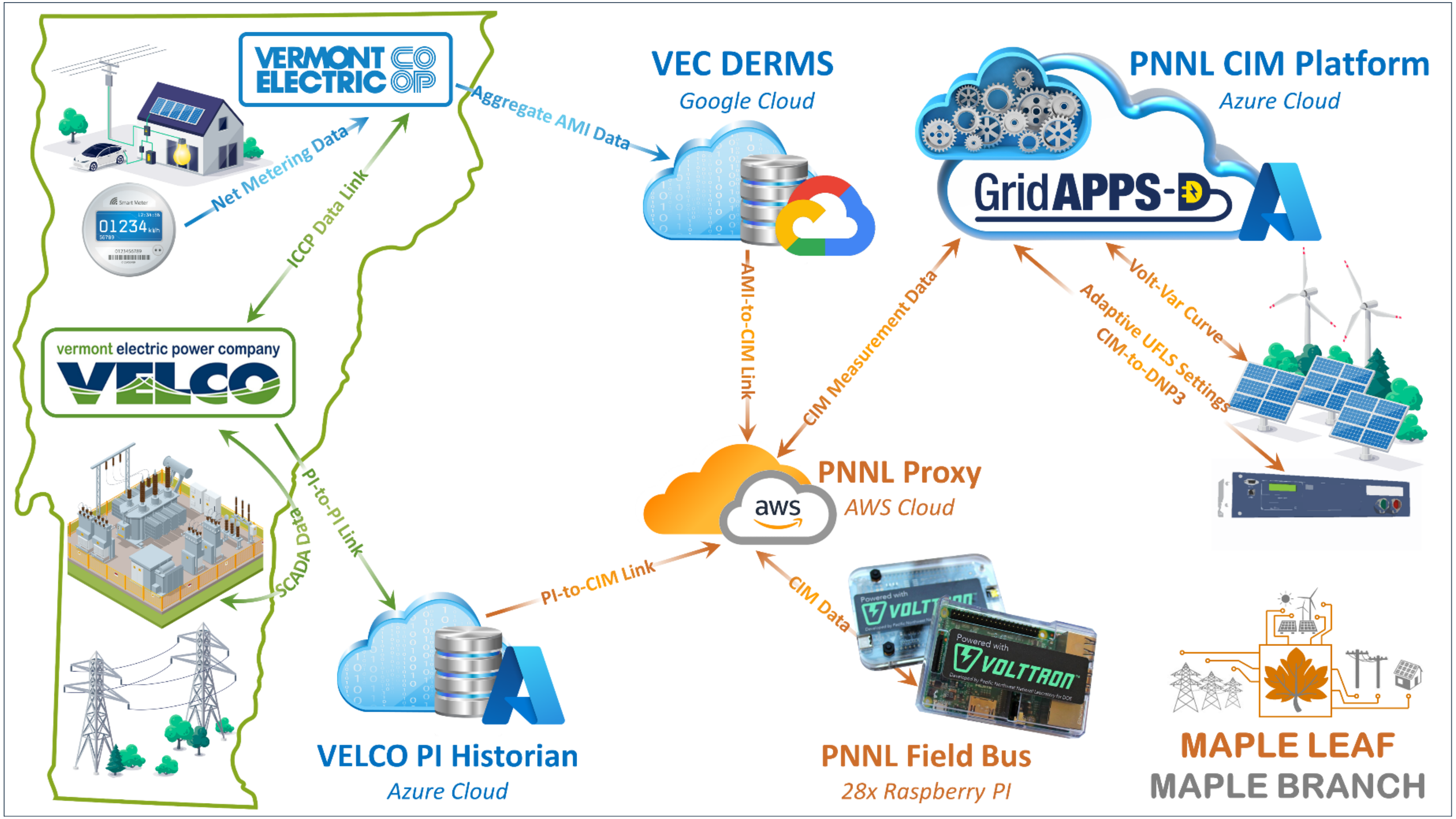
The Importance of Use-Inspired R&D

- DOE Projects are having a direct benefit on VELCO's network model management software initiatives
- The Project Team is a sounding board for innovative ideas, and a hub for sharing standards-based solutions that are scalable across industry
- DOE projects are enhancing collaboration between VELCO, Vermont Electric Cooperative, and ISO-NE

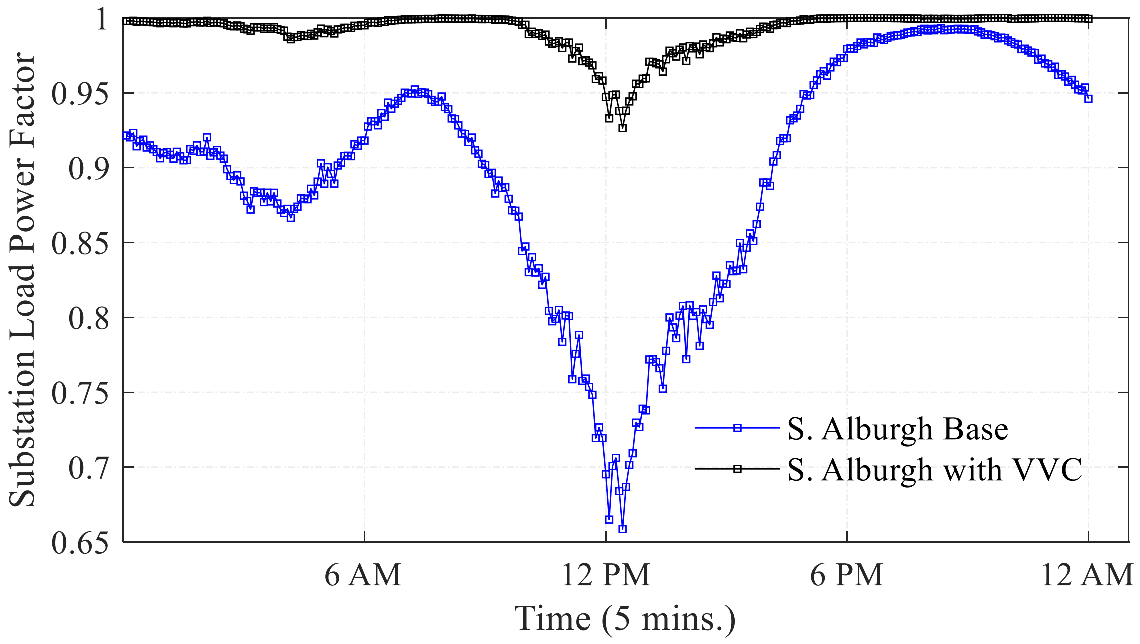
T+D Multi-Cloud CIM-Based Testbed

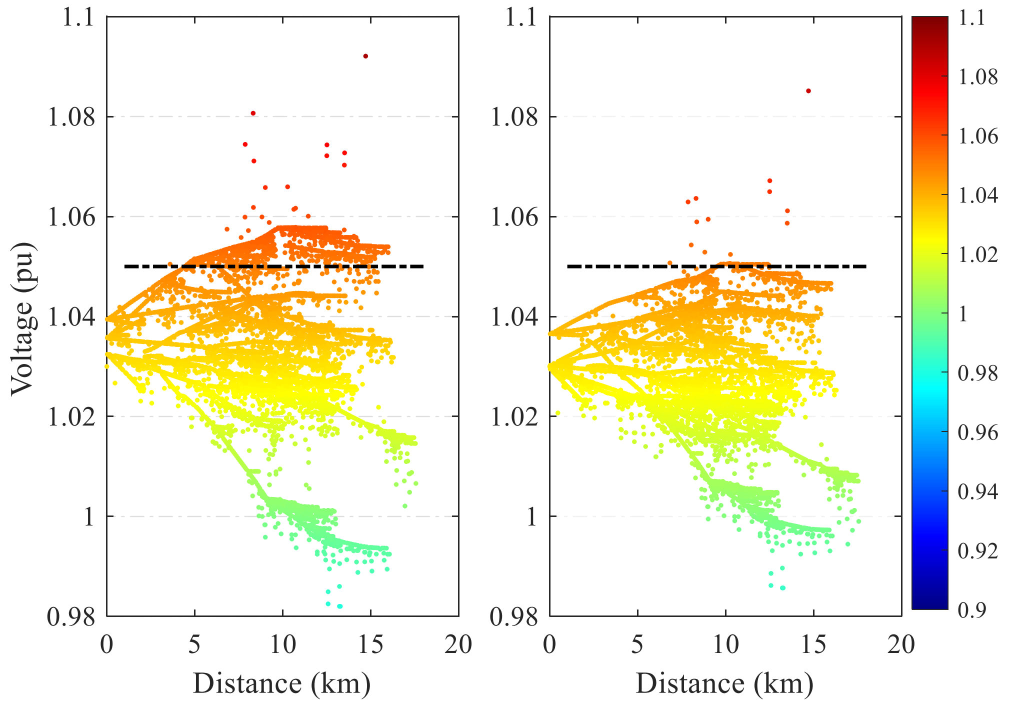


Volt-VAR Curve Performance for S. Alburgh

- Load power factor improved with reactive power contribution from inverters
  - Less Q exchanged at the interface

- Overvoltage significantly reduced with reactive power absorption during peak PV generation





