



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



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

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

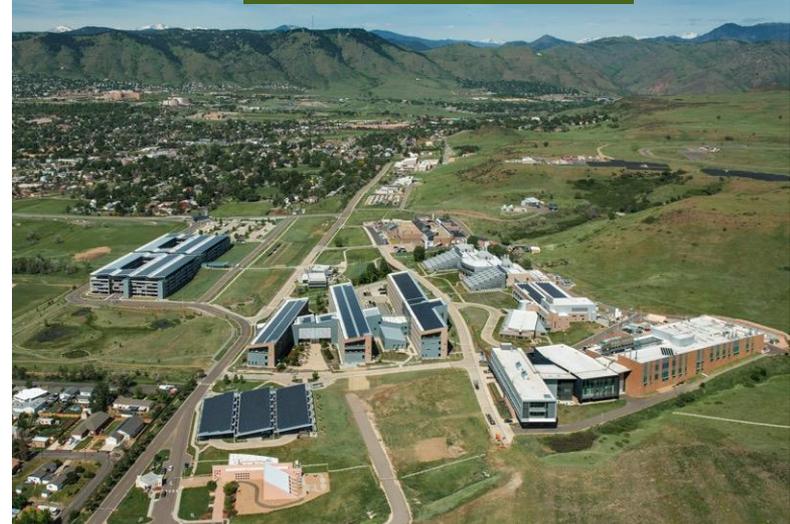
NREL Overview

- 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



Main Campus in Golden, CO



Photos by NREL

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 ft²/20,000 m²)
Space for ~200 NREL staff and research partners

Key research areas for the ESIF include:

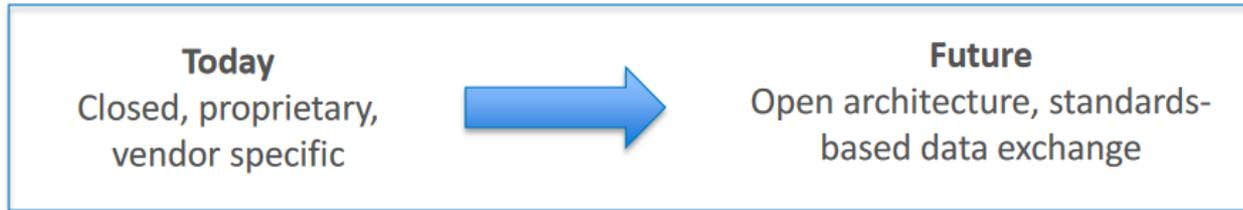
- **Cybersecurity**
- **Energy resilience**
- **Grid systems integration**
- **Building technologies and thermal**
- **Advanced mobility**
- **Renewable fuels/gas and energy.**



DOE ADMS and DERMS Core Development



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

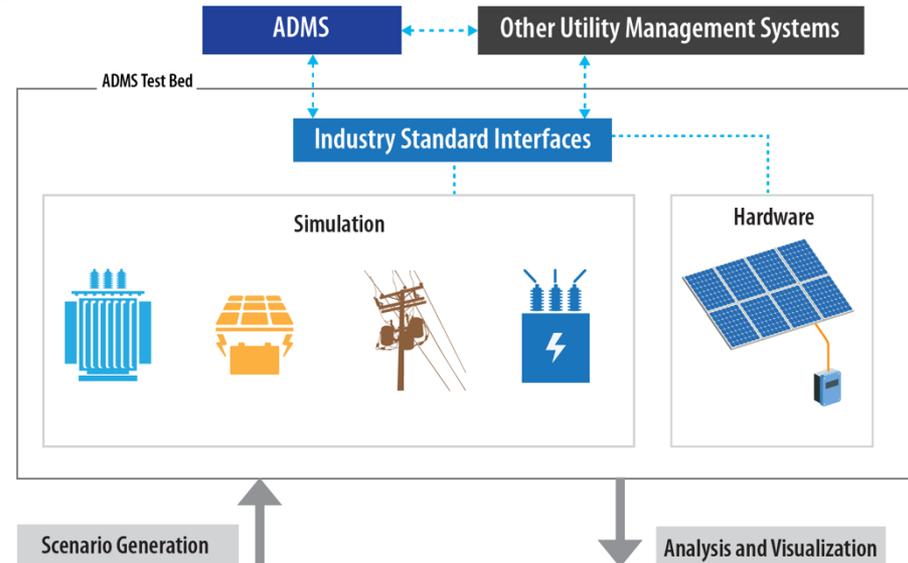


Goal: Accelerate industry adoption of ADMS to:

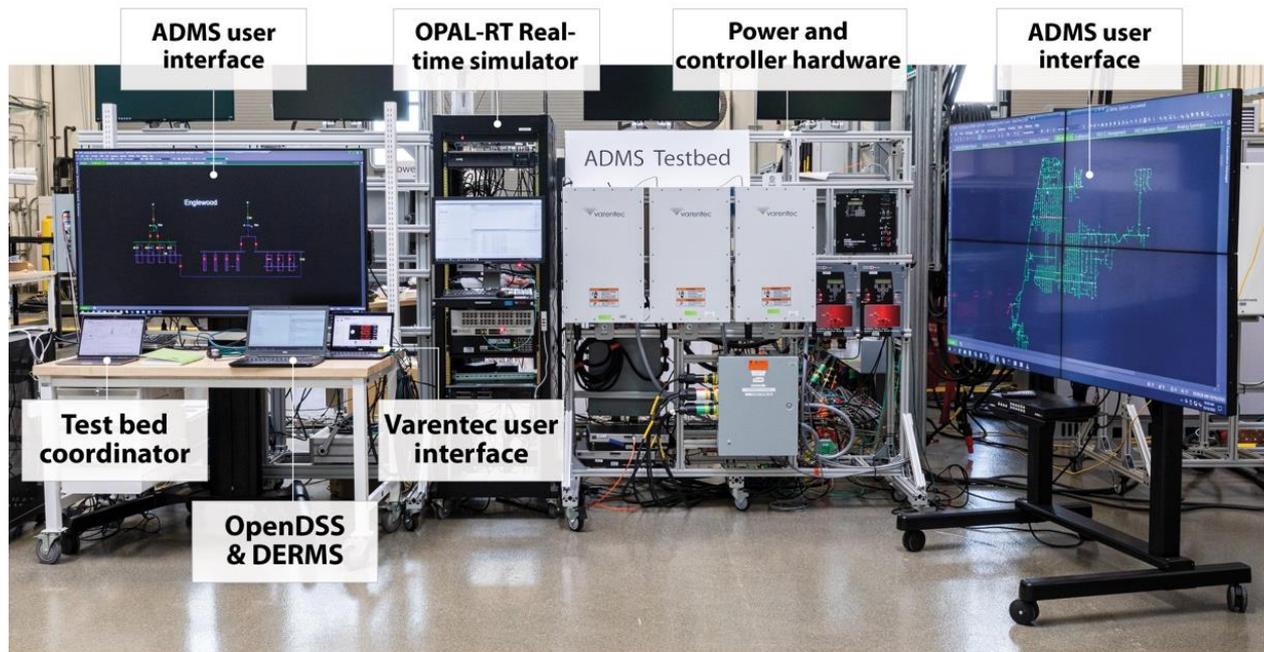
- Improve normal operations with high levels of distributed energy resources (DERs).
- Improve resilience and reliability.

