- Partnered with industry stakeholders to identify and prioritize use cases important to both T&D operators.
- 2 use cases were identified

2021 GRIDS Workshop Participant list

- CenterPoint
- Clallam County PUD
- Orcas Power & Light Coop
- Knoxville Utilities Board (KUB)
- Tennessee Valley Authority (TVA)
- Central Lincoln PUD
- Oncor
- Pacific Northwest National Laboratory (PNNL)
- Southern California Edison (SCE)

T&D Survey Questions

1. What is the current method/process of communicating operations data to distribution utilities?
   - Currently, how does transmission decide when to send information to distribution? In the future, how would transmission like to send information to distribution?
   - How are generation/transmission outages, that may require a reduction or shift in distribution load, communicated?
   - What communication media is used to transmit the information (fax, telephone, email, ESB, other)?
   - Are standardized data interfaces used to communicate information between Transmission and Distribution? If so, what standards are utilized?
2. What information from Distribution operators is/would be useful to Transmission?
   a. What type of Real-time Data would be useful?
   b. What type of Periodic Data would be useful? How often should this data be received?
3. What data is NOT permissible to share (e.g. due to Market/vertical integration regulations)? (Optional)
4. During what type of scenarios will the Transmission operator act based on Distribution information?

Network Model Management

Planning and Operational Model Exchange by T&D utilities

- Topics discussed within the white paper:
  - Time-based modeling
  - Merging operations and planning models (Model alignment)
  - Justification of using CIM

https://grids.ornl.gov

GRIDS Phase 1

Significant gaps exist within the current communication processes at the T&D interface

Use Cases: CIM Profiles were created for these use cases in preparation for implementation

Unplanned Outage Coordination from Transmission to Distribution

1 Description of the Use Case

1.1 Name of Use Case

Use Case Identification		
ID	*Domain(s)*	*Name of Use Case*
	61968 Part 3, 5, 8, and 9 Messaging and 62325-21	DER Trip after Distribution Circuit Fault Message Use Case

1.2 Version Management

Version Management						
Changes / Version	*Date*	*Name Author(s) or Committee*	*Domain Expert*	*Area of Expertise / Domain / Role*	*Title*	*Approval Status* draft, for comments, for voting, final
1	1/27/2022	WG-13, WG14	Chuck DuBose	Power System Engineer	Principle Engineer	draft for internal discussion
2	3/3/2022	WG-21	Margaret Goodrich			
3	3/9/2022	WG-13, WG14	Chuck DuBose	Power System Engineer	Principle Engineer	Added additional use case for tripping inverters

1.3 Scope and Objectives of Use Case

Scope and Objectives of Use Case	
Related business case	Reference IEC 61968-9, End Device Control Messages; IEC61968-5, DER Group Messages; IEC61968-3, Unplanned Outage Message; IEC 61968-8, Title TBD; IEC 62325-21, Title TBD
Scope	This case covers the requirements for a message to remove residential or bulk DER sources by group or individually from a distribution circuit which has been tripped due to a fault.
Objective	To define how the current Connect/Disconnect messages for meters and group DER are used and to define the need for a new message to command a single DER. Creation of a message to disconnect a single DER from all or portions of a distribution circuit in response to a fault detected on the circuit. This would require the creation of a new message to command a single DER.

1.4 Narrative of Use Case

Narrative of Use Case

Short description – max 3 sentences

Disconnect all customers with DER and Bulk DER from faulted circuit after protection device tripping and reconnect after circuit restoration. If the DER is residential, the disconnect happens with the EndDeviceControl message for the Meter or group DER disconnect message. If the disconnect is for the Bulk DER, the DER Group Disconnect message is used.

Complete description

Fault Impedance Background:
Fault impedance is the impedance between the energized equipment and ground. The Fault impedance plus the culmination of the source impedance of all online generators along with all parallel lines and transformers of the transmission system to the distribution bus plus the series line impedance to the fault location determine the voltage at the fault. Fault impedance is dependent on what comes in contact with energized equipment. High impedance faults are extensively an overhead line problem.

Typically, an energized wire in contact with a grounded wire or equipment has no fault impedance. An overhead phase wire lying on the ground is generally determined to have a low fault impedance. But a

TVA TENNESSEE VALLEY AUTHORITY

KUB

DER Trip after Distribution Circuit Fault Message

1 Description of the Use Case

1.1 Name of Use Case

Use Case Identification		
ID	*Domain(s)*	*Name of Use Case*
	61968-3 Outage messaging	Unplanned Outage Coordination from Transmission to Distribution

1.2 Version Management

Version Management						
Changes / Version	*Date*	*Name Author(s) or Committee*	*Domain Expert*	*Area of Expertise / Domain / Role*	*Title*	*Approval Status* draft, for comments, for voting, final
1	2/2/2022	WG-13, WG14	Chuck DuBose	Power System Engineer	Principle Engineer	draft for internal discussion
2	2/7/2022	WG13, WG14	Margaret Goodrich	IT and Software Engineer	Software Engineer	Draft
3	2/10/2022	WG-13, WG14	Chuck DuBose	Power System Engineer	Principle Engineer	Additional edits
4	2/27/2022	WG13, WG14	Margaret Goodrich	IT and Software Engineer	Software Engineer	Review and edits
5	2/28/2022	WG-13, WG14	Chuck DuBose	Power System Engineer	Principle Engineer	Accepted all track changes and tweaks before presentation to the group

1.3 Scope and Objectives of Use Case

Scope and Objectives of Use Case	
Related business case	IEC 61968-3, Unplanned Outage Message
Scope	Coordinate unplanned outages from Transmission to Distribution
Objective	Define Message(s) and formats required to complete the coordination of unplanned outages from Transmission to Distribution.

1.4 Narrative of Use Case

Narrative of Use Case

Short description – max 3 sentences

This Use Case will explore the unplanned outage message flows currently in place in Transmission and Distribution and determine how these could be coordinated to provide a more reliable and resilient Grid. The current state of the Transmission and Distribution Grid is to be reviewed and possible information flows defined. Current and new messages and formats are identified to improve the coordination of the unplanned outages. The problem of disparate formats for communication are also explored and possible solutions are provided.

Complete description

Power System Background:
Distribution transformers may be connected to any transmission voltage level less than or equal to 345KV. Predominantly, the bulk of distribution is served from the 230kv and below voltage levels. Since distribution substations must be near the load they serve, only some may be located in large transmission substations with multiple transmission voltage levels and multiple lines at multiple transmission voltage levels. More than likely, distribution substations are located on transmission lines which are routed through areas in proximity to the load. Areas of light load are served by lower voltage lines, or a high voltage line routed in

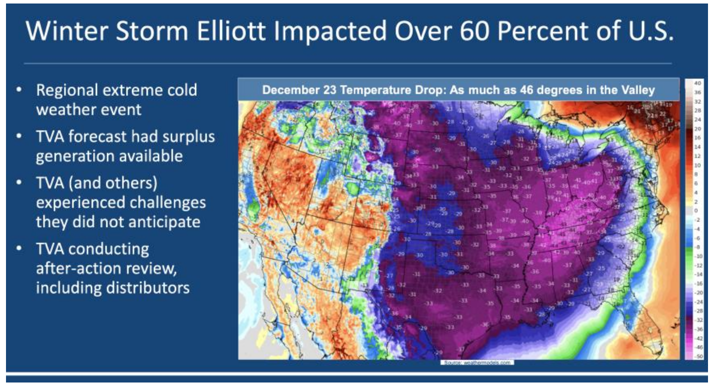
SOUTHERN CALIFORNIA EDISON®
Energy for What's Ahead[SM]

Sources:
tva.com/
https://www.kub.org/
https://www.sce.com/

GRIDS Phase 2

Emergency Event T&D Report: 2022 Winter Storm Elliot

- To understand and address the gaps in communication between the transmission and distribution operators – emergency alerts reporting
- ORNL interviewed 3 utilities (KUB, NES, MLGW)
- **Lessons learned:** Lack of preparedness and effective communication processes at the T&D interface



Electric Industry Standards Landscape

- ORNL is working to help the industry make informed decisions when adopting communication standards
- First edition of the **"Electric Utility Industry Standards Landscape"** will be released within a few weeks.

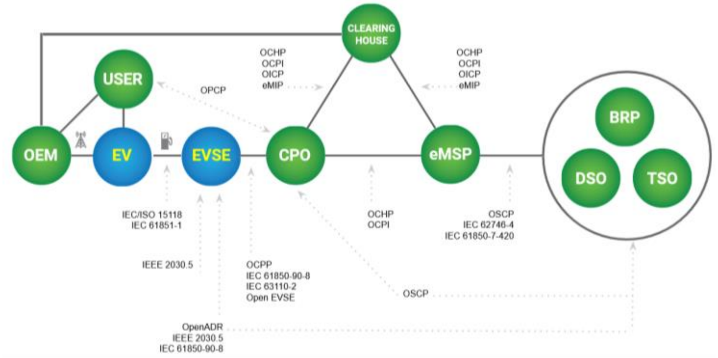
Communications Protocol	Data Domains										
	Device			Grid				Optimization			
	Capabilities	Configuration	Conditions	Topology	Behavior	State	Constraints	Services	Negotiation	Fulfillment	Compensation
IEC 62746 Series	●	○	○	○	○	○	○	●	●	●	●
OpenADR / IEC 62746-10	○	●	●	○	○	○	○	○	●	●	○
IEC 61850-7-420	●	●	●	○	○	○	○	○	○	○	○
IEEE 2030.5	●	●	●	○	○	○	○	○	●	●	○

Source: https://www.kub.org/uploads/Board_Presentation_-_January_2023.pdf

EV Protocols Landscape

Define EV data flow ecosystems for utilities modeling purposes

- **OCPP 2.0.1** standards data ingestion into DSO/TSO systems using OpenADR/IEEE 2030.5
- Engage with **Charge Point Operators** (such as ChargePoint, Electrify America, etc.) for other standards data streams to send to utilities
- Standardized aggregated EV **load data** for modeling



2019 Polar Vortex in Michigan

What happened?

A combination of extreme weather and energy emergency events during January 30-31, 2019 challenged the natural gas and electric systems in Michigan. Though service was maintained, Michigan's energy supply and delivery systems were strained due to the extreme weather event dubbed Polar Vortex 19, or PV19, during which temperatures dropped below -25° F. The abnormal weather caused reduced regional power plant output and historically high natural gas demand, at the same time as an unexpected failure of critical natural gas infrastructure.

The regional electric grid operator, Midcontinent Independent System Operator (MISO), declared a system-wide (15 states) electric emergency requiring all generation to operate at maximum output.

On the morning of January 30, a fire ignited at the Ray Compressor Station, Consumers Energy's largest natural gas storage facility (supplying over one third of customer needs at peak times), leading to a severe disruption of natural gas supply and deliverability.

Photo Credit: Todd McInturf/The Detroit News

The impact of these overlapping emergencies led Michigan utilities to request conservation measures and the State Emergency Operations Center to make a broad public appeal to all residents to conserve natural gas. The statewide appeal included a text message alert from the Michigan State Police.

Observations from PV19

The fire at the Ray Compressor Station and ensuing natural gas incident provides a useful opportunity to reflect on the effectiveness of public information and crisis communication between the State and private industry, as well as the general public and media. While this specific incident serves as an example, the lessons learned are universal and should be considered during future emergency situations regardless of utility partner.

- Greater efforts should have been made to ensure the public understood not only the cause of the incident, but realistic potential impacts and actions taken by government and industry to remedy the situation. Public information staff should work more closely with outside media to ensure accurate information is available and publicized widely.
- The need for a public request to conserve natural gas usage should have been anticipated and prepared sooner, so that communication materials were drafted and vetted prior to usage, thus saving valuable time. By delivering this messaging sooner, greater participation and cooperation by the public was likely to have occurred.
- As is typical of other emergency events, the utility, in this case Consumers Energy, held briefings with numerous state partners, including: the Governor's office, Legislature, MPSC Staff and Commissioners, Staff at SEOC, and local emergency managers. This responsiveness and flexibility resulted in the unintentional consequences of confusing narratives, timelines, and wasted resources. The State should streamline and consolidate these communication paths for future emergency events.

9.3.1.5 Emergency Management

Emergency Management Recommendations

- **EM-1: D**uring PV19, communications during the event were confusing, inconsistent, and erratic. **The Commission recommends Staff:**
  - **EM-1.1: Provide timely and consistent energy emergency communication to the public via the MPSC website, social media, and other outlets to provide contextual understanding of event cause, remediation, and duration, as well as important safety tips.**
  - **EM-1.2: Develop drafts of energy emergency messaging to be used in traditional and social media, so that initial review and approval can occur well in advance of potential need as part of a comprehensive emergency communications plan.**
  - **EM-1.3: Annually provide an emergency contact list to energy providers in electric, natural gas, petroleum and regional transmission organizations.**

- Major manufacturers had agreed to cut their energy usage by cutting production, and that accounted for a reduction of 120 million cubic feet of natural gas, but the utility was still 300 million cubic feet short of the reductions it needed.
- Poppe decided to go to Facebook live to plead with customers to turn down their heat. "People were going to bed and our load wasn't dropping off much," she said. "And we were forecasting that we were going to need 3.7 billion cubic feet for the next day."
- The utility contacted Gov. Gretchen Whitmer and the state's Emergency Operation Center and all agreed to send out the emergency text message asking customers to turn down the heat at 10:30 p.m., roughly 12 hours after the initial incident. "We knew we needed residential customers. It was important that we sent the emergency text," she said. "We had a 10-percent reduction almost immediately. ... That call worked and Michiganders did their job. They saved the day."

Sources:
https://www.freep.com/story/news/politics/2019/02/20/consumers-energy-alert-fire-emergency/2929762002/
https://wsbt.com/news/local/gallery/fire-at-michigan-gas-plant-prompts-emergency-alert-asking-residents-to-conserve-heat?photo=1
https://www.michigan.gov/-/media/Project/Websites/mic/Other/Michigan_Statewide_Energy_Assessment.pdf?rev=aa63634fa02845efa4913541f4e02340

Emergency Event T&D Report: Winter Storm Elliot

Goal: to understand and address the gaps in communication between the transmission and distribution operators – emergency alerts

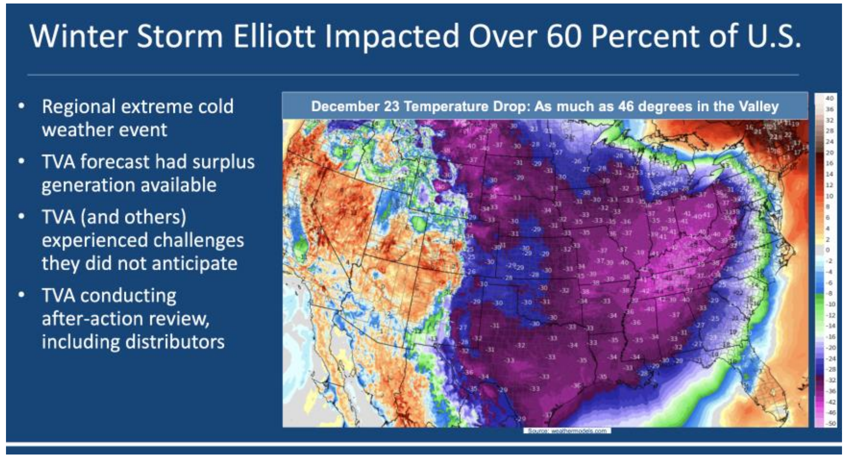
- NERC EEA Alerts, ELCP, and Flex alerts

ORNL interviewed 3 LPCs (KUB, MLGW, and NES)

- Overall experience went well. The utilities were more prepared on the 2nd day. Need of better communication and situational awareness.

Lesson learned

- Lack of preparedness
- Lack of effective communication processes at the transmission and distribution interface
- Lack of standard procedures for communicating with power companies and residents



CLIMATE POLITICS SCIENCE

Winter storms put the US power grid to the test. It failed.

America's aging energy infrastructure and reliance on fossil fuels pushed local power grids to the brink.

By Rebecca Leber | @rebleber | rebecca.leber@vox.com | Dec 27, 2022, 2:30pm EST

Sources:
https://www.kub.org/uploads/Board_Presentation_-_January_2023.pdf
https://www.vox.com/energy-and-environment/2022/12/27/23527327/winter-storm-power-outages

Winter Storm Elliot Report: Recommendations

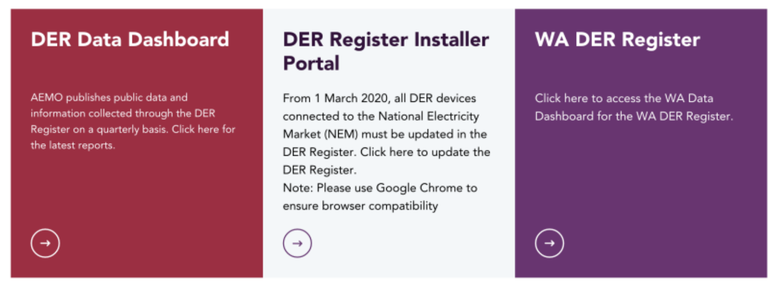
- Standardize communication messaging and methods via **EEAs** and Flex Alerts
- **Automate communications** about outages between power generators and distributors
- **Share real-time data** on generation and load (i.e., for TVA and monopoly utilities in the Southeast)
- Implement **mass texting** to TVA/LPC service territories
- Implement **advanced notification** of outages as much as possible to allow better planning for restoration issues caused by extreme weather
- EEA vs ECLP vs PSA alerts lineup
- Establish better procedures for communication with residents

GRIDS Phase 2/Future Work

Meeting NERC standards for Transmission Planners (TP) to collect specific DER model data from Distribution Planners (DP)

AEMO (Australian Energy Market Operator): DER Registry

Australia has operational digitalized DER registration Portal today



Meeting NERC MOD-032 Standard Requirements

9. Distributed Energy Resource (DER) data[4] [DP, TO (when DER is not associated with a registered DP)]
   a. Location (bus from item 1) and if DER feeder is subject to UFLS and/or UVLS
   b. Real power capability (minimum and maximum)
   c. Reactive power capability (minimum and maximum)
   d. Generator type (solar, battery, etc.)
   e. In-service date or other information to be used to make assumptions about DER capabilities related to ride-through, voltage control and/or frequency control.