Orchestrating Applications for a Modular and Distributed ADMS Platform

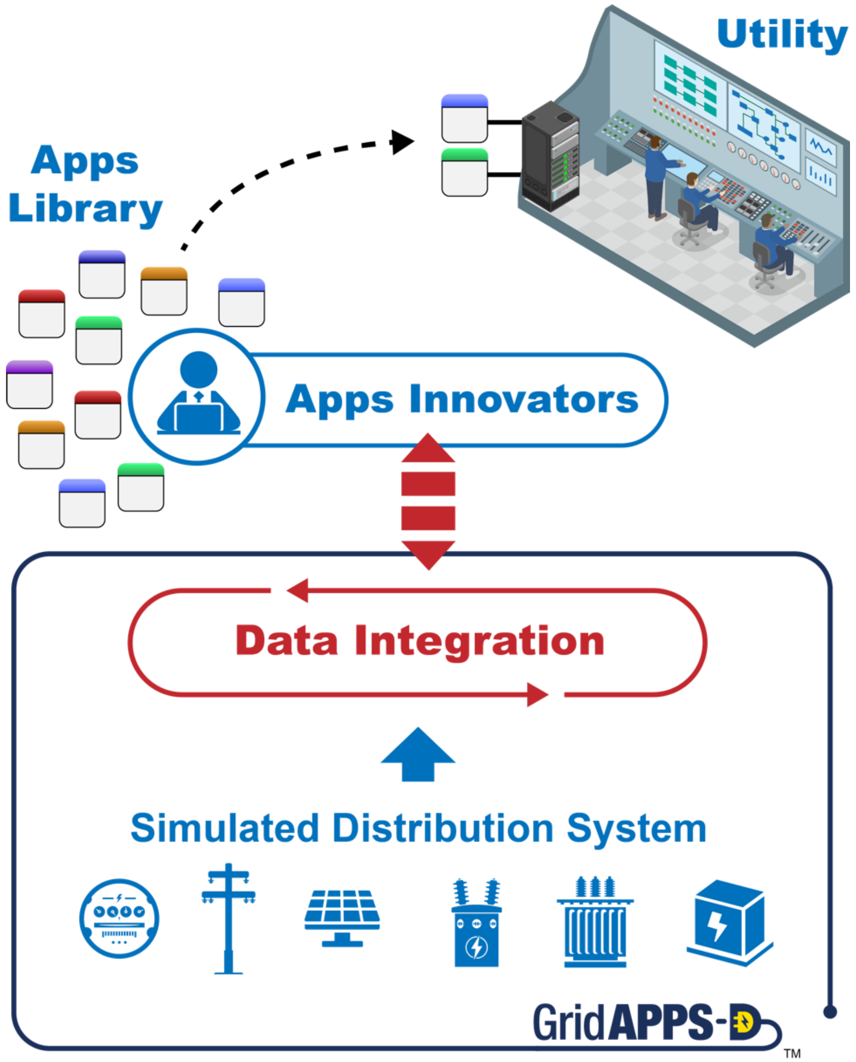
Andy Reiman

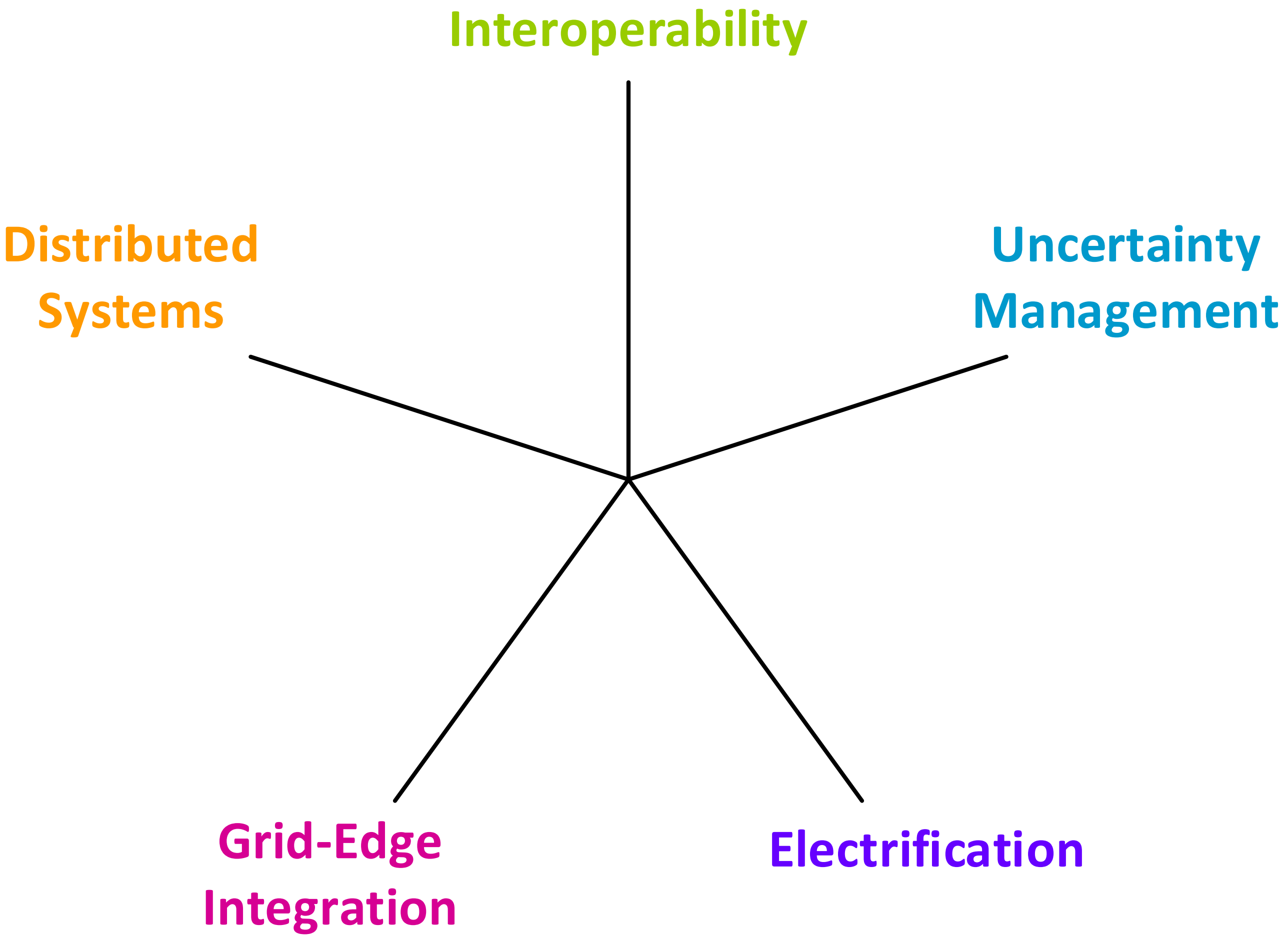
PNNL

U.S. Department of ENERGY | Office of Electricity

Advanced Distribution Operations and GridAPPS-D

Vision: An ecosystem of interoperable distribution system management software applications for utilities, solution providers, and researchers to support an advanced multi-stakeholder, multi-objective grid.





Mission: to support the ability of utilities to operate the emerging grid of the future through research, development, and demonstration of advanced algorithms and systems.

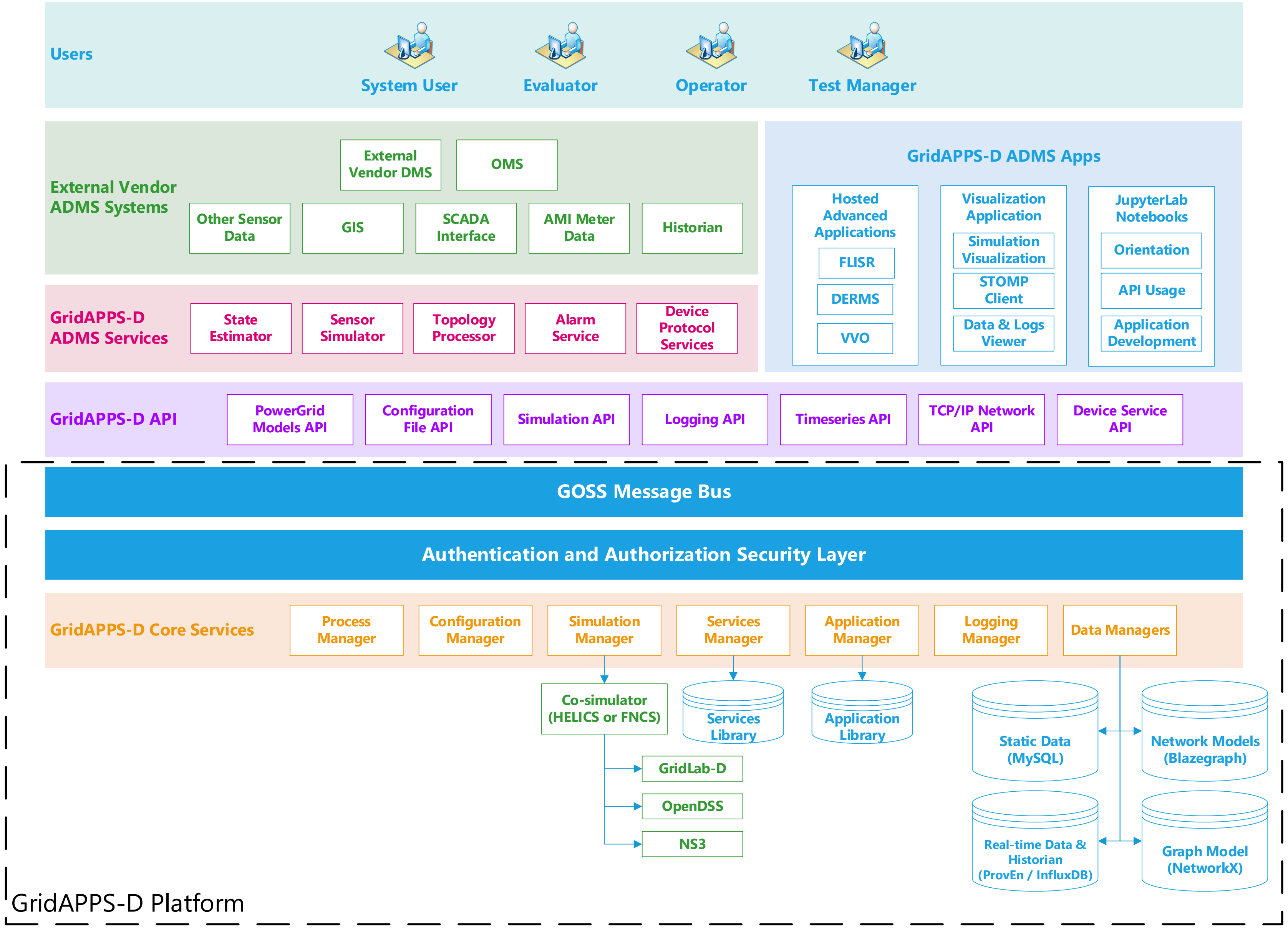
Open App-Hosting Platform Paradigm

Why have an Open Platform?

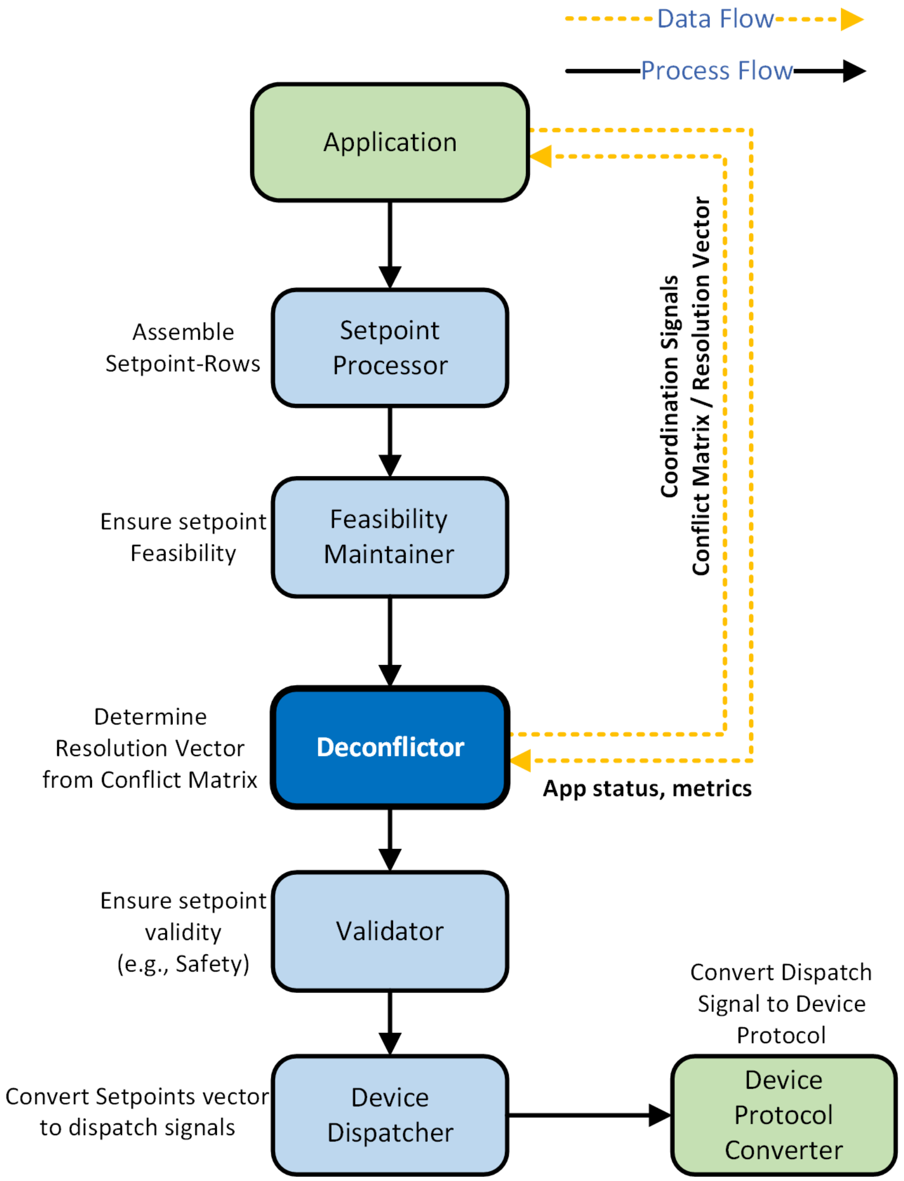
- Leverages marketplace of ideas.
- Reduces barrier to entry for specialized app developers.
- More integration by the app developer and less by the system operator.