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

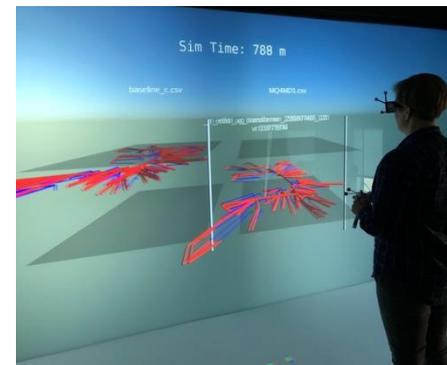
- Set up a realistic laboratory environment.
- Simulate real distribution systems.
- Integrate distribution system hardware.
- Use industry-standard communications.
- Create advanced visualization capability.



ADMS Test Bed



2D real-time visualization



3D visualization

Photos by NREL

ADMS Test Bed



Other Utility
Management Systems

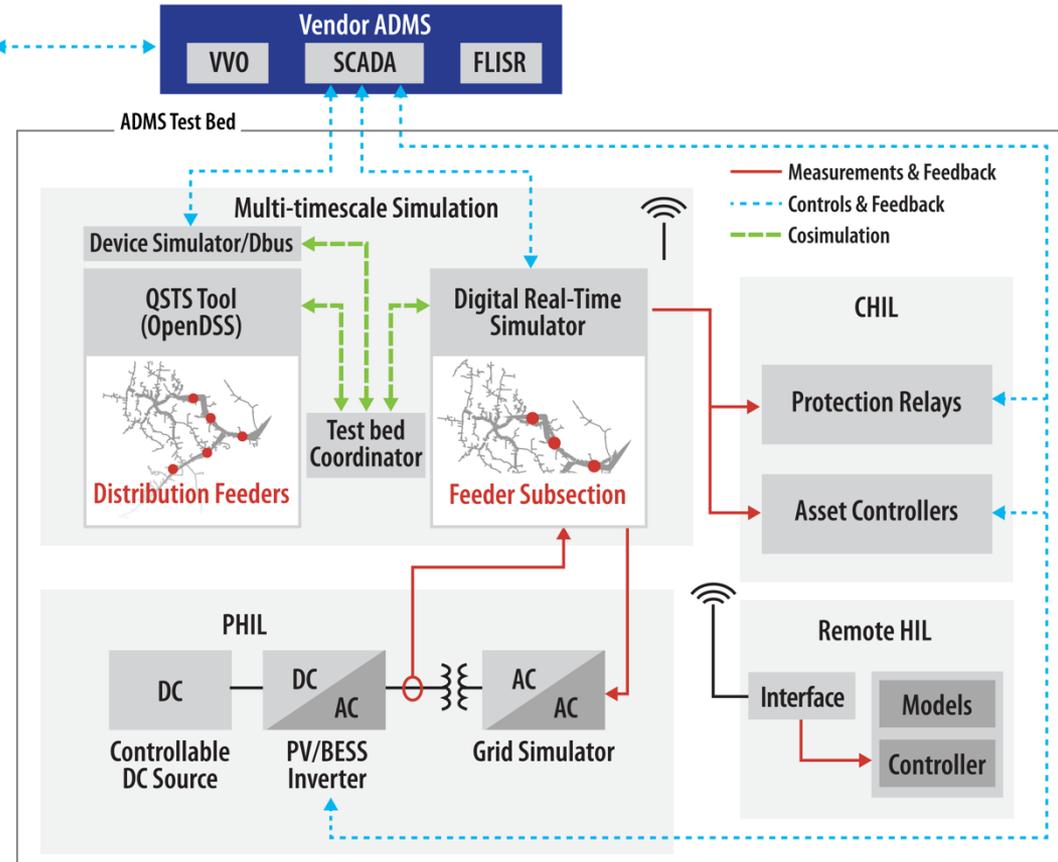
Microgrid Controller

DERMS

Transmission EMS

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.