10. Distributed Energy Resource (DER) data [DP, TO (when DER is not associated with a registered DP)]
11. Other information requested by the Planning Coordinator or Transmission Planner necessary for modeling purposes. [BA, GO, DP, TO, TSP]

MOD-032 Data exchange requirements

CIM model review and upgrade for completeness for IEEE 1547-2018 integrations that already exist

Work with PNNL to ready the CIM model which has the IEEE 1547 model integration

- To avoid Dual modeling for same parameters) – Issue tracking

Build Message Profiles for the use cases identified

- MOD-032 requirements
- DER Registry
- DER Settings data
  - Control data -- Short term planning of DOs

Adaptor Hub software — (Endpoints - query and get responses) (Enable DSO-TSO Communication)

Sources:
https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Reliability_Guideline_DER_Data_Collection_for_Modeling.pdf
https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2019/der-register/final/der-register-information-guidelines.pdf?la=en

Thank you

Supriya Chinthavali, ORNL
chinthavalis@ornl.gov

Power Sector Transmission & Distribution Data and Information

WEBINAR SERIES

GRIDS - Data Standards Landscape

Scott Coe

GridOptimize

U.S. DEPARTMENT OF ENERGY OFFICE OF ELECTRICITY

Los Alamos NATIONAL LABORATORY

OAK RIDGE National Laboratory

Pacific Northwest NATIONAL LABORATORY

Data Standards Landscape

The Data Standards Landscape aims to create insights into the wide range of communication protocols commonly considered within electric utilities and throughout the broader electricity industry.

The teams is categorizing key features of each standard in a consistent manner, with the goal of a fostering a better understanding among potential users and enabling smarter decision-making when protocol sections are made.

Data Standards Differentiation

- **Information Models**
  - Documents data objects with attributes for each object
  - Documents relationships among objects
  - Often documented in Unified Modeling Language (UML)
- **Communication Protocols**
  - Focused on data exchanges
  - Format of the data elements narrowly defined
  - Adds how the information is exchanged
  - May or may not be building using an Information Model
- **Data Requirements**
  - Defines the data required by information consumers
  - Used as inputs for both Information Models and Communication Protocols

Data Domains & Sub-Domains

Data Domains	Sub-Domains	Example Data
Asset / Equipment	**Capabilities**	Ratings, capacity, nameplate information, datasheet information
	Configuration	Steady state response, protection settings, dynamic response, operational mode
	Conditions	Open/close, current flow, temperature, Setpoints, operational limits, mode settings
Grid	**Topology**	How equipment are connected (nodes & terminals)
	Behavour	Electrical characteristics: ratings, impedances
	State	Currents, voltages, phase angles
	Constraints	firm load, thermal line limits, reserve requirements, weather-sensitivities
Grid Optimization	**Services**	Service definitions, service qualifications, aggregation membership
	Negotiation	price-sensitive loads/gen, available services (at a price)
	Fulfillment	Setpoints, energy prices, grid support prices, "Green" level
	Compensation	Performance, payments

Assessing Data Domains For Each Protocol

Communications Protocol	Data Domains										
	Device			Grid				Optimization			
	Capabilities	Configuration	Conditions	Topology	Behavoir	State	Constraints	Services	Negotiation	Fulfillment	Compensation
IEC 62746 Series	●	○	○	○	○	○	○	●	●	●	●
OpenADR / IEC 62746-10	○	●	●	○	○	○	○	○	●	●	○
IEC 61850-7-420	●	●	●	○	○	○	○	○	○	○	○
IEEE 2030.5	●	●	●	○	○	○	○	○	●	●	○

Resources vs. Devices

VIRTUAL GRID RESOURCES

Resources large enough for a utility to monitor and/or control
treated from an a technology-agnostic perspective,
including both physical resources and virtual collections of devices

CUSTOMER ENERGY DEVICES

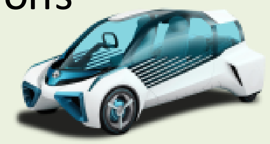
Devices focused on the production and/or storage of electrical energy

BUILDING & HOME AUTOMATION

Devices focused on energy management in homes, businesses, campuses, and industries

ELECTRIC VEHICLES

Electrical vehicles and charging infrastructure covering personal, commercial, and mass-transit implementations



Standard Landscape (Current State)

INFORMATION MODELS

Common Information Model @ UCA
IEC 61850 Model @ IEC
Multispeak Model @ NRECA

TRADITIONAL GRID RESOURCES

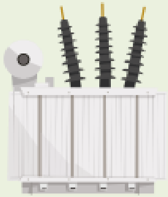
IEC 61968 (CIM Support Profiles)
IEC 61970 (CIM Grid Profiles)
IEC 62325 (CIM Market Profiles)
ICCP / TASE.2 / IEC 60870-6
Multispeak (Profiles)

VIRTUAL GRID RESOURCES

IEC 62746-4 (CIM Customer EMS)
OpenADR / IEC 62746-10
IEC 61850-7-420
IEEE 2030.5

TRADITIONAL GRID INFRASTRUCTURE

DNP3 / IEEE 1815
IEC 61850
OpenFMB
SCADA / IEC 60870-5



CUSTOMER ENERGY DEVICES

MESA
SunSpec Modbus

Data Requirements
CENELEC EN 50549
IEC 62786
IEEE 1547

BUILDING & HOME AUTOMATION

ANSI/CTA 2045
BACnet
KNX / EN 50090 / ISO/IEC 14543
Matter
Zigbee / IEEE 802.15.4
Z-Wave
S2 / IEC 63402
EE-Bus
Echonet / IEC 62394

ELECTRIC VEHICLES

EMIP
IEC 61850-90-8
IEC 61851-1
IEC 63110
ISO 15118
OpenEVSE
OCHP
OCPI
OCPP
OICP
OSCP
OPCP

Connections
NACS
CCS
SAE J1772 / IEC 62196
CHAdeMO
GB/T
SAE J2954

LOW-LEVEL MESSAGING

DDS | CAN/ISO 11898 | GOOSE | LonWorks / ISO/IEC 14908 | Modbus | MMS | MQTT / ISO/IEC 20922 | NATS | REST | SOAP

Future Plans

- Explore More Protocols
- Diver Deeper into Existing Protocols
- Solicit Subject Matter Expert Feedback
- Provide More Granular Assessments
    - ● Extensive support for Data Domain
    - ◕ Rich support for Data Domain
    - ◑ Moderate support for Data Domain
    - ◔ Light support for Data Domain
    - ○ Little-to-no support for Data Domain

Thank you

Scott Coe, Gridoptimize
scott.coe@gridoptimize.com

PNNL-SA-191074

Power Sector Transmission & Distribution Data and Information

WEBINAR SERIES

MAPLE LEAF and MAPLE BRANCH:
Standards-based Data Integration in the Cloud

Alex Anderson, PhD
Pacific Northwest National Laboratory (PNNL)
Dan Kopin
Vermont Electric Power Company (VELCO)

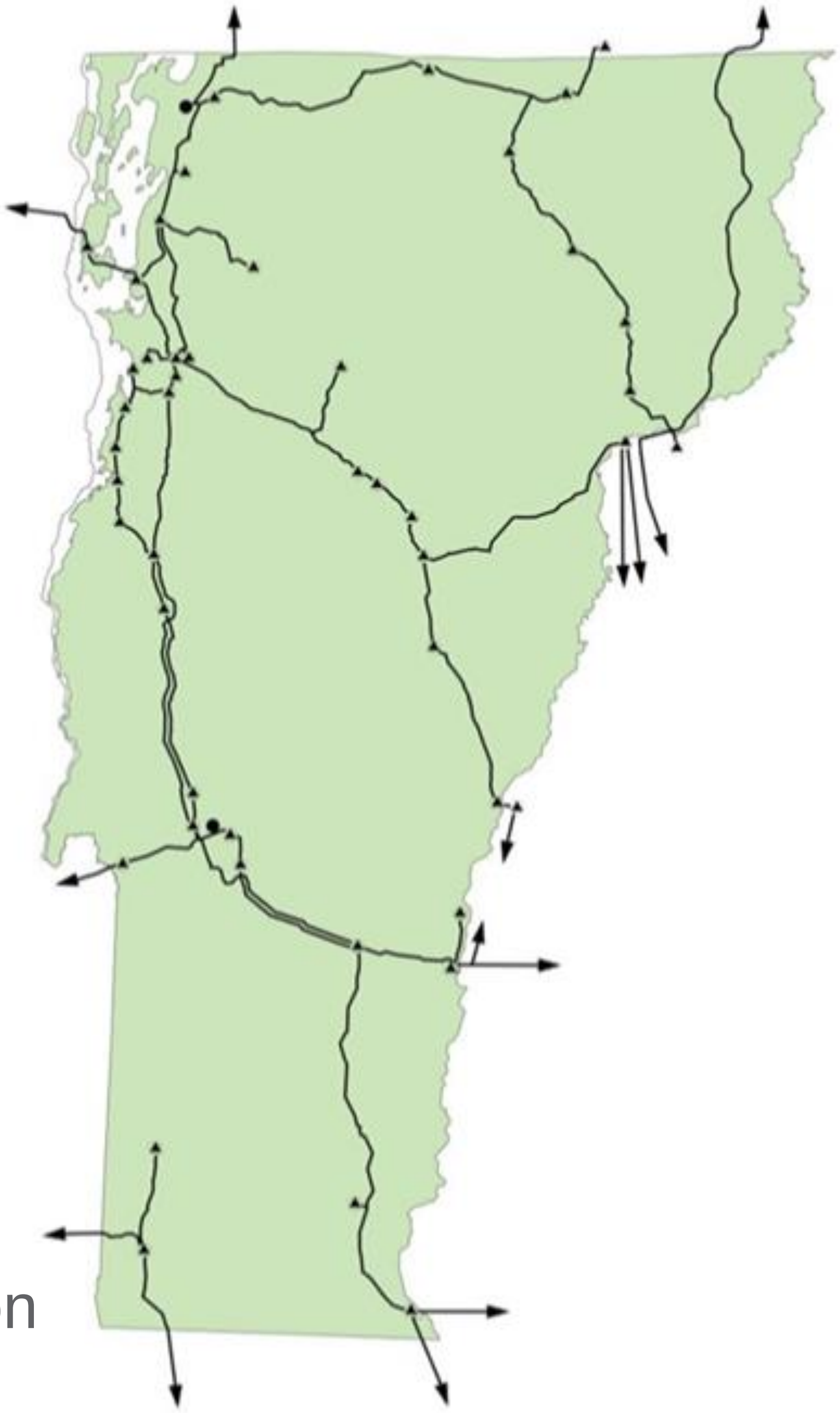
U.S. DEPARTMENT OF ENERGY OFFICE OF ELECTRICITY
Los Alamos NATIONAL LABORATORY
OAK RIDGE National Laboratory
Pacific Northwest NATIONAL LABORATORY

Background – VELCO and Vermont

- Formed in 1956 by local utilities to share access to clean hydro power and maintain the state's transmission grid
- First statewide, "transmission-only" company
- Owned by Vermont's 17 distribution utilities and Vermont Low Income Trust for Electricity

- 738 miles of transmission line, 115 kV and higher
- 14,000 acres of rights-of-way
- 55 substations, switching stations and terminal facilities
- 1600+ miles of fiber optic communication networks that monitor and control the electric system and contributes to Vermonters' high-speed data internet access

- VELCO ownership model facilitates high levels of collaboration between transmission and distribution stakeholders



MAPLE LEAF Project Overview

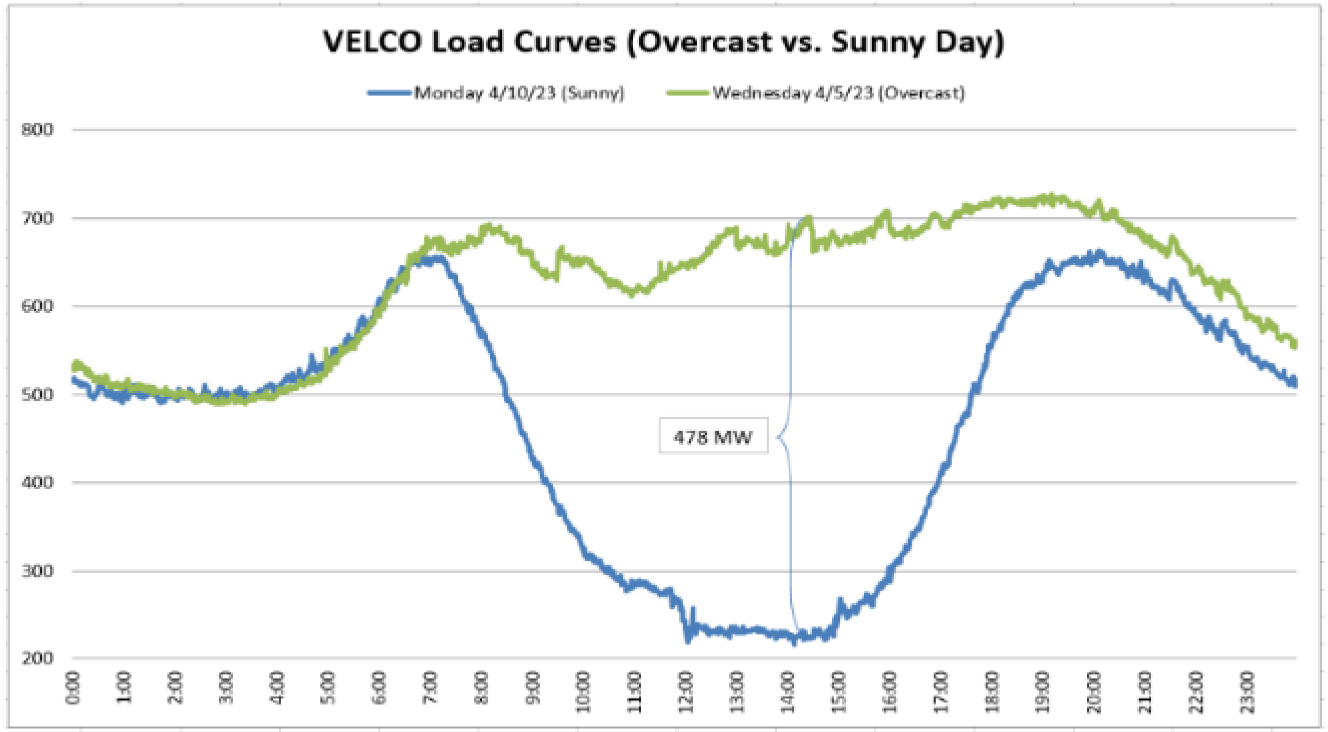
MAPLE-LEAF

- **MAPLE LEAF**: “Model-based Adaptive Protection & Load-shedding Environment Leveraging Estimates for Advanced Flexibility”
- Focusing on providing system flexibility through data integration and coordination of distributed assets across transmission-distribution boundary
- Adaptive update of under-frequency load shedding (UFLS) is main use case
- Goal to build operational proof-of-concept to update UFLS setpoints in response to real-time variations of renewable DER

Pacific Northwest NATIONAL LABORATORY | vermont electric power company VELCO | VERMONT ELECTRIC CO OP | GREEN MOUNTAIN POWER | The UNIVERSITY of VERMONT | Dynamic Organics | DLL Solutions

Background – DER in Vermont

- Vermont served by 1 TOP (VELCO) and 17 distribution utilities (DU's)
  - Total all-time peak load: **1118 MW**
  - Distribution-connected PV: **478 MW**
- High penetration of DERs disrupting traditional operations practices

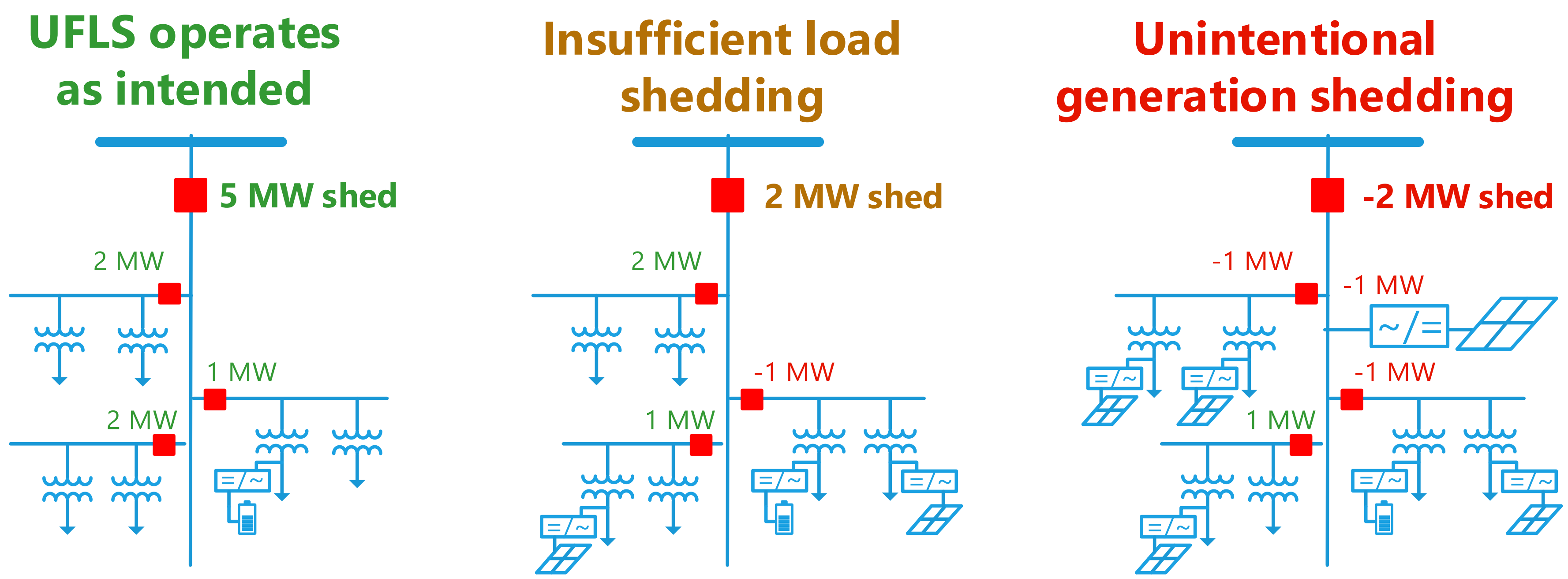


- For first time, state has become a net exporter of renewable energy
- Examining two specific use cases
  - MAPLE LEAF: Impacts to under-frequency load shedding
  - MAPLE BRANCH: Impacts to power factor at T-D interface

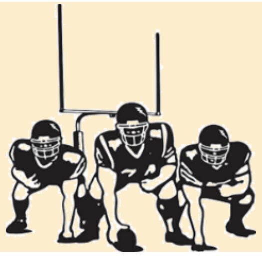
Background – UFLS Mis-operation

- NERC standard PRC-006-NPCC-2:
  - UFLS required with two stages for distribution utilities over 50 MW of peak load
  - Five UFLS stages required for peak load >100 MW
  - UFLS relay settings set annually based on single-hour peak load

High DER penetrations may result in unintentional shedding of distributed generation during a large frequency event

