NREL
Transforming ENERGY

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

Peak Load Management in Distribution Systems Using ADMS and DERMS

Annabelle Pratt, Ph.D.
Chief Engineer, Grid Automation & Control (GAC) Group
June 9, 2021

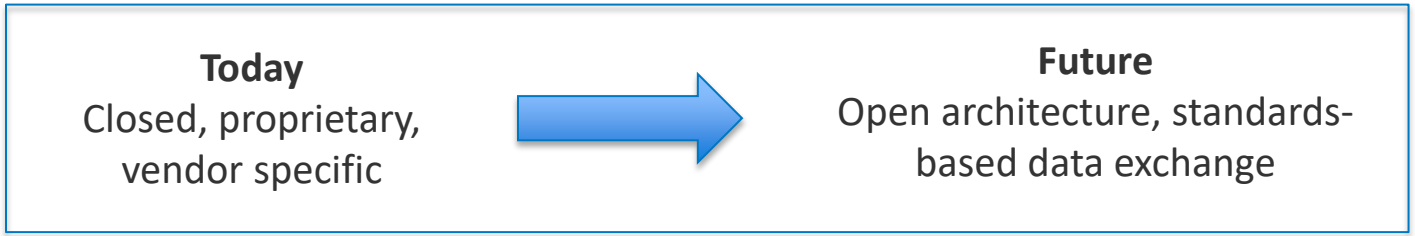
Contents

- ADMS Test Bed Overview
- Peak Load Management Use Case
- Future Use Cases and Events

ADMS Test Bed Overview

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.



Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

Four program areas:

Platform: Develop 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.

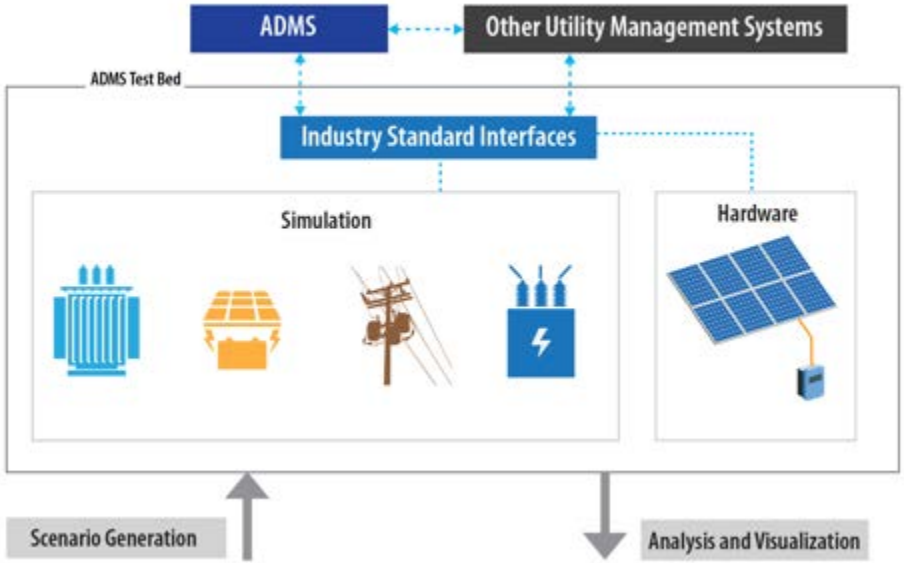
ADMS Test Bed

Goal: Accelerate industry adoption of ADMS to:

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

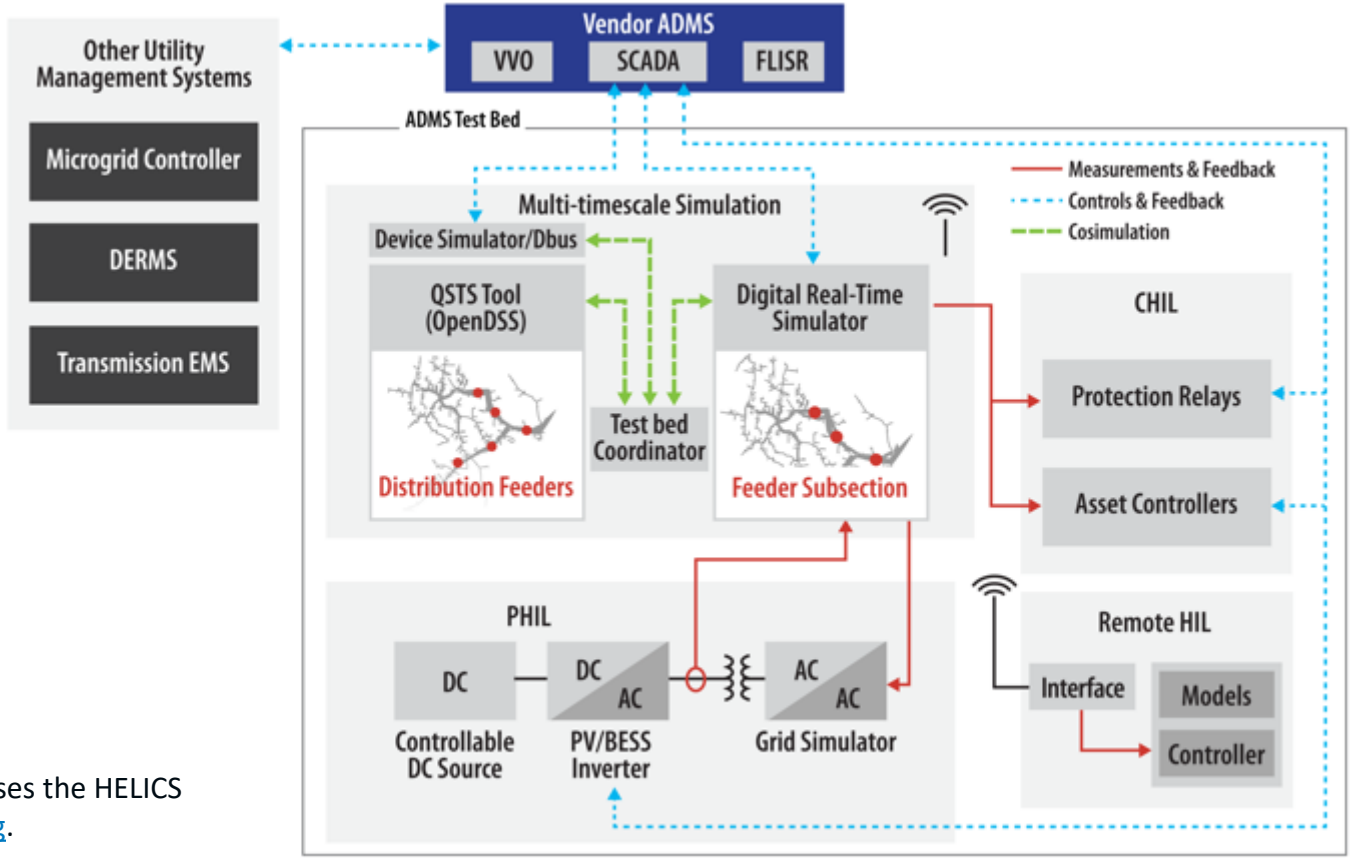
Approach: Partner with utilities and vendors to evaluate specific use cases and applications:

- 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

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY



The test bed coordinator uses the HELICS framework: www.helics.org.

ADMS Test Bed

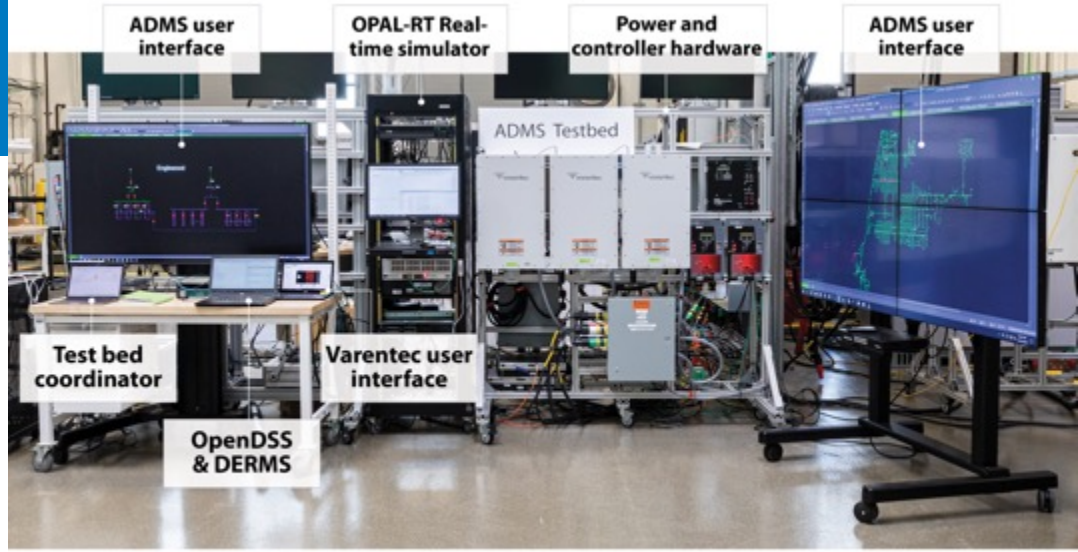
Expected outcome:

Increased industry confidence in ADMS technology through:

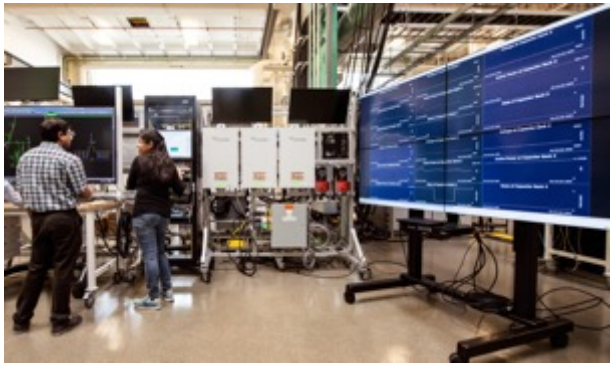
- Laboratory demonstration of applications for specific use cases
- Analysis and potential application to other utilities.

ADMS test bed capabilities:

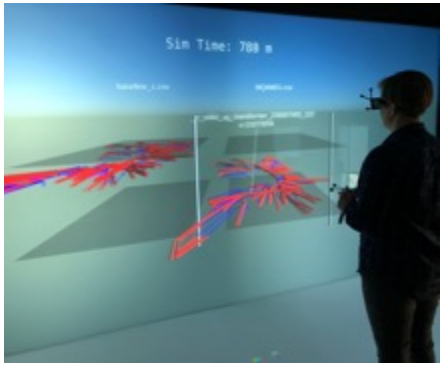
- Multi-timescale co-simulation using HELICS (OpenDSS/OPAL-RT/RTDS)
- Hardware integration
- Communications interfaces
- Data collection and visualization.



Photos by NREL

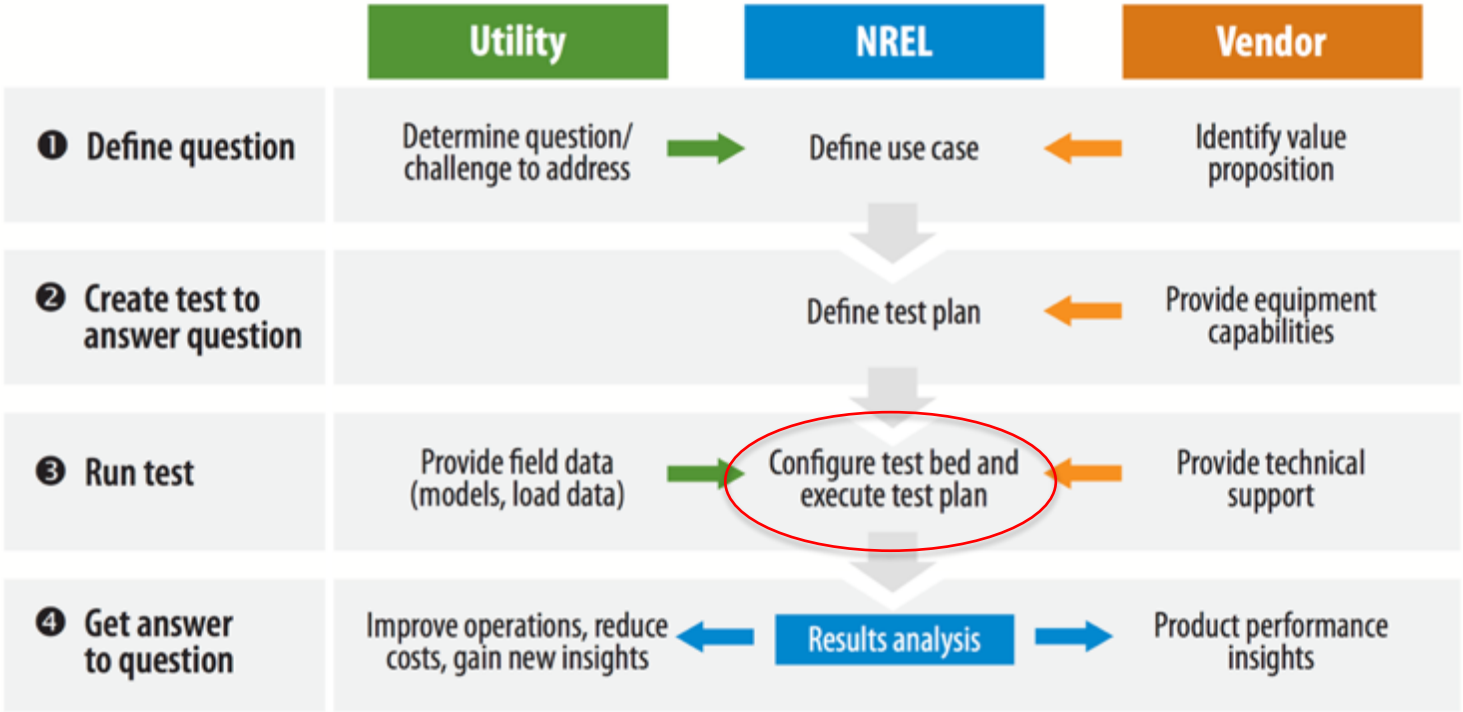


2D real-time visualization



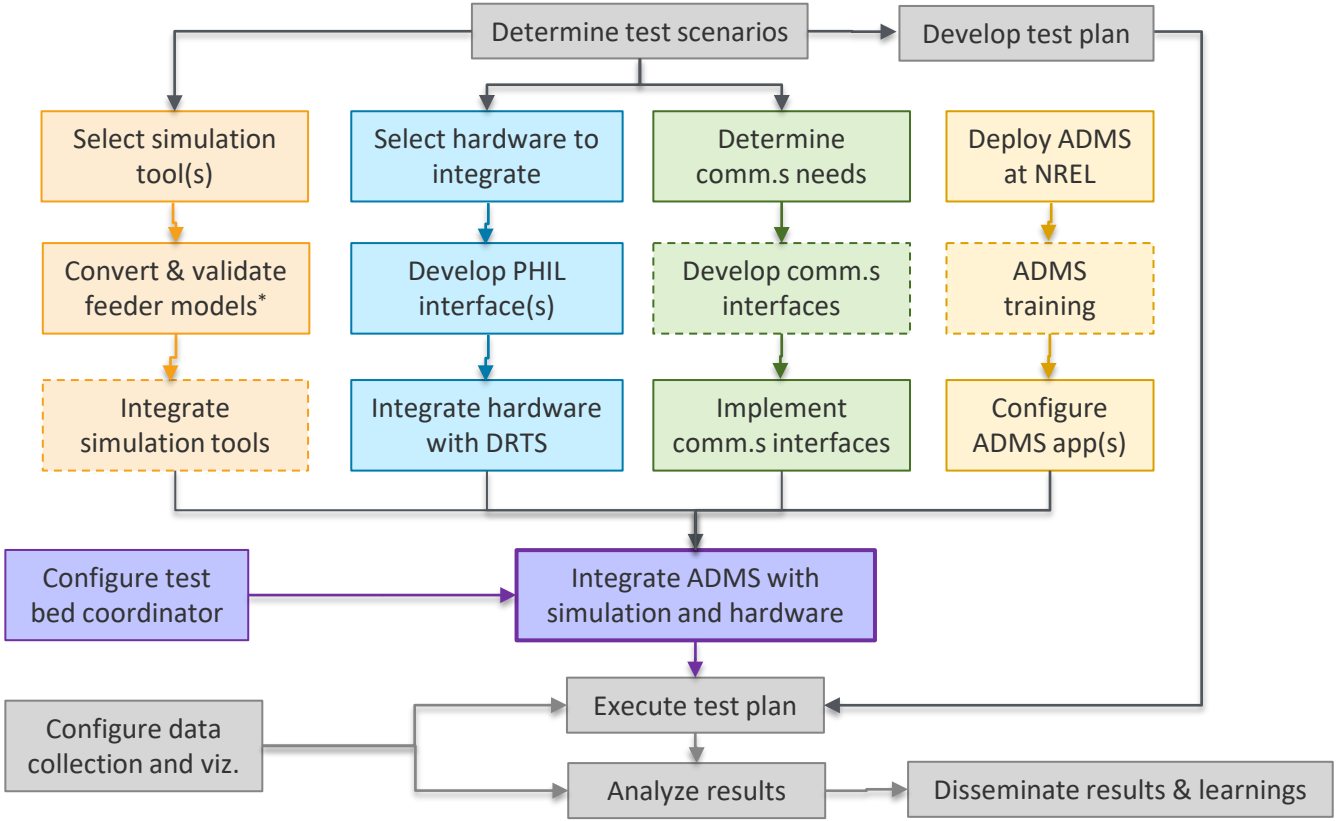
3D visualization

Defining an ADMS Test Bed Use Case



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," ISGT, 2021.

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 → May 2021
- AMI-based, data-centric grid operations
  - SDG&E + GridAPPS-D → May 2021
- ADMS network model quality impact on VVO
  - Xcel Energy/Schneider Electric → June 2021
- FLISR in the presence of DERs
  - Central Georgia EMC/Survalent → Feb. 2022
- Federated DERMS for high PV system
  - Southern Company/Oracle + GridAPPS-D → Apr. 2022
- T&D co-optimization for enabling ADN to support bulk grid
  - Xcel Energy + GridAPPS-D → Mar. 2022

Other projects that use ADMS test bed capabilities:

- Non-wires alternatives
  - Holy Cross Energy, Survalent, Heila
- ECO-IDEA
  - Xcel Energy, Varentec, EPRI
- FAST-DERMS
  - SDG&E, Oracle, EPRI + GridAPPS-D
- GO-SOLAR
  - HECO
- SolarExpert
- Resilient Operation of Networked Microgrids (RONM)
- AURORA

Peak Load Management Use Case

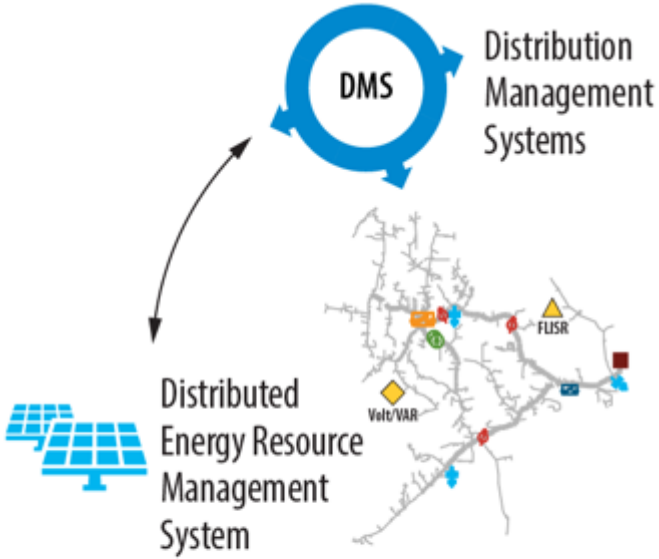
Why PLM?

- Grid infrastructure is rated to ensure reliable power at peak load.
- Growth in peak demand leads to operational challenges:
  - Power quality and reliability issues
  - Need for network upgrades
  - Poor energy efficiency.
- No load growth and/or significant DER growth challenges utilities to deliver reliable and affordable power with reduced energy sales.
- Peak demand charges are often a significant expense.
- Peak load management (PLM) helps address these challenges.
- PLM strategies include:
  - DERs, such as battery energy storage systems (BESS) and electric vehicles
  - Demand-side management
  - Conservation voltage reduction (CVR)

Photos by NREL

Why Evaluate ADMS and DERMS Operations?

- The penetration level of DERs is increasing.
- DERs affect distribution system operations—e.g., voltage profiles.
- ADMS needs—at a minimum—visibility of DERs.
- DERs could be managed by a distributed energy resource management system (DERMS) rather than directly by an ADMS.
- Uncoordinated DERMS operations might be counter to ADMS objectives—e.g., Volt/Var optimization reduces voltage, but DERs boost voltage through VAR support.

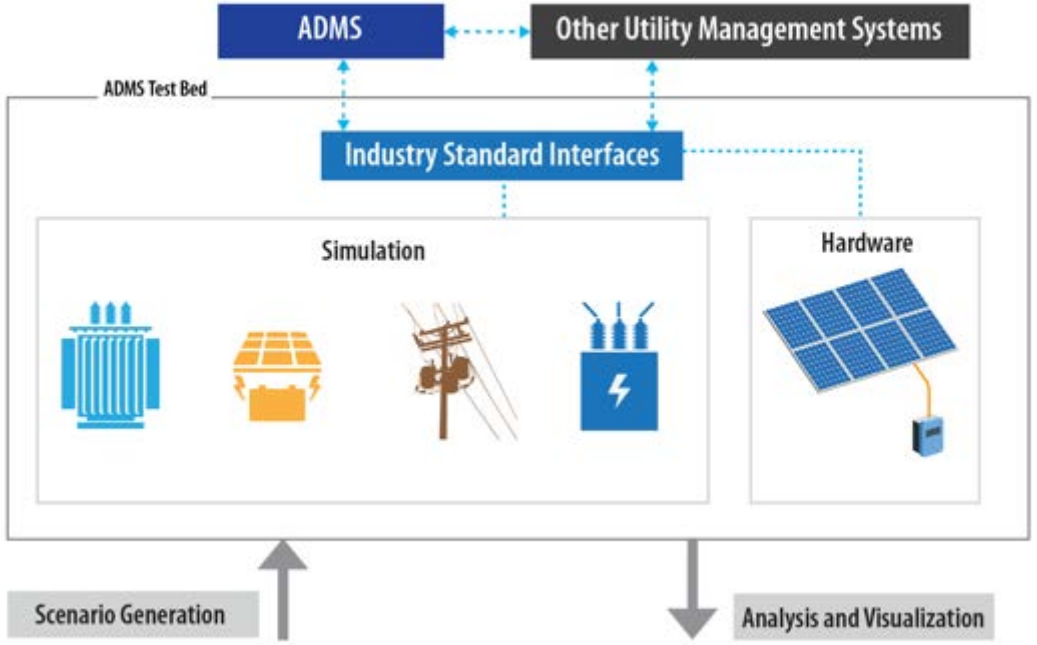


PLM with ADMS and DERMS

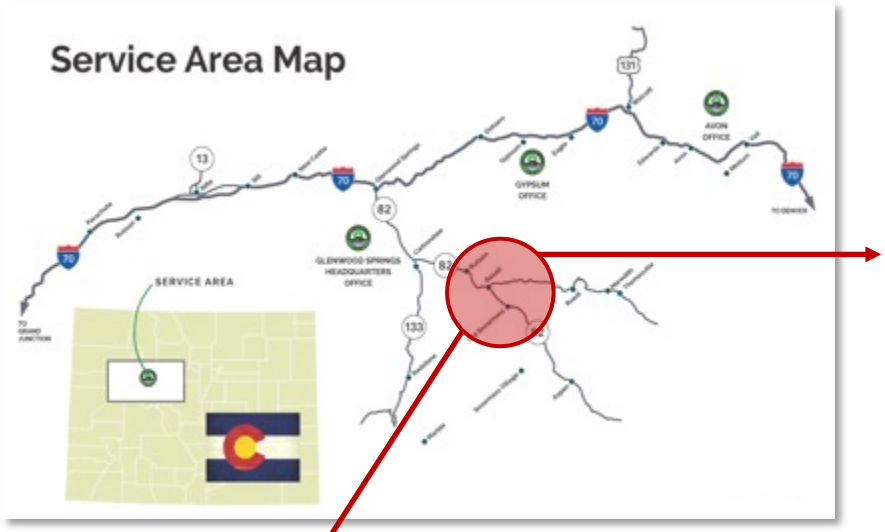
Objective

Evaluate the performance of PLM performed across ADMS and DERMS:

- Effectiveness of DERMS in complementing ADMS operations
- Communications interface between ADMS and DERMS.



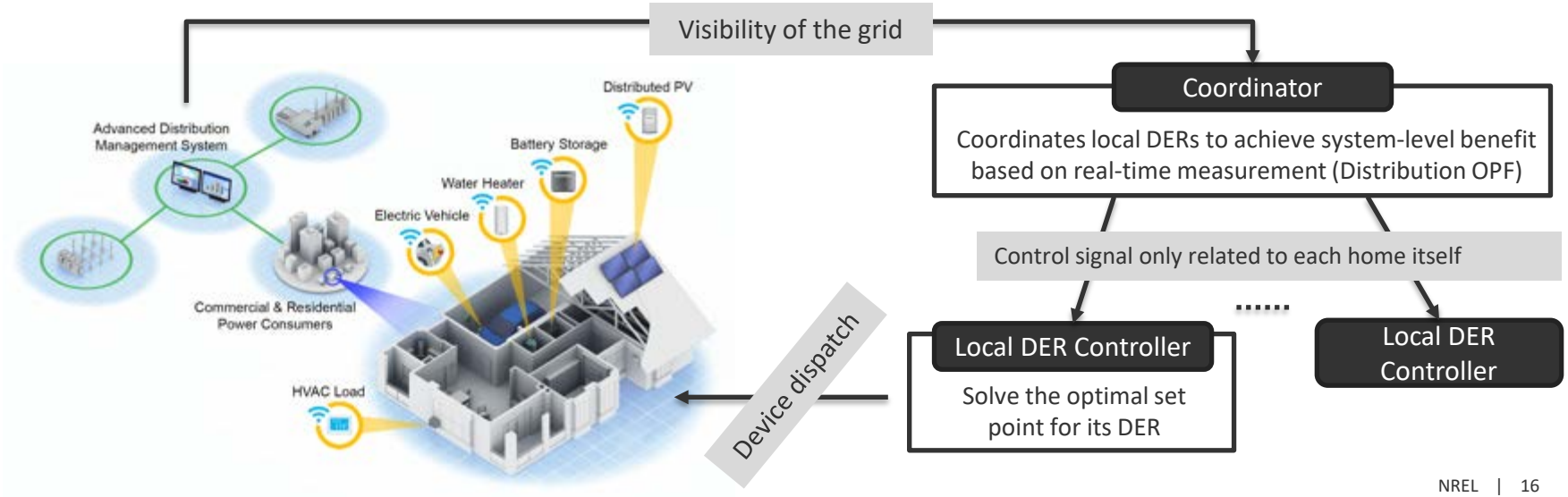
Feeder Information



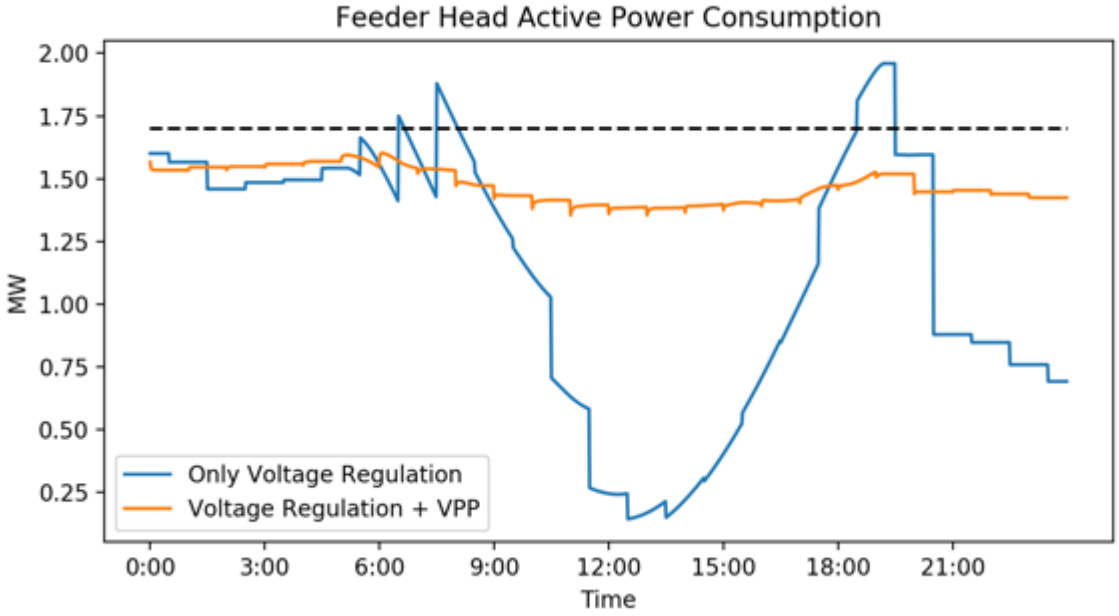
- Approx. 1,100 loads with 163 all-electric residential loads
- Existing 226 kW of residential PV at 38 locations + 200-kW PV power plant
- Modeled ~1.6-MW PV and ~1-MW BESS at all-electric homes
- House loads modeled as ZIP with coefficients [0.24, 0.36, 0.4]
  - CVR factor = 0.84.

DERMS

- Originally developed at the National Renewable Energy Laboratory (NREL) under an Advanced Research Project Agency-Energy project
- Deployed in the field as part of a project with Holy Cross Energy
- Adapted for this project.

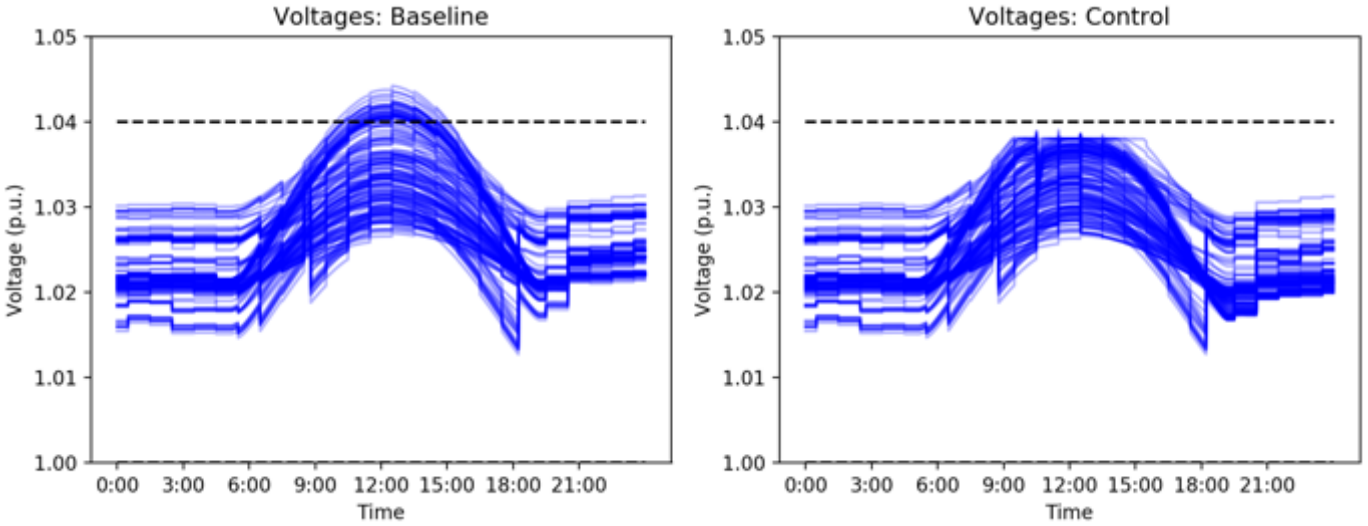


DERMS Function: VPP



Use the flexibility provided by DERs to enable the distribution feeder to work as a virtual power plant (VPP).

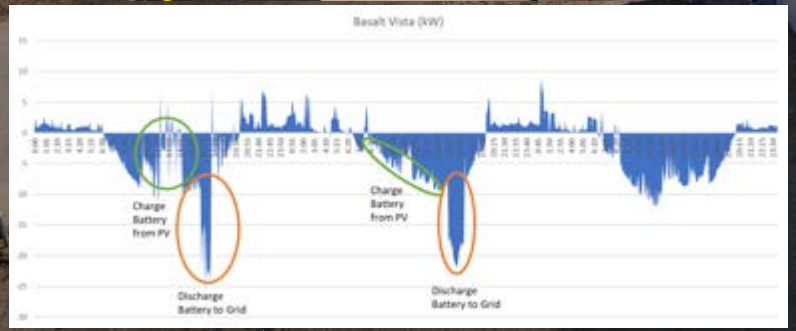
DERMS Function: Voltage Regulation



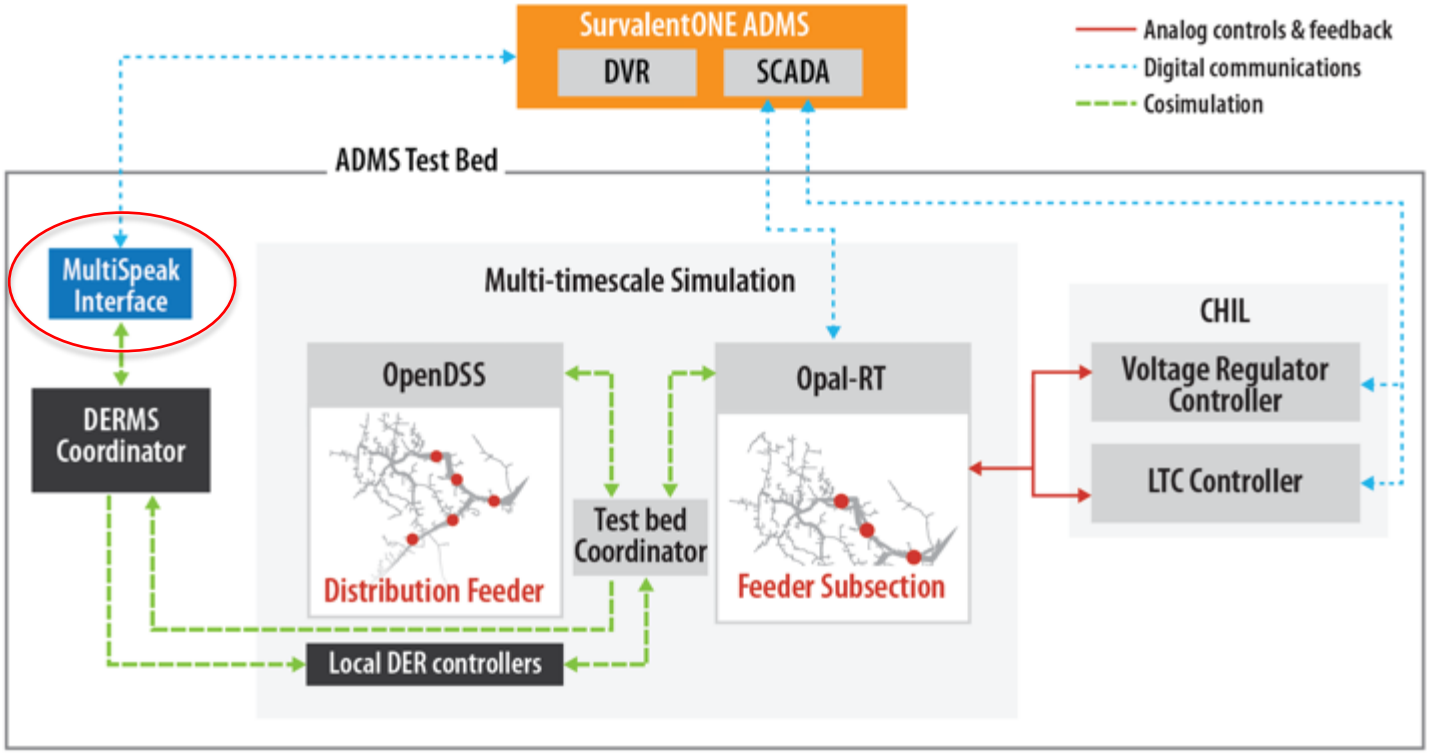
Use reactive power capability from smart inverters to regulate distribution voltage without curtailing PV generation.

Live Learning Lab

Local DER Controllers



Test Bed Setup



Partners

Holy Cross Energy

Survalent

NRECA

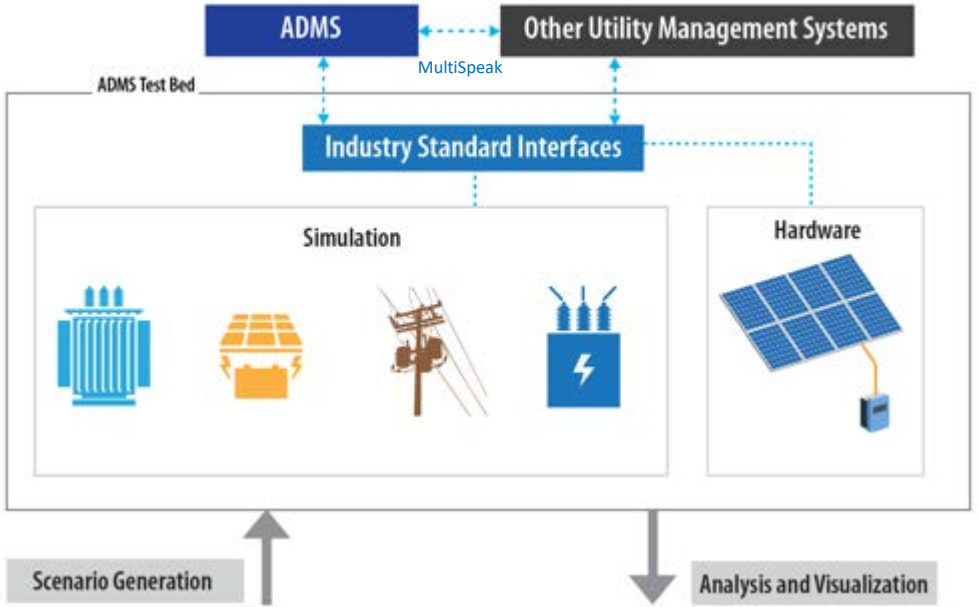
EPRI

PNNL

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 Green Technologies Conference, 2021.

ADMS and DERMS Coordination with MultiSpeak

1. Voltages and feeder head powers
2. Load management request and *feeder head power references*
3. DER group capacity



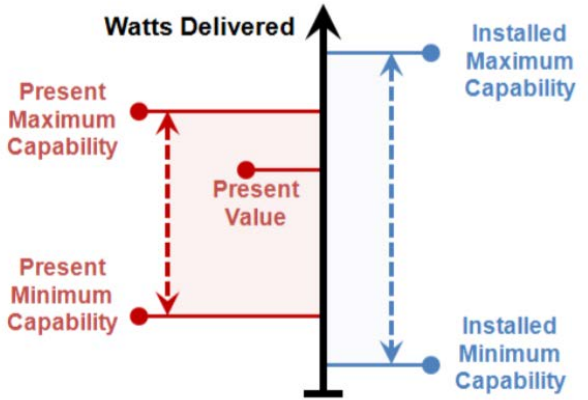
DERMS Capacity and Status Monitoring

The National Rural Electric Cooperative Association (NRECA) defined a method in MultiSpeak to communicate DER capacity:

- Made available in MultiSpeak sandbox for the project
- ADMS can use this to determine DERMS power set points.
- Based on the Electric Power Research Institute's (EPRI's) *Common Functions for DER Group Management, 3rd Ed.*

The purpose of this function is to read/report the present status of a DER group:

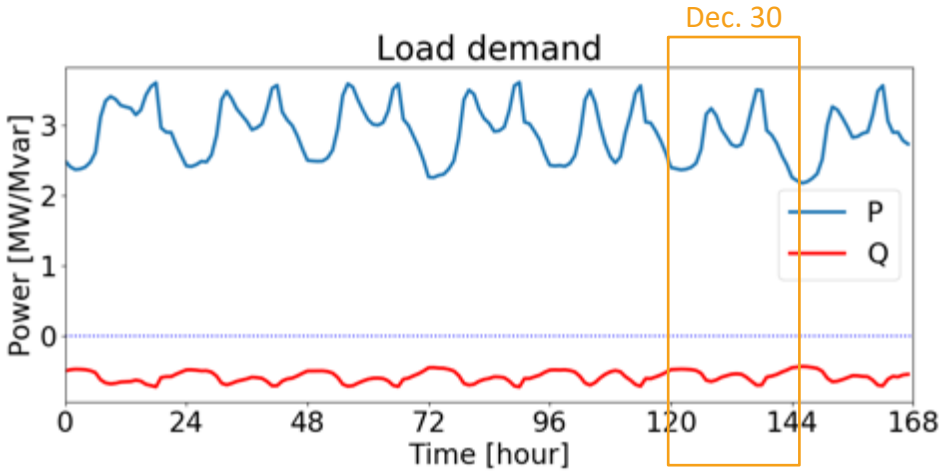
- Present value
- Maximum value to which it can presently be adjusted
- Minimum value to which it can presently be adjusted.

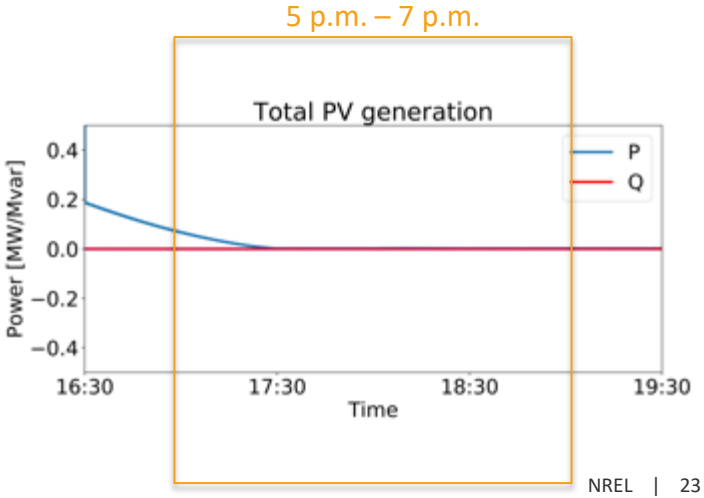


Scenarios

- Simulate Dec. 30, 2019, 4:30 p.m.–7:30 p.m.—peak price, evening peak load, PV tapering off

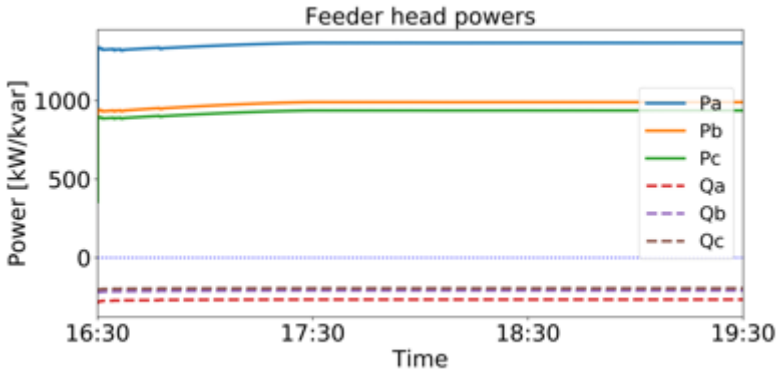
- Scenarios:
  - Baseline with default control set points
  - ADMS performing dynamic voltage regulation (DVR) only
  - DERMS only (VPP + voltage regulation)
  - ADMS + DERMS (VPP only)
  - ADMS + DERMS (VPP + voltage regulation)

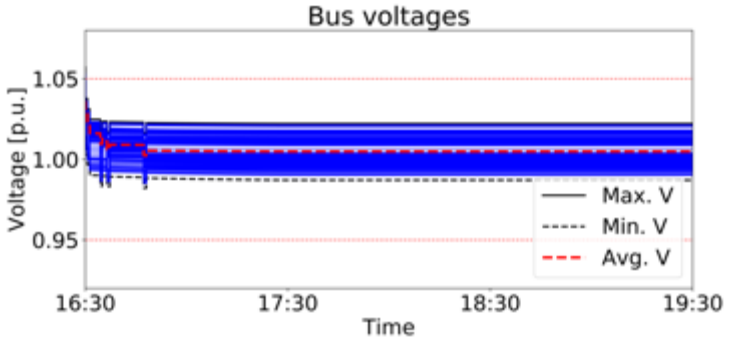


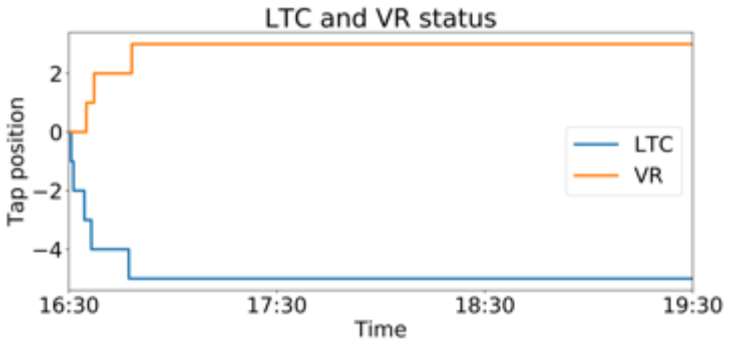


Baseline—Default Control Set Points

- Total feeder power of 3 MW with phase imbalance
- Voltages around nominal.

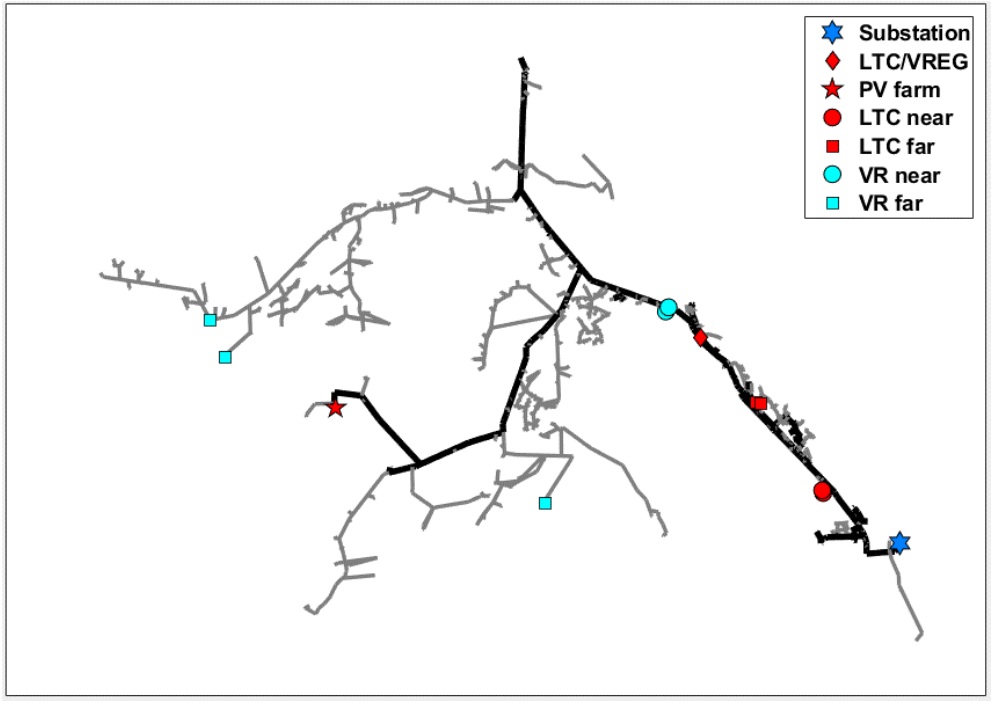






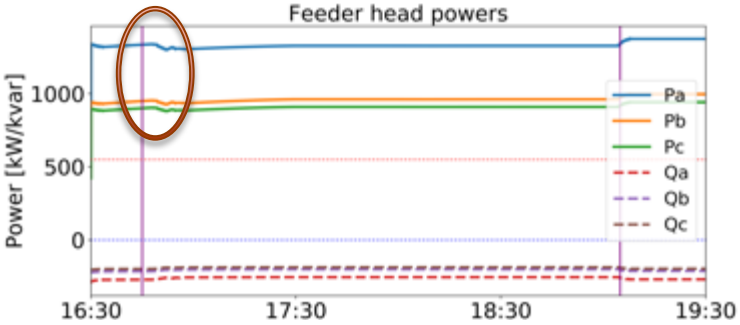
ADMS DVR

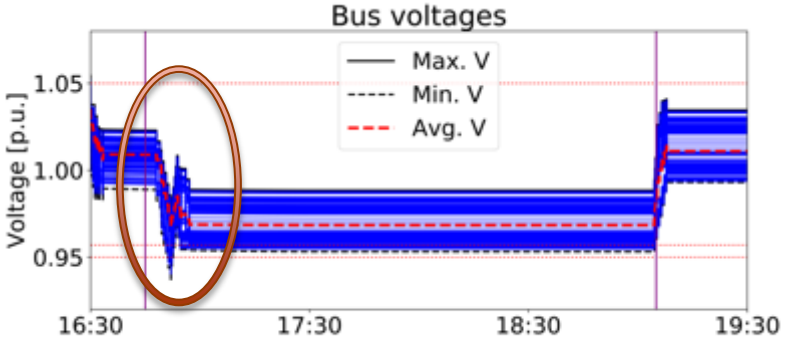
- Feedback locations downstream of load tap changer (LTC) and line voltage regulator (VR)

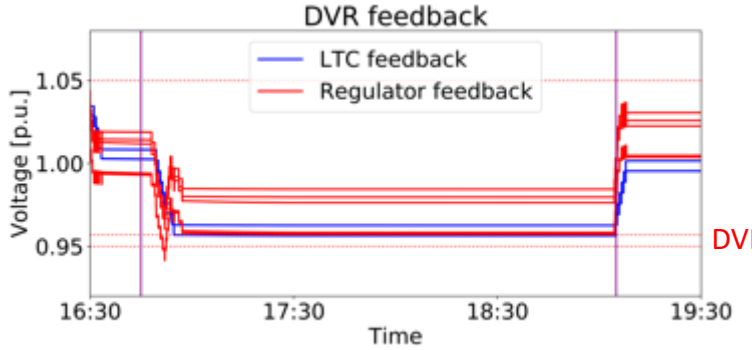


ADMS Only

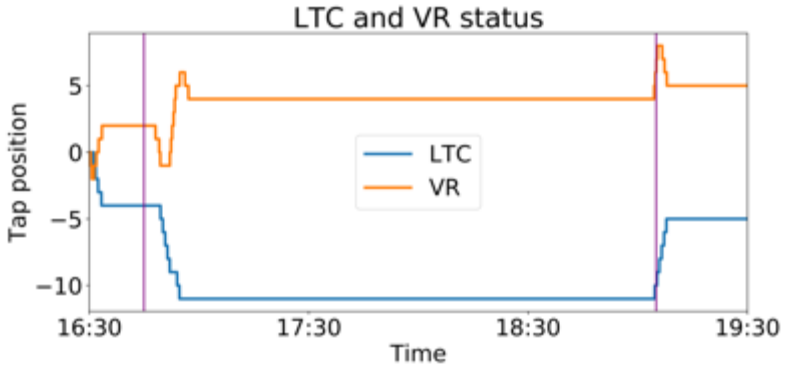
- ADMS reduces voltages to reduce power using LTC and VR.
- CVR energy savings of ~2%.





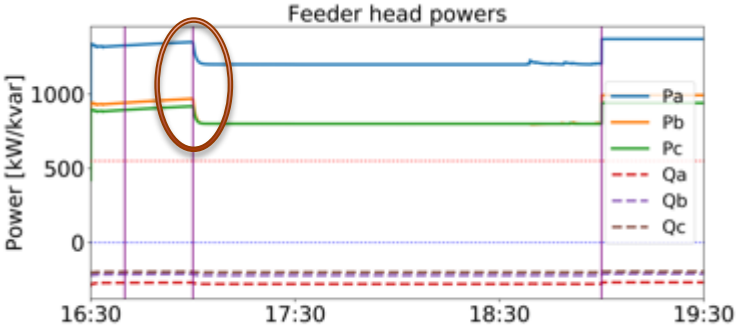


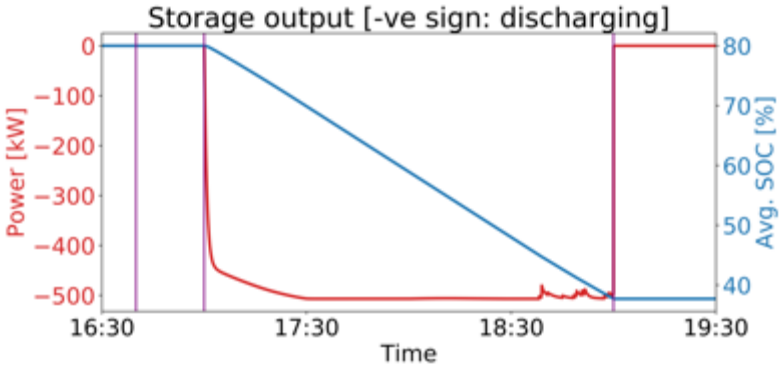
DVR Limits

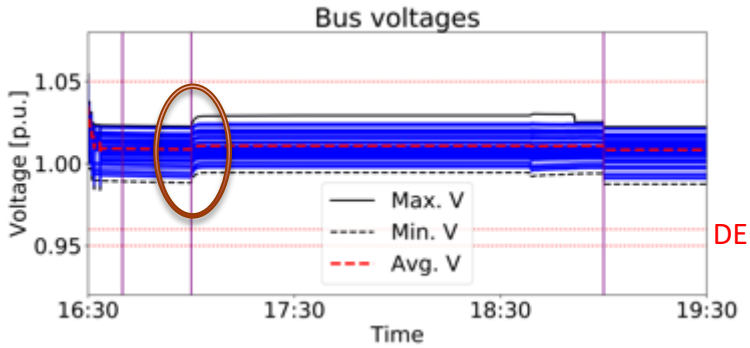


DERMS Only

- VPP function regulates feeder head powers to target values using batteries.
- Slight voltage increase due to batteries; no voltage regulation needed.



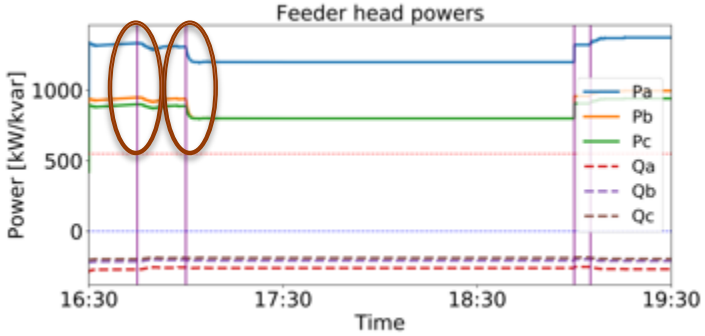


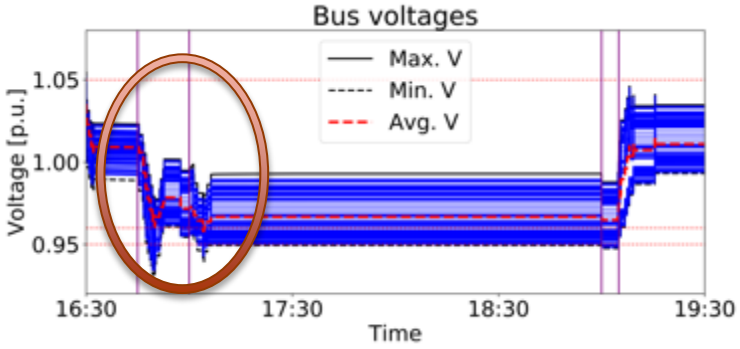


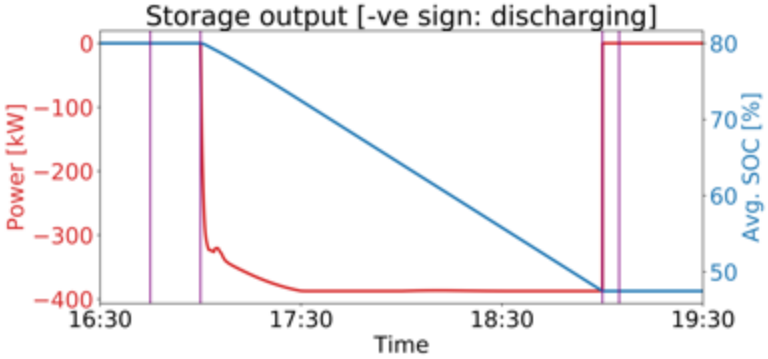
DERMS Limit

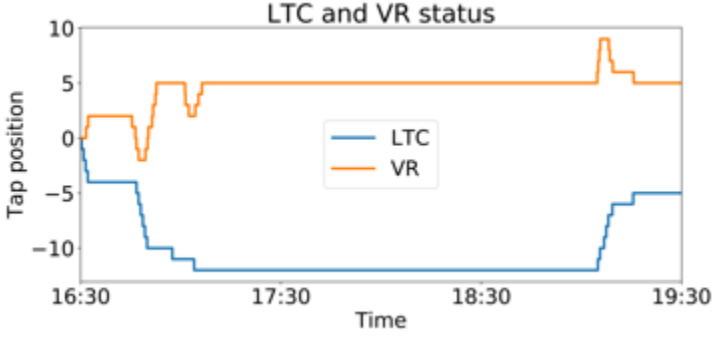
DVR + DERMS (VPP Only)

- ADMS dynamic voltage regulation reduces voltages using LTC and VR to reduce power.
- DERMS VPP uses batteries to reduce feeder head powers.



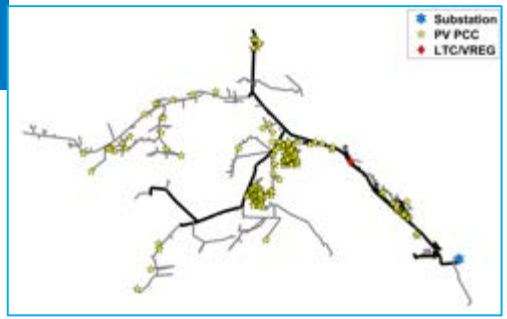


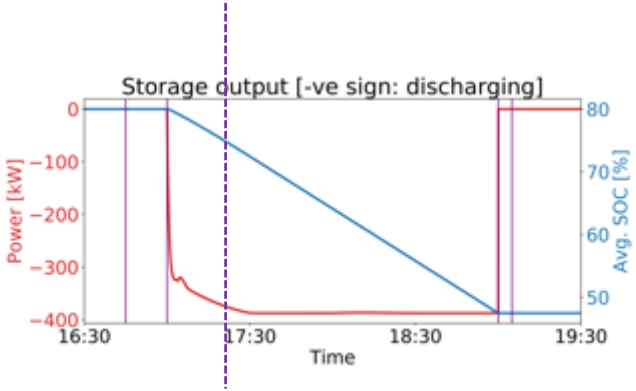


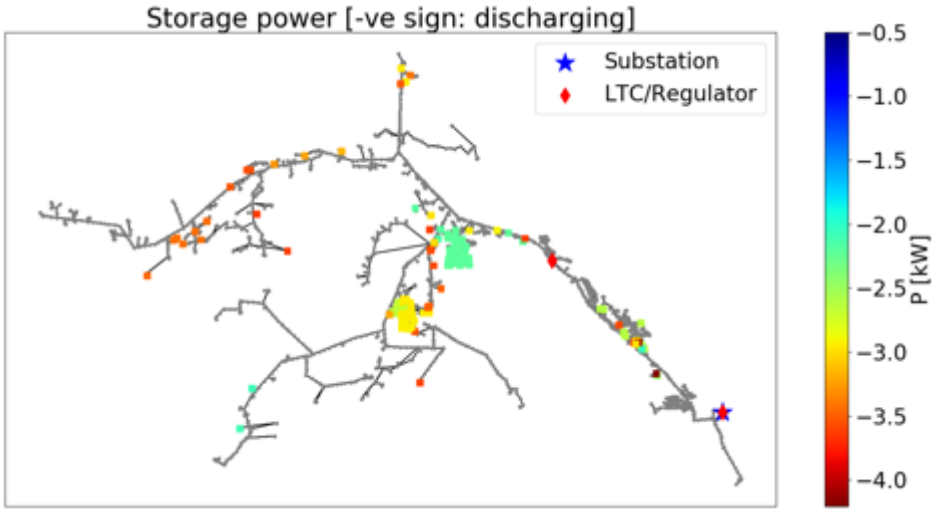


DVR + DERMS (VPP Only)

- DERMS VPP uses batteries to reduce feeder head powers.

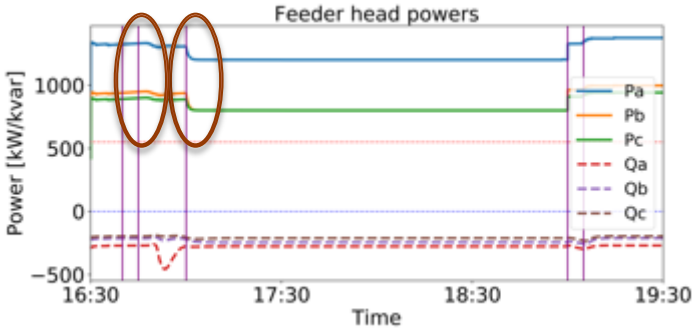


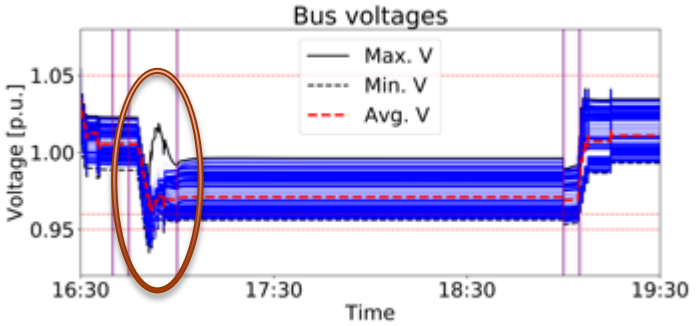


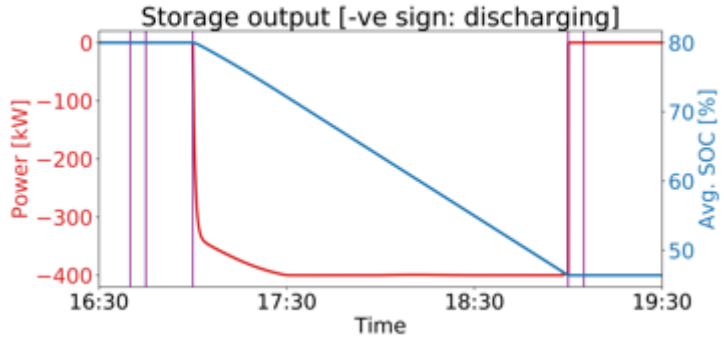