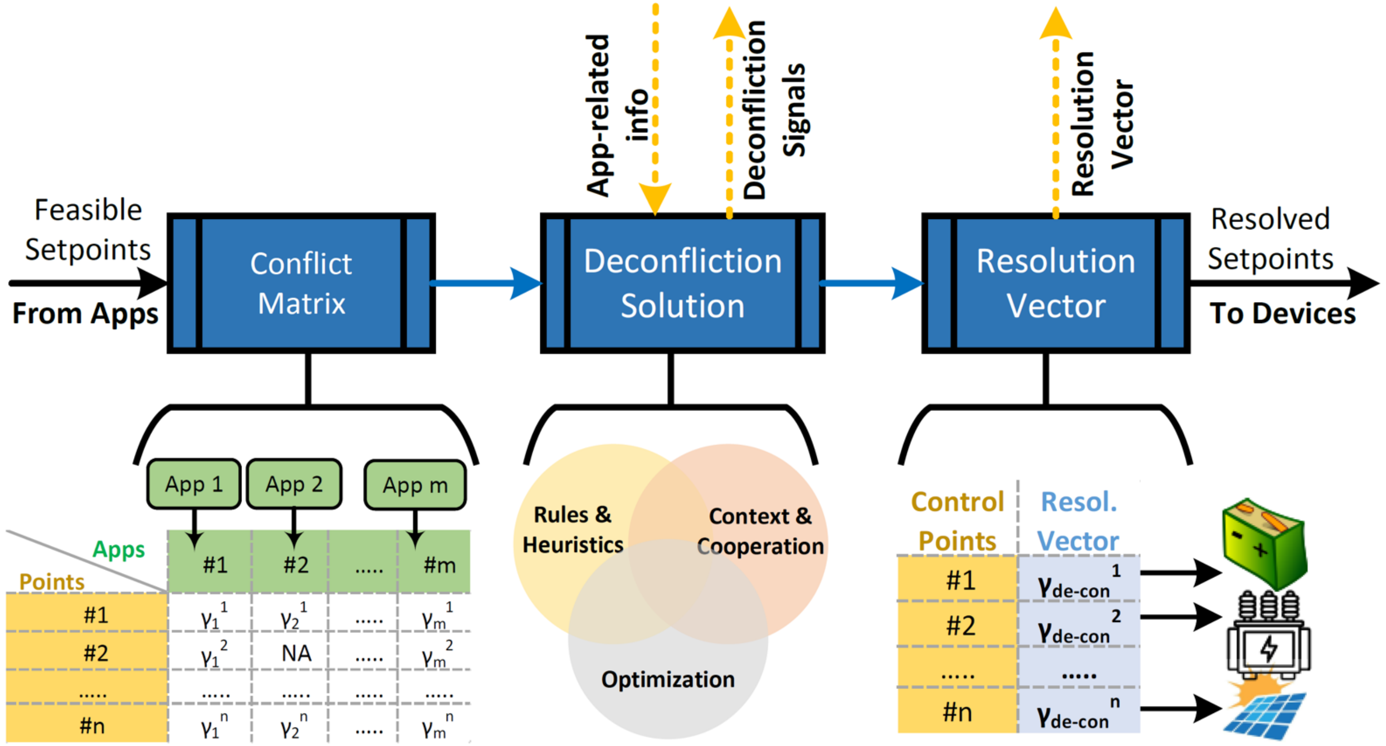
Why Deconfliction?

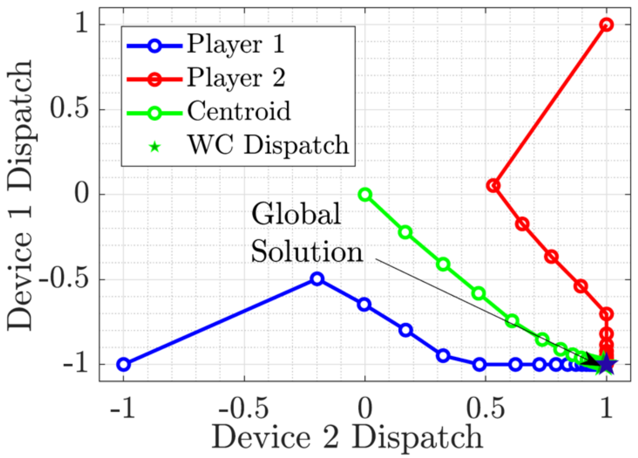
- Apps may produce conflicting control setpoints.
- Apps may be less trustworthy.

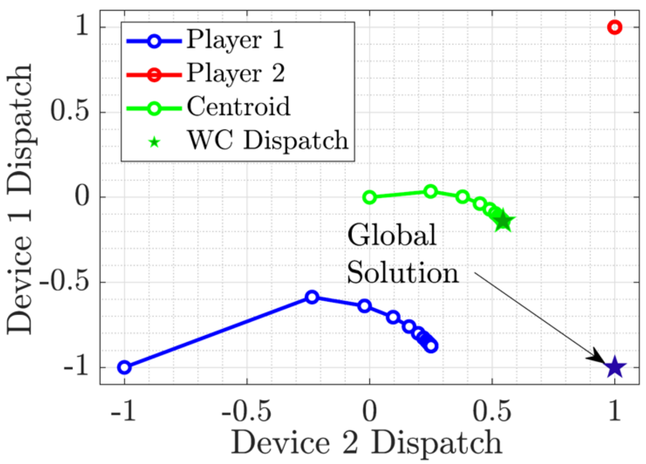


Deconfliction as a Framework for App Cooperation

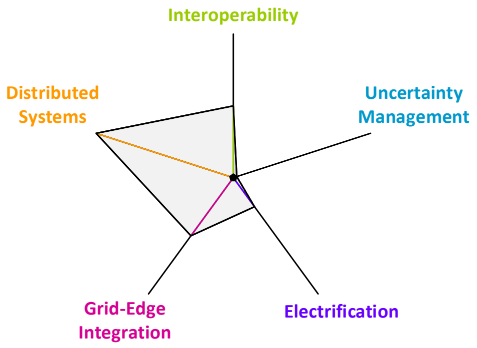


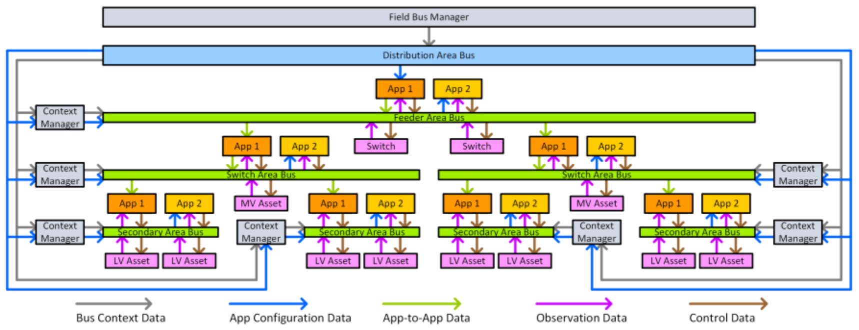




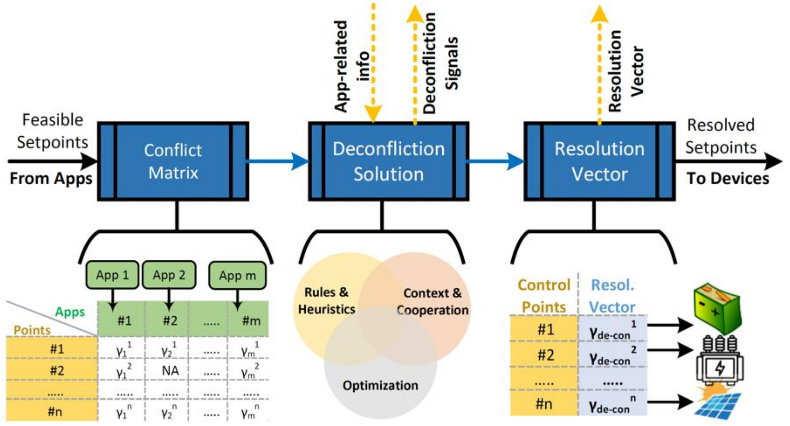


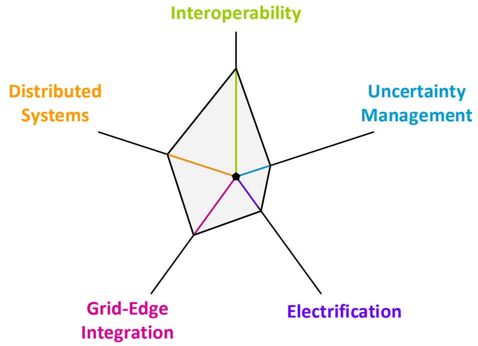
GridAPPS-D at DSO-Scale

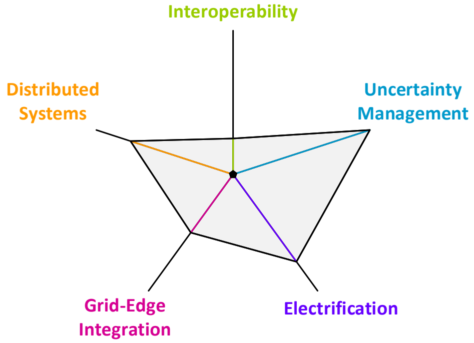


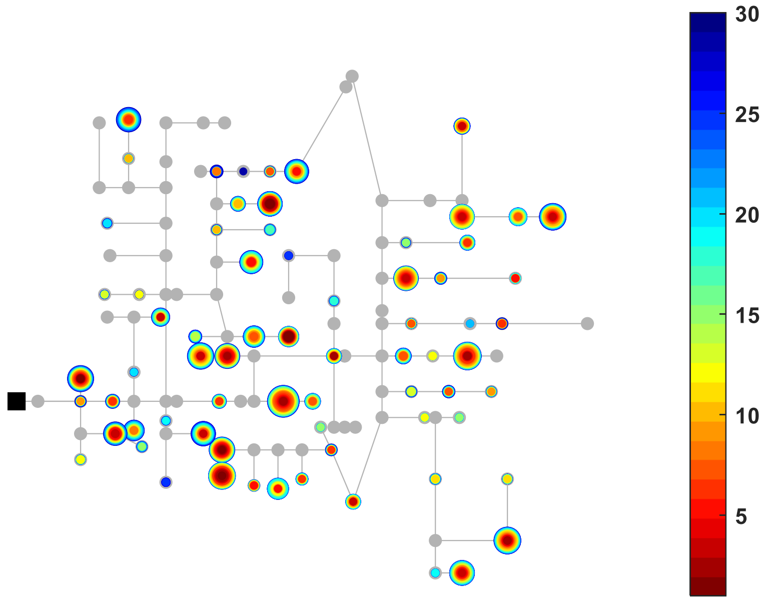


Application Deconfliction

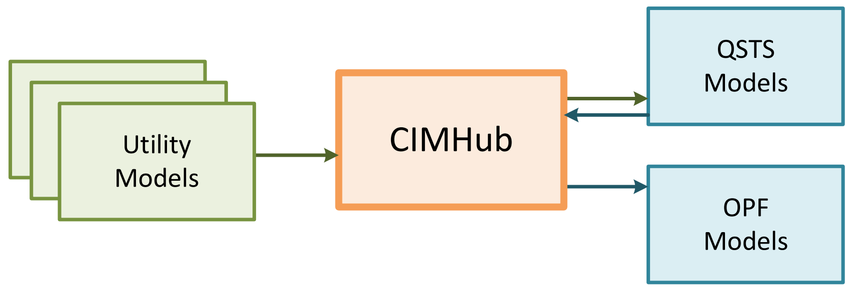


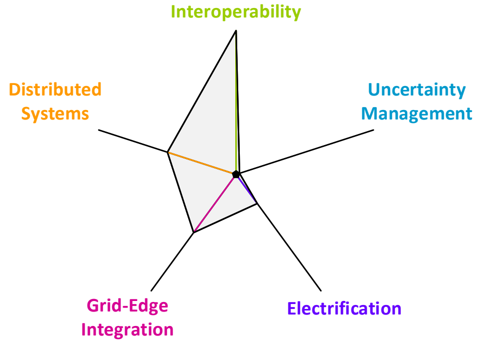






Stochastic Dynamic Operating Envelope





Standards-Based Model Exchange between Entities

Thank you!