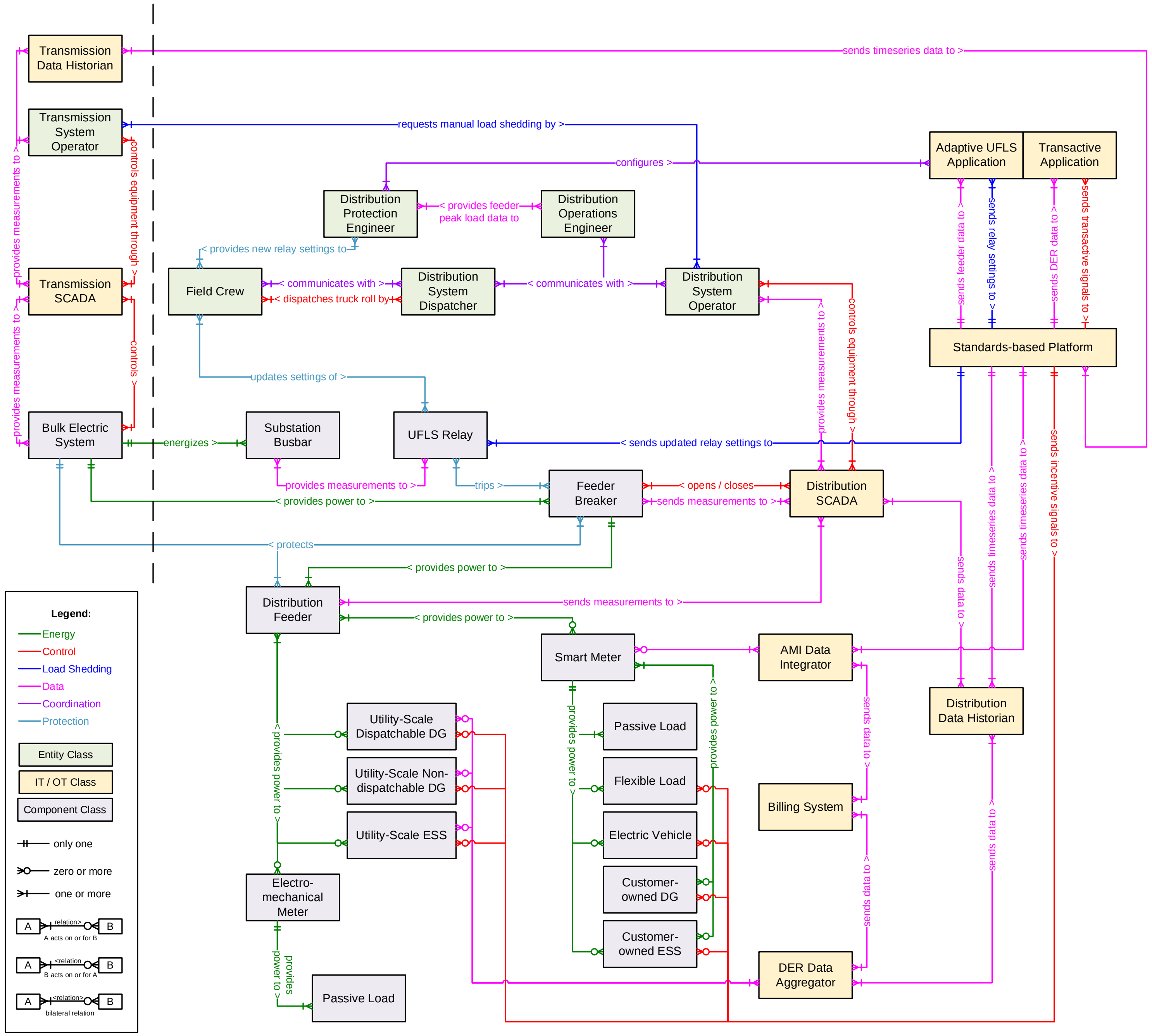


Adaptive UFLS Visual Analogy

Analogy		Timeframe	Purpose	Coordination
	Game planning, review of historical tapes & metrics	1 day to 1 month	Load and renewables forecasts used to inform predictive state estimates	Centralized: Validation of performance with analysis of metrics
	Huddle with all players to choose next play call	1 min to 1 hour	Adaptive UFLS application determines optimum group settings for current conditions – This is focus of MAPLE LEAF use cases	Hierarchical: Upper-level agents communicate with lower-level agents to get feeder head measurements and decision criteria
	Players line up in formation and prepare for snap	1 sec to 1 min	Adaptive setpoints are sent to relays, which are armed and ready	Distributed: Lower-level agents communicate to send group settings to relays
	Each player runs their route using individual real-time decisions	10 ms to 100 ms	Each UFLS-enabled relay independently detects the frequency event and opens the associated breaker if appropriate	Decentralized: Communication between UFLS relays and agents not feasible during frequency event

Grid Architecture Approach

- *“Do you build a house by hanging the windows or pouring the foundation?”*
- Grid Architecture defines the **structure** and **interactions** between organizations, software, equipment, networks, and humans
- Adaptive protection will require complex set of integration and interactions across T-D boundary



MAPLE LEAF Data Integration

New data-rich environment using Common Information Model (CIM) will provide access to a single source of aggregated & correlated transmission + distribution data:

- Existing data streams
  - SCADA, field telemetry, large (>1MW) DERs
- Existing data not aggregated in real time
  - AMI, DER output, net metering, EV stations
- Emerging data streams
  - IoT/IIoT devices, smart inverters, PMUs

Silos of Power Systems Data Environments

EMS/ADMS
- SCADA/RT Data
- Substations
- Breakers
- Transformers
- LTC Taps
- Generators
- Alarms, Events, Ops Log
- Load Model

Network Planning
- Bus-branch Power Flow
- Protection Settings
- Load Growth
- New Capacity
- Non-wire Alternatives

GIS
- All Physical Components
- Wire Sizing and Spacing
- All Switches incl. Sectionalizers
- Power Poles
- Customer Connections

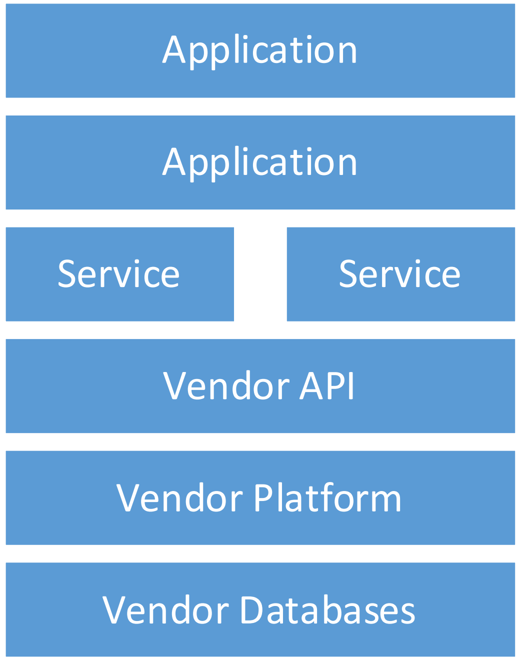
Customer Billing
- Metering (AMI, Net Metering)
- Charging Stations
- Customer Info
- Premise Info
- Rooftop Solar
- Distributed Generation

Asset Management
- Equipment & Asset Health
- Field Testing & Non-Electrical Measurements
- Substation Configuration
- Asset Programs

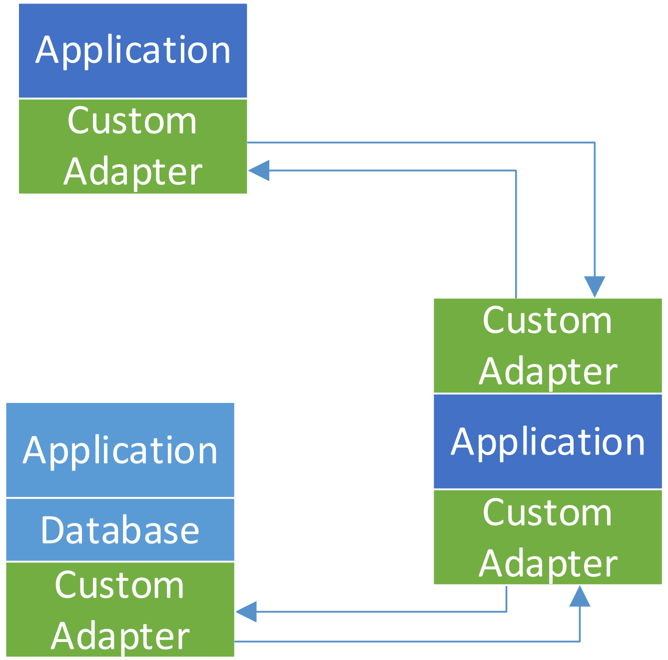
Spreadsheets & Manuals
- Operations procedures
- Safety Manuals
- Regulatory & Other Reporting
- Engineering Study Results

Approaches to Data Integration

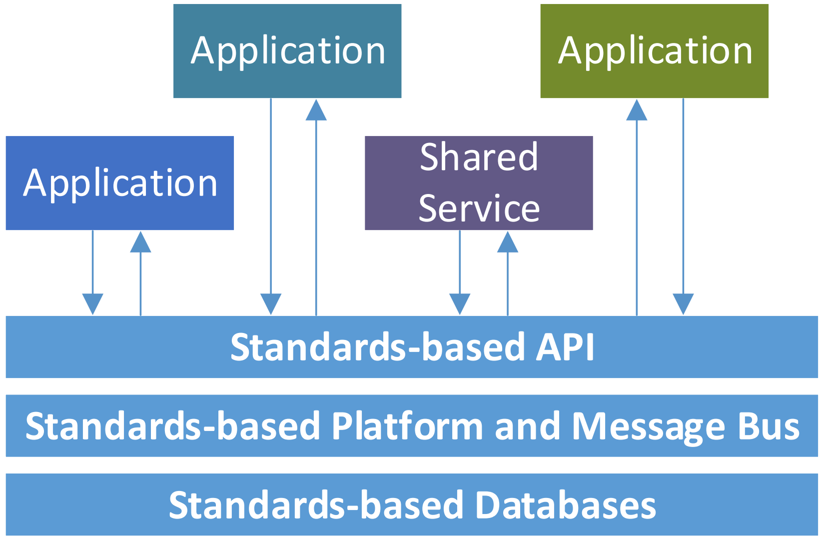
Single-vendor EMS/ADMS
Proprietary Data Format
Proprietary API



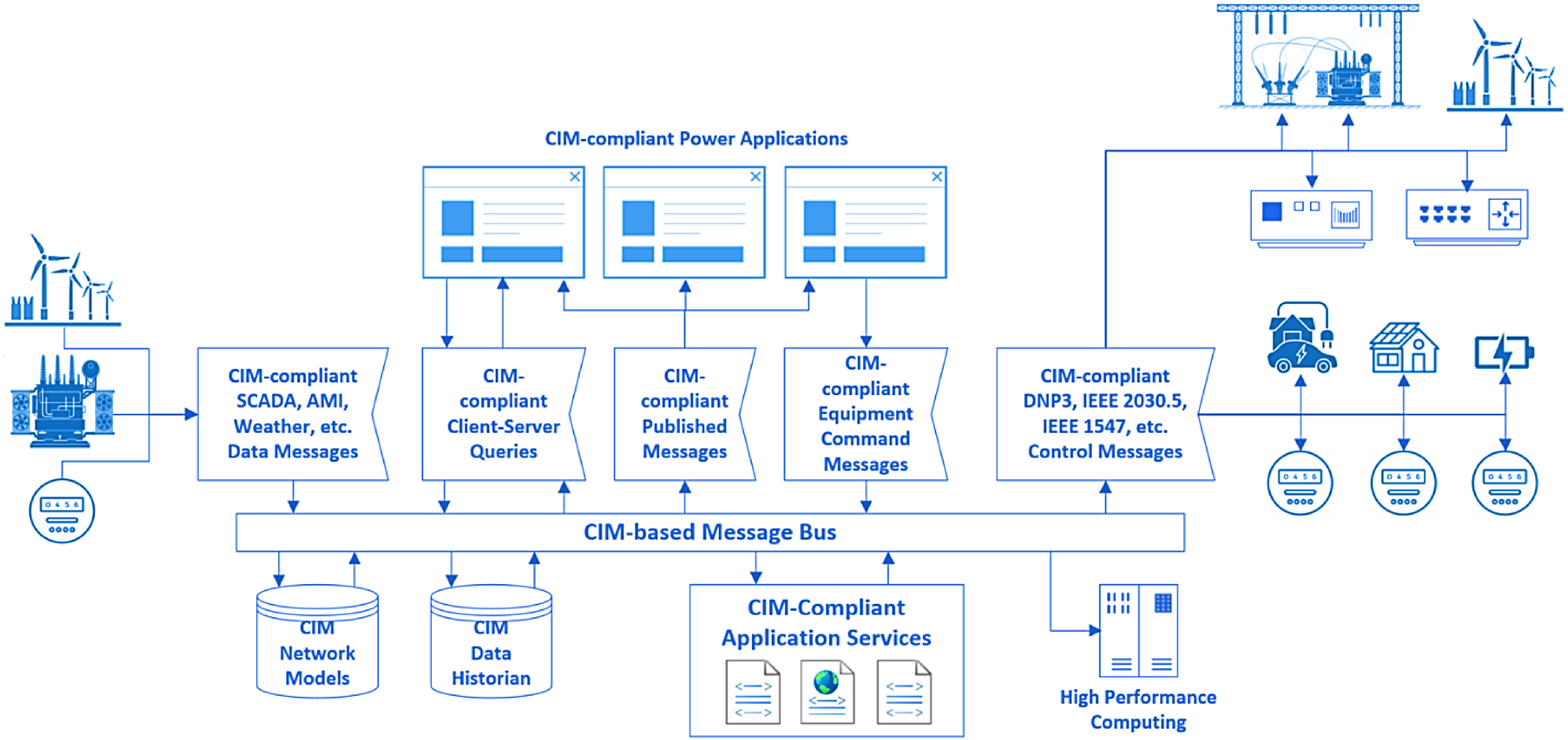
Custom Application Integration
(Very costly & fragile)



Standards-based Platform using an
Agreed-upon Information Model



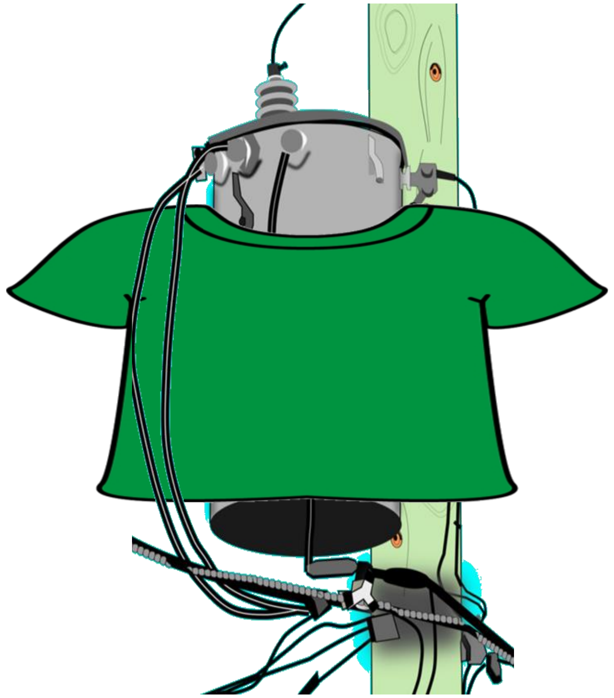
Standards-Based Platform Concept



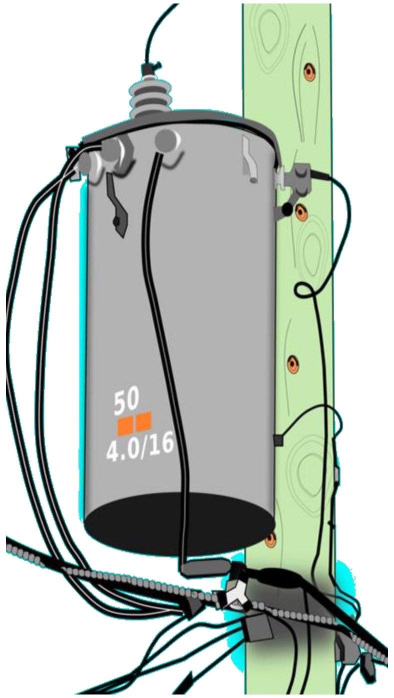
Need for a Consensus-based Vocabulary

- Information models provide an *ontology* to be able to ensure correct semantics and syntax used for messages, data, network models

Syntactically Correct:
"My transformer has a green shirt."



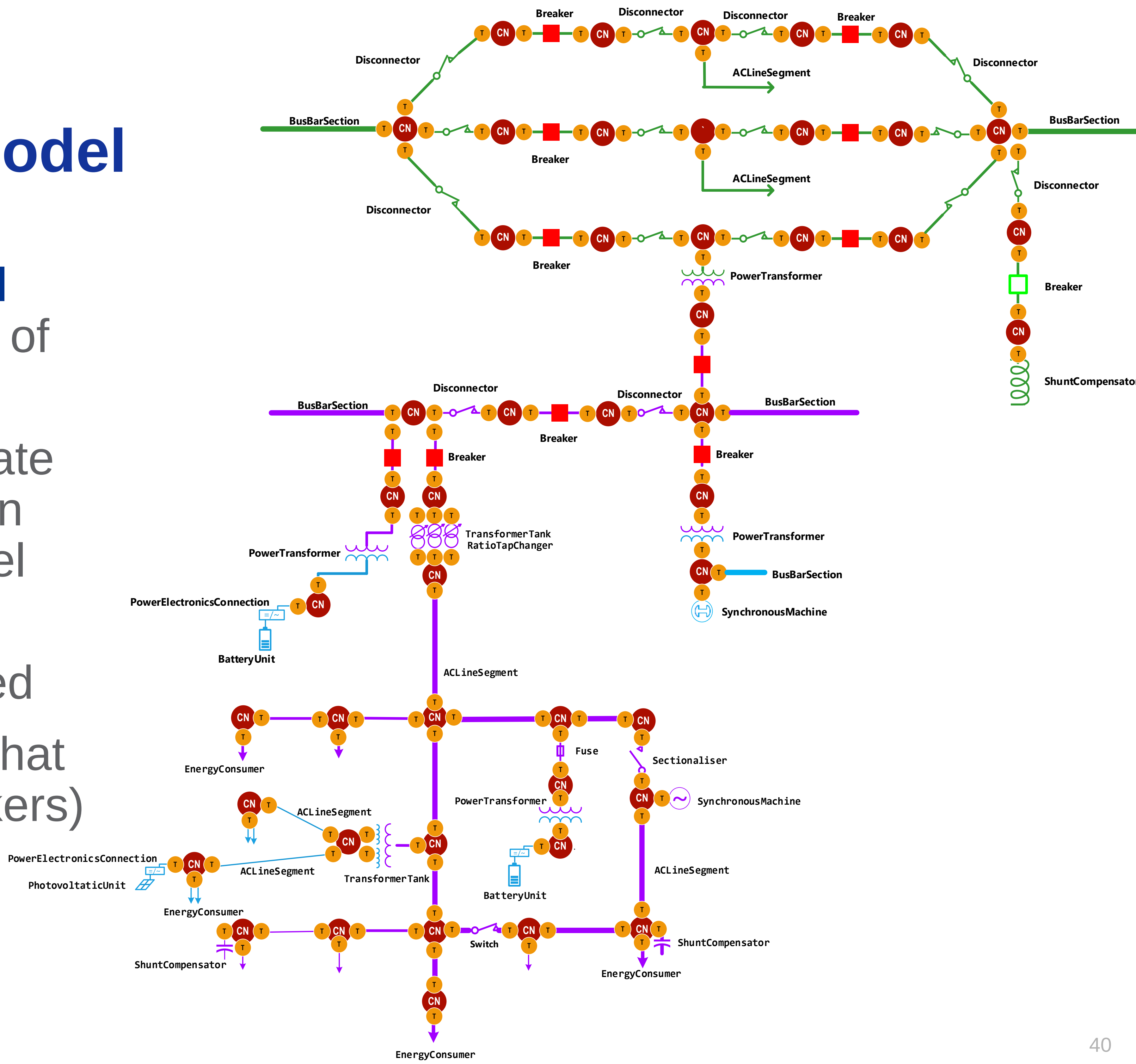
Semantically Correct:
"TransformerTank #50 has a high-side voltage rating of 4.0 kV."