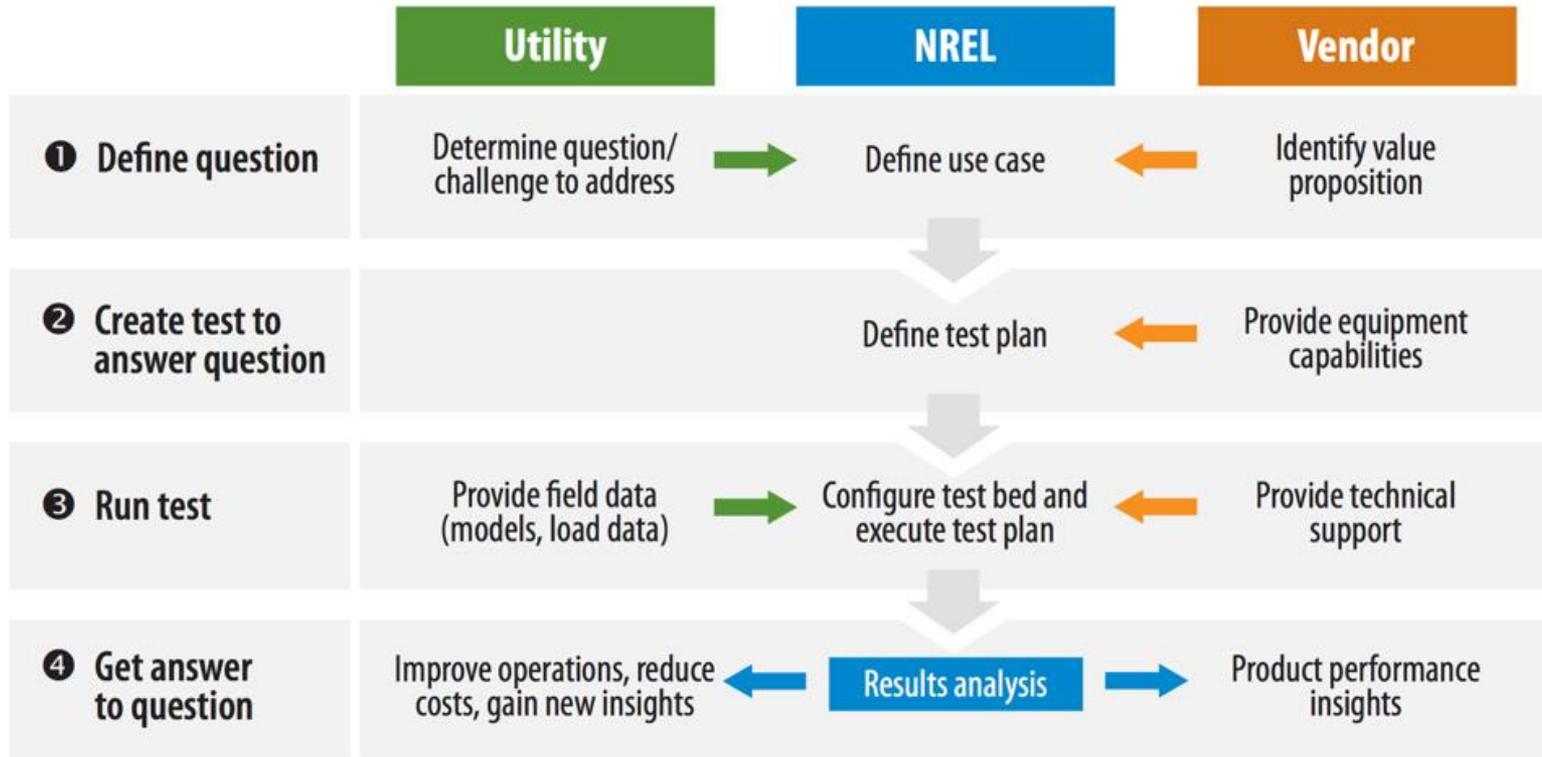


ADMS Test Bed Use Case Development

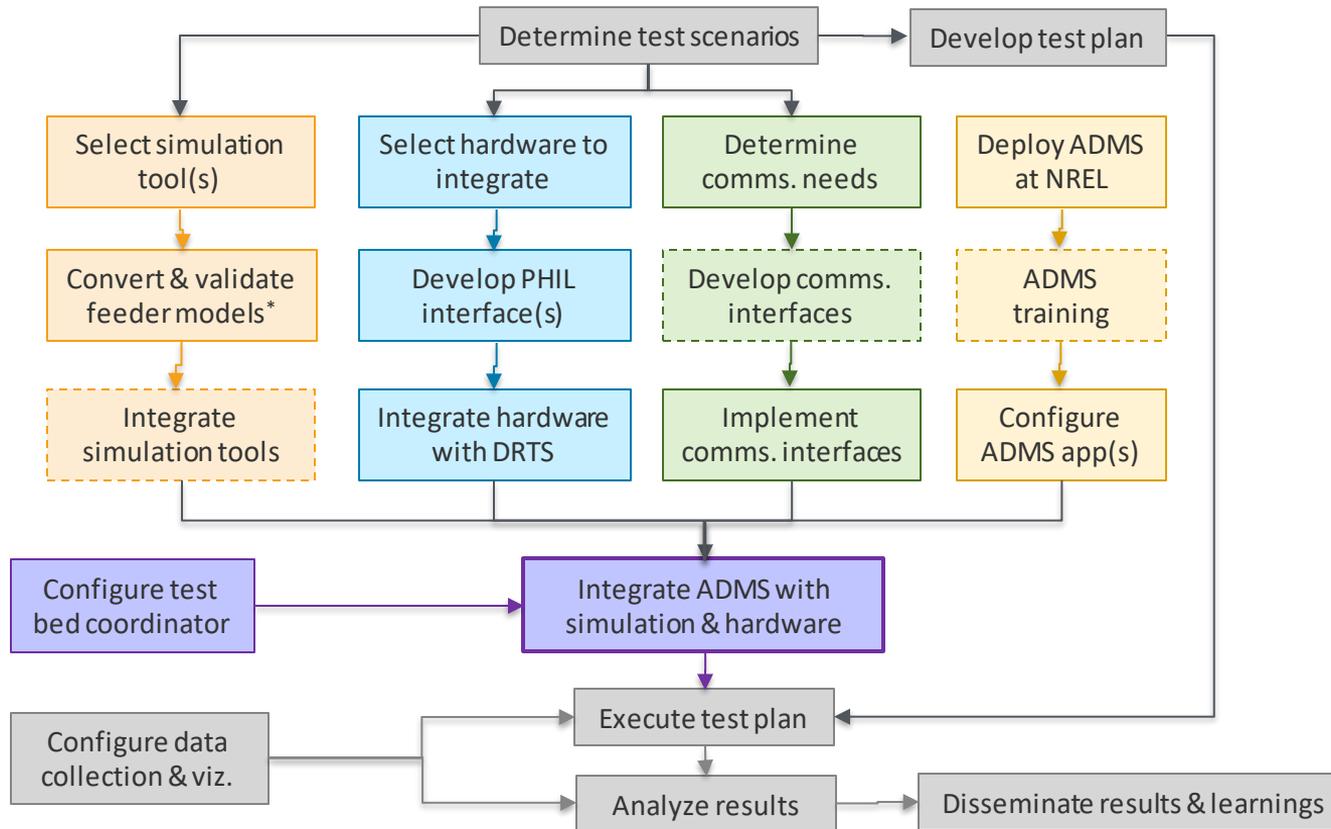


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Configuring the Test Bed



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

ADMS Test Bed Use Cases

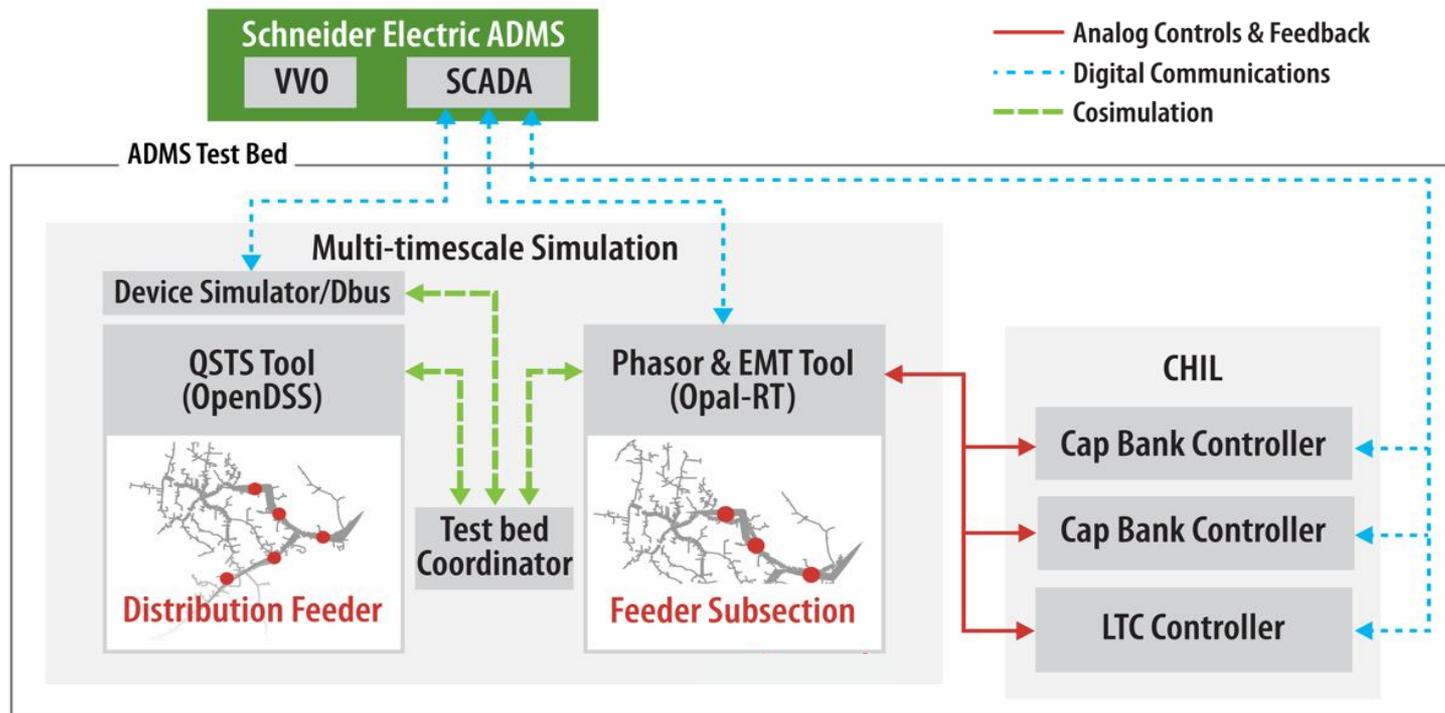


- Peak load management with ADMS and DERMS
 - Holy Cross Energy/Survalent
- **ADMS network model quality impact on VVO**
 - **Xcel Energy/Schneider Electric**
- AMI-based, data-centric grid operations
 - SDG&E + GridAPPS-D
- FLISR in the presence of DERs
 - Central Georgia EMC/Survalent → August 2022
- 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