PI

Andy Reiman

andrew.reiman@pnnl.gov

Technical Area Leaders

Poorva Sharma   Shiva Poudel   Monish Mukherjee   Rabayet Sadnan

Technical Team

Craig Allwardt	Alex Anderson	Gary Black	Andy Fisher
Tara Gibson	Nathan Gray	Tonya Martin	Tylor Slay
	Orestis Vasios	Joshua Yip	

Thank you to our Sponsor and Program Manager:

Chris Irwin

Low-Current Arcing Detection and Location for Wildfire Mitigation

Jhi-Young Joo, Ph.D.
joo3@llnl.gov
Lawrence Livermore National Laboratory

U.S. Department of ENERGY | Office of Electricity

LLNL-PRES-871001

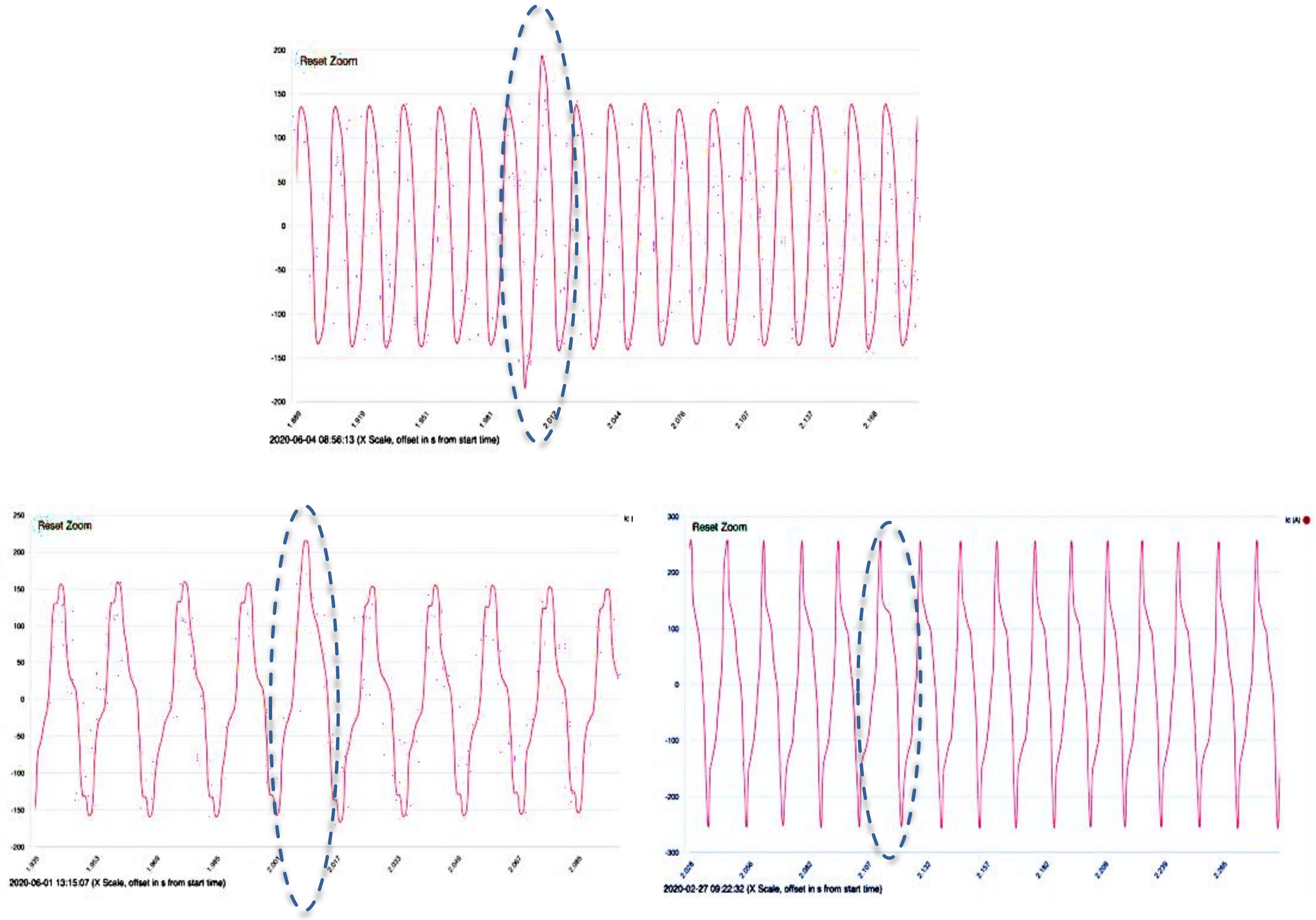
Fires caused by electric equipment

Dixie Fire, 2021

- **Impacts** can be catastrophic
- **Causes**
  - Foreign object (e.g., vegetation) contact
  - Conductor slapping
  - Broken conductor
  - Equipment failure
- **Challenges**
  - Traditional fault detection and protection scheme
  - Complex distribution systems
- **Mitigations**
  - Vegetation maintenance
  - Fire monitoring
  - Covered conductors/undergrounding
  - **Novel fault detection strategies**

Detect early signs of failure (arcing) with high-resolution measurements

Digital fault recorder at a distribution substation
Photo courtesy of Southern California Edison



Data source: DOE Grid Event Signature Library (GESL)
https://gesl.ornl.gov

Collaborative effort

- DOE National Laboratories
- Utility
- Vendors

Lawrence Livermore National Laboratory

Lead

Power engineering and data analytics

Oak Ridge National Laboratory

Lab partner

Signal processing and analytics

Southern California Edison®
An EDISON INTERNATIONAL® Company

Utility partner

Data analytics and field expertise

RA Right Analytics

SEL Schweitzer Engineering Laboratories

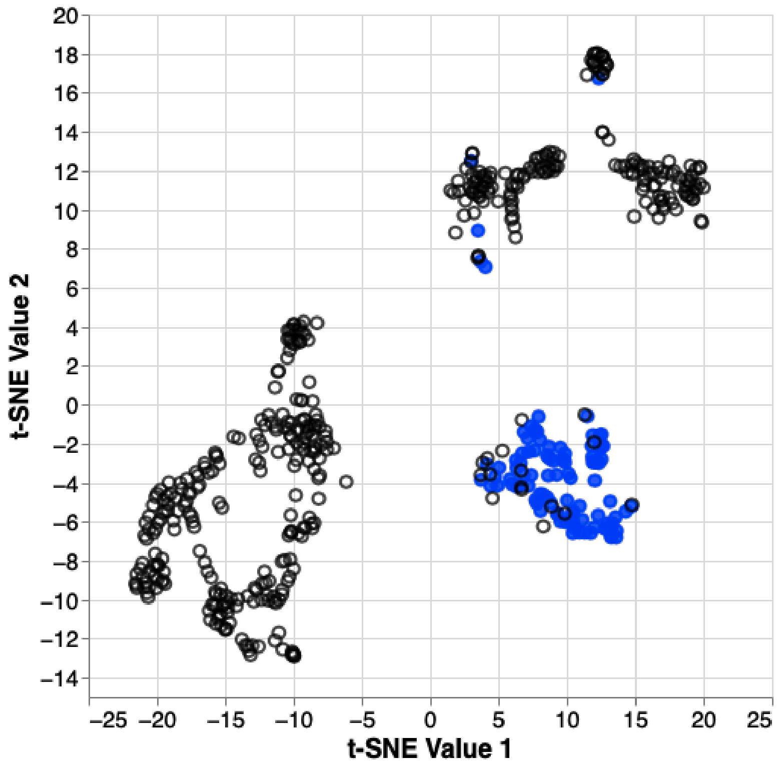
Vendors

Simulations; Advisory

Classification of arcing segments

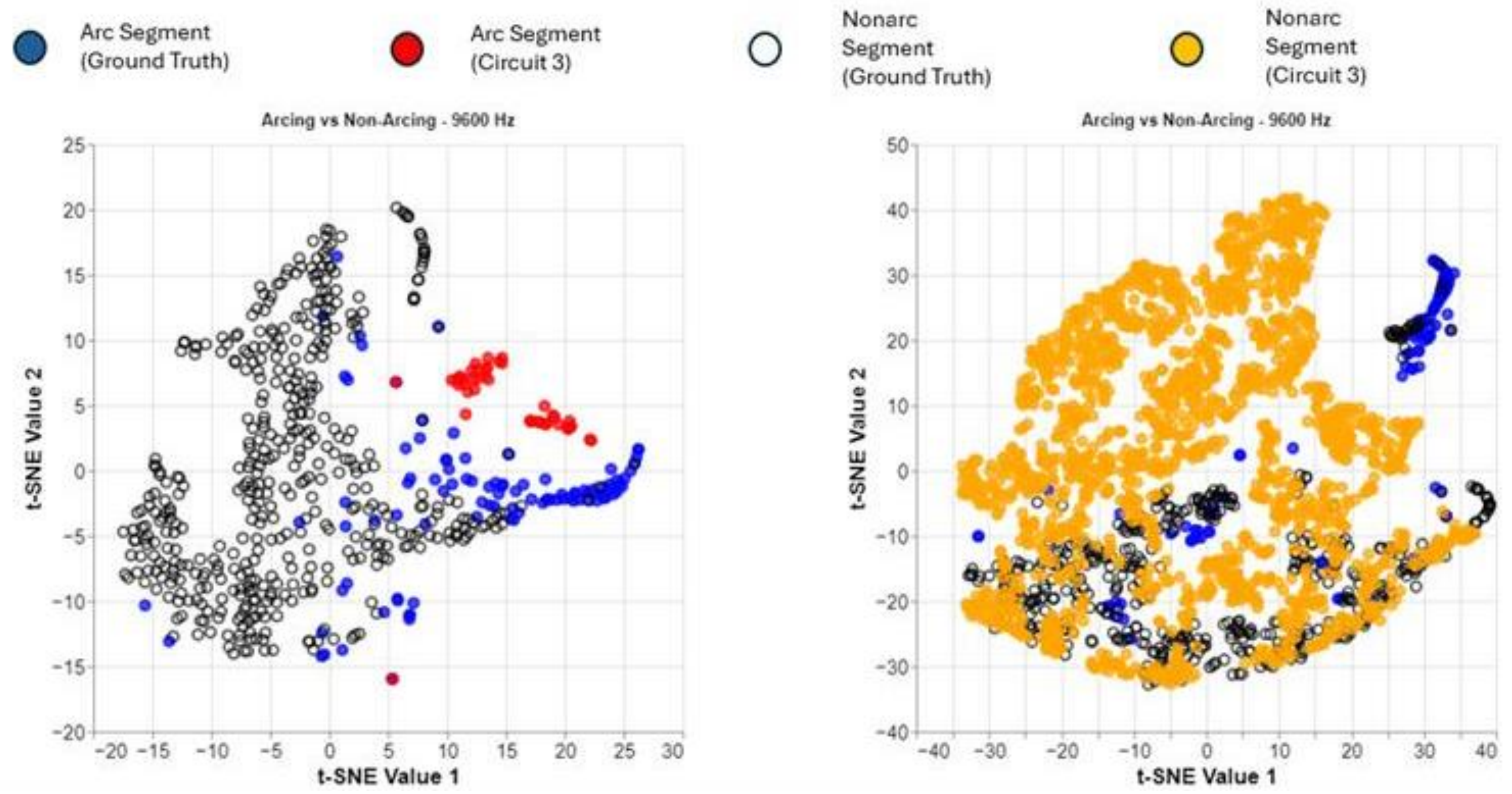
~90% accuracy tested with ground-truth datasets

- Training datasets from GESL



t-SNE plot of the feature vectors (GESL data, **15,360 Hz** samples)

- Application to utility data



t-SNE plots of the feature vectors (SCE data, **9,600 Hz** samples)

Thank you

U.S. Department of ENERGY | Office of Electricity

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

Towards Robust Transmission Grid with Uncertainty-tolerant Controls

Dr Hong Wang, Oak Ridge National Laboratory

FIEEE, FIET, FInstMC and FAAIA

Project Team: ORNL, SNL, PNNL, UNCC, BPA, Duke Energy, and Hitachi Energy

U.S. Department of ENERGY | Office of Electricity

Project Overview – Objectives/Impact

Challenges:

The power system dynamics faces **reduced inertia, more dynamic** and **uncertain** due to increased renewables penetration