- Agreed-upon information models such as CIM provide the consensus-based vocabulary needed for interpreting messages + data and ensuring objects are defined in a consistent manner

T+D Combined CIM Model

- Common Information Model provides consistent naming of classes and attributes
- Enables synthesis of separate transmission and distribution models into combined model
- Applications can use model queries to obtain info needed
- Only mapping is to ensure that boundary equipment (breakers) use consistent mRIDs across all models



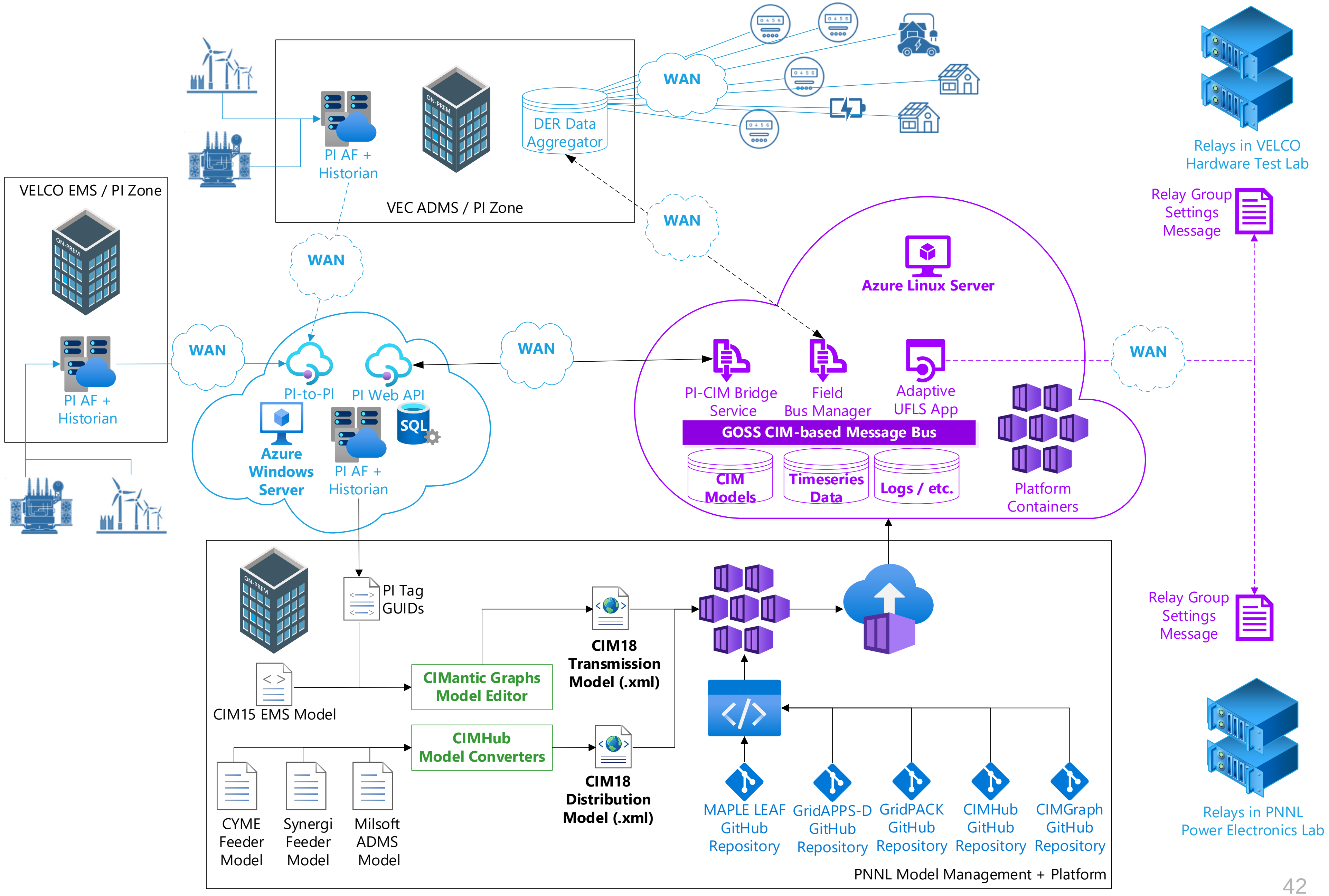
Cloud-based DER Data Integration

- Cloud-based data integration identified as viable path for ingesting + making available DER data from multiple utilities for MAPLE LEAF research platform.

- Piloting data integration in MAPLE LEAF Azure cloud testbed:
  - DER locations, nameplates, in-service date
  - DER measurements, AMI data, BTM resources
  - SCADA data via PI Historian
  - Distribution Feeder Models
  - Node-breaker EMS Transmission Models

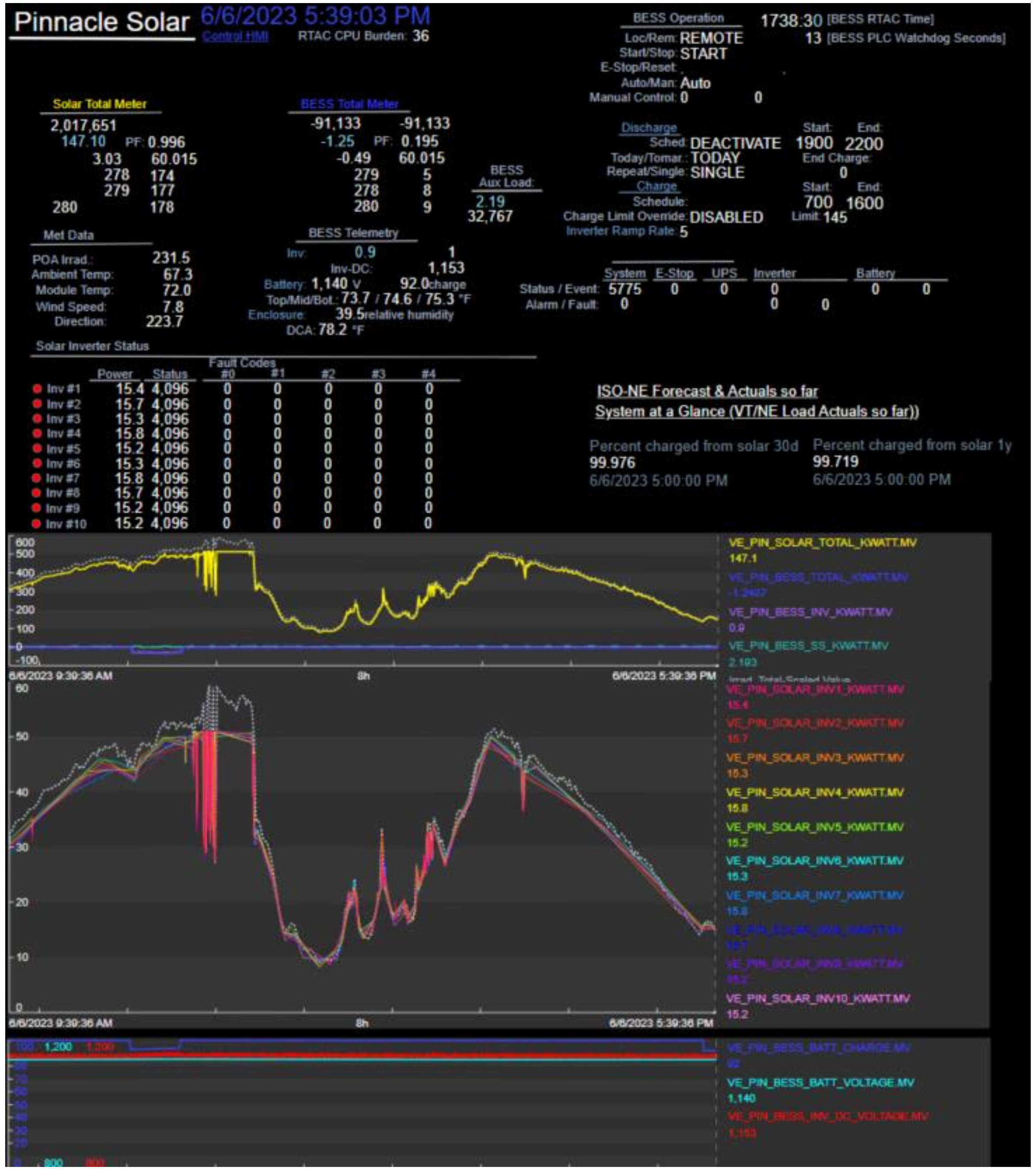
Cloud-based Testbed Architecture

- Have created Azure cloud testbed for real-time data integration
- Leveraging CIM and GridAPPS-D Platform
- Avoiding NERC CIP data security by pulling from PI Asset Framework + Historian
- Data is published to adaptive UFLS app over GOSS message bus
- May send relay update commands in year 3



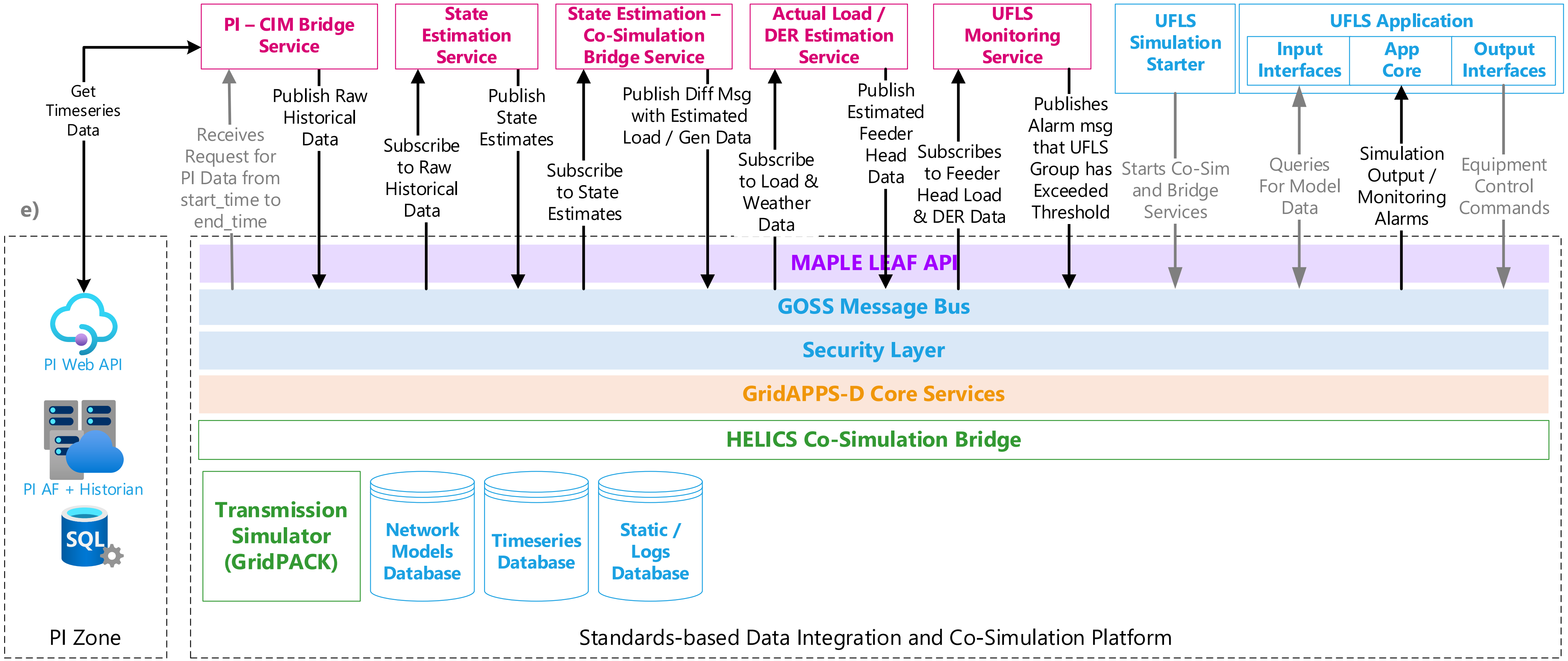
PI – to – PI Cloud Live Data Stream

- Real-time data link from VELCO PI Asset Framework + Historian to Azure cloud testbed
- Have started with VELCO-owned Pinnacle Solar PV farm with real-time + 2 years historical data
- Currently adding in distribution utility data (pending approval of data transfer authorizations)
- Data will be accessible to CIM-based platform / apps through PI-CIM bridge



Application Implementation Concept

- Service-based implementation of UFLS app leveraging structure of CIM-based message bus & real-time co-simulation



MAPLE BRANCH Project Overview

- **MAPLE BRANCH**: “Model-based Adaptive PLatform Environment for Broad Area Network Control Hierarchy”
- Focusing on providing system flexibility through data integration and coordination of distributed assets across transmission-distribution boundary
- Correcting power factor and volt-var optimization issues at T-D boundary caused by high penetrations of DERs and distribution-connected renewables

Pacific Northwest NATIONAL LABORATORY

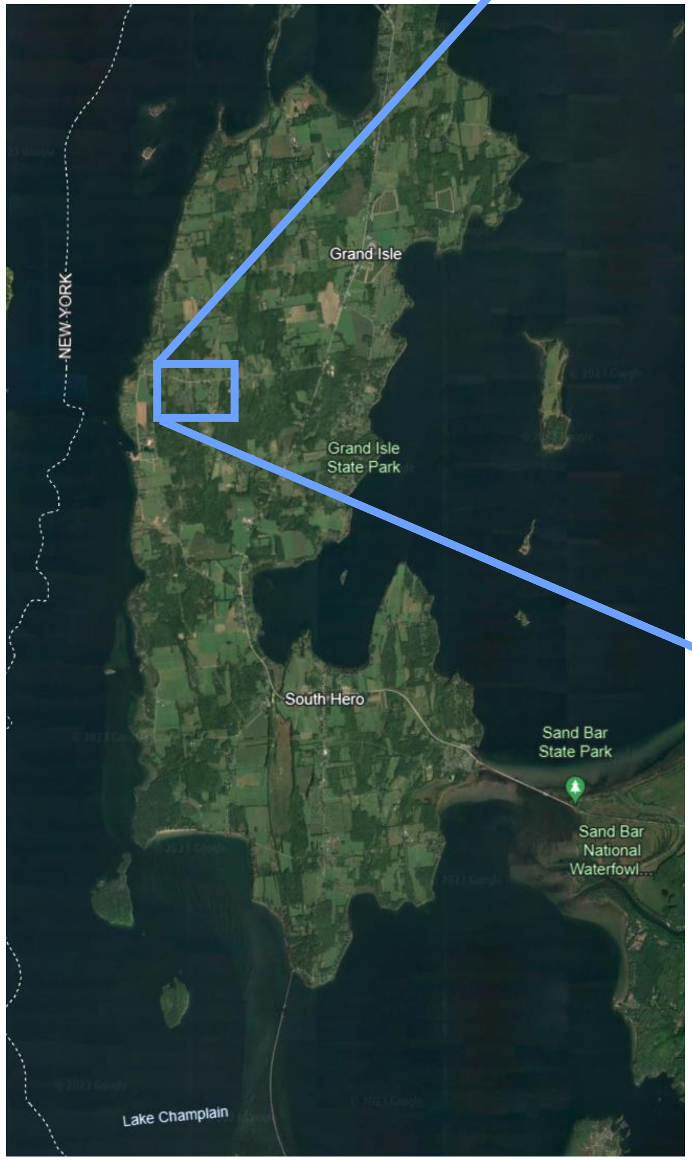
vermont electric power company VELCO

VERMONT ELECTRIC CO OP INC

OAK RIDGE National Laboratory

Background – DER Penetration

- High DER penetrations impacting ability to maintain voltage profile and power factor at T-D boundary
- Manual cap bank switching untenable long-term option
- Out-of-merit dispatch of generation required by ISO procedures to address significant deviations from load power factor



4.8 MW Grand Isle solar farm, connected at end of 12.47 kV distribution feeder

DERs and Voltage Regulation Resources

- Large number of DERs and limited number of traditional voltage control resources across study network (two meshed distribution feeders)

SCADA-connected Solar:
4.8 MW Grand Isle PV farm
1.0 MW Alburgh PV farm
4x 150kW PV sites
1x 500kW PV sites

Other DERs:
EV chargers: **80+**
Heat pumps: **722**
Tesla Powerwall: **7**

Customer BTM Solar:
South Hero Feeder: **1.5 MW**
South Alburgh Feeder: **1.4 MW**