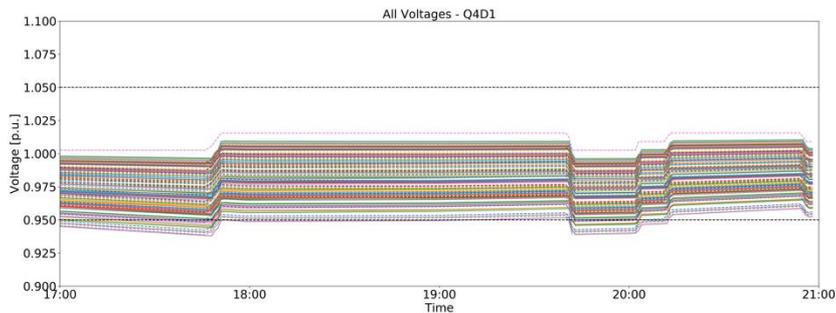


Partners:
Xcel Energy
Schneider Electric
PNNL
EPRI
Opal-RT

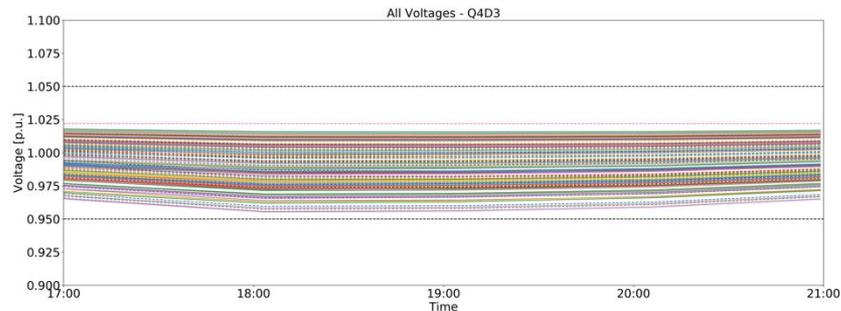
ADMS network model quality Use Case: Post-Processed Results



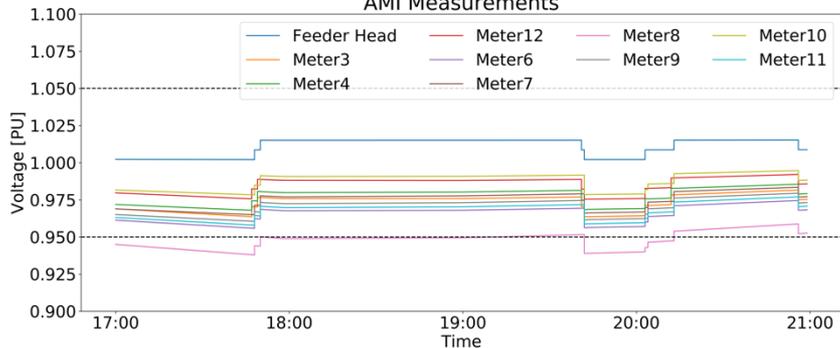
Q4D1 (High model quality; feeder head only measurements)



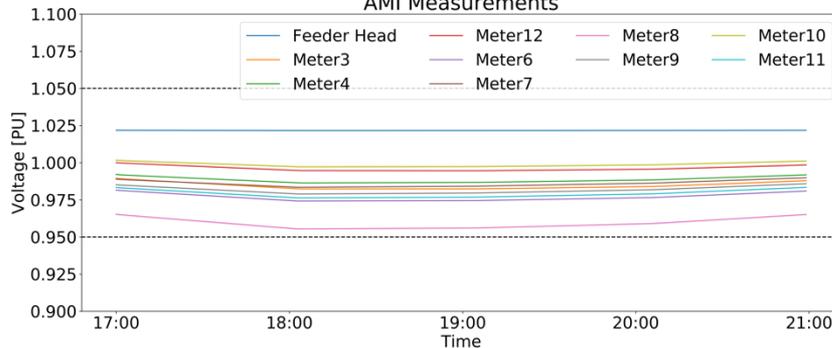
Q4D3 (High model quality; feeder head + 10 AMI measurements)



AMI Measurements

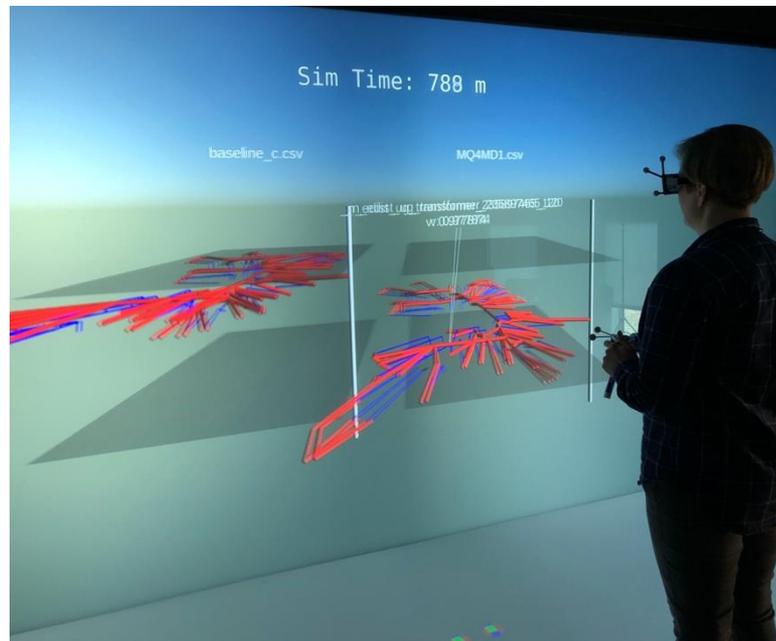
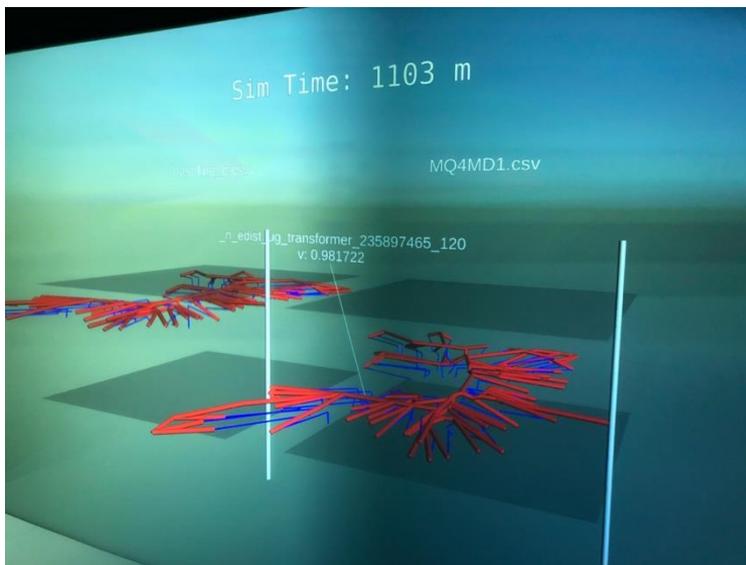
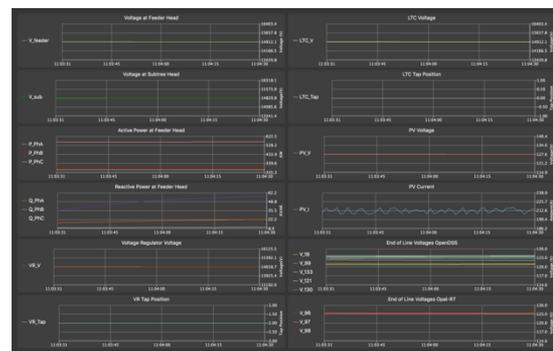