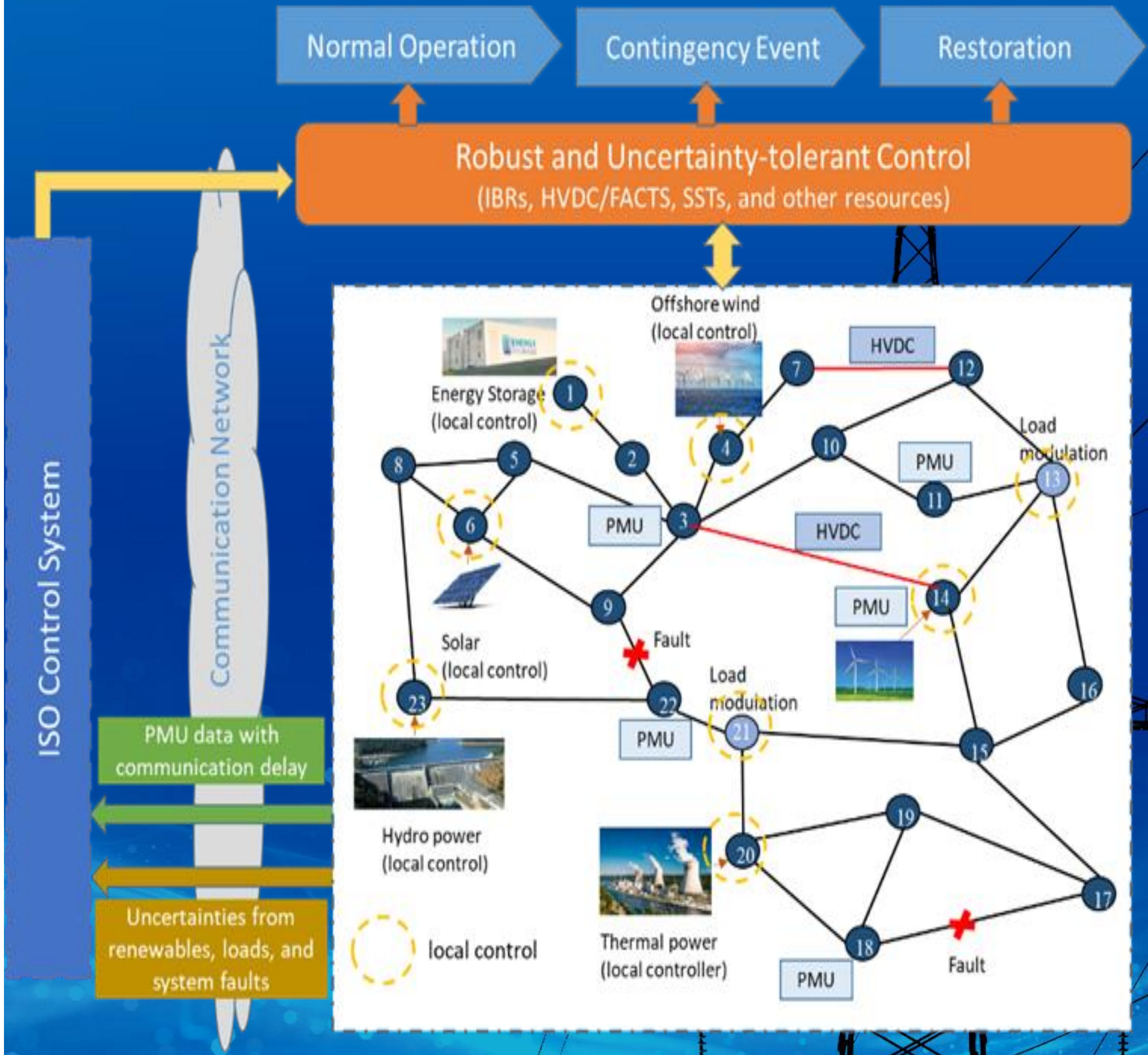
Objective:

To develop a set of advanced **fast**, **flexible**, **robust**, and **uncertainty-tolerant control technologies** for the transmission network systems in terms of novel stochastic distribution control, architecture communications and fast energy storage control

Impact:

Produce **a novel and next generation control suite** for transmission systems - integrating local, AGC and stochastic distribution control

Duration: 2023 - 2026

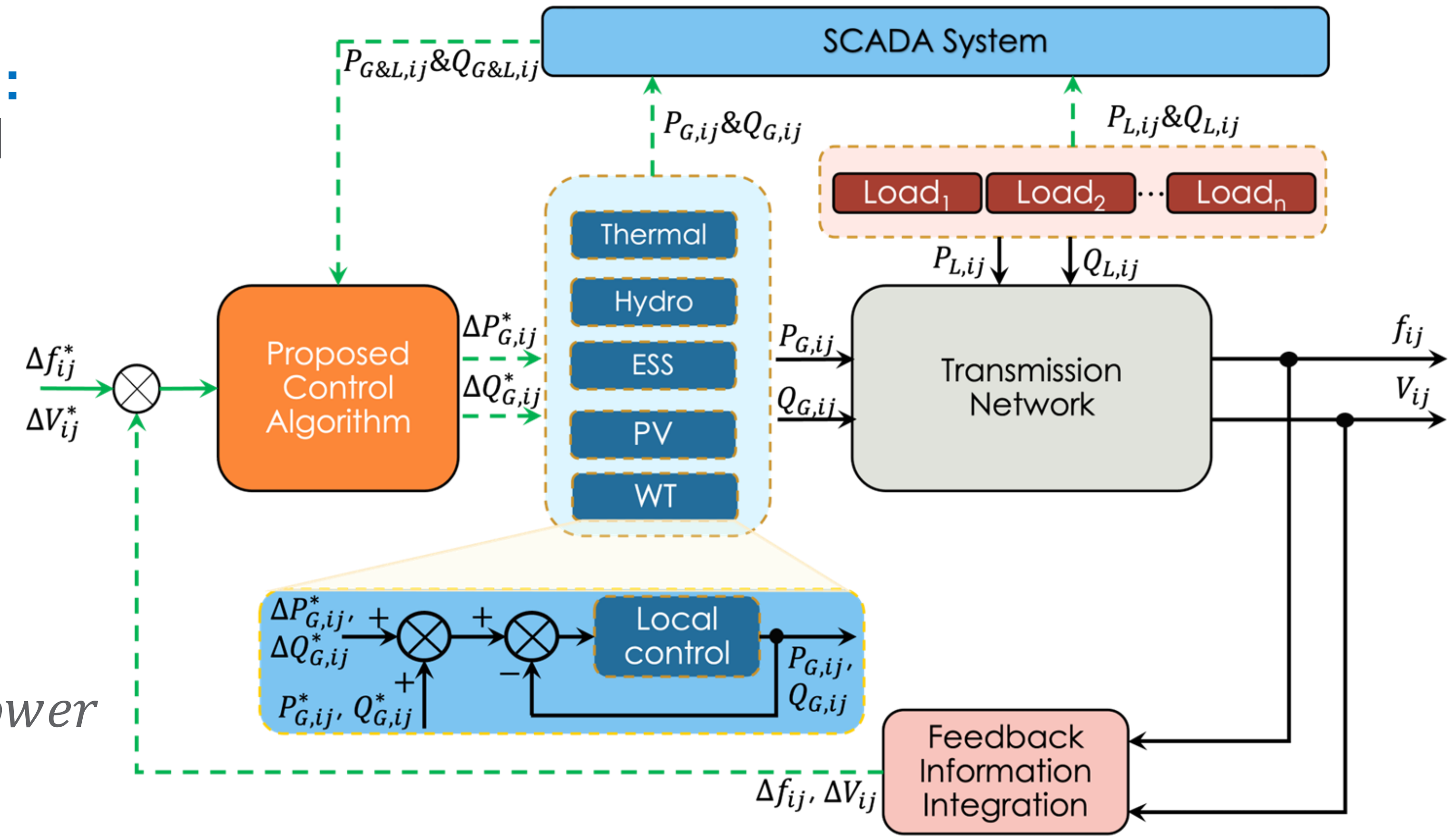


Novel Probability Density Function (PDF) Control – Next Generation Transmission Control

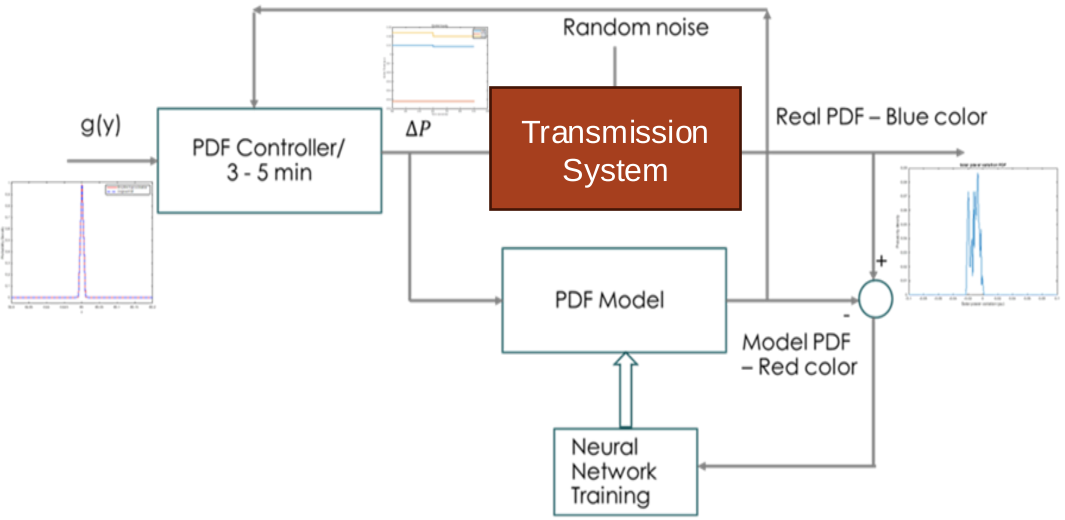
First Phase Frequency Regulation (Primary):
Up to 15 - 30 seconds - performed by local generation resources

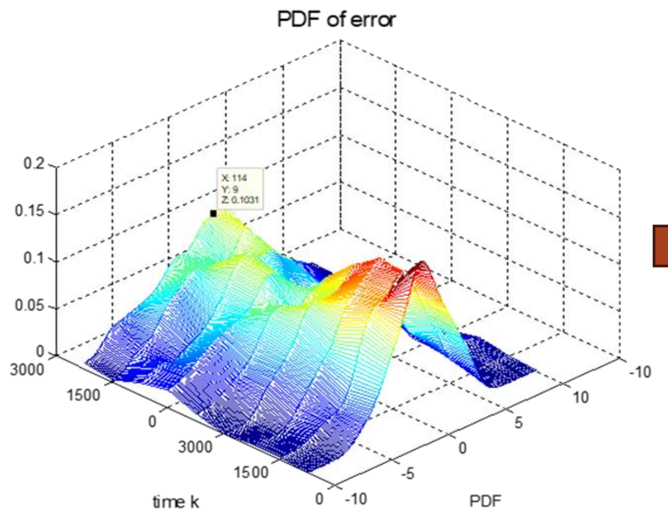
Automatic Generation Control:
from 30 second to 10mins