Voltage Control:
Fixed Capacitor Banks: **6**
Substation Regulators: **2**

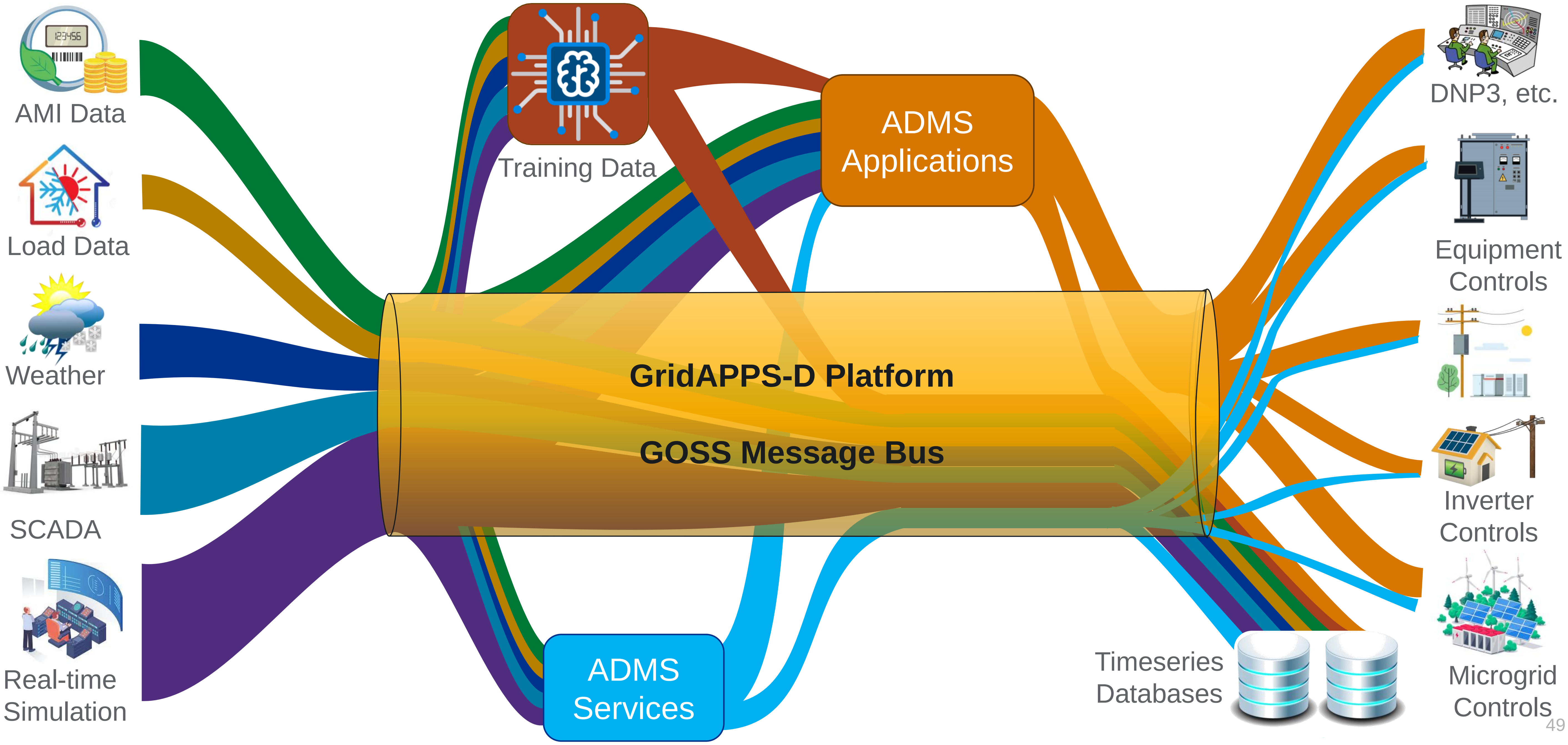
Operationally Relevant Questions

- How should Vermont Distribution Utilities meet ISO load power factor requirements at the South Hero interface and South Alburg interface while maintaining power quality at the distribution-level?

- For a non-inverter-based solution (i.e., cap banks, voltage regulators), what would be the optimal location and placement of the devices?

- For an inverter-based solution, what would be the optimal location and placement of the devices?

GridAPPS-D Platform for Data Integration & Co-Simulation



Summary

- The MAPLE LEAF and MAPLE BRANCH projects enable VELCO to cost effectively undertake research that generates real-world solution options to address key grid resiliency challenges VELCO faces right now.

- VELCO is grateful for the opportunity to work with the national labs’ team, and benefit from their cutting-edge technology and support.

- PNNL partnership improves VELCO’s collective ability to deliver a more affordable, reliable, equitable and sustainable grid.

Thank you

Alexander Anderson, PNNL
Alexander.Anderson@pnnl.gov

Dan Kopin, VELCO
dkopin@velco.com

Short Break

Power Sector Transmission & Distribution Data and Information

WEBINAR SERIES

Microgrid Communication and Data Flows

Cameron Brooks

Executive Director, Think Microgrid

U.S. DEPARTMENT OF ENERGY OFFICE OF ELECTRICITY

Los Alamos NATIONAL LABORATORY

OAK RIDGE National Laboratory

Pacific Northwest NATIONAL LABORATORY

Research Partnership

Animating questions:

- Can a consensus ‘data flow landscape’ be articulated?
- Can the corresponding ’taxonomy’ of data flows be characterized?
- What are current challenges and technical support opportunities?

U.S. Department of Energy | Office of Electricity

Oak Ridge National Laboratory

Think Microgrid

Microgrid Test Bed (COMMANDER)

- EPB Test Configurations
- Communications Protocols

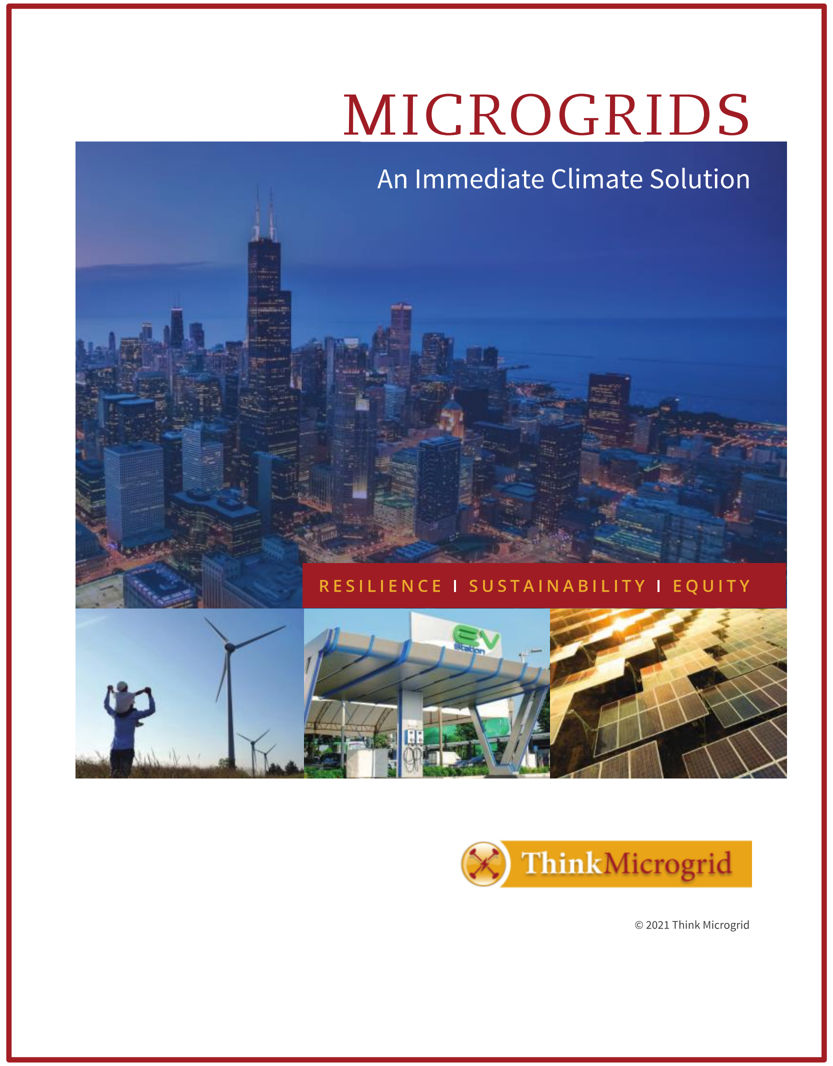
Stakeholder Engagement

- Microgrid Industry
- System Operators (utilities)
- Regulators and Policy Community

Think Microgrid

- A coalition of industry leaders with mission to provide a unified voice for the microgrid industry through **education**, **evangelism** and **engagement** with policy makers, public agencies and community leaders.

Vision Paper



Microgrids: An Immediate Climate Solution

- Technology Overview
- Policy Opportunities
- Project Highlights
- Complementary and interwoven opportunities to address resilience, clean energy and equity

  https://e9radar.link/thinkvision

Coming soon…

- State Policy Scorecard 2023

Project Objectives

1. Data Landscape Map

- Rooted in informational interviews and specific microgrids
- Intended to be applicable in wide range of contexts and market structures
- An implied ‘taxonomy’ based on four key attributes

2. Convening

- Nov. 7 – Knoxville, Tennessee
- Validate findings and characterize data needs

3. Findings Report and Guidance

- Presuming opportunities for research, technical assistance and convening

DOE Program Vision

Office of ELECTRICITY

Microgrid Program Strategy

Office of Electricity

The DOE Microgrid R&D Program vision is to facilitate the nation's transition to (1) a more resilient and reliable, (2) more decarbonized electricity infrastructure, in which (3) microgrids have a reduced cost and implementation times, while ensuring that microgrids support an equitable energy transition through prioritized provision of at least 40% of microgrid benefits going to disadvantaged communities in a secure manner. These three enumerated strategic goals are developed in the context that the United States' electricity system is becoming more distributed in nature, and that disruptions to the electricity delivery system (EDS) are occurring more frequently and with greater severity. The vision statement follows.

> *By 2035, microgrids are envisioned to be essential building blocks of the future electricity delivery system to support resilience, decarbonization, and affordability. Microgrids will be increasingly important for integration and aggregation of high penetration distributed energy resources. Microgrids will accelerate the transformation toward a more distributed and flexible architecture in a socially equitable and secure manner.*

The vision assumes a significant increase of DER penetration during the next decade, reaching 30-50% of the total generation capacity. In that context, the Microgrid R&D program seeks to accomplish these three goals:

Goal 1: Promote microgrids as a core solution for increasing the **resilience and reliability** of the EDS, supporting critical infrastructure and reducing social burdens during blue and black sky events

Goal 2: Ensure that microgrids serve as a driver of **decarbonization** for the US EDS by acting as a point of aggregation for larger number of DERs, with 50% of new installed DER capacity within microgrids coming from carbon-free energy sources by 2030.

Goal 3: **Decrease microgrid capital costs** by 15% by 2031, while reducing **project development, construction and commissioning** times by 20%.

"By 2035, microgrids are envisioned to be essential building blocks of the future electricity delivery system to support resilience, decarbonization, and affordability….

The vision assumes a significant increase of DER penetration during the next decade, reaching 30-50% of the total generation capacity."

Why are these conversations important?

1. **Urgently Achieving Scale**
   - Realizing this vision requires robust digital infrastructure…

2. **Defining Digital Interconnection**
   - At each interface, there are corresponding rights and responsibilities…

3. **Informing Market Design**
   - There is a social economy surrounding the grid
   - Markets (broadly defined) are combination of technology, economy and policy

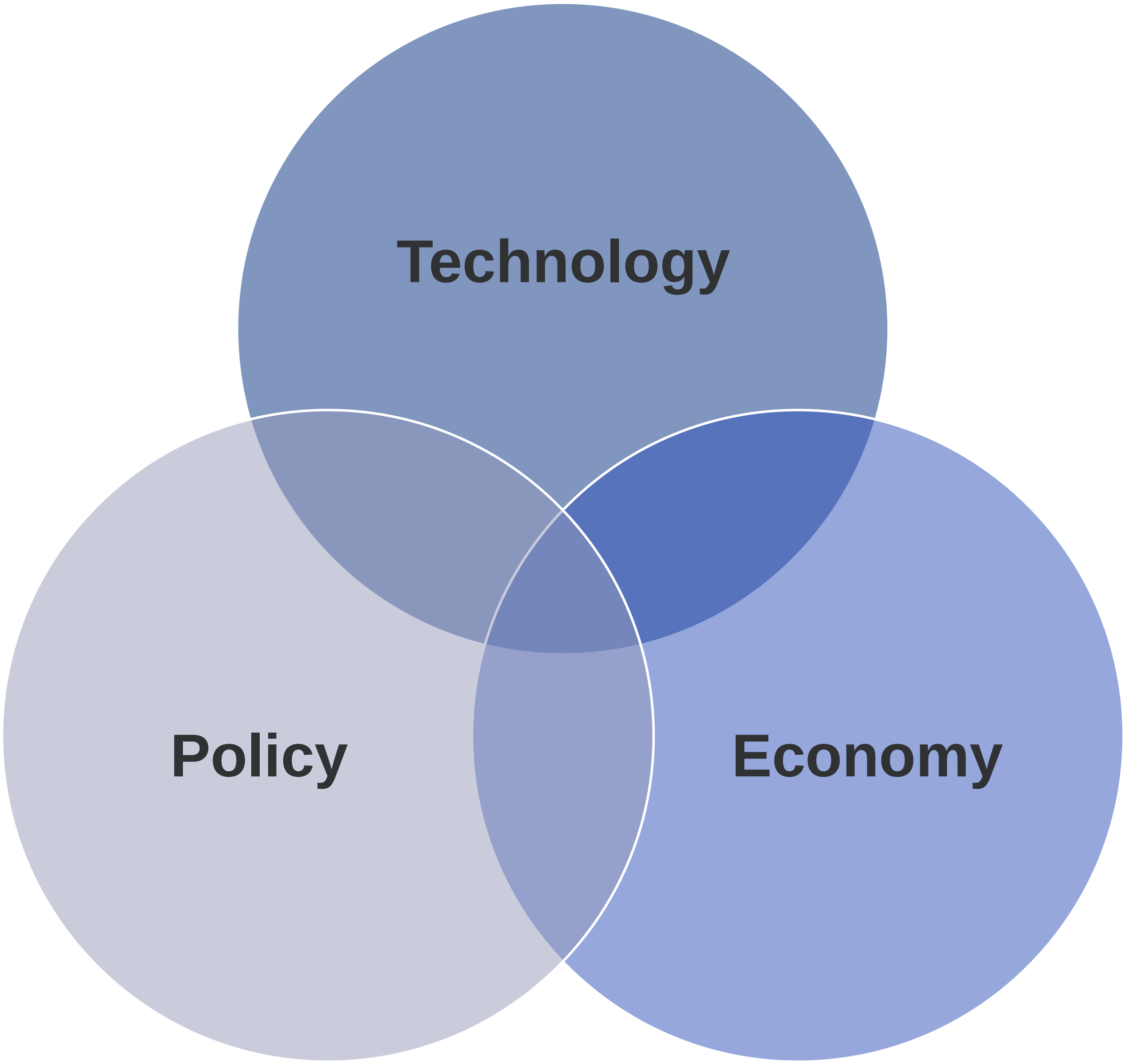
Why are these conversations important?

1. **Urgently Achieving Scale**
   - Realizing this vision requires robust digital infrastructure…

2. **Defining Digital Interconnection**
   - At each interface, there are corresponding rights and responsibilities…

3. **Informing Market Design**
   - There is a social economy surrounding the grid
   - Markets (broadly defined) are combination of technology, economy and policy

Market Design as “social economy”



DATA LANDSCAPE MAP

Four component characteristics (or ‘dimensions’)…

1. **ACTORS**	Who is sharing or requiring information?
2. **TYPES**	What information is being shared?
3. **TIME**	What time horizon is applicable?
4. **PATHWAY**	Where is data flowing?

DATA LANDSCAPE MAP

Four component characteristics (or ‘dimensions’)…

1. **ACTORS**	Who is sharing or requiring information?
2. **TYPES**	What information is being shared?
3. **TIME**	What time horizon is applicable?
4. **PATHWAY**	Where is data flowing?

ACTORS

1. Scale (voltage)

bulk power
distribution
grid services
microgrid
grid edge

ACTORS

1. Scale (voltage)

- bulk power
- distribution
- grid services
- microgrid
- grid edge

ACTORS

grid architecture	grid operations	utility customer	regulated markets	private markets	public stakeholders
Bulk Power	Transmission Operator	Transmission Owners	Bulk Power Market		Federal Regulator
Distribution	Distribution Operator	**UTILITY**	Distribution Market		**State Regulator**
Grid Services		Distribution Services	Energy Retailers		State Executive… Energy Office… Agencies
Microgrid	**Microgrid Operator**			Energy Services	Local Government
Customer	**CUSTOMER**			Data Services	Public Stakeholders Corporations

DATA LANDSCAPE MAP

Four component characteristics (or 'dimensions')…

1. ACTORS	Who is sharing or requiring information?
2. **TYPES**	What information is being shared?
3. TIME	What time horizon is applicable?
4. PATHWAY	Where is data flowing?

TYPES

ARCHITECTURAL	OPERATIONAL		FINANCIAL		PERFORMANCE
grid architecture	der operations	utility operations	regulated markets	policy	stakeholders
Bulk Power	Transmission Operator	Transmission Owners	Bulk Power Market		Federal Regulator
Distribution	Distribution Operator	**UTILITY**	Distribution Market		**State Regulator**
		Distribution Services	Energy Retailers		State Executive… Energy Office… Agencies
Microgrid	**Microgrid Operator**			Energy Services	Local Government
Customer	**CUSTOMER**			Data Services	Public Stakeholders Corporations

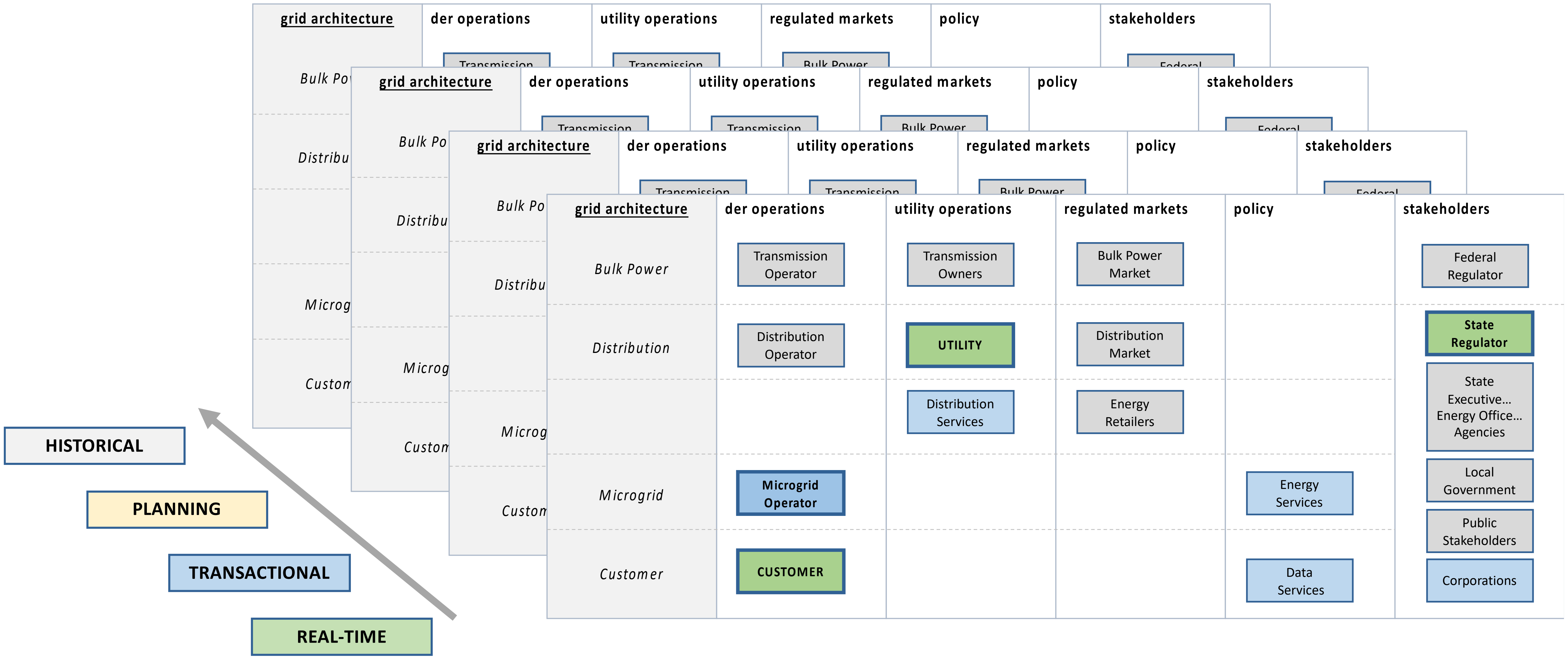
CUSTOMER

DATA LANDSCAPE MAP

Four component characteristics (or 'dimensions')…

1. **ACTORS**	Who is sharing or requiring information?
2. **TYPES**	What information is being shared?
3. **TIME**	What time horizon is applicable?
4. **PATHWAY**	Where is data flowing?

