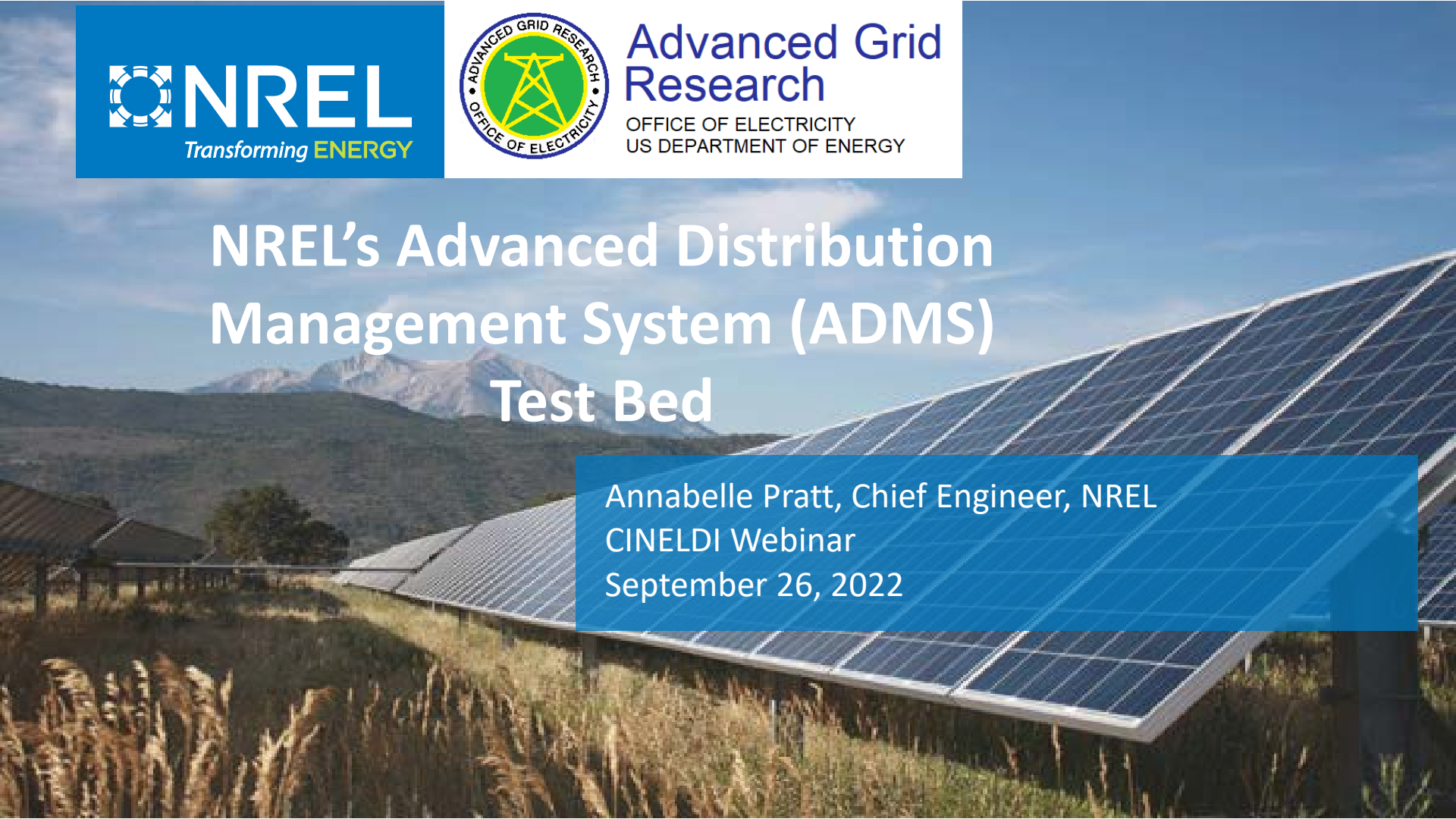
NREL
Transforming ENERGY

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

NREL's Advanced Distribution Management System (ADMS) Test Bed

Annabelle Pratt, Chief Engineer, NREL
CINELDI Webinar
September 26, 2022



DOE National Laboratories Overview

Source: http://energy.gov/maps/doe-national-laboratories

The National Renewable Energy Laboratory (NREL) is operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE).

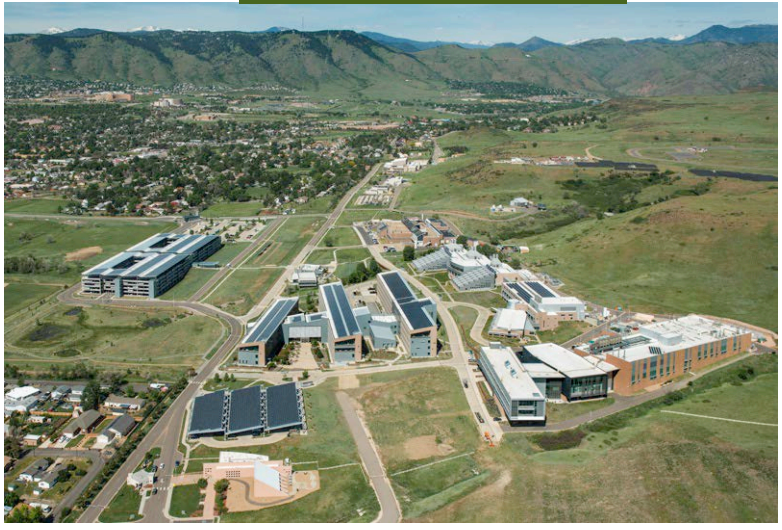
NREL Overview

- NREL is the only national laboratory ***dedicated*** to renewable energy and energy-efficiency research and development (R&D).
- Research ranges from fundamental ***science to technology*** solutions.
- ***Collaboration*** with industry and university partners is a hallmark.

Flatirons Campus in Boulder, CO

Photos by NREL

Main Campus in Golden, CO



The Energy Systems Integration Facility (ESIF) is a critical resource in the energy systems R&D ecosystem.

1. Thought Leadership
2. Cutting-Edge Research
3. Data & Modeling Tools
4. Scientific & Engineering Expertise
5. World-Class Computing & Laboratory Facilities

ESIF—A National User Facility

NREL's largest R&D facility (182,500 ft^2/20,000 m^2)

Space for ~200 NREL staff and research partners

Key research areas for the ESIF include:

- **Cybersecurity**
- **Energy resilience**
- **Grid systems integration**
- **Building technologies and thermal**
- **Advanced mobility**
- **Renewable fuels/gas and energy.**

Photos by NREL

DOE ADMS and DERMS Core Development

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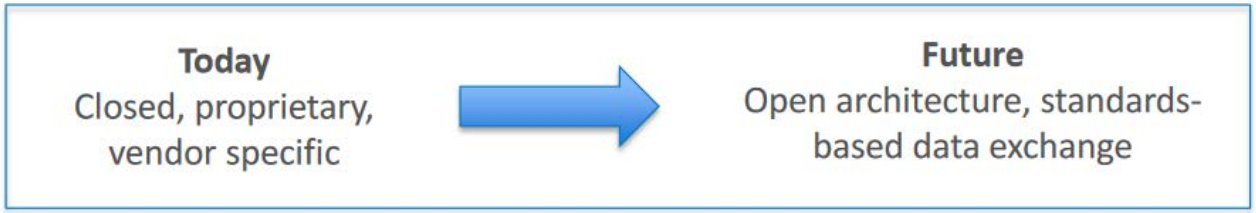
Transform utility electric distribution management systems to enable the integration and management of all assets and functions across the utility enterprise regardless of vendor or technology.



Four program areas:

Platform: Develop an open-source platform; evaluate advanced applications.

Test bed: Build a vendor-neutral test bed to evaluate existing and future advanced distribution management system (ADMS) functionalities in a realistic setting.

Applications: Develop an initial suite of ADMS applications.

Advanced control: Develop new integrated optimization and control solutions.

ADMS Test Bed

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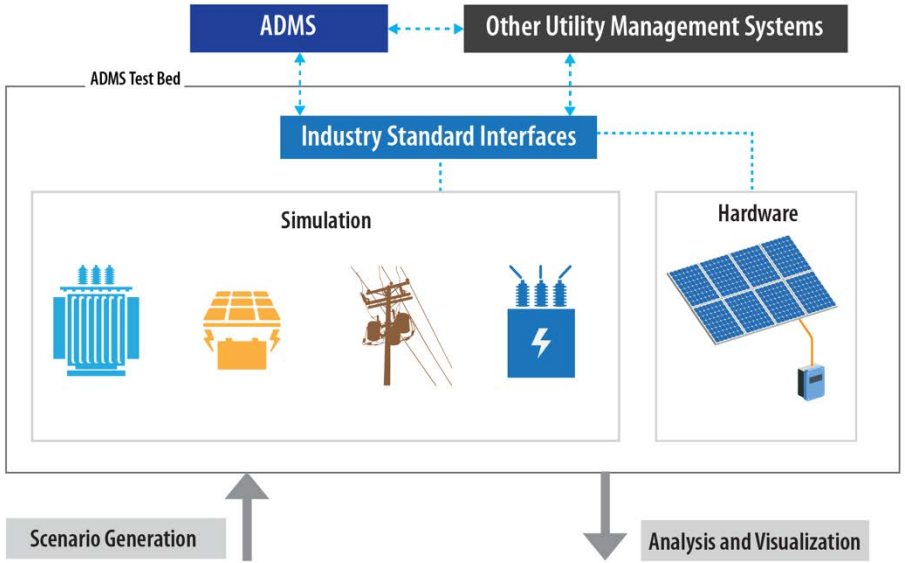
Goal: Accelerate industry adoption of ADMS to:

- Improve normal operations with high levels of distributed energy resources (DERs).
- Improve resilience and reliability.

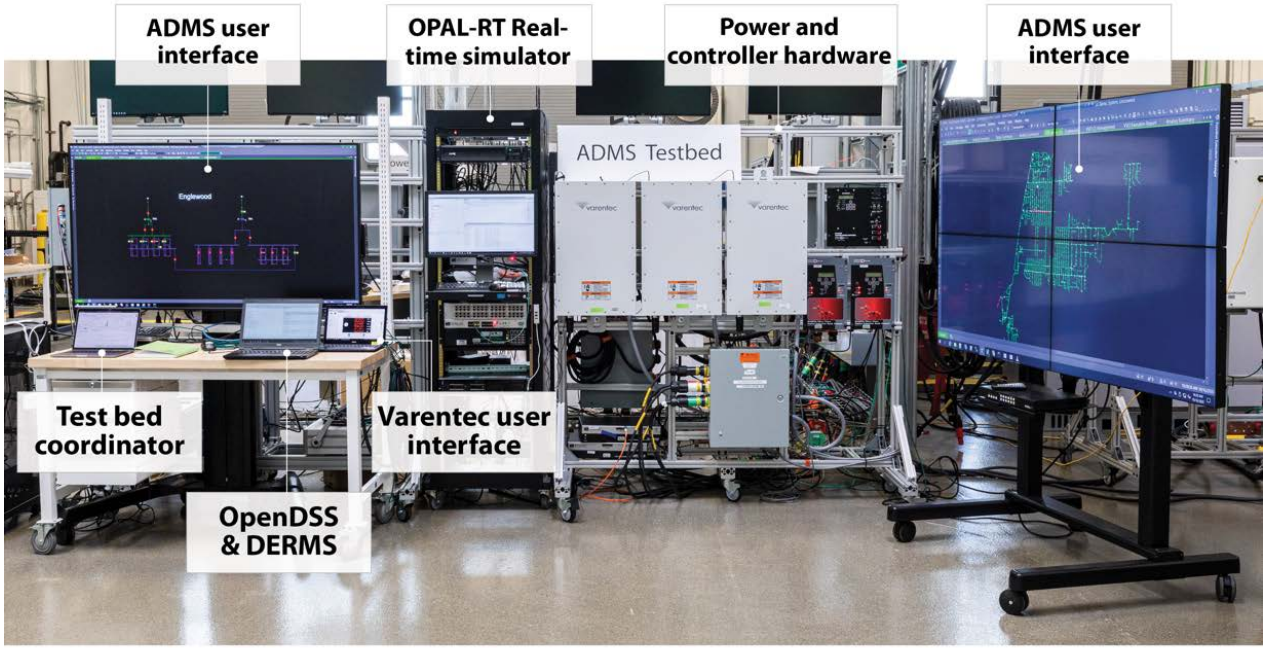
Approach: Partner with utilities and vendors to evaluate specific use cases and applications to:

- Set up a realistic laboratory environment.
- Simulate real distribution systems.
- Integrate distribution system hardware.
- Use industry-standard communications.
- Create advanced visualization capability.



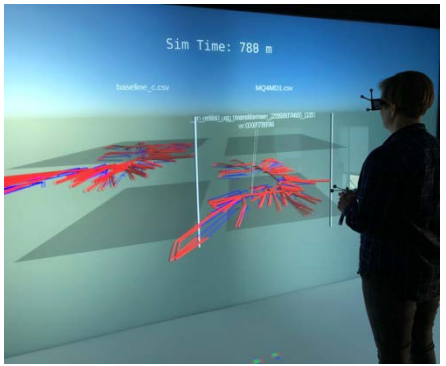
https://www.nrel.gov/grid/advanced-distribution-management.html

ADMS Test Bed



Photos by NREL

2D real-time visualization



3D visualization

ADMS Test Bed

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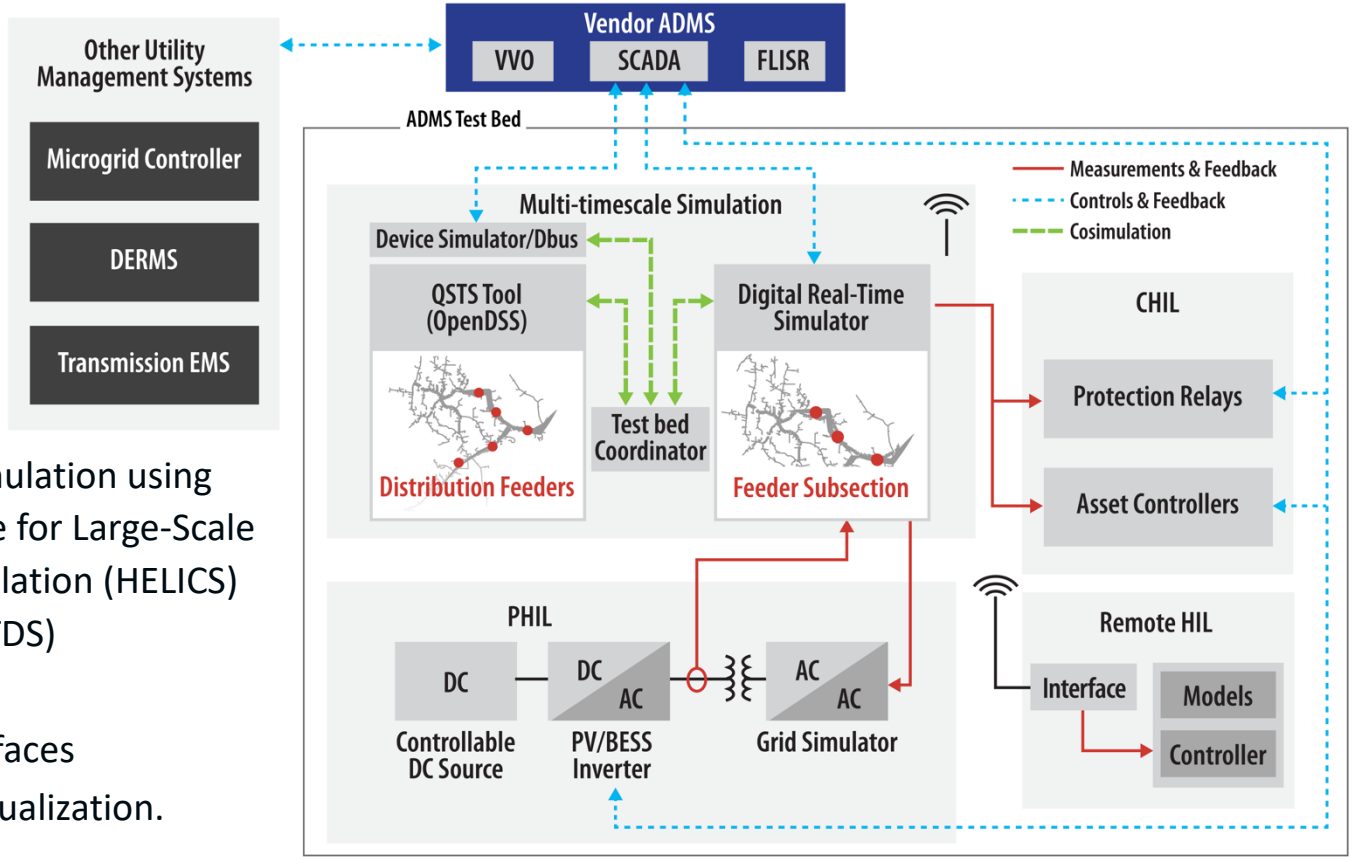
ADMS Test Bed capabilities include:

- Multi-timescale co-simulation using the Hierarchical Engine for Large-Scale Infrastructure Co-Simulation (HELICS) (OpenDSS/OPAL-RT/RTDS)
- Hardware integration
- Communications interfaces
- Data collection and visualization.



ADMS Test Bed
Use Case Development

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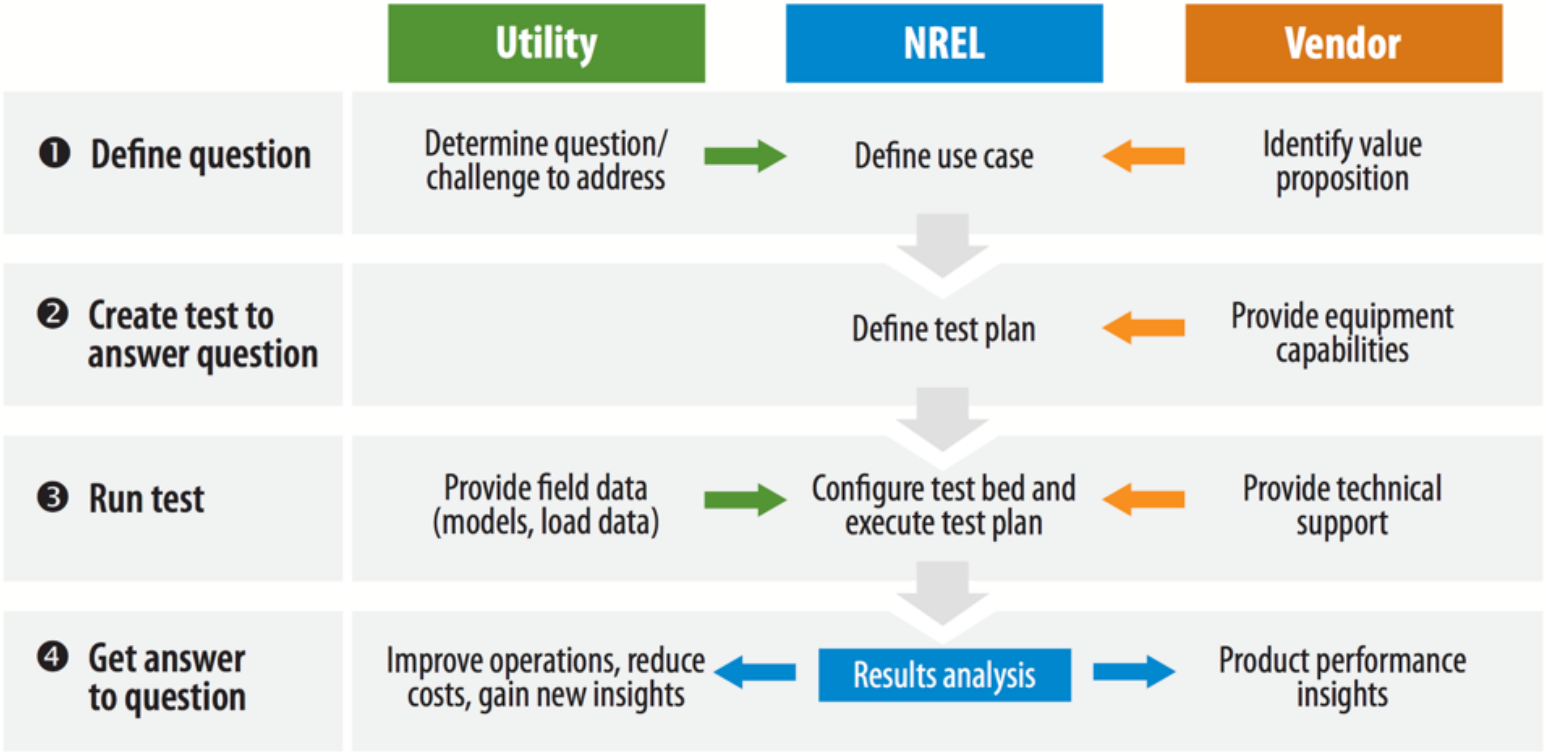
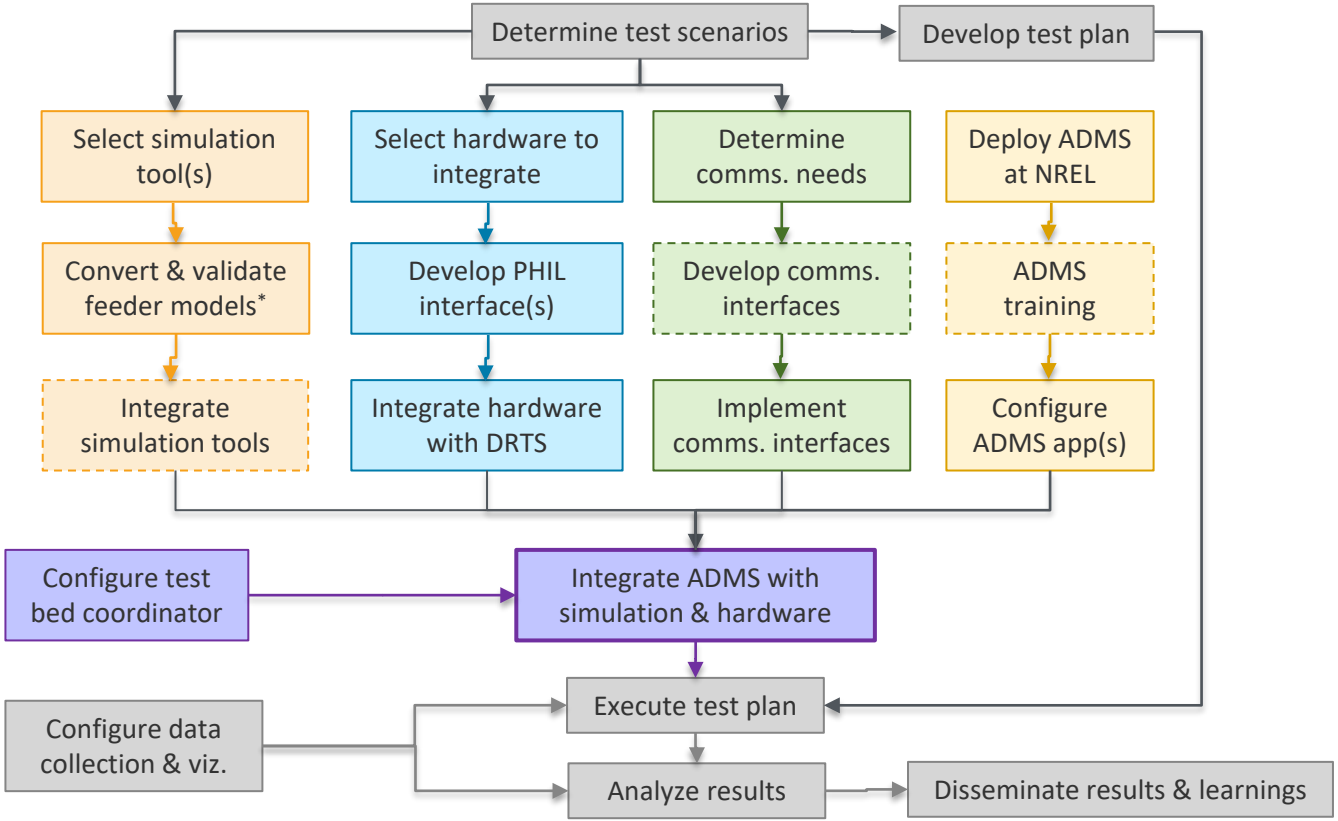


Configuring the Test Bed



* NREL's Distribution Transformation Tool (DiTTo): https://github.com/NREL/ditto.

ADMS Test Bed Use Cases

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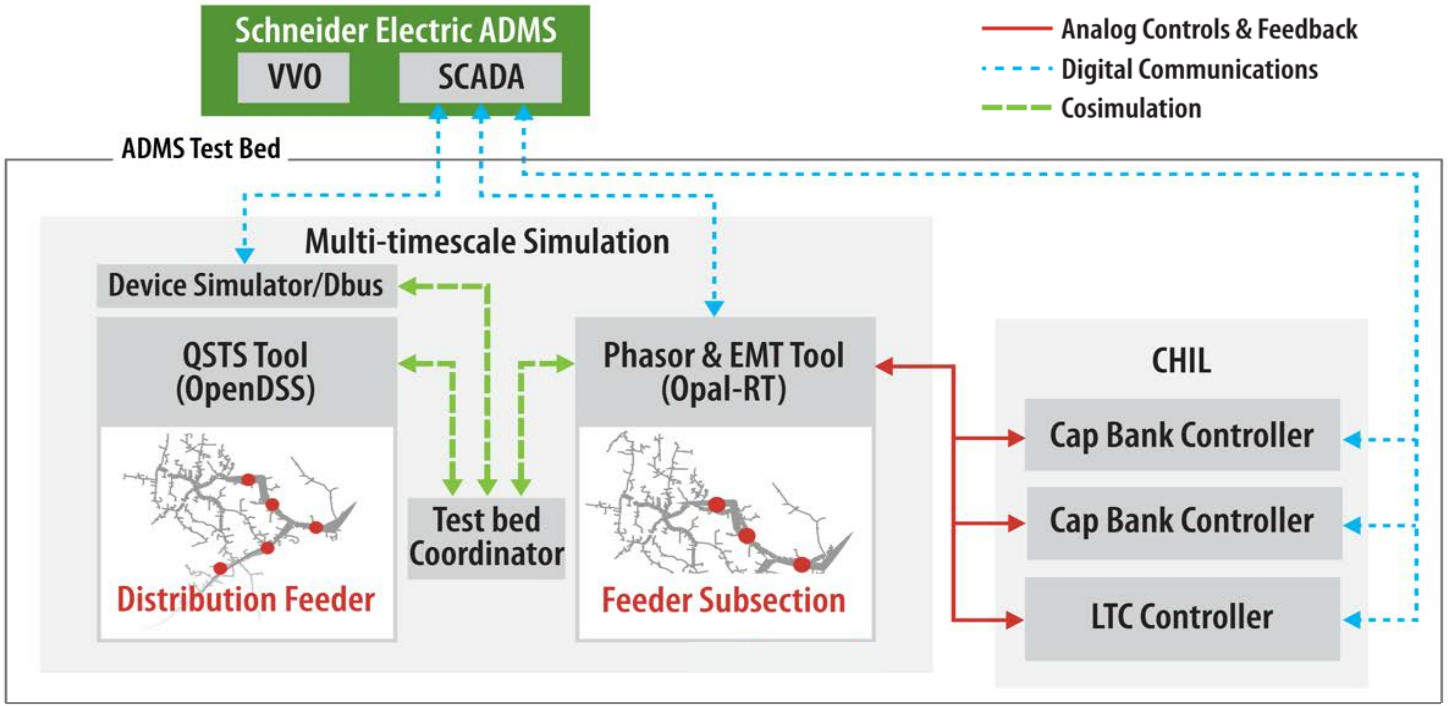
- Peak load management with ADMS and DERMS
  - Holy Cross Energy/Survalent
- **ADMS network model quality impact on VVO**
  - **Xcel Energy/Schneider Electric**
- AMI-based, data-centric grid operations
  - SDG&E + GridAPPS-D
- FLISR in the presence of DERs
  - Central Georgia EMC/Survalent → August 2022
- Federated DERMS for high PV system
  - Southern Company/Oracle + GridAPPS-D → February 2023
- DER controls strategies for T&D grid services
  - Xcel Energy + GridAPPS-D → September 2022
- Modeling and co-optimizing grid operations and facility operations with interoperable ADMS, VPP, microgrids, and grid-edge DERs
  - Shell + Spirae → October 2023
- Integration of advance grid monitoring and analytics with ADMS FLISR application
  - IEC + EGM → December 2023

ADMS test bed capabilities used by:

- Non-wires alternatives
- ECO-IDEA
- GO-SOLAR
- SolarExpert
- FAST-DERMS
  - SDG&E, Oracle, EPRI + GridAPPS-D → April 2023
- Resilient Operation of Networked Microgrids (RONM)
  - SDG&E, Cobb EMC → Nov 2022
- REORG
  - Holy Cross Energy, Minsait ACS → Mar 2024
- PV Integration using a Virtual Airgap (PIVA)
  GridBright, SDG&E → Sep 2023

ADMS network model quality Use Case: Lab Setup



Partners:
Xcel Energy
Schneider Electric
PNNL
EPRI
Opal-RT

ADMS network model quality Use Case: Post-Processed Results

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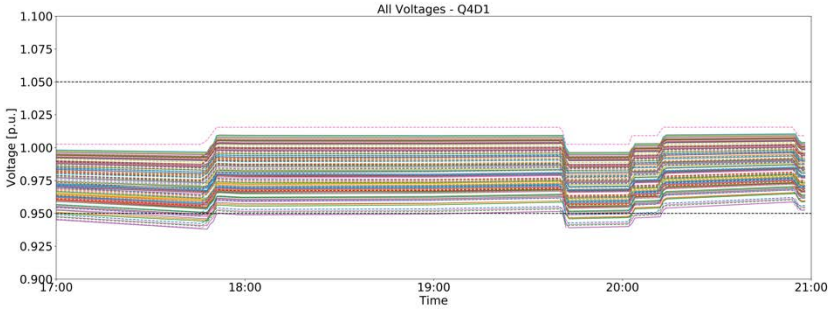
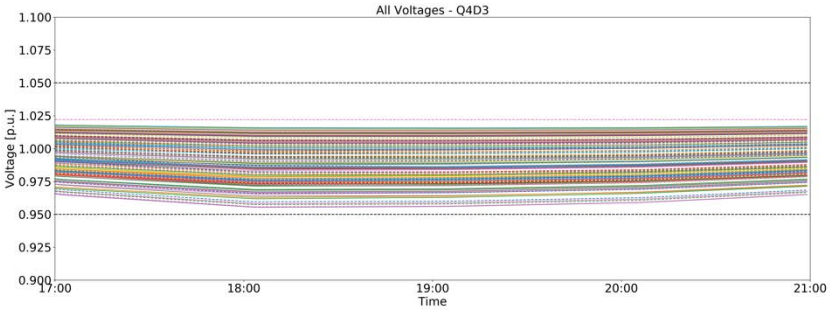
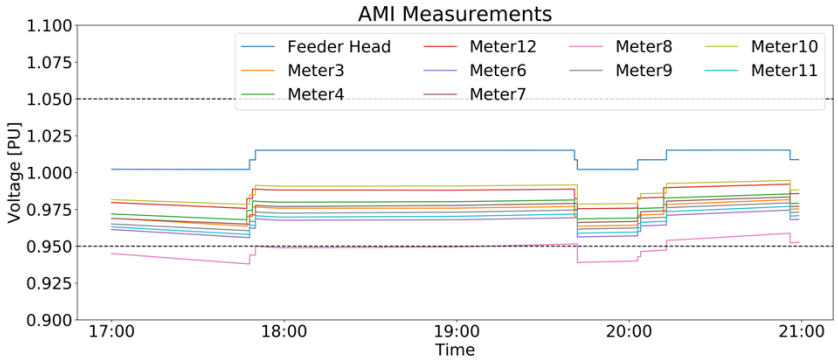
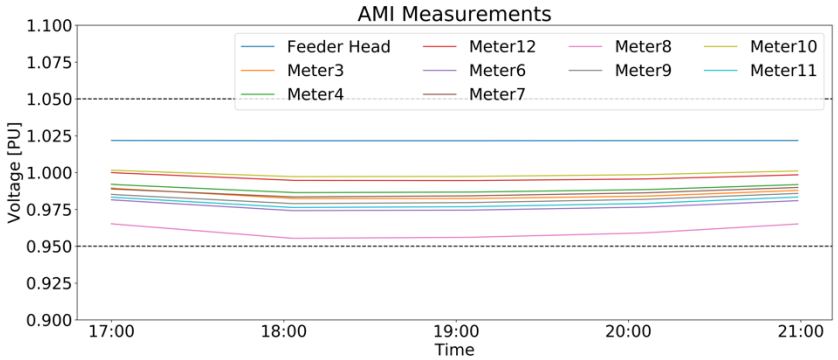
Q4D1 (High model quality; feeder head only measurements)



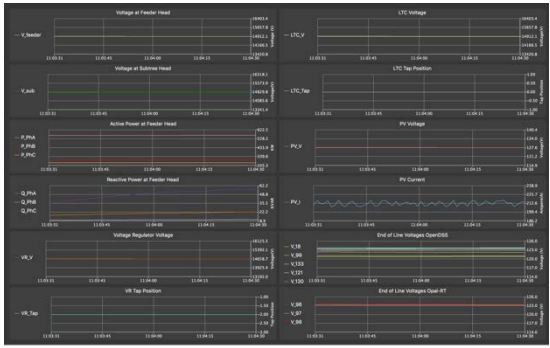
Q4D3 (High model quality; feeder head + 10 AMI measurements)



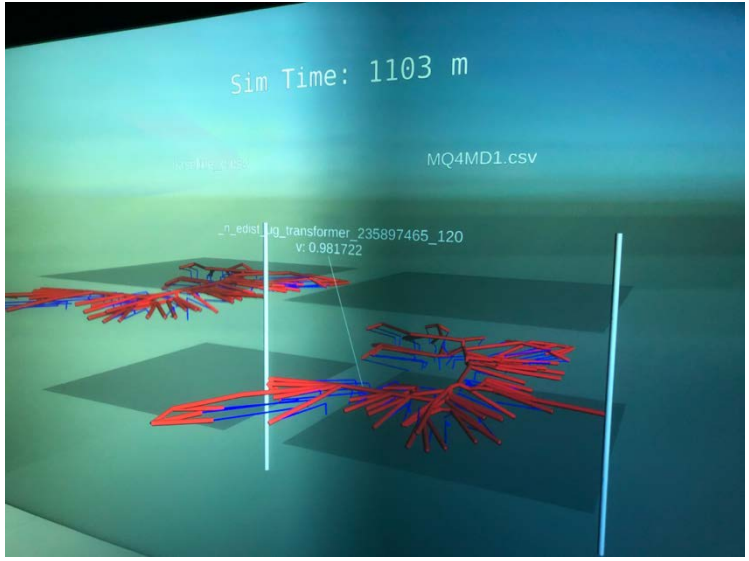


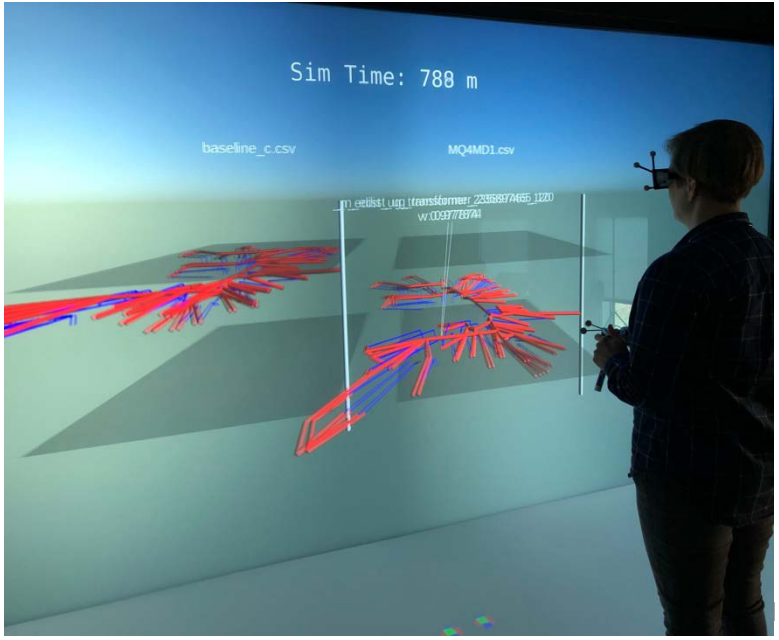


ADMS network model quality Use Case: Post-Processed 3D Visualization



- Real-time data streaming for 2D visualization
- 3D visualization of results.





Photos by NREL

Upcoming Events

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ADMS Test Bed Workshop

- Planned for in person at NREL, Golden, CO, Nov. 7–8, 2022
- *Register by Sept. 27; foreign national forms due Sept. 29.*
- 2022 Advanced Distribution Management System Test Bed Workshop | Grid Modernization | NREL.

Survalent User Conference

- Atlanta, GA, Oct. 19–20

Survalent. UC 22 2022 Global User Conference

For Further Reading

- H. Padullaparti, A. Pratt, I. Mendoza, S. Tiwari, M. Baggu, C. Bilby, and Y. Ngo, "Peak Load Management in Distribution Systems Using Legacy Utility Equipment and Distributed Energy Resources," IEEE GreenTech, 2021.
- A. Pratt, H. Padullaparti, I. Mendoza, M. Baggu, Y. Ngo, and H. Arant, "Defining a Use Case for the ADMS Test Bed: Fault Location, Isolation, and Service Restoration with Distributed Energy Resources," IEEE ISGT, 2021.
- K. Prabakar, N. Wunder, N. Brunhart-Lupo, C. Pailing, K. Potter, M. Eash, and K. Munch, "Open-Source Framework for Data Storage and Visualization of Real-Time Experiments," Kansas Power and Energy Conference, July 2020.
- A. Pratt, I. Mendoza, M. U. Usman, S. Tiwari, H. Padullaparti, M. Baggu, and E. Lightner, "Using an Advanced Distribution Management System Test Bed to Evaluate the Impact of Model Quality on Volt/VAR Optimization," IEEE T&D, Chicago, Illinois, October 2020.
- A. Pratt, M. Baggu, S. Veda, F. Ding, I. Mendoza, and E. Lightner, "Testbed to Evaluate Advanced Distribution Management Systems for Modern Power Systems," IEEE Eurocon, July 2019.
- S. Veda, H. Wu, M. Martin, and M. Baggu, "Developing Use Cases for the Evaluation of ADMS Applications to Accelerate Technology Adoption," IEEE GreenTech, March 2017.
- S. Veda, M. Baggu, and A. Pratt, "Defining a Use Case for ADMS Testbed: Data Quality Requirements for ADMS Deployment," IEEE ISGT, February 2019.
- J. Wang, B. Lundstrom, I. Mendoza, and A. Pratt, "Systematic Characterization of Power Hardware-in-the-Loop Evaluation Platform Stability," IEEE ECCE, September 2019.
- K. Prabakar, B. Palmintier, A. Pratt, A. Hariri, I. Mendoza, and M. Baggu, "Improving the Performance of Integrated Power-Hardware-in-the-Loop and Quasi-Static Time-Series Simulations," *IEEE Transactions on Industrial Electronics* (2020), DOI: 10.1109/TIE.2020.3029465.

Thank You

www.nrel.gov

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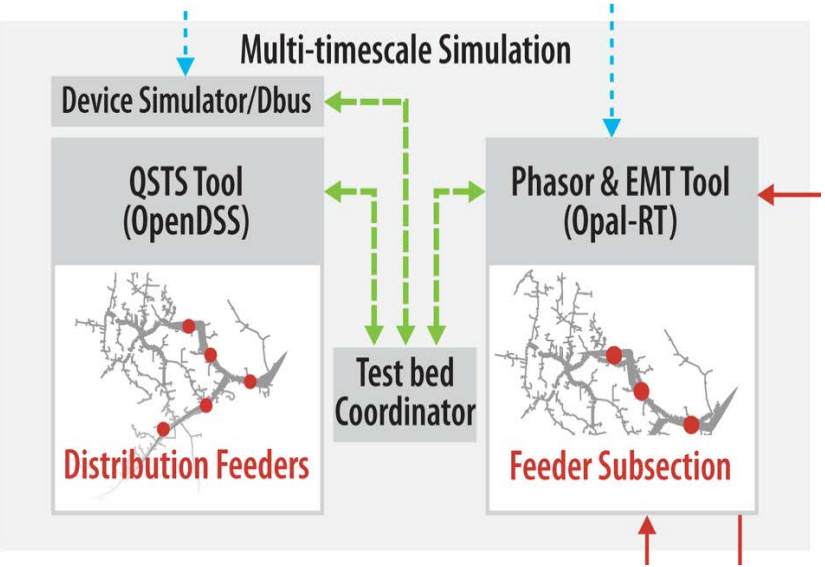
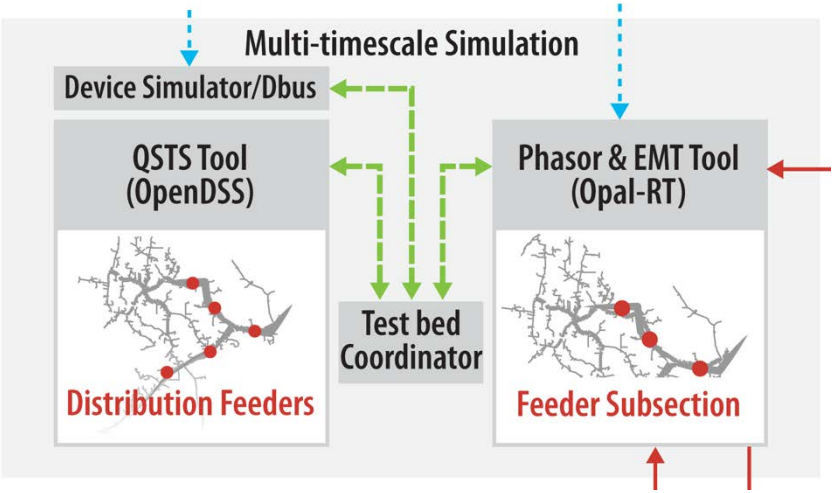
Multi-Timescale Simulation

- Can select one or more simulators to fit use case.
- Can run parts of the feeder in different simulators.
- We have used/are using:
  - OpenDSS by EPRI:
    - Quasi-static time series (QSTS)
    - 1-s minimum time step; minutes typical.
  - ePHASORSIM by OPAL-RT:
    - Dynamic phasor, 1- to 10-ms time step.
  - eMEGASIM by OPAL-RT:
    - Electromagnetic (EMT) simulation.
  - RTDS EMT simulations.



Multi-Timescale Simulation Cont.

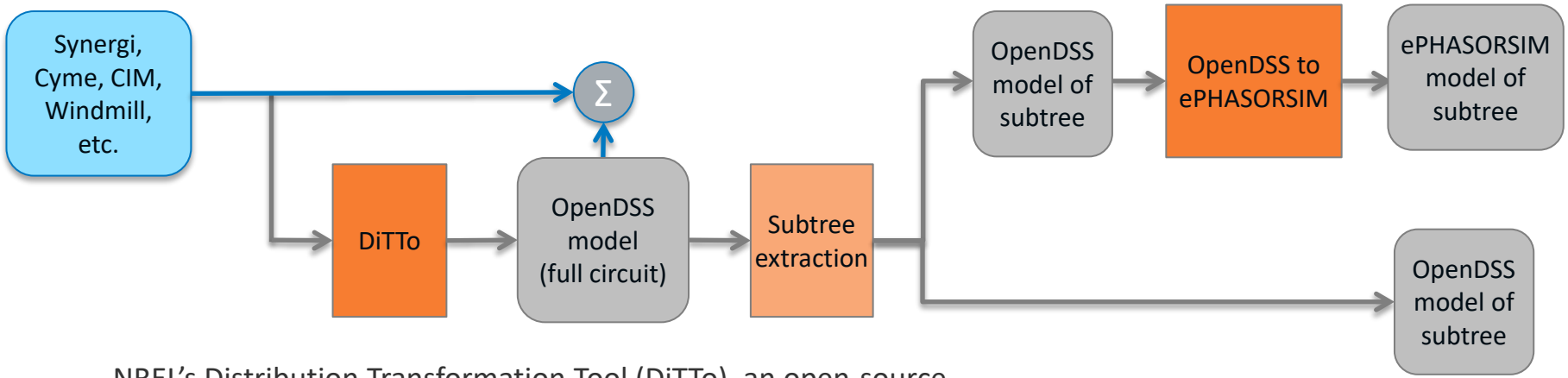
- Orchestrated by test bed coordinator software
- Written in Python
- Uses the HELICS framework:
  - U.S. Department of Energy investment through the Grid Modernization Initiative
  - www.helics.org.



Model Conversion Tools

- *Model reduction is required for real-time simulators—can use NREL or commercial tools.*
- *Example conversion flow*

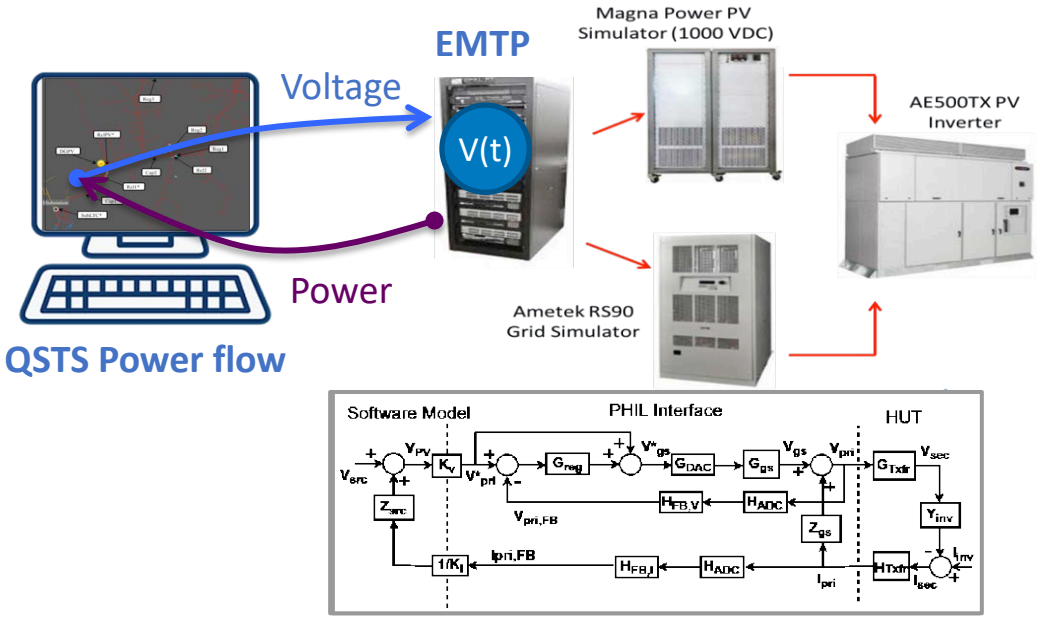
https://github.com/NREL/DSS2ePHASOR

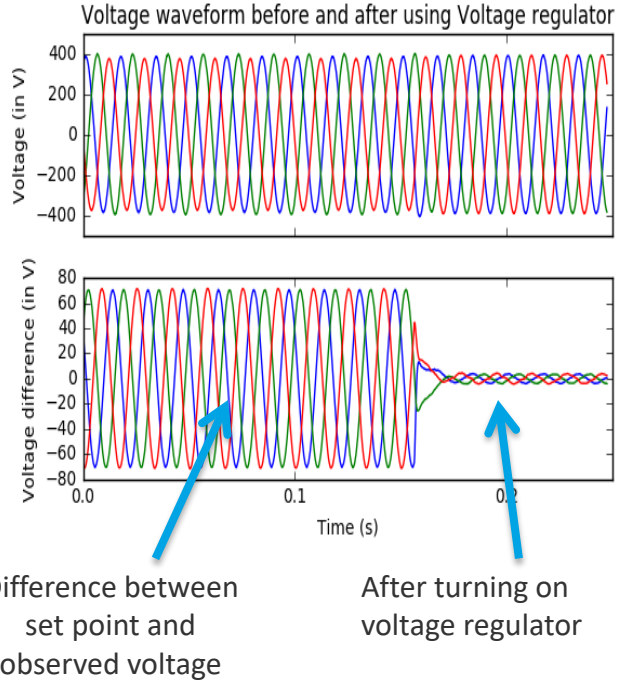


NREL's Distribution Transformation Tool (DiTTo), an open-source framework to convert various distribution system modeling formats: https://github.com/NREL/ditto.

Hardware Integration

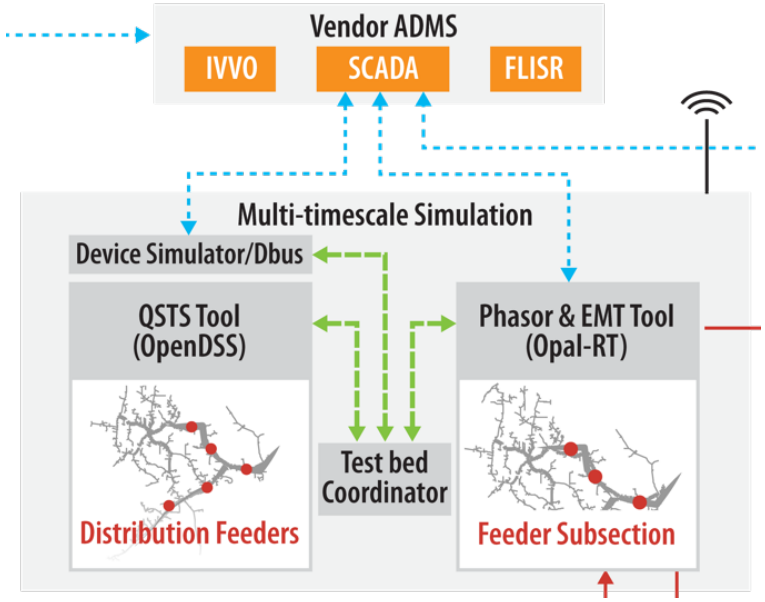
- Hardware-in-the-loop integration of controller and/or power hardware
- NREL-owned equipment is available for use.





Communications Interfaces

- Uses industry-standard interfaces
- Distributed Network Protocol 3 (DNP3):
  - ADMS to OpenDSS:
    - Device simulator developed by EPRI to provide communications interface.
  - ADMS to OPAL-RT/RTDS:
    - DNP3 drivers available.
- Currently implementing 2030.5 clients:
  - Developed by EPRI.
- Modbus is being set up for some hardware.
- MultiSpeak.



Data Collection and Management

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- Architected and implemented data management tools
- C++ code on GitHub (https://github.com/NREL/rts-vis-app and https://github.com/NREL/rts-data)
- 3D visualization was also developed.

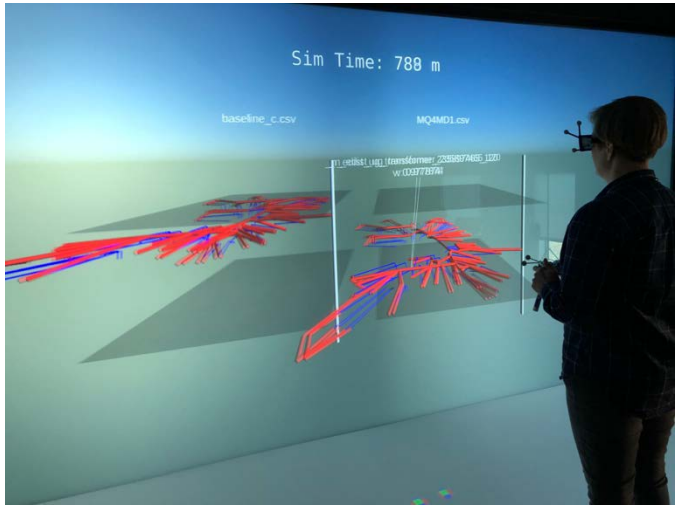
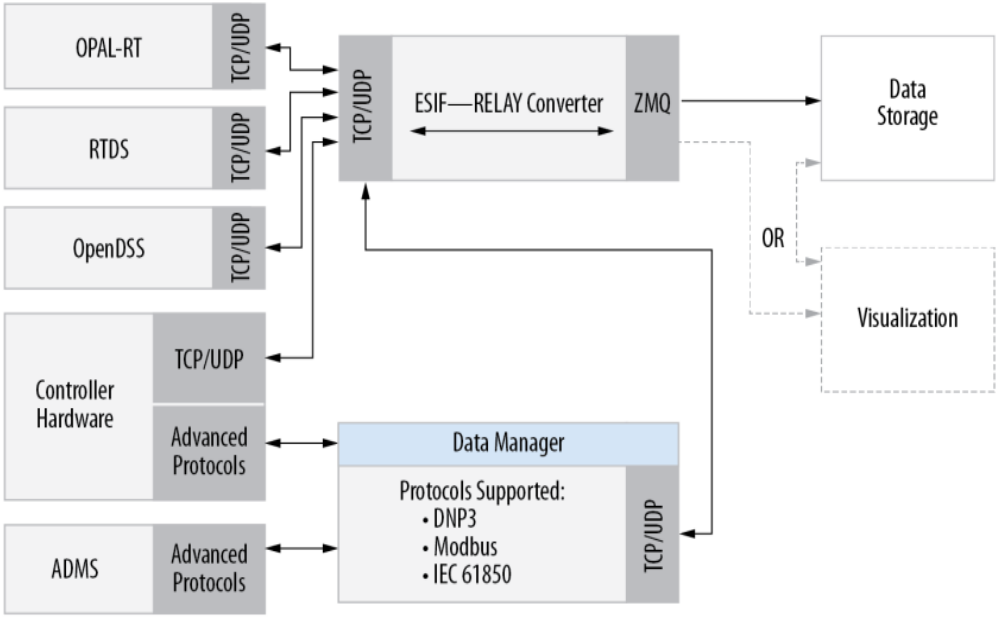
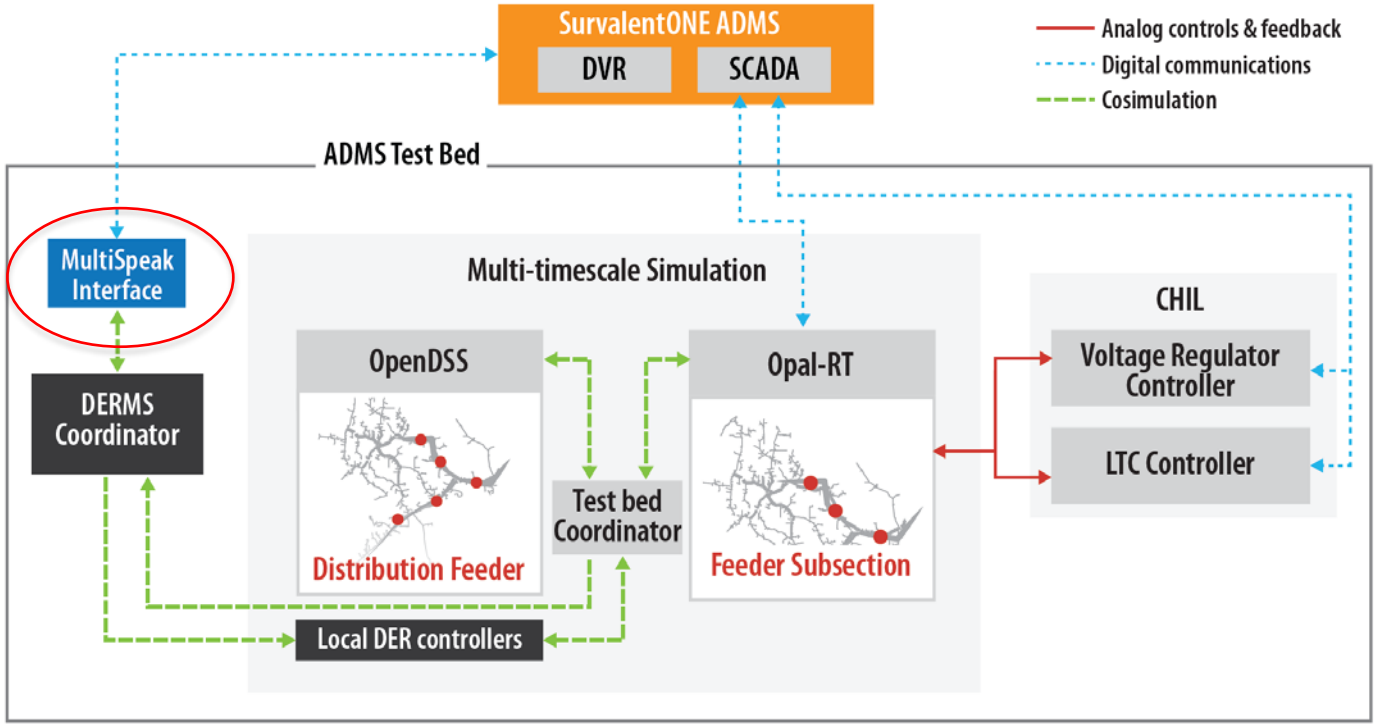


Photo by NREL



Peak Load Management Use Case: Test Bed Setup



Partners

Holy Cross Energy

Survalent

NRECA

EPRI

PNNL

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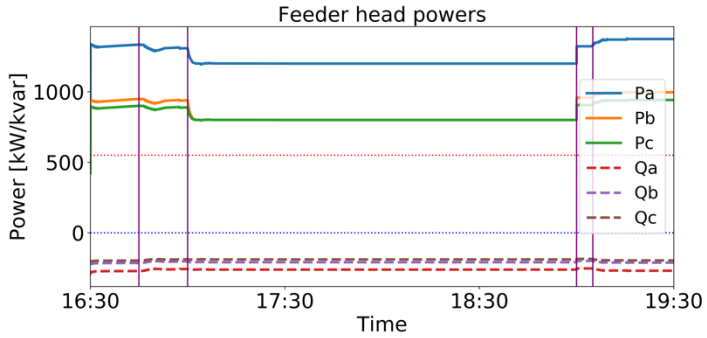
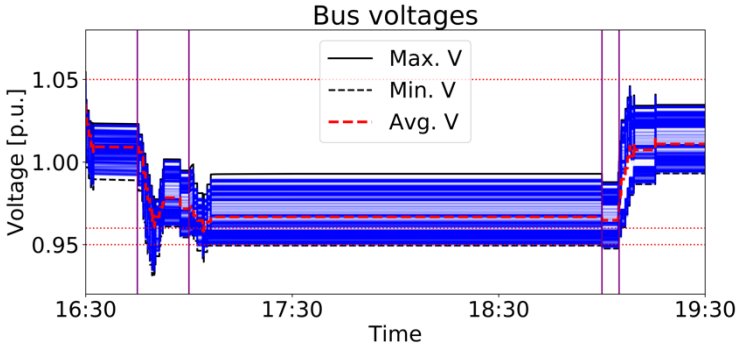
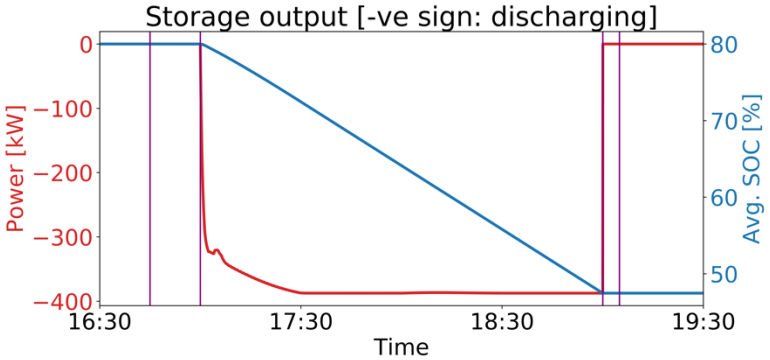
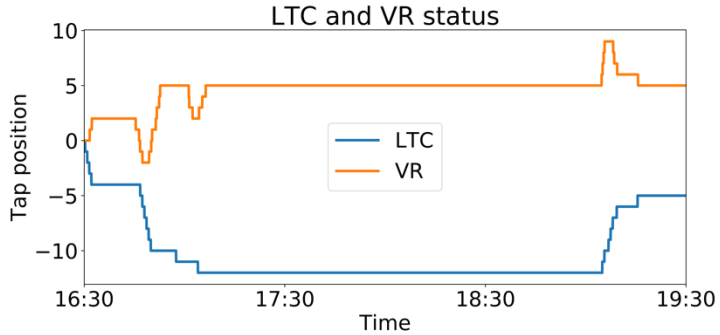
Peak Load Management Use Case: Post-Processed Results









Peak Load Management Use Case: Post-Processed Results Cont.

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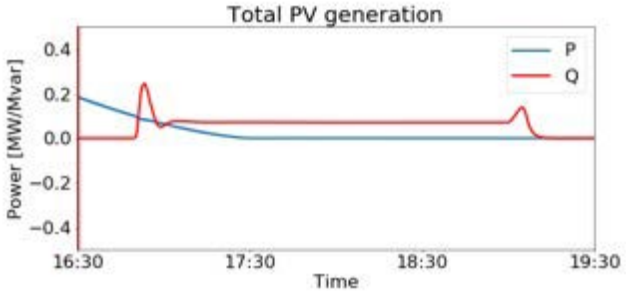

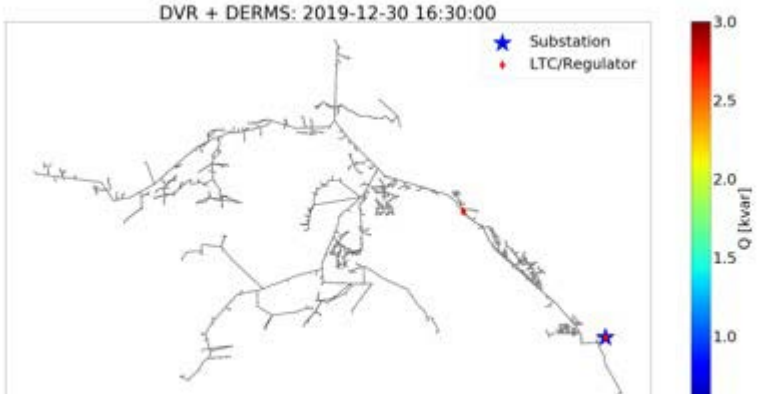

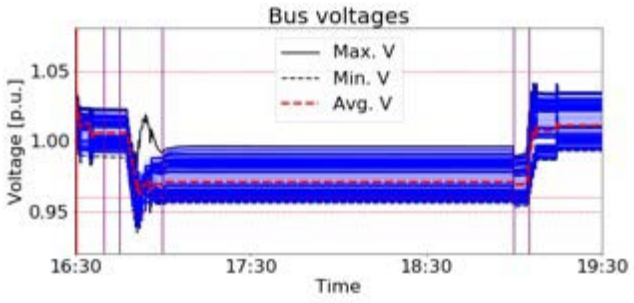

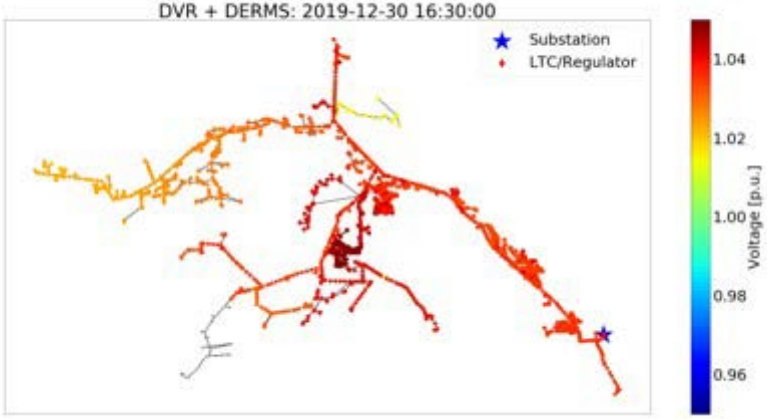

FAST-DERMS Project

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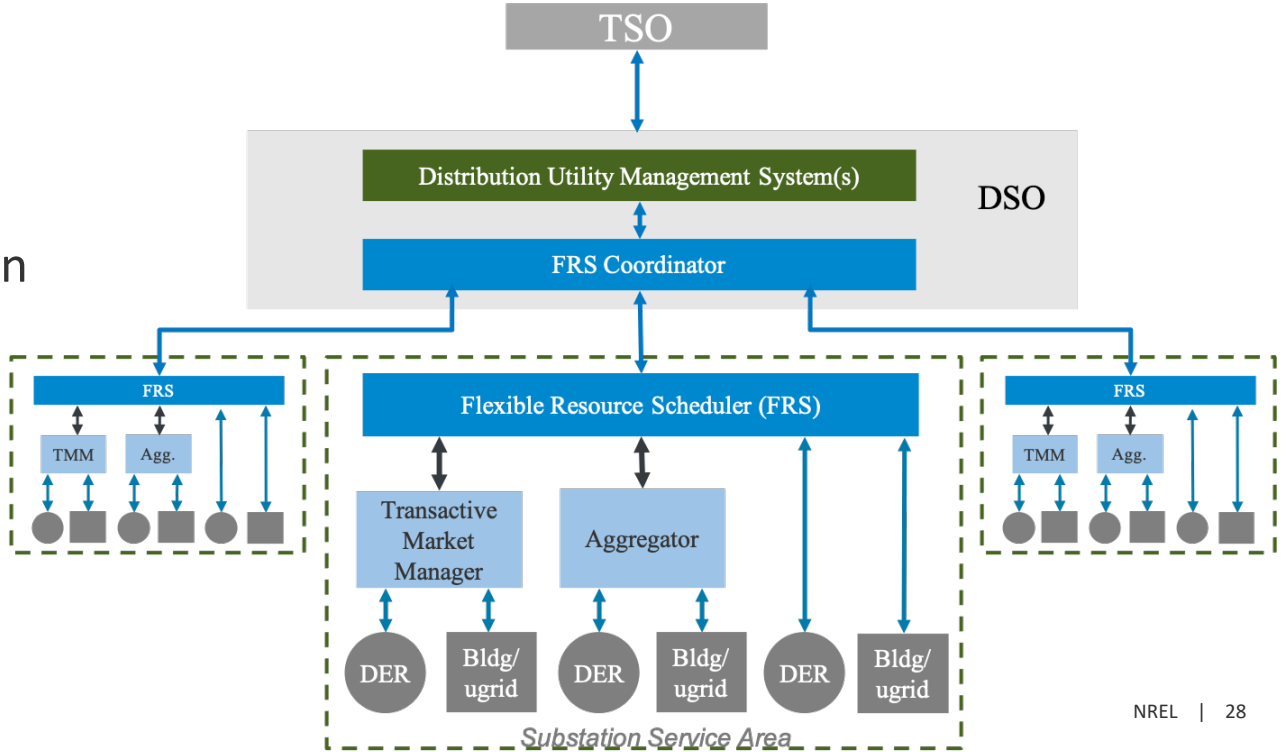
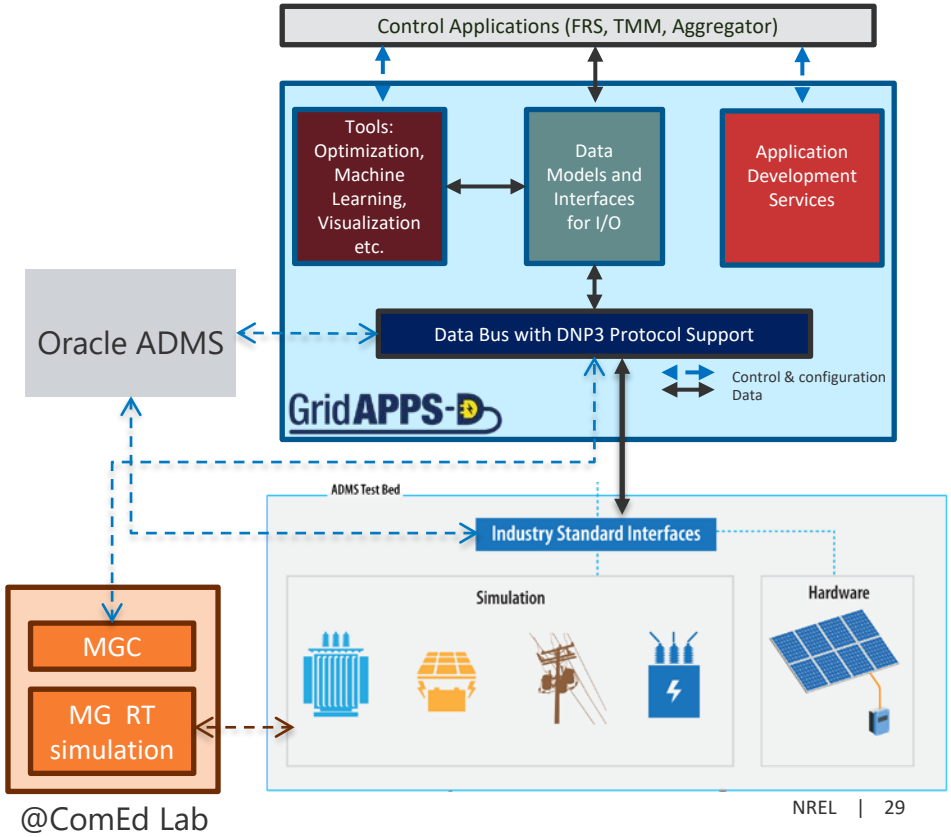
Develop a controls architecture to manage a broad range of DERs across the grid for bulk system services through transactive, aggregation, and direct control methods.

- "Total DSO"
- Laminar coordination
- Distributed.



FAST-DERMS Lab Setup

- GridAPPS-D platform:
  - FRS, aggregators, transactive market manager and HEMS
- Oracle commercial ADMS
- NREL's Object-oriented Controllable High-resolution Residential Energy (OCHRE™) residential building simulator
- High-performance computer
- 2030.5 communications.

Partners:

- SDG&E, Southern Company, ComEd, New York Power Authority, Oracle, GridBright, EPRI, LBNL, PNNL, ORNL, ISU, UNCC.