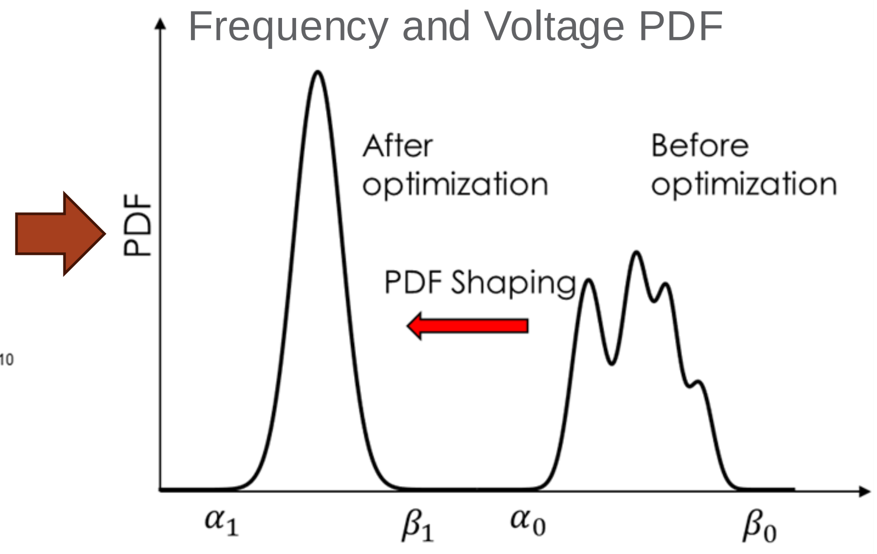
Our Probability Density Function Control:
from 1.5 – 5 mins



$$J\frac{d\omega}{dt} = Power\ Sources + Renewables\ - Load\ Power$$

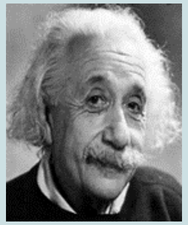


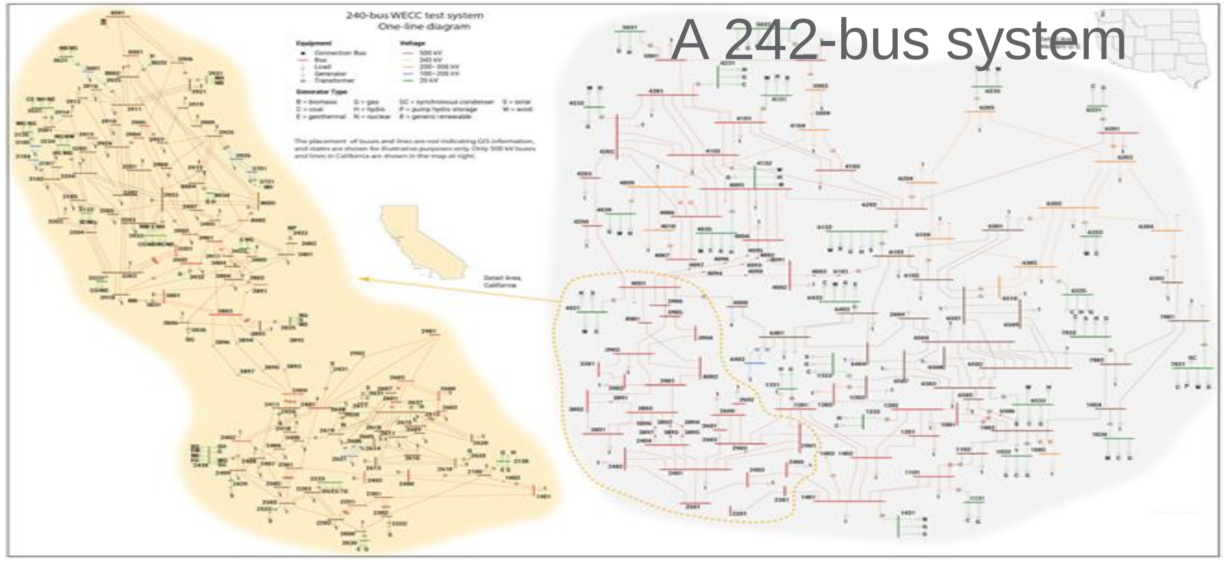


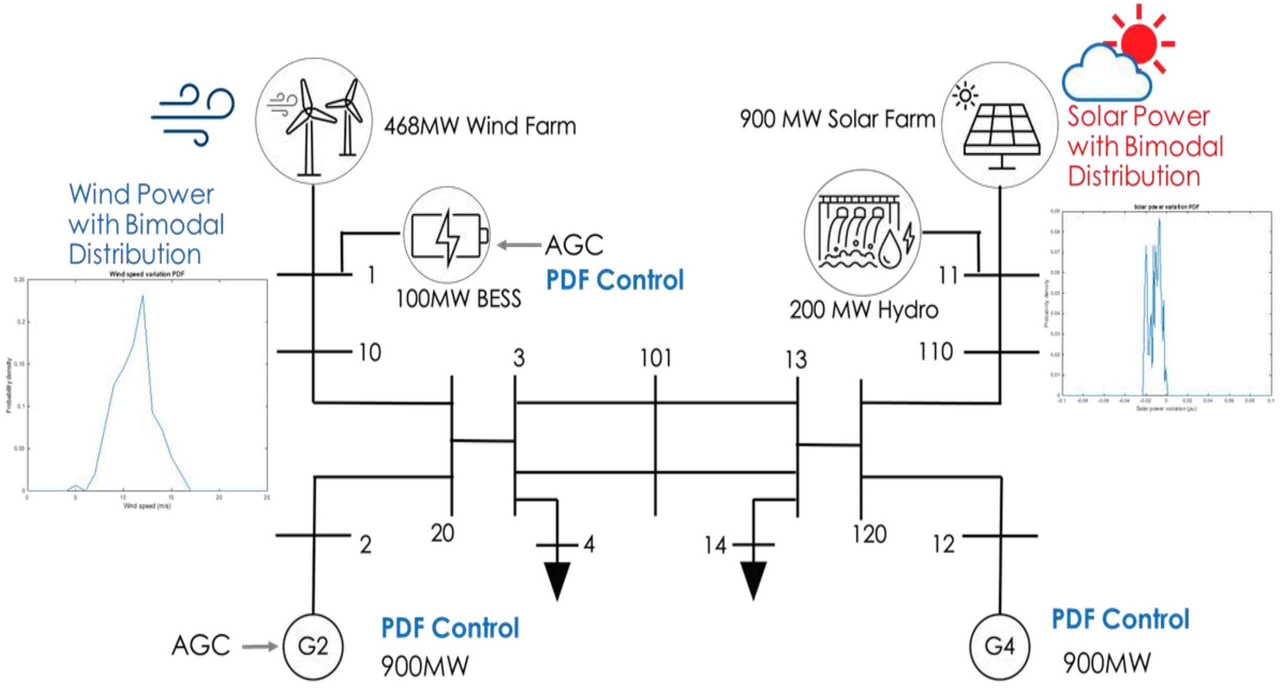


Narrow PDF = Less Uncertainties

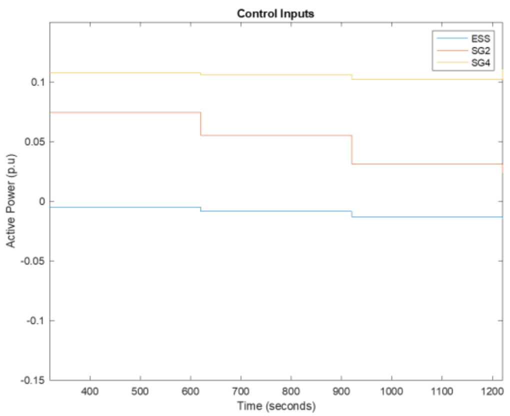
PDF Control vs Traditional Stochastic Control - What is new and some promising results

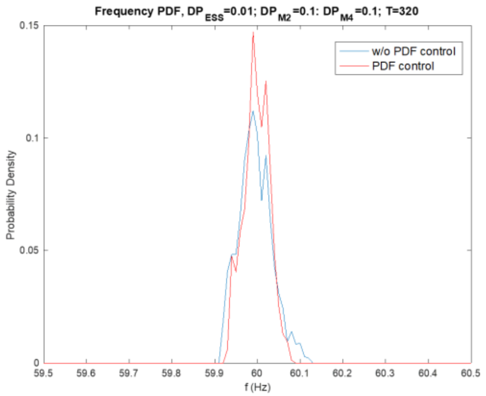
Traditional Stochastic Control	My Stochastic Distribution Control
• Stochastic differential equations - Gaussian Driven Systems (**Einstein**, **Ito**, et, all , 1904, 1944, 1950) = Solving PDEs   • Mean and Variance Control • Largely Linear Systems • Example: 1. Minimum Variance Control (1970), 2. Kalman Filter and 3. LQG Control (1965), 4. Neural Nets Modelling, etc	• Non-Gaussian Dynamic Systems - Some PDFs measurable for a lot of PDF shaping required processes! • Total probabilistic control (controlling PDF means controlling all the aspects of a random variable) • Wide applications: 1. Modelling, 2. Filtering and state estimation, 3. Data miming, 4. Stochastic optimization, etc





AGC: Automatic Generation Control





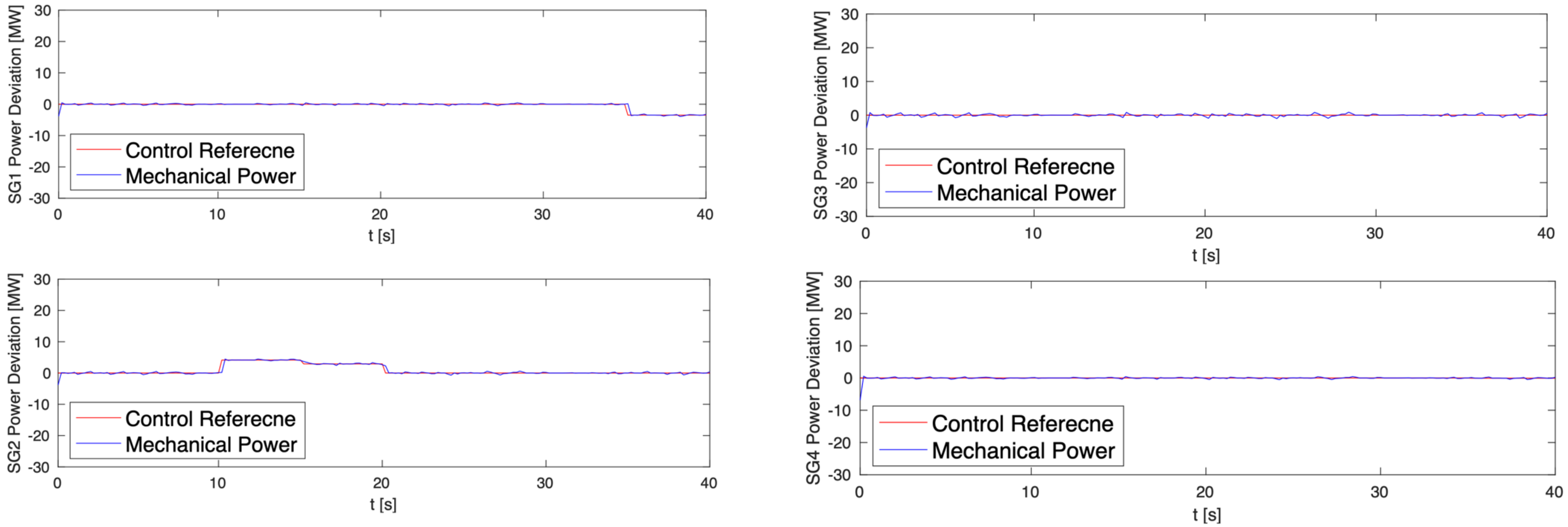
- Journal Publications
  - "Review of Challenges and Research Opportunities for Control of Transmission Grids," in IEEE Access, vol. 12, pp. 94543-94569, 2024, doi: 10.1109/ACCESS.2024.3425272. (**Published**).
  - "Probability Density Function (PDF) Control of Frequency Fluctuations in Transmission Grids," in IEEE Power Engineering Letters, (**Under Review**).
- Conference Publications
  - "Towards the Flexibility of HVDC-Interconnected Systems: A Novel Emergency Frequency Response Model", 2024 IEEE Power & Energy Society General Meeting (PESGM), (**Accepted**).
  - S Wang, W Du, G Zhang, H Wang and Z Huang, Model Gap Quantification and Evaluation, 2024 UKACC 14th International Conference on Control (CONTROL) 10-12 April, 2024. Winchester, UK

MPC-based Multi-time Scale Frequency Regulation (UNCC)

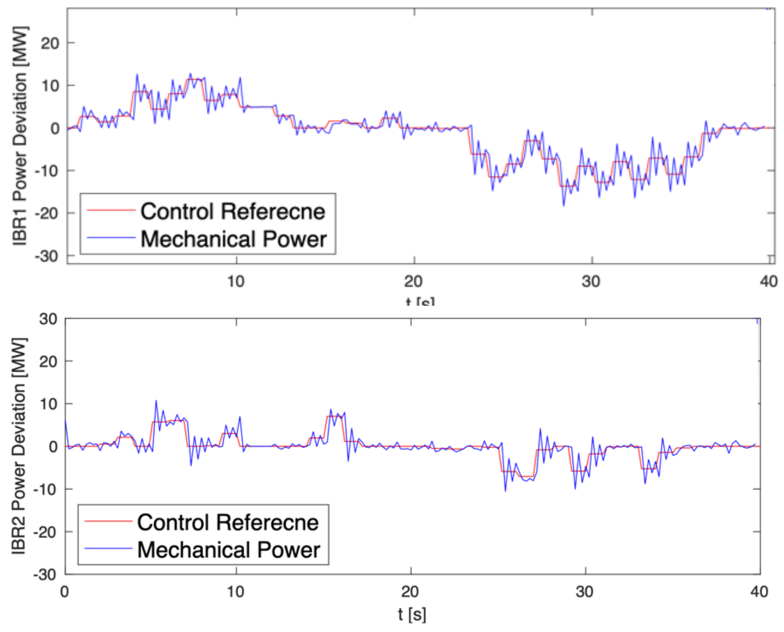
- Developed a model-predictive control (MPC)-based multi-time scale coordinated AGC controls for fast-responding IBRs and slower-responding synchronous generators (SGs)
- The approach prioritizes the resources with higher ramping capability and lower costs for providing frequency support – **form effective selection of generation resources for PDF control.**