TIME


grid architecture
der operations
utility operations
regulated markets
policy
stakeholders
Bulk Power
Distribution
Microgrid
Customer
Transmission Operator
Distribution Operator
Microgrid Operator
CUSTOMER
Transmission Owners
UTILITY
Distribution Services
Bulk Power Market
Distribution Market
Energy Retailers
Energy Services
Data Services
Federal Regulator
State Regulator
State Executive... Energy Office... Agencies
Local Government
Public Stakeholders
Corporations
HISTORICAL
PLANNING
TRANSACTIONAL
REAL-TIME

DATA LANDSCAPE MAP

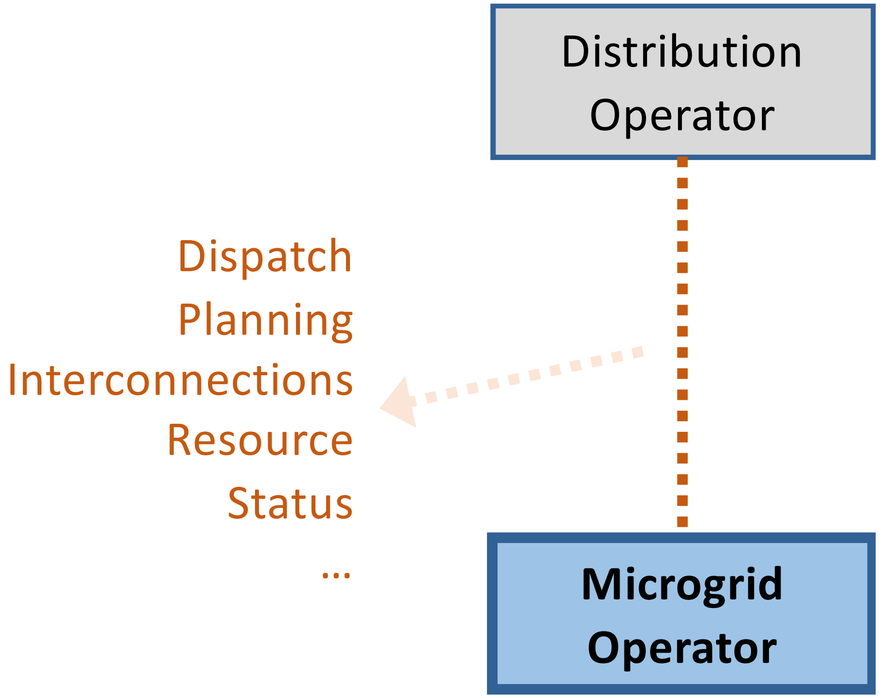
Four component characteristics (or ‘dimensions’)…

1. **ACTORS** Who is sharing or requiring information?
2. **TYPES** What information is being shared?
3. **TIME** What time horizon is applicable?
4. **PATHWAY** Where is data flowing?

PATHWAY

grid architecture	grid operations	utility customer	regulated markets	private markets	public stakeholders
Bulk Power	Transmission Operator	Transmission Owners	Bulk Power Market		Federal Regulator
Distribution	Distribution Operator	**UTILITY**	Distribution Market		**State Regulator**
Grid Services		Distribution Services	Energy Retailers		State Executive… Energy Office… Agencies
Microgrid	**Microgrid Operator**			Energy Services	Local Government
Customer	**CUSTOMER**			Data Services	Public Stakeholders Corporations

PATHWAY


Distribution Operator
Dispatch
Planning
Interconnections
Resource
Status
...
Microgrid Operator

TAXONOMY

ARCHITECTURAL	OPERATIONAL	FINANCIAL	PERFORMANCE	CUSTOMER
• Grid Topology • Interconnection and registration • Critical facilities • Equity demographics • Adjacent Infrastructure • Planning Information • Communication Systems	• Customer Energy Usage • Dispatch Signals • DER authentication and status • Grid Conditions • Weather	• Power Prices • Capacity market information • Utility rates & tariffs • Settlement information • Fuel prices	• Resource Mix • Emissions profile • Reliability • Resilience	• Account Information • Enrollment • Customer demographic • Customer Assets

Moving Forward

- **Convening:**
  - November 7, 2023
  - Knoxville, Tennessee
  - *Inquiries and participant recommendations welcome*

- **Findings Report:**
  - Summary of data landscape map and taxonomy
  - Opportunities and Recommendations

The data conversation is now…and its relevance is growing more urgent.

Thank you

Cameron Brooks, Think Microgrid
cbrooks@e9insight.com

Power Sector Transmission & Distribution Data and Information

WEBINAR SERIES

Discovery Through Situational Awareness

Jim Follum

PNNL

U.S. DEPARTMENT OF ENERGY OFFICE OF ELECTRICITY

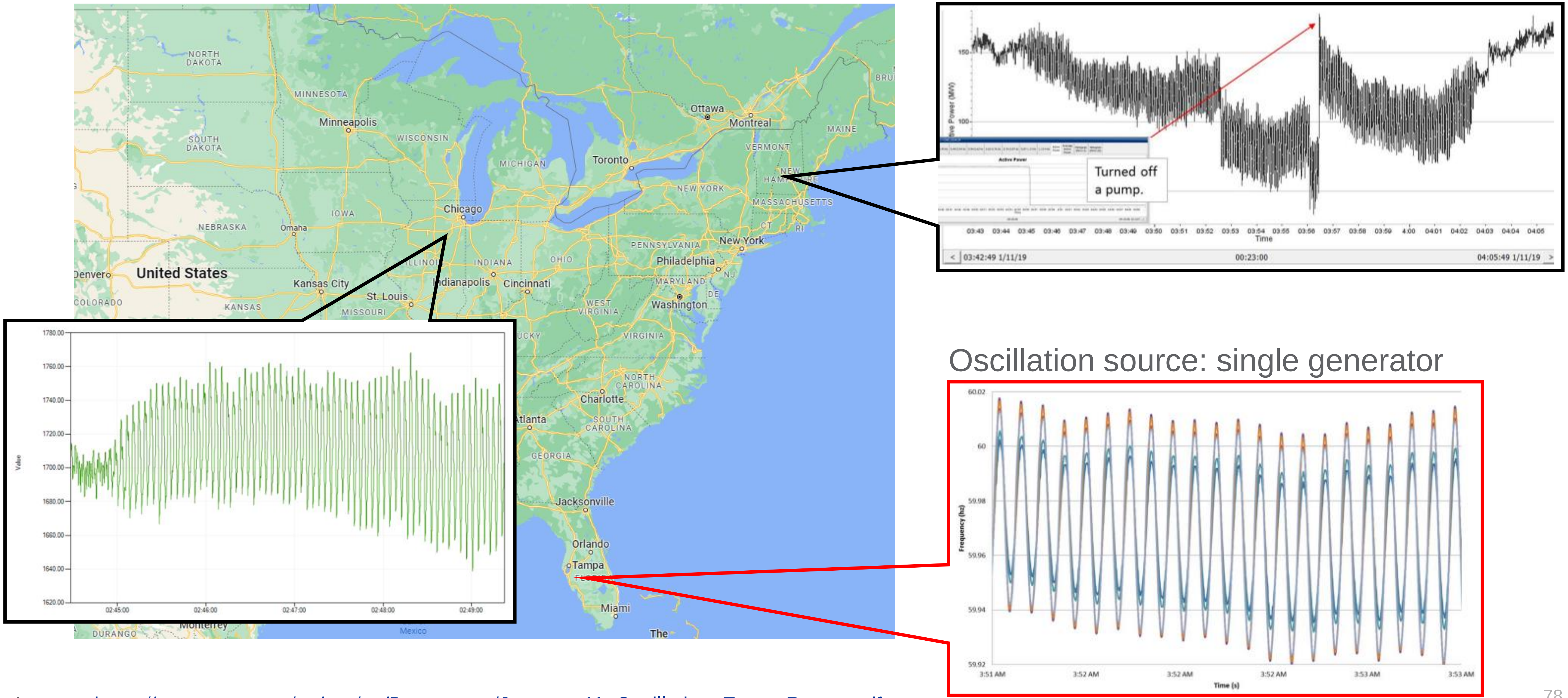
Los Alamos NATIONAL LABORATORY

OAK RIDGE National Laboratory

Pacific Northwest NATIONAL LABORATORY

PNNL-SA-191005

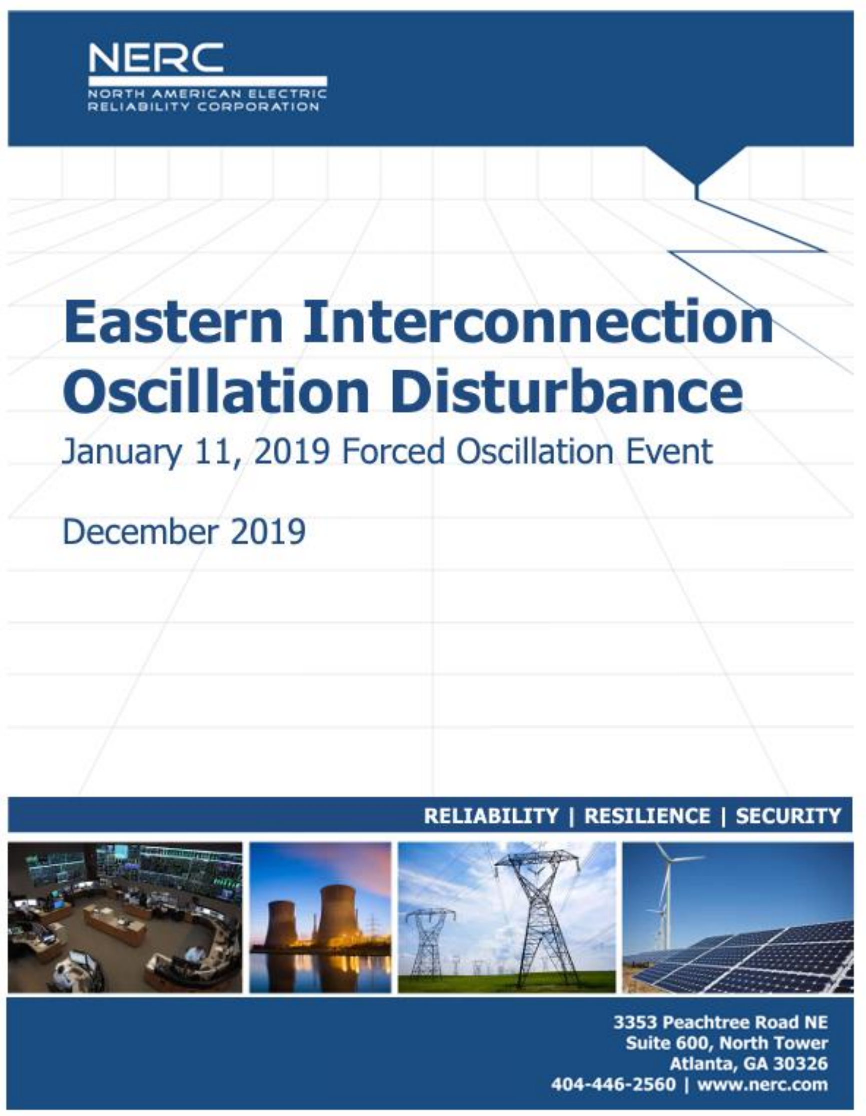
Motivation



Oscillation source: single generator

Images: https://www.nerc.com/pa/rrm/ea/Documents/January_11_Oscillation_Event_Report.pdf

Motivation



Key Findings

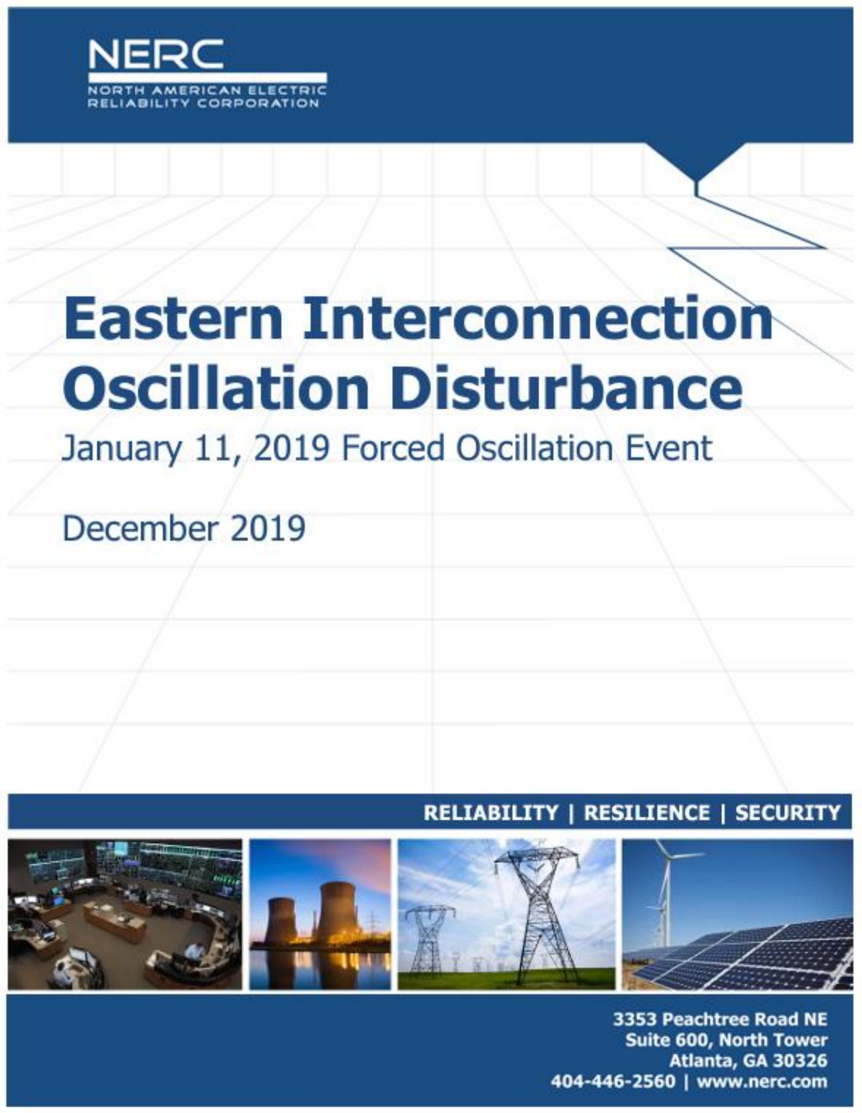
Key findings identified during the analysis of the forced oscillation within the plant include the following:

- A failed PT connection and errored voltage measurement in the PLI turbine controls caused a steam turbine at a combined-cycle power plant to oscillate for around 18 minutes before local plant personnel removed the unit from service.
- While redundancy was built into the plant control and protection system inputs, the turbine controls relied on a single PT measurement. This measurement was different from the protection system input PT measurement. Hence, the protection system was unaffected by the failed PT measurement.
- PLI operation caused the intercept valves of the steam turbine to shut and reopen periodically with a cyclical period of about four seconds. This resulted in oscillatory power output with a frequency of around 0.25 Hz.
- Many different alarms that needed troubleshooting to identify their root causes challenged the plant operators. Prioritization of operator alarms is as much an issue for generator control centers as it is for transmission energy management systems.

Key findings identified during the analysis focused on the wide-area impacts of the oscillation disturbance include the following:

- The 0.25 Hz forced oscillation interacted with the natural system mode near that frequency, causing the entire EI to experience the forced oscillation. Two out of the three conditions required[4] for a forced oscillation to strongly resonate with a natural system mode were satisfied. The oscillation frequencies between the forced oscillation and the natural system mode matched, and the source location was in a high participation area of the natural system mode. However, the natural system mode was well-damped.
- The generating unit experienced oscillations of around 200 MW peak-to-peak; however, power swings were observed as far as the New England area of about 50 MW.
- RCs were aware of the oscillation event relatively quickly by using both SCADA data and advanced applications and PMU measurements. RCs sought coordination activities, including use of the RC hotline; however, the RC hotline was inoperable due to technical issues. RCs were forced to call neighboring RCs individually that led to misinformation and mischaracterization of the event initially. Wide-area operator action did not contribute to mitigating the oscillation event, and most tools were ineffective at identifying a source location for the oscillation.
- The forced oscillation appears to have grown in energy until the unit (forcing function) was disconnected from the BPS.
- From an interconnection-wide standpoint, the GridEye/FNET system provided one of the most effective means of quickly understanding the extent of the disturbance. Frequency disturbance recorders and SCADA measurements available to NERC helped quickly identify a potential source of the oscillation and the severity of the event.