AMI Measurements



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



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.](#)

Survallent User Conference

- Atlanta, GA, Oct. 19–20



A recent @ESIFLabs workshop showcased our advanced distribution management system (ADMS) test bed, which helps utilities evaluate their ability to monitor and coordinate #AdvancedEnergy assets for a more efficient and secure #grid. Learn more about it at bit.ly/2qesFsr



9:00 AM · Dec 20, 2019 · Sprout Social



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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NREL/PR-5D00-82323

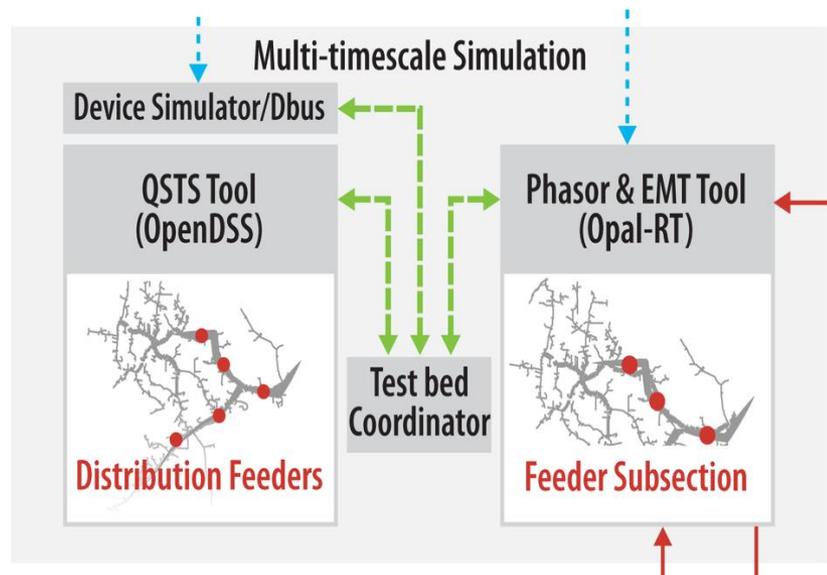
This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Electricity, Advanced Grid Research & Development, and the Solar Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.



Multi-Timescale Simulation

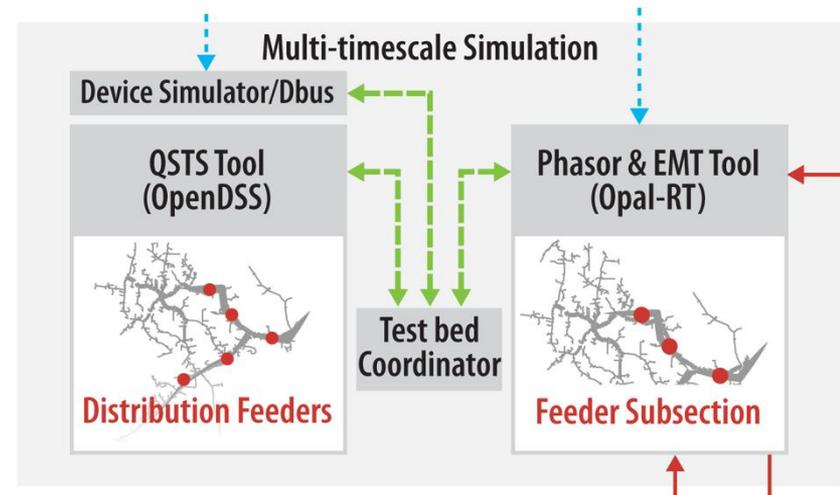


- Can select one or more simulators to fit use case.
- Can run parts of the feeder in different simulators.
- We have used/are using:
 - OpenDSS by EPRI:
 - Quasi-static time series (QSTS)
 - 1-s minimum time step; minutes typical.
 - ePHASORSIM by OPAL-RT:
 - Dynamic phasor, 1- to 10-ms time step.
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



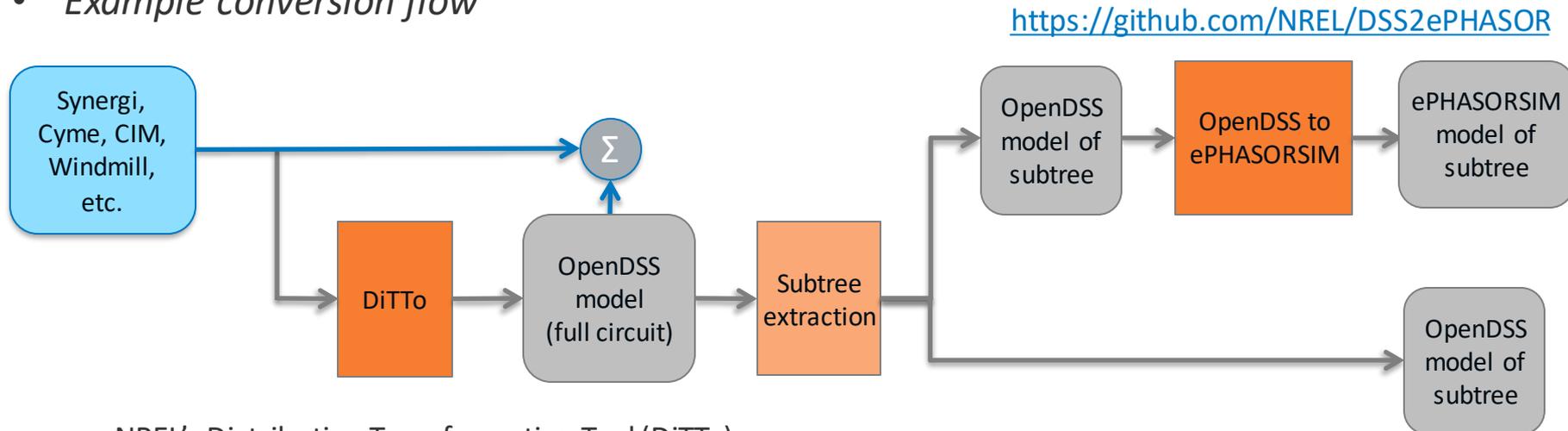
Multi-Timescale Simulation Cont.