Numerical experiments

- ➢ SGs with lower ramp rates are not selected (SG3 and SG4) – priority selection
- ➢ IBRs with more control flexibility contribute more to regulation (validated by the comparison between IBR and SG) – multi-time scales



Output of SGs

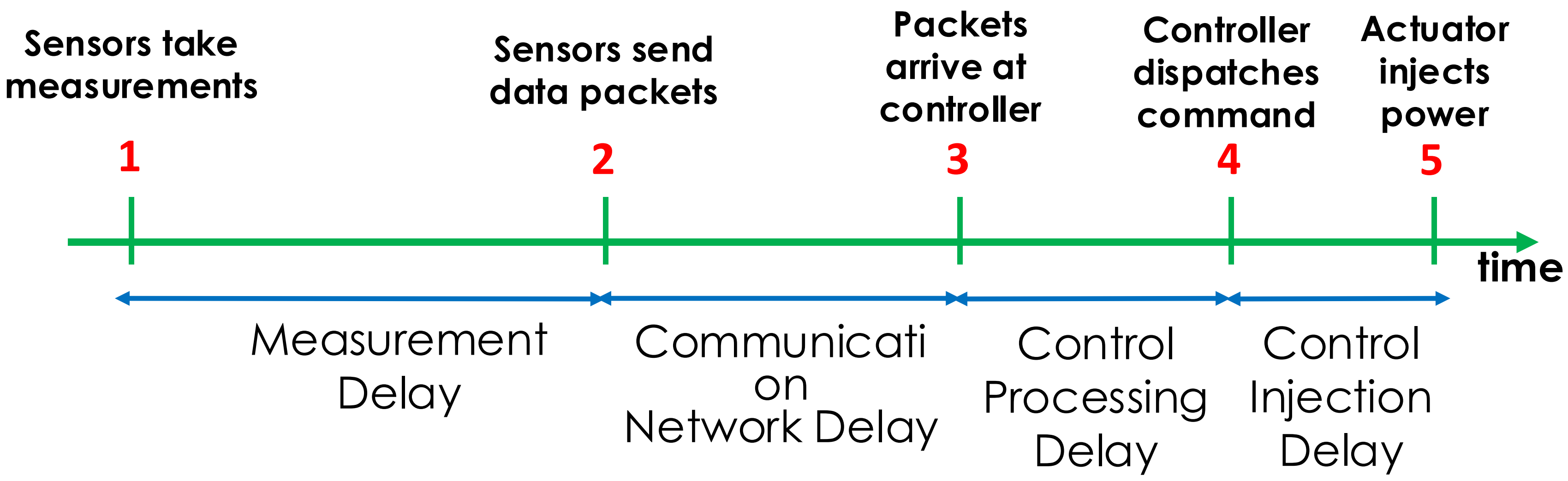


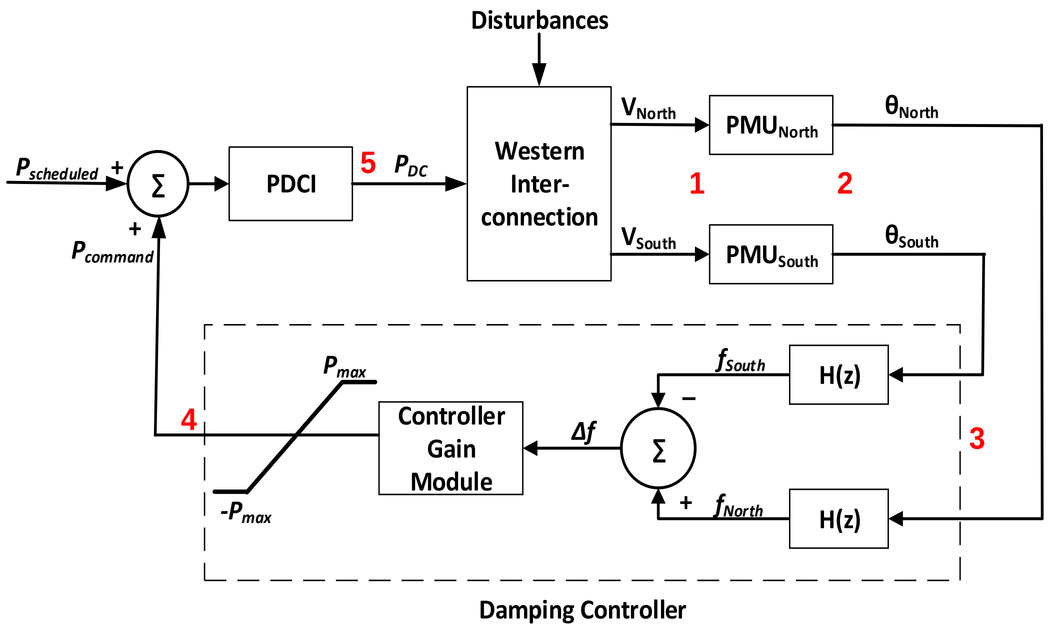
Output of IBRs

Fast, Robust Controls Tolerant to Communications Uncertainties (SNL)

Objective:

- develop distributed control solutions by leveraging wide-area information to achieve system-wide objectives using control architecture developed in Task 1.
- consider communication constraints such as delays and data package drops/corruption.

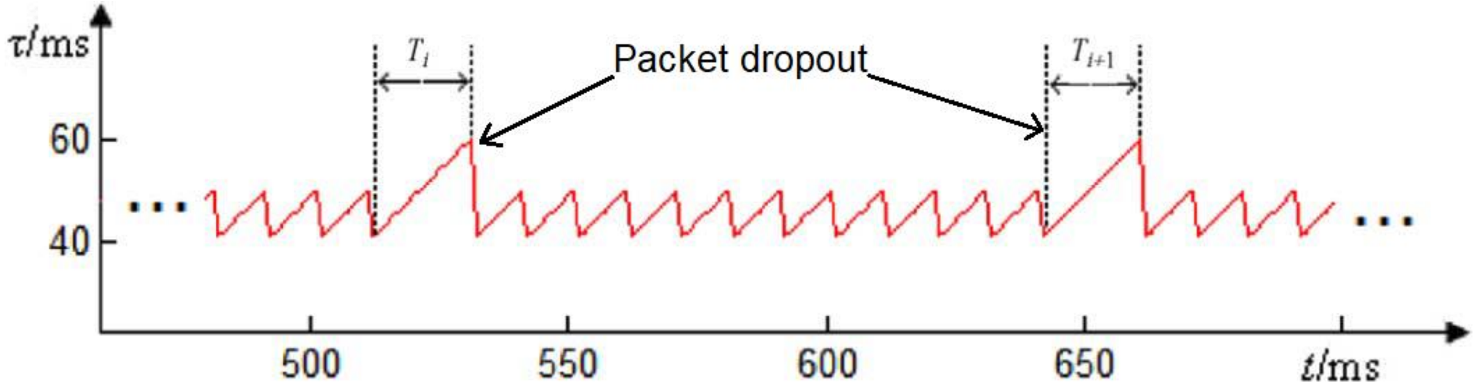




Analysis, Modelling, and Simulation Communication-Induced Uncertainties (PNNL)

❖ Uncertainties in networked communication

- ➢ Communication Delays
- ➢ Data Packet Dropout
- ➢ Data Packet Disordering

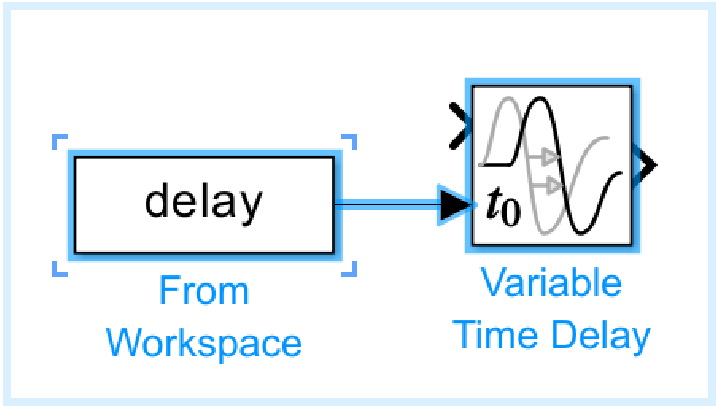


❖ Uncertainties Modelling:

- ➢ Communication system: Data packet, discrete signal
- ➢ Power grid dynamic: input signals, continuous
- ➢ Use ZOH (zero order hold) to connect the discrete communication network with continuous power grid network

❖ Uncertainties Simulation

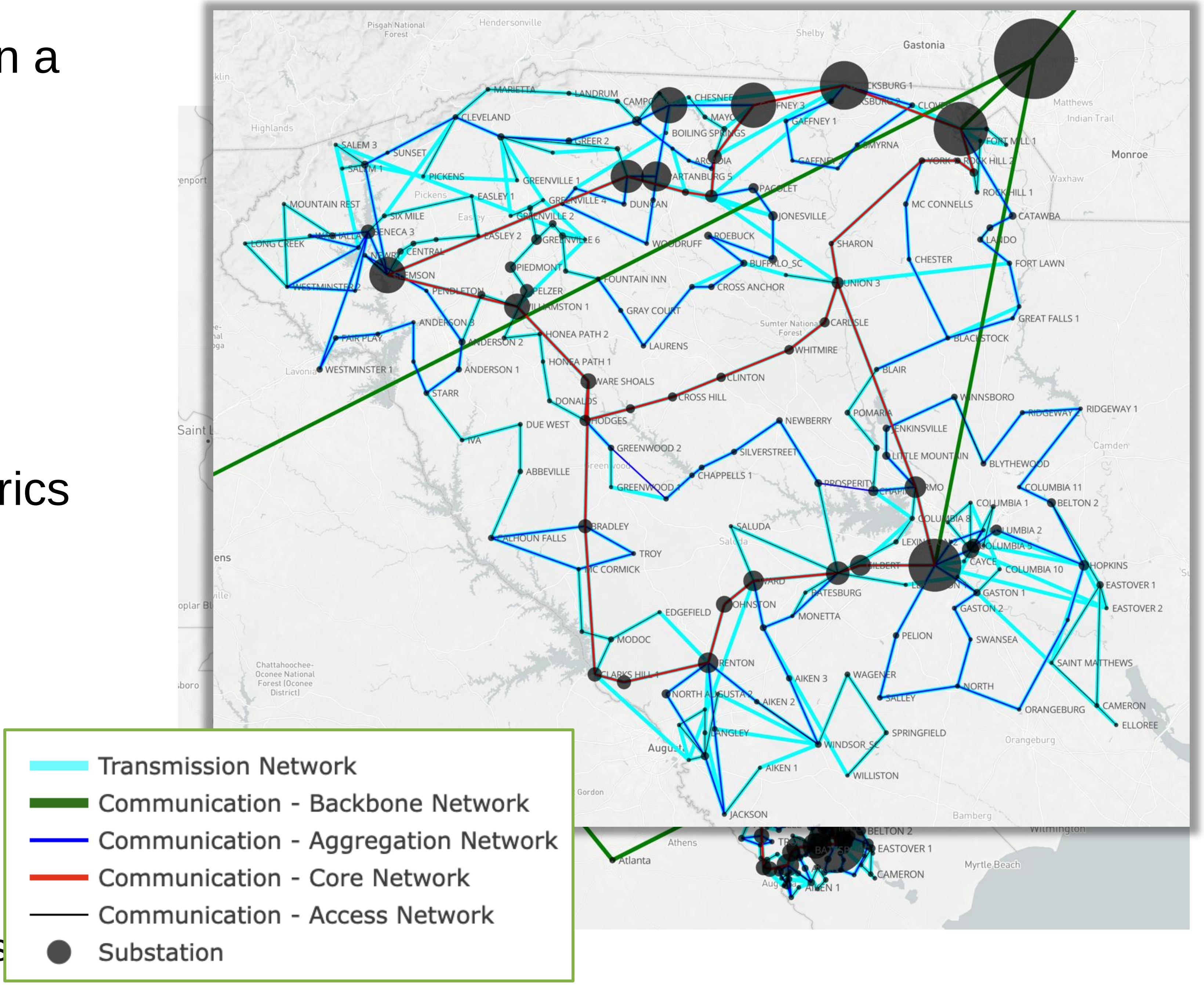
- ➢ Matlab Simulink
- ➢ Model time-varying delay in m.file
- ➢ then feed the time-varying delay to Simulink to perform the whole closed-loop system (hybrid system) simulation