Motivation



Recommendations

Recommendations based on the key findings identified for the forced oscillation within the plant include the following:

- Generator turbine controls, including PLI and other types of controls that could result in a cyclic behavior from the generator, should avoid using a reset timer that has a period close to the reciprocal of the natural system modes (i.e., T = 1/f). Generally, this is in the range of 0.1–0.8 Hz; this relates to cyclical timers in the range of 1.25 seconds to 10 seconds. In particular, the frequency of the following dominant interconnection-wide modes should be avoided:5
  - Eastern Interconnection: 0.16–0.33 Hz (3.3–6.5 seconds)
  - Texas Interconnection: 0.6–0.75 Hz (1.33–1.66 seconds)
  - Western Interconnection: 0.24–0.42 Hz (2.38–4.17 seconds)
- Turbine controls should not have a single point of failure, including PT and current transformer input measurements that could fail and cause abnormal or unexpected turbine actions.
- The PLI circuit design in the turbine and generator control systems should consider tripping the unit after a short time for these types of persistent alarms to ensure integrity and safety of plant equipment and personnel.
- Training for Generator Operators (GOPs), RCs, Balancing Authorities (BAs), and Transmission Operators (TOPs) outlining root cause analysis and specific actions to take or not to take during oscillation events should be developed and reviewed periodically.

Recommendations based on the key findings focused on the wide-area impacts of the oscillation disturbance include the following:

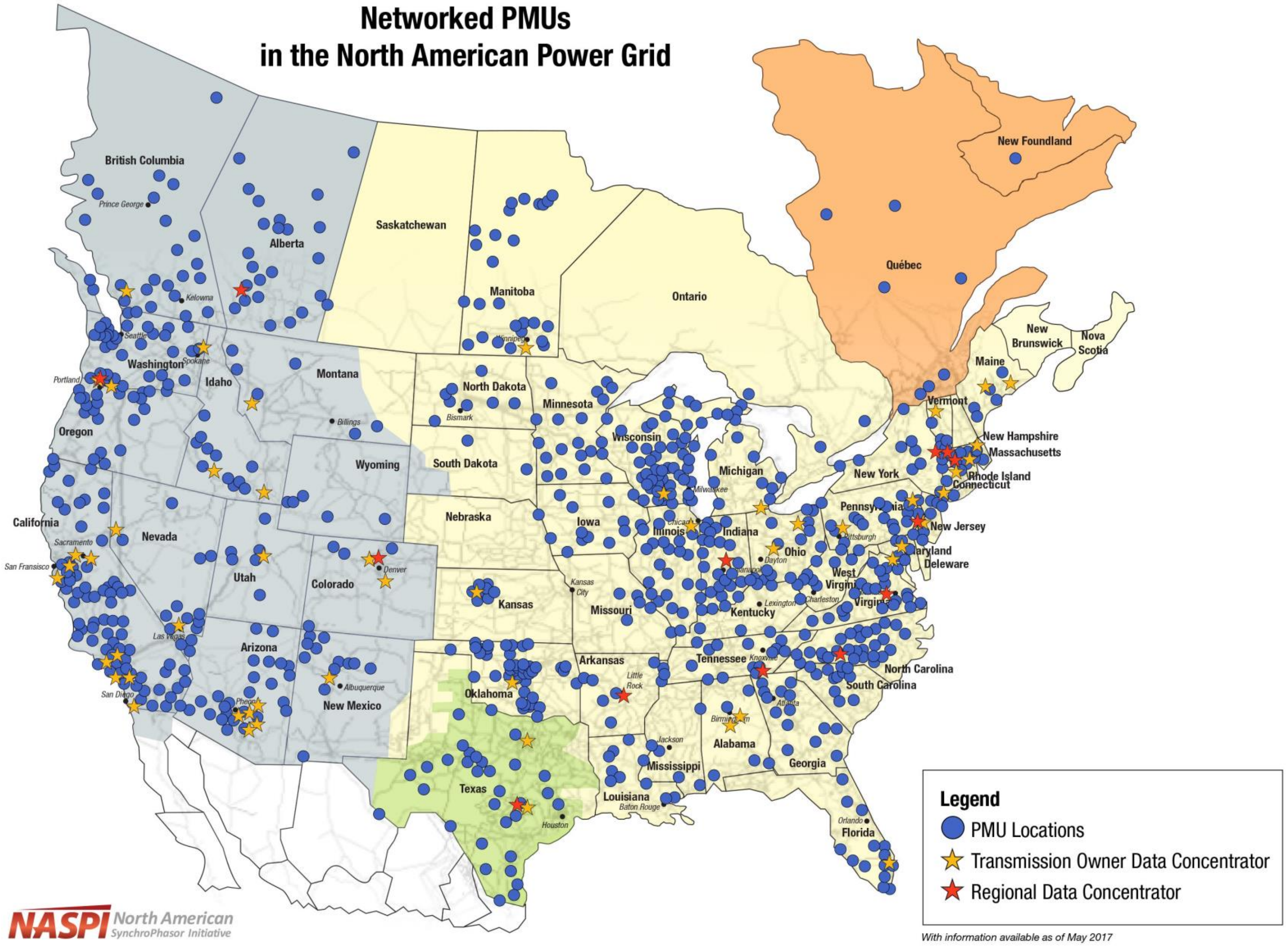
- RCs should have real-time oscillation detection tools in place to identify when oscillations are occurring, determine if it is limited locally within their footprint or across a wider area, and distinguish between forced oscillations and poorly damped natural system modes.
- RCs should improve communication with neighboring RCs in the event of widespread oscillation disturbances on the BPS. Operating procedures could be an effective means of ensuring this coordination upon identification of an oscillation.
- RCs should consider jointly developing interconnection-wide oscillation detection and source location applications using interconnection-wide PMU and SCADA data.
- The industry should develop open-source, publicly available robust tools for performing oscillation analysis that can be used by various entities:
  - The industry should seek improvements to standardized data formats for offline engineering analysis using large volumes of PMU data.
  - The NERC Synchronized Measurement Subcommittee (SMS) should develop guidance on oscillation analysis methods to encourage consistency in monitored quantities and thresholds.
- Based on a survey of RCs, NERC SMS should develop a white paper identifying any potential gaps or areas for improvement in the NERC Reliability Standards pertaining to RC-to-RC coordination and the use of PMU data.
- Commercially available simulation software should develop or improve the capability of simulating forced oscillations such that grid planners can analyze the effects of these oscillations across the BPS.

Eastern Interconnection Situational Awareness and Monitoring System (ESAMS) Concept

- Software tool developed by Electric Power Group (EPG) and PNNL with leadership from LBNL
- Purpose
  - Introduce a common, high-level interconnection-wide view based on synchrophasor information
  - Improve coordination among reliability coordinators
- Core capabilities
  - Analyze Phasor Measurement Unit (PMU) data streamed from across the grid
  - Detect oscillations in power and system frequency impacting a wide area
  - Determine which reliability coordinator the oscillation is originating from
  - Deliver notifications via email

Phasor Measurement Units

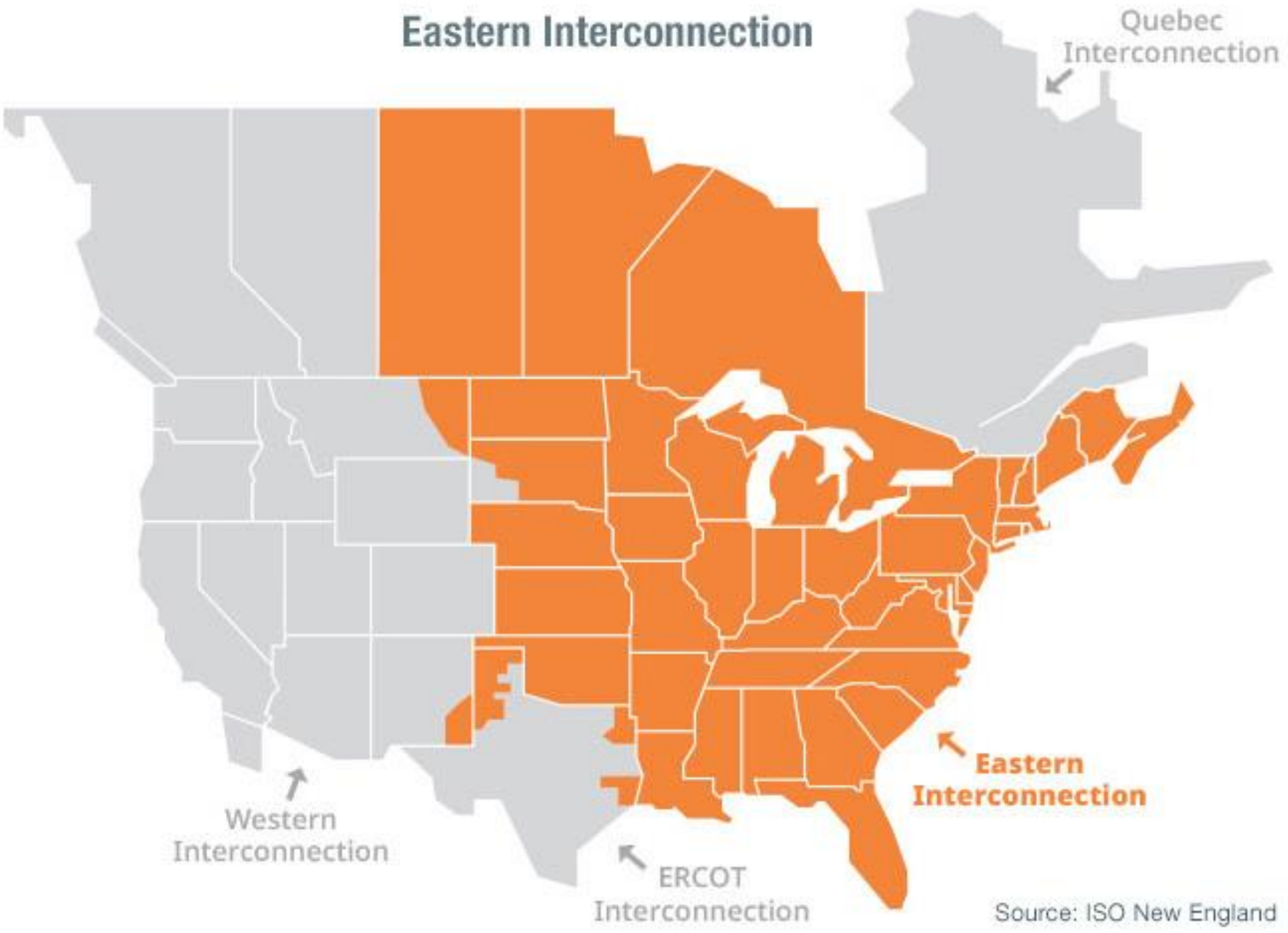
- Report phasors (magnitude and angle) of voltage and current
- High reporting rate, typically 30 or 60 reports per second
- Time-synchronized at point of measurement, typically using GPS



Source: https://www.naspi.org/node/749

Data Sharing

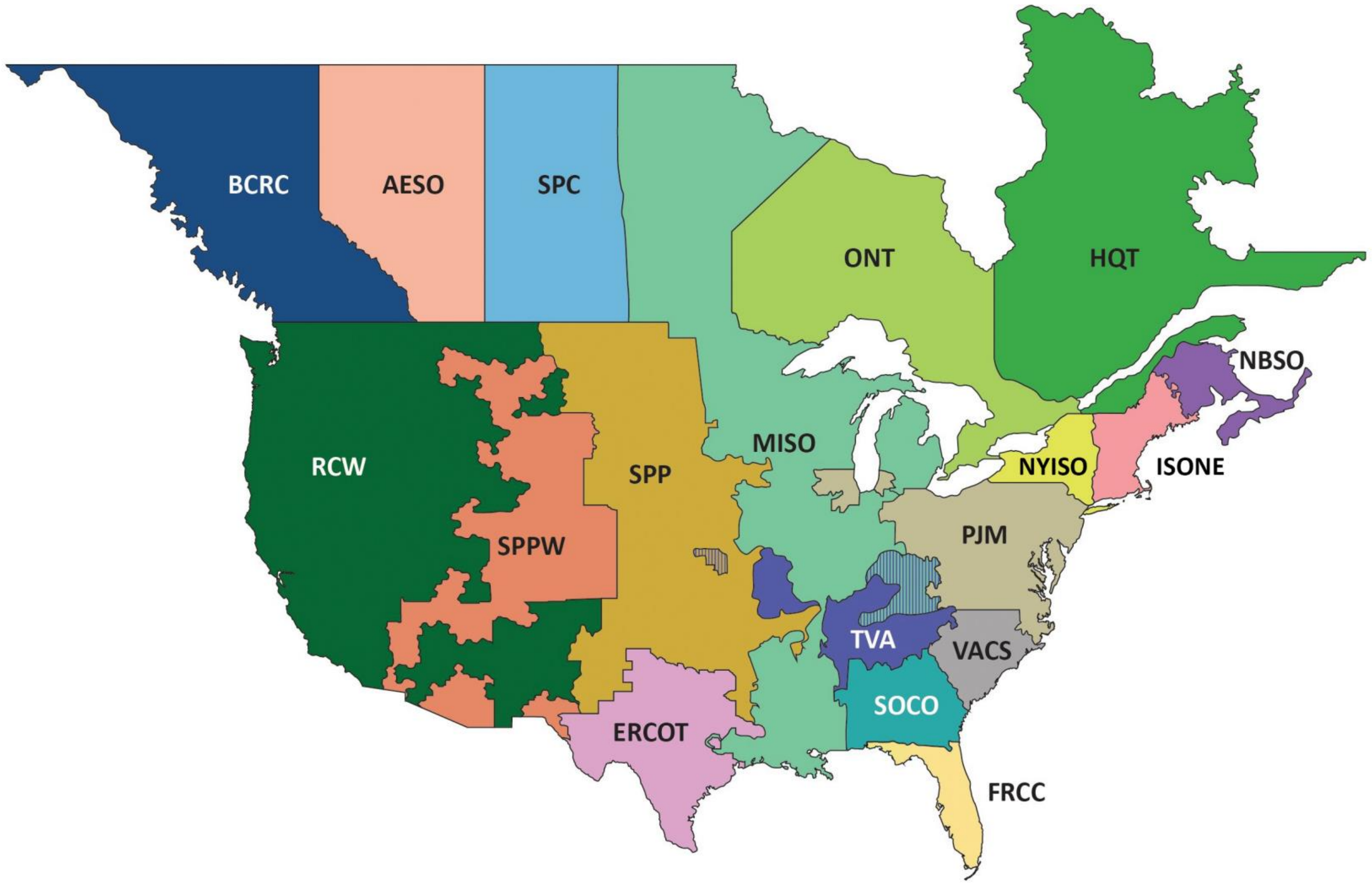
- ESAMS's wide-area view was dependent on synchrophasor data being streamed across the interconnection



Source: https://www.iso-ne.com/about/key-stats/maps-and-diagrams

Data Sharing

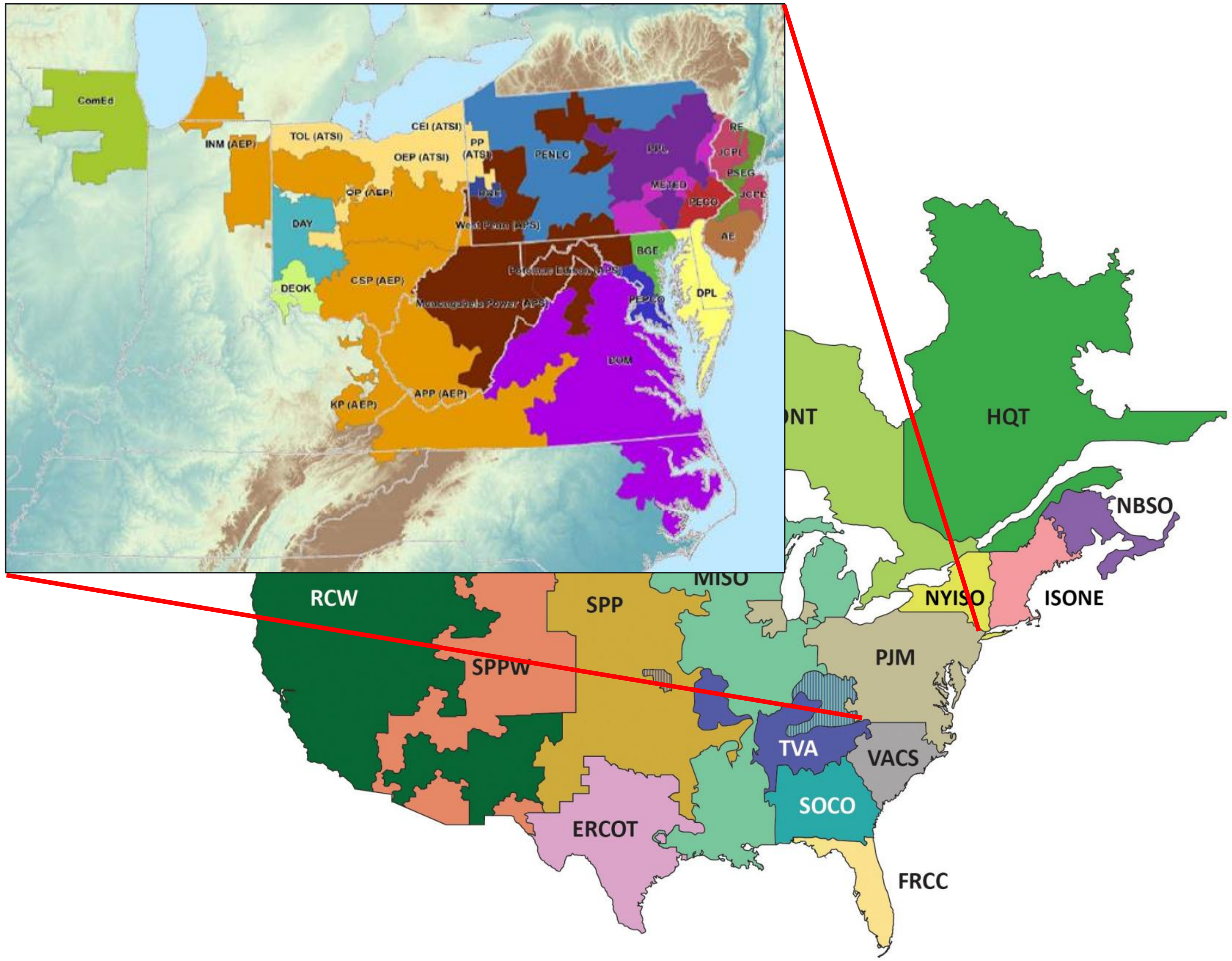
- Reliability Coordinators (RCs) are typically the organizations most interested in wide-area oscillations



Source: https://www.nerc.com/pa/rrm/bpsa/Pages/RCs.aspx

Challenge: Data Quality

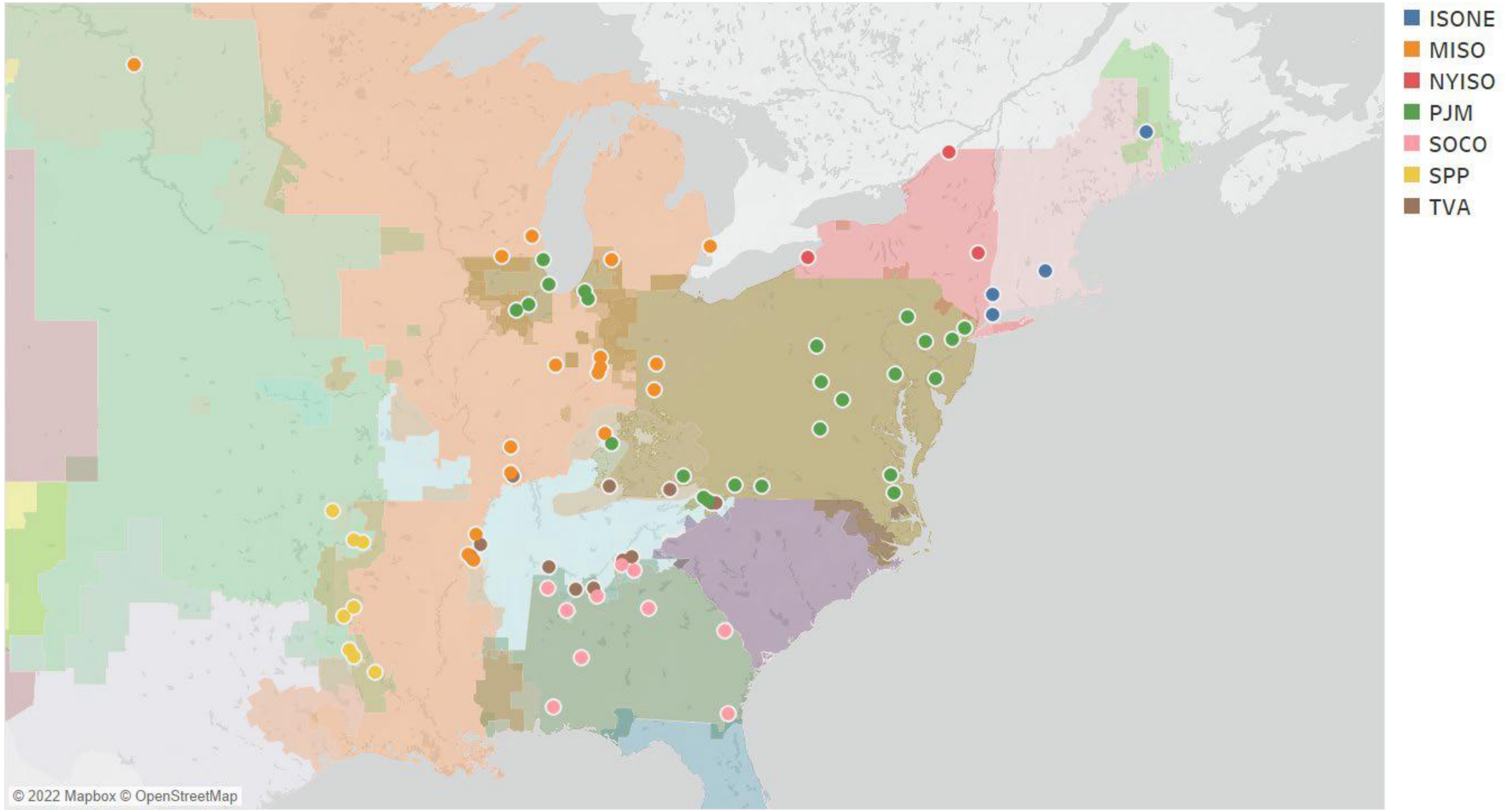
- Reliability Coordinators (RCs) are typically the organizations most interested in wide-area oscillations
- However, it’s the transmission system owners (TOs) that own the PMUs
- If a TO is uninterested in PMU data, measurement quality suffers



Source: https://www.nerc.com/pa/rrm/bpsa/Pages/RCs.aspx
Source: https://www.pjm.com/~/media/committees-groups/committees/mic/20140604/20140604-item-09f-qualifying-transmission-upgrade-qtu-credit-requirement-education.ashx

Data Sharing in ESAMS

- ESAMS was hosted by PJM
- Six other organizations provided data: SPP, MISO, NYISO, ISONE, SOCO, TVA
- Data was shared across EIDSN's Electric Information network (EInet)
  - EIDSN is a corporation established by Reliability Coordinators in 2014 to facilitate sharing SCADA and PMU data



Source: J. Eto, N. Nayak, S. Mo, K. Martin, S. Xue, H. Silva-Saravia, J. Chen, J. Follum, N. Betzsold, S. Biswas, T. Yin, "Eastern Interconnection Situational Awareness Monitoring System (ESAMS) Demonstration Project." Lawrence Berkeley National Laboratory, 2022.

Challenge: Data Sensitivity

- PMU data from the bulk power system is considered Critical Energy Infrastructure Information (CEII), and operating entities are careful to protect it
- Through EIDSN, the reliability coordinators participating in ESAMS could easily share data
- A Non-Disclosure Agreement (NDA) was established to allow PNNL and EPG to access raw measurements and results

Challenge: Data Volume

- Operating entities have mature systems for archiving PMU data
- For the ESAMS demonstration, storage was limited for high-volume PMU data
- We retained about a week of input data
- Following notification emails, relevant data was distributed to the project team for validation and retention

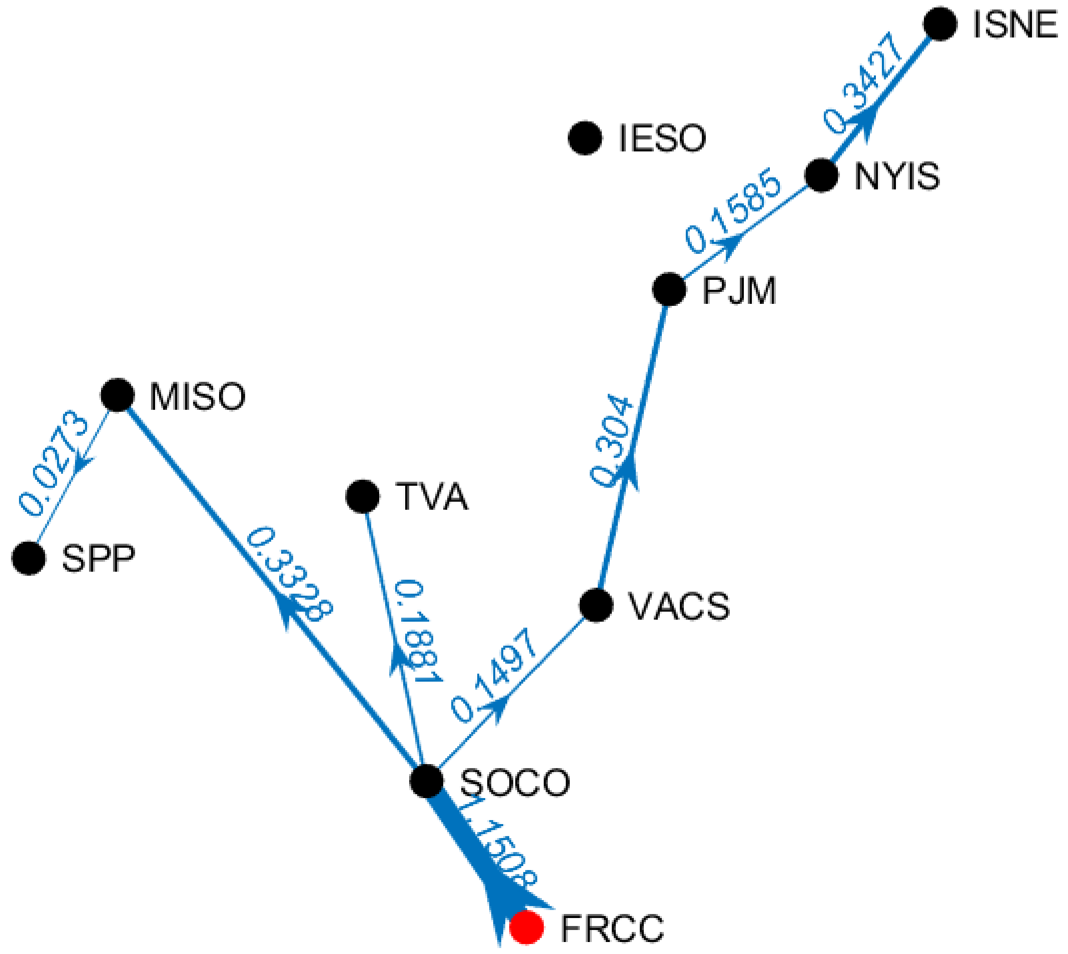
Synchrophasor Data	Storage Requirement
4 PMUs, each with: • 8 phasors (32 total) • 6 analogs (24 total) • 2 digital words (8 total)	**30-Day Archive:** 60 GB **60-Day Archive:** 120 GB

- Archiving at 60 messages/second
- Archiving floating point data
- 2 digital words = 32 discrete status bits

Source: https://selinc.com/api/download/8196/

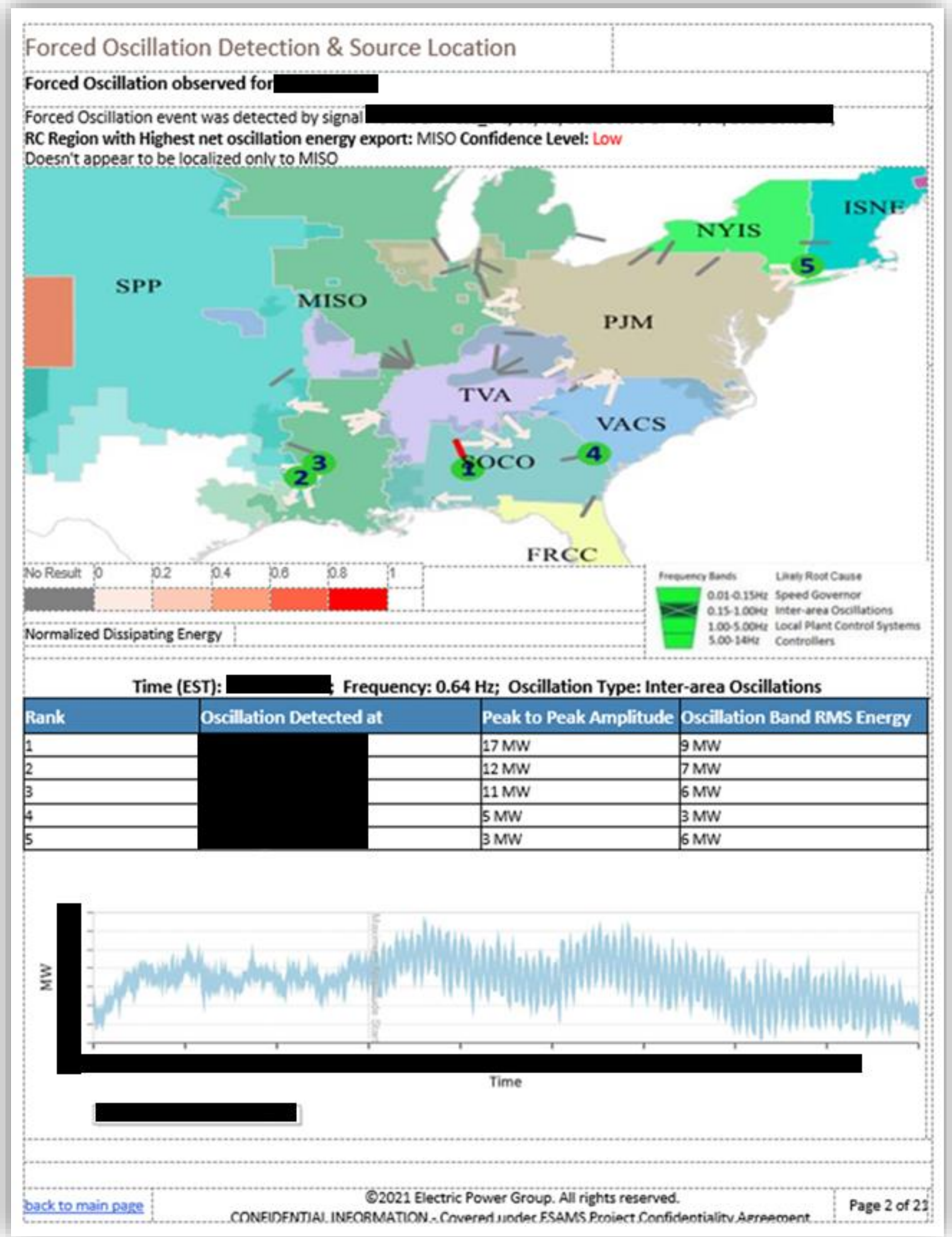
Example Results: Regional Oscillation Source Localization

- Live demonstration ran from June 2021 through March 2022
- ESAMS analyzed measurements from PMU's monitoring tie-lines between operating entities
- When a wide-area oscillation was detected, its energy flow through the system was tracked back to the source



Example Results: Regional Oscillation Source Localization

- Live demonstration ran from June 2021 through March 2022
- ESAMS analyzed measurements from PMU's monitoring tie-lines between operating entities
- When a wide-area oscillation was detected, its energy flow through the system was tracked back to the source
- Event reports were then emailed to participants
- 65 oscillation events reported


Forced Oscillation Detection & Source Location

Forced Oscillation observed for [redacted]

Forced Oscillation event was detected by signal [redacted]
RC Region with Highest net oscillation energy export: MISO **Confidence Level:** Low
Doesn't appear to be localized only to MISO

Time (EST): [redacted]**; Frequency: 0.64 Hz; Oscillation Type: Inter-area Oscillations**

Rank	Oscillation Detected at	Peak to Peak Amplitude	Oscillation Band RMS Energy
1	[redacted]	17 MW	9 MW
2		12 MW	7 MW
3		11 MW	6 MW
4		5 MW	3 MW
5		3 MW	6 MW

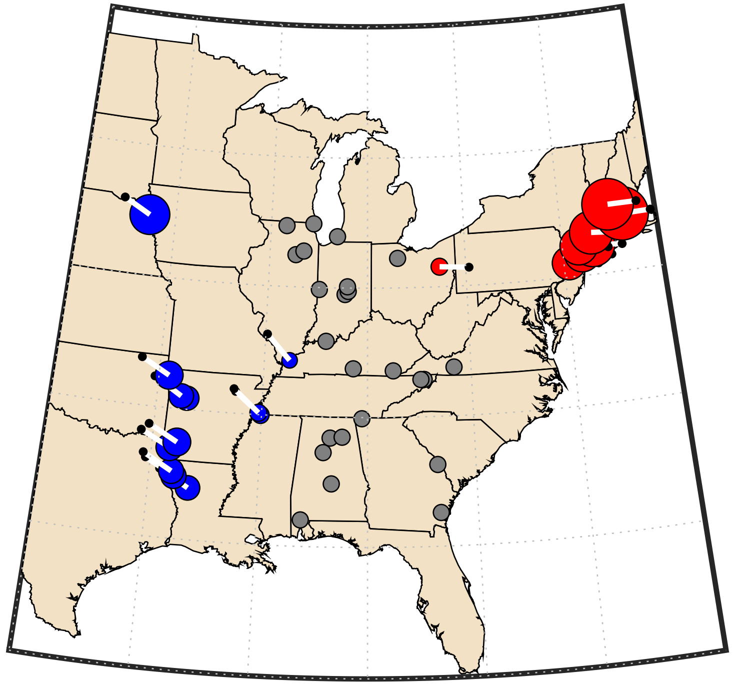
[redacted]

back to main page

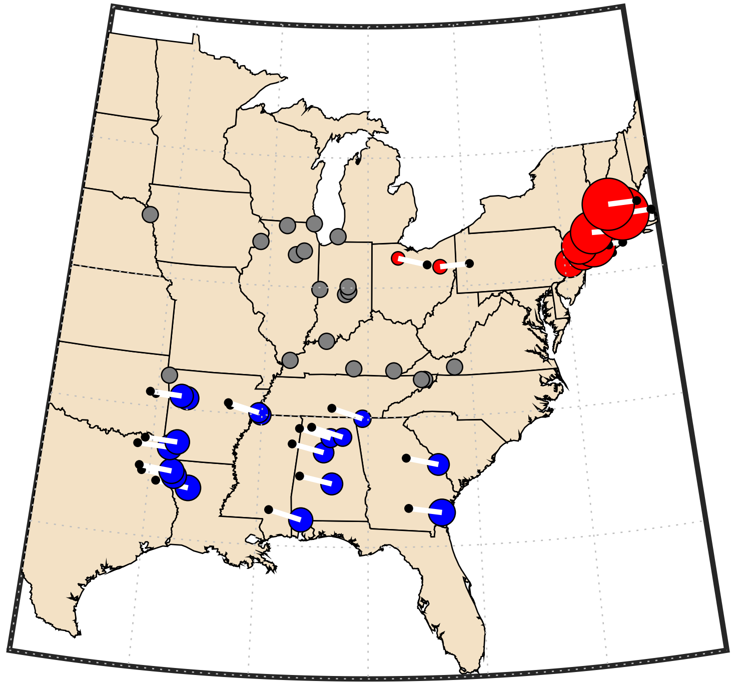
Page 2 of 21

Example Results: Inter-Area Mode Monitoring

- ESAMS's wide-area visibility also enabled continuous tracking of low-level natural (modal) oscillations
- For effective tracking, measurements from each end of the mode's shape are needed



Northeast-Midwest Mode
Approximately 0.22 Hz



Northeast-South Mode
Approximately 0.18 Hz

Conclusion

- Findings
  - An interconnection-scale view of the grid can provide reliability benefits to system operators
  - Transmission PMU data can be shared over existing networks to support applications
  - Challenges regarding data quality, sensitivity, and volume are surmountable
  - Further work necessary to make applications available to system operators
- Ongoing work
  - ESAMS deployed at Southern Company (SOCO) for further evaluation
  - Continuous tracking of natural oscillations to be deployed at Southwest Power Pool (SPP)
  - Cloud-hosted deployment proposed to DOE

Thank you

Jim Follum, PNNL
james.follum@pnnl.gov

POWER SECTOR TRANSMISSION & DISTRIBUTION DATA AND INFORMATION WEBINAR SERIES

TOPIC 1: T&D Information Sharing

Wednesday, October 11 | 10:00 a.m. to 12:30 p.m. PDT

TOPIC 2: Cross-sector & Open Data Sharing and Risks

Wednesday, October 18 | 10:00 a.m. to 12:00 p.m. PDT

TOPIC 3: Sensor Systems and Platforms

Wednesday, October 25 | 10:00 a.m. to 12:00 p.m. PDT

TOPIC 4: Sensor Data and Device Research

Wednesday, November 1 | 10:00 a.m. to 12:00 p.m. PDT

REGISTER TODAY!

U.S. DEPARTMENT OF ENERGY OFFICE OF ELECTRICITY

Los Alamos NATIONAL LABORATORY

OAK RIDGE National Laboratory

Pacific Northwest NATIONAL LABORATORY