- 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*

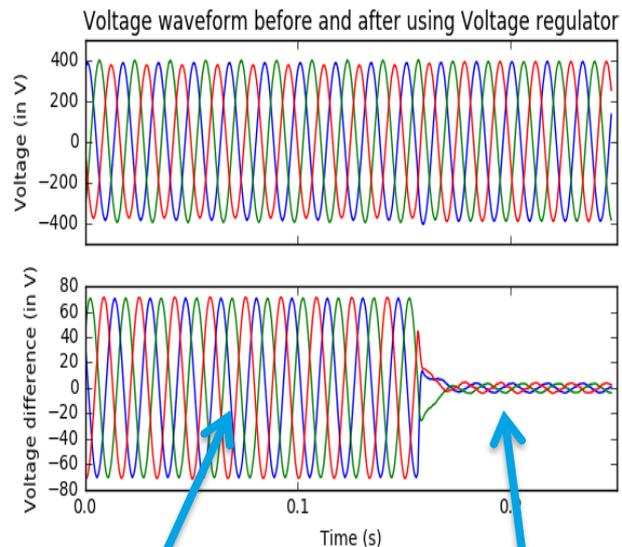
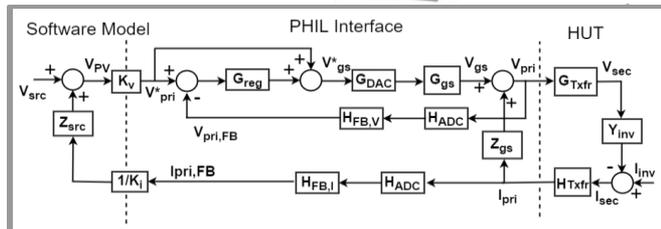
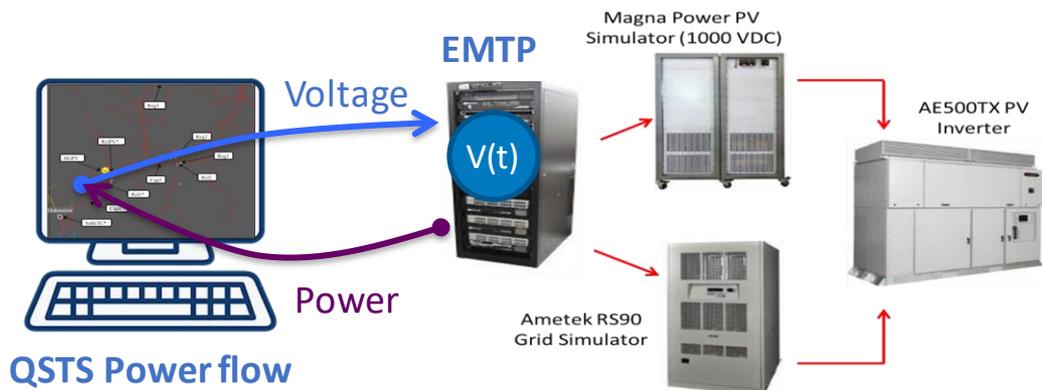


NREL's Distribution Transformation Tool (DiTTo), an open-source framework to convert various distribution system modeling formats:

<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.



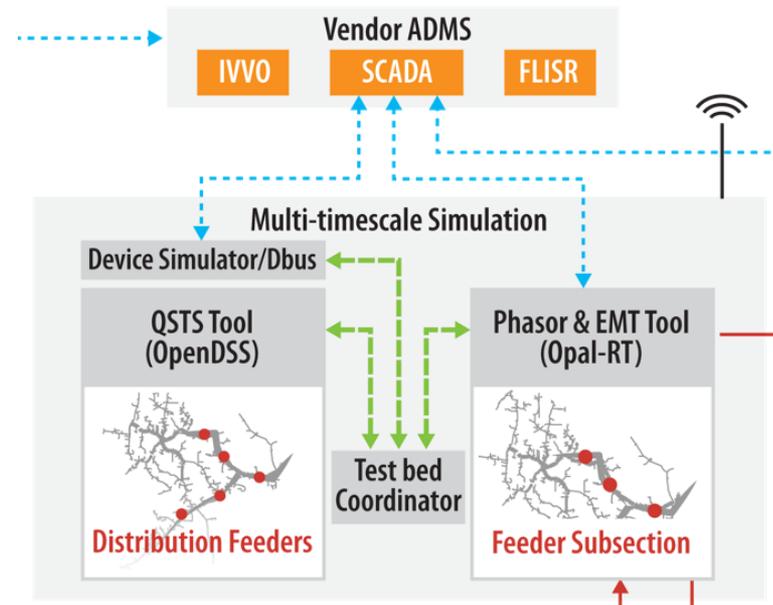
Difference between set point and observed voltage

After turning on voltage regulator

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

- 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.

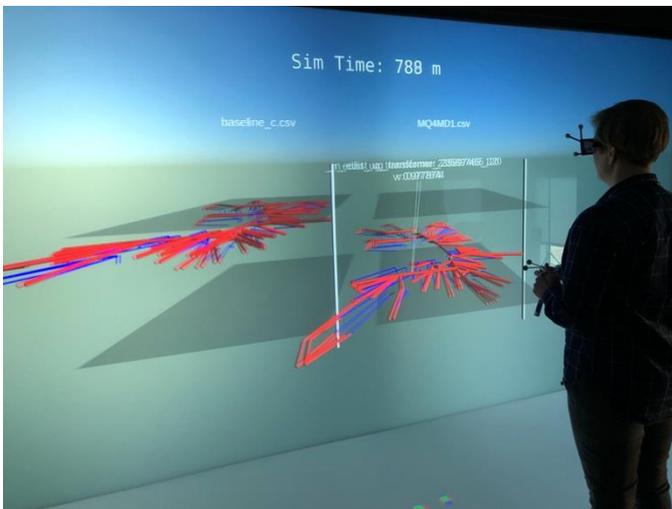
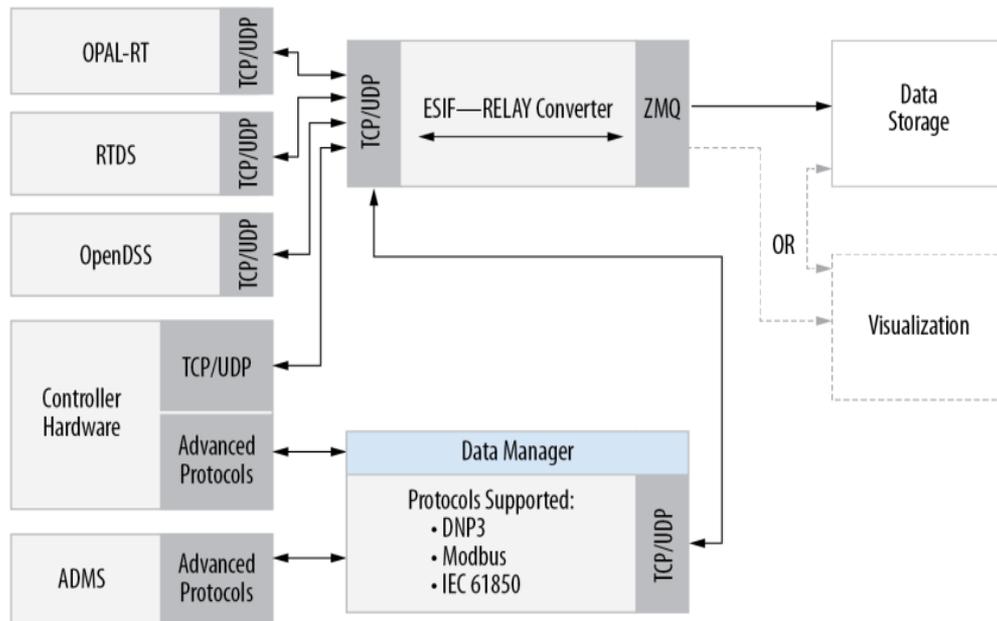
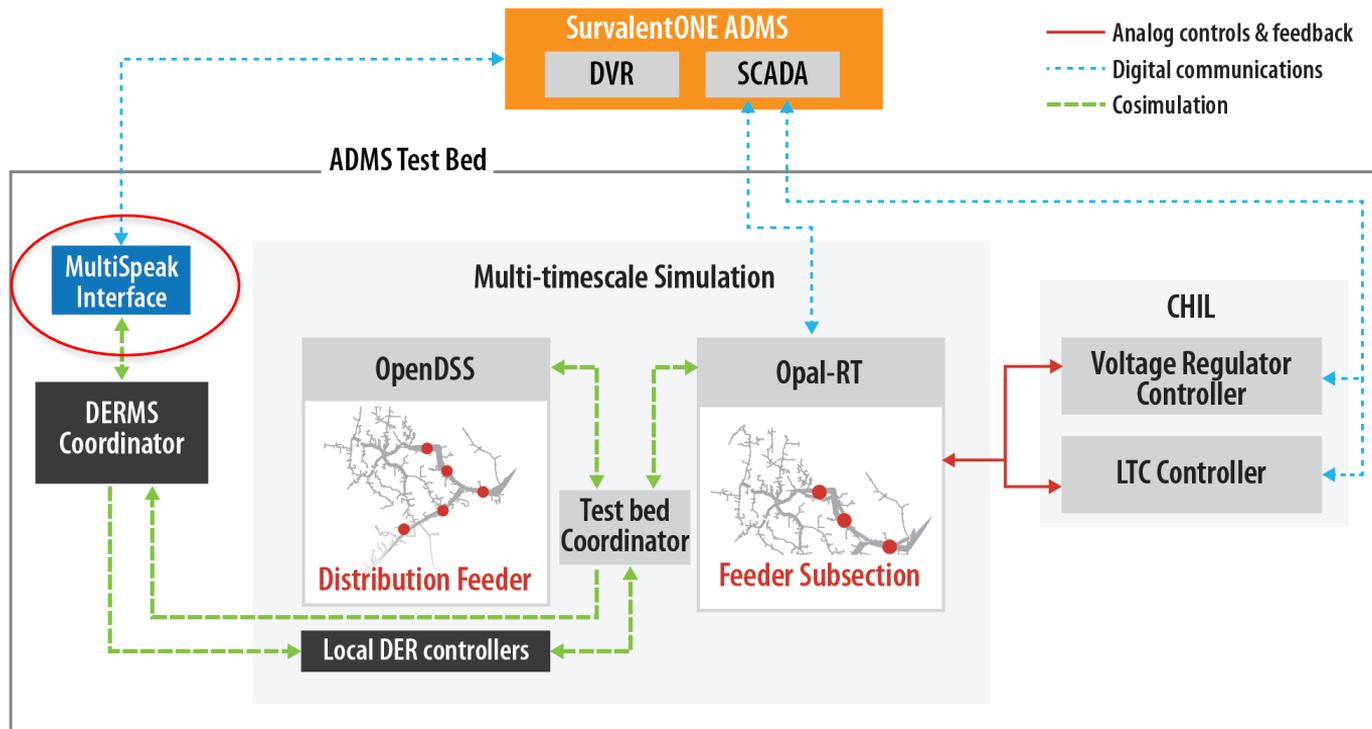


Photo by NREL



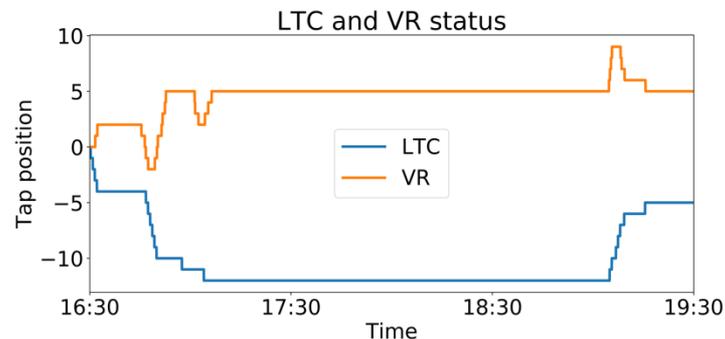
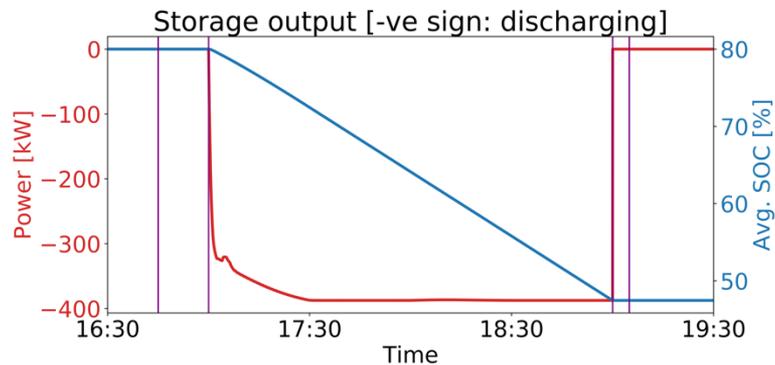
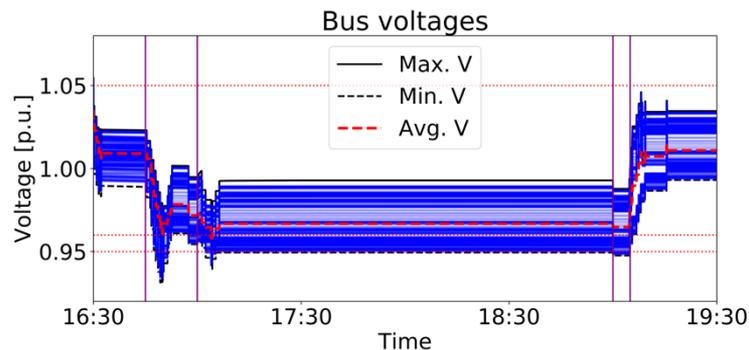
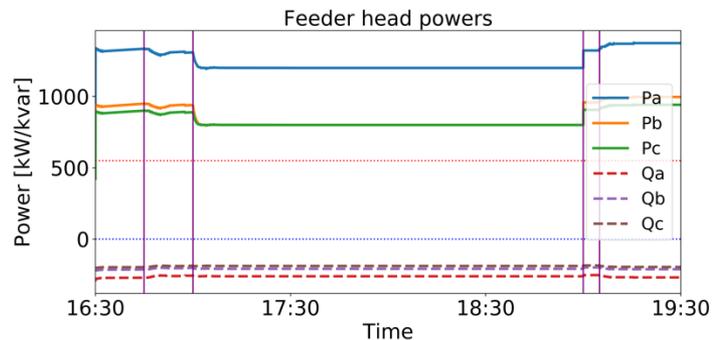
Peak Load Management Use Case: Test Bed Setup



Partners

Holy Cross Energy
Survalent
NRECA
EPRI
PNNL

Peak Load Management Use Case: Post-Processed Results

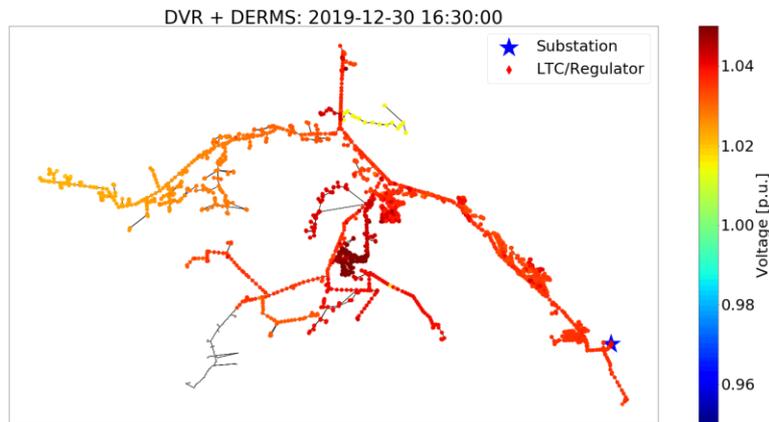
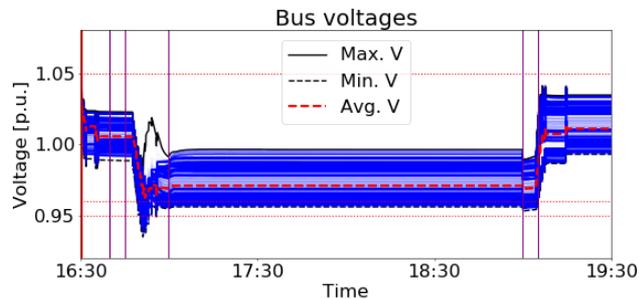
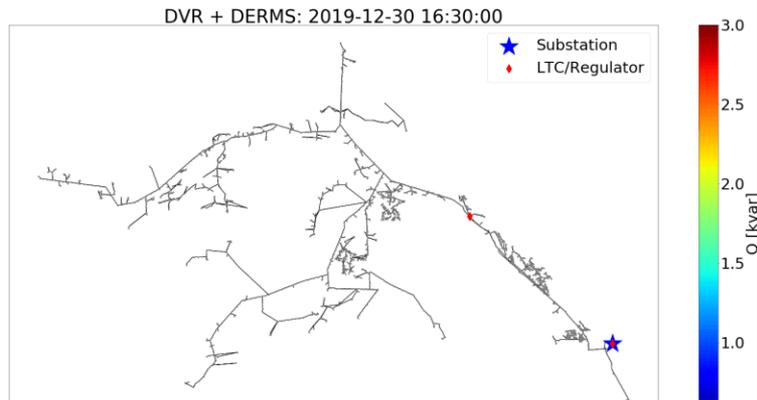
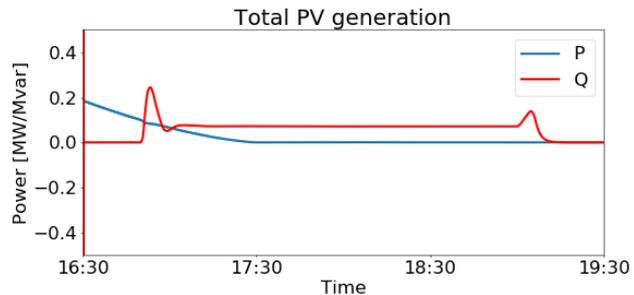


Peak Load Management Use Case: Post-Processed Results Cont.



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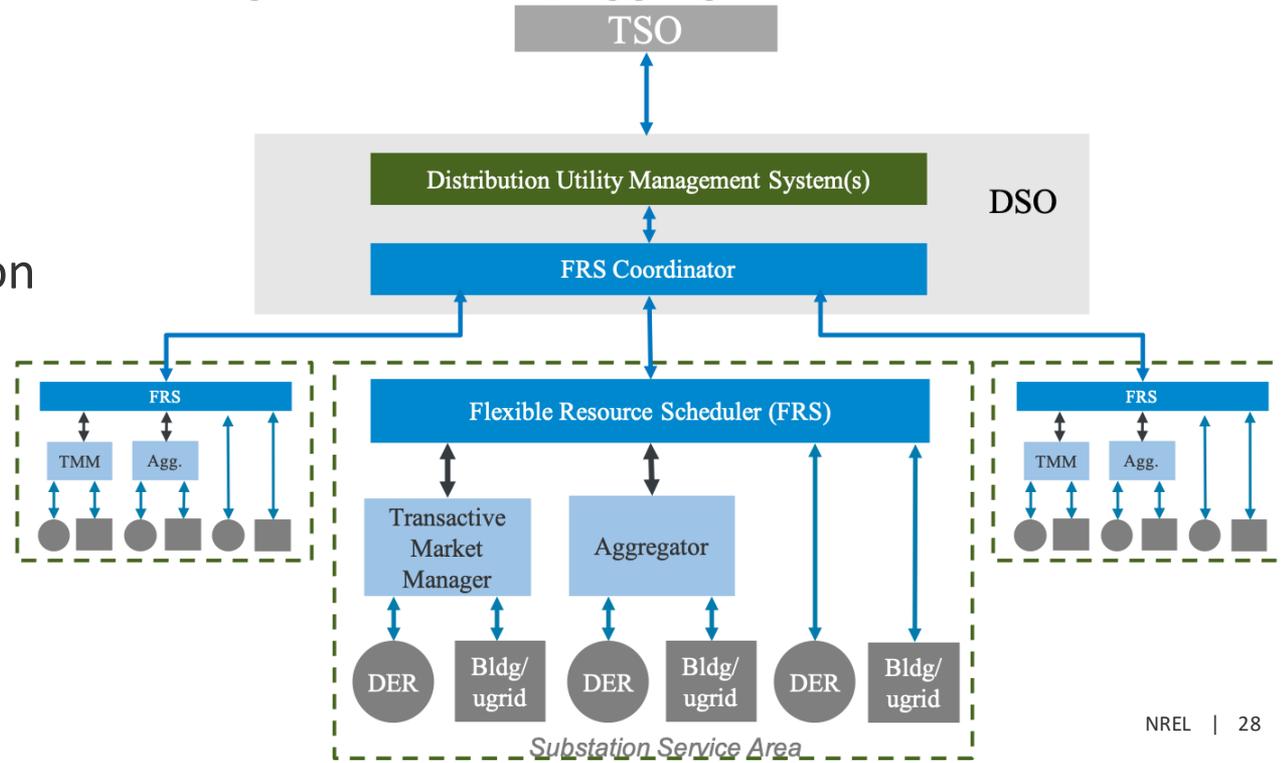
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FAST-DERMS Project

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.