OAK RIDGE National Laboratory

Modeling of Communication Architecture (PNNL)

- Modeled communication network in a weighted graph
- Developed delay-based weights
  - Propagation delay
  - Transmit delay
  - Switching delay
  - Queueing delay
- Computed the graph theoretic metrics to analyze the communication efficiency
  - Closeness Centrality
  - Betweenness Centrality
  - Efficiency Drop
- Next steps
  - Verification with simulations
  - Siting of PMUs, PDCs and controllers



Thank you

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Sector Coupling: Electrified Transportation

Bhaskar Mitra, Seemita Pal,

Michael Kintner-Meyer, and Hayden Reeve

Pacific Northwest National Lab

OE Sponsor: Chris Irwin

U.S. Department of ENERGY | Office of Electricity

PNNL is operated by Battelle for the U.S. Department of Energy

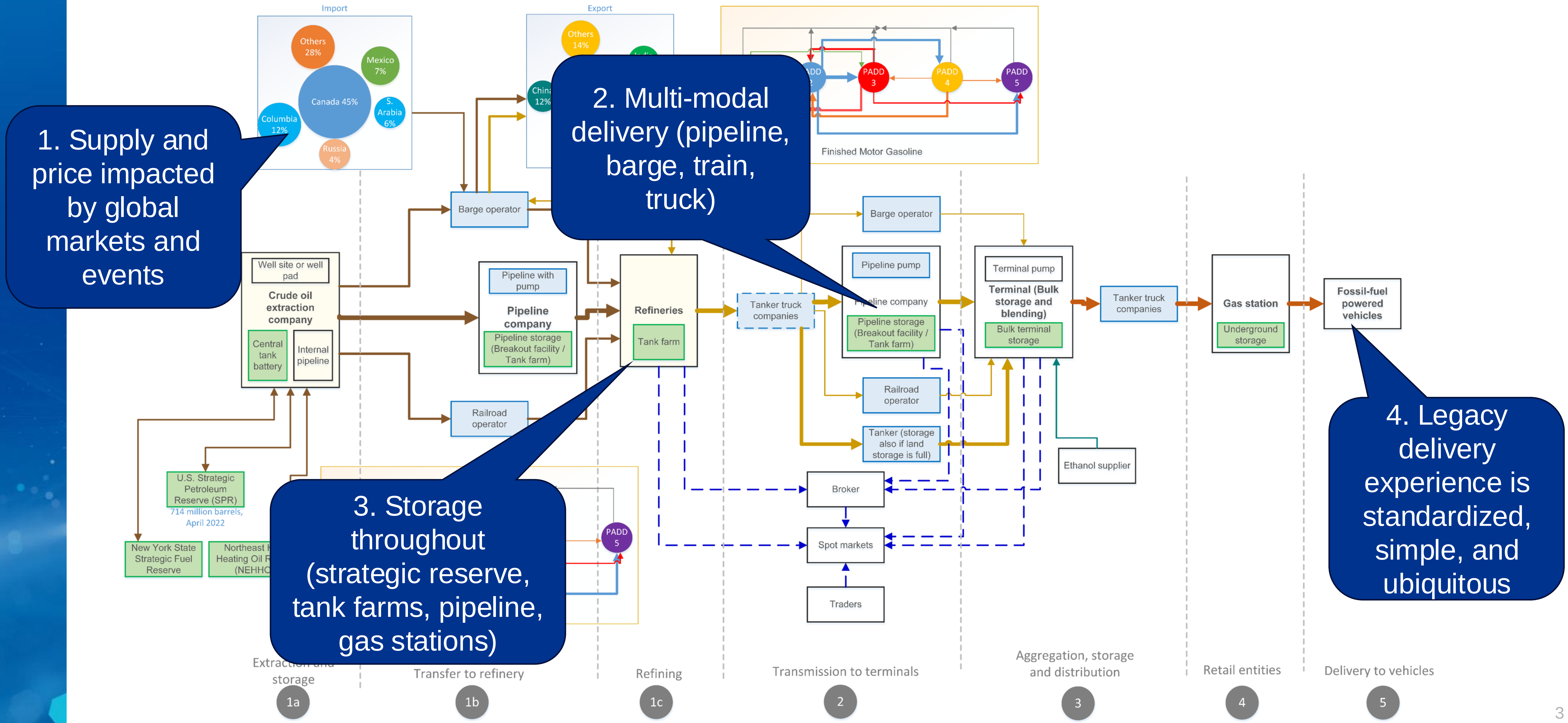
Motivation and Objective

- The transportation system is rapidly electrifying, displacing the functions of the present-day fossil fuel sector

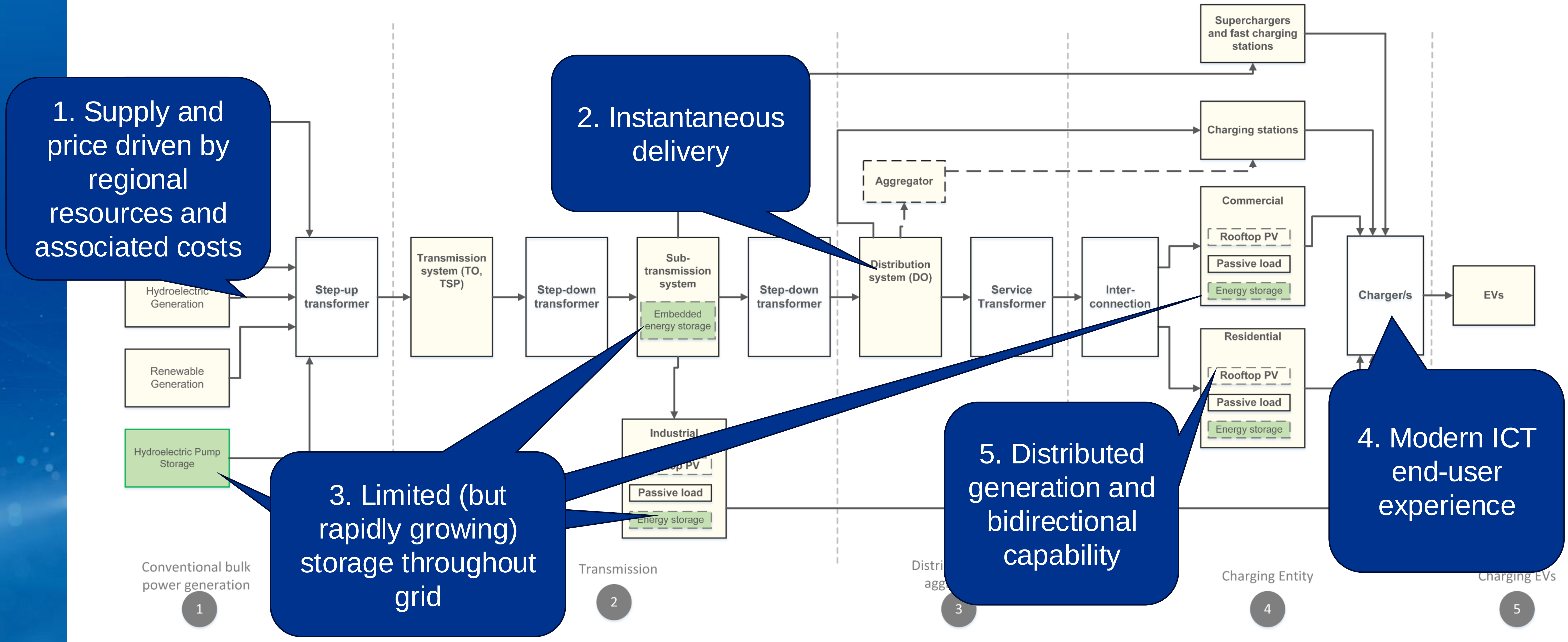
- Ensuring this rapid transition is smooth necessitates understanding the functional requirements of the emerging electrified transportation system and the understanding structure and performance of the current fossil fuel delivery system, which is less well understood and documented

- Sector Coupling is an emerging discipline to ensure the underlying structures, couplings, and attributes of these systems are identified, strengths leveraged, and weaknesses addressed

Fuel Supply Chain: Key Attributes



Electricity Supply Chain: Key Attributes



Ensuring Supply During Extreme Events

Demand surges can create shortages prior to extreme events

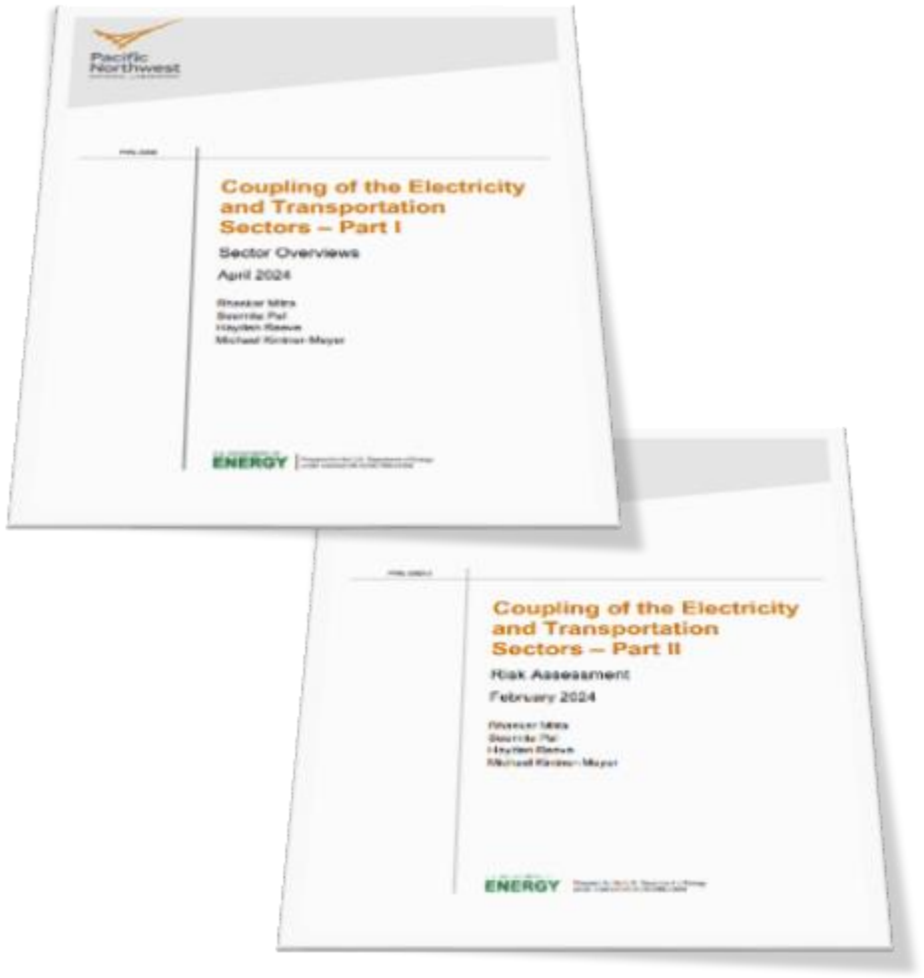
Disparities in restoration and replenishment time between sectors

Disparities in robustness of end-use experience

Distributed and bidirectional power generation

Summary

- Understanding and leveraging system structures and attributes to meet requirements will be critical to a smooth transition
- Sector Coupling plays a key role of illuminating these features in complex coupled systems
- Current focus on sector communication structure coupling & coordination frameworks at grid interfaces
- Currently supporting Oregon (through CESER funding) under their State Energy Security Plan
- Reports: PNNL-35826
  - [Coupling of the Electricity and Transportation Sectors - Part I: Sector Overviews](#)
  - [Coupling of the Electricity and Transportation Sectors - Part II: Risk Assessment](#)



Thank you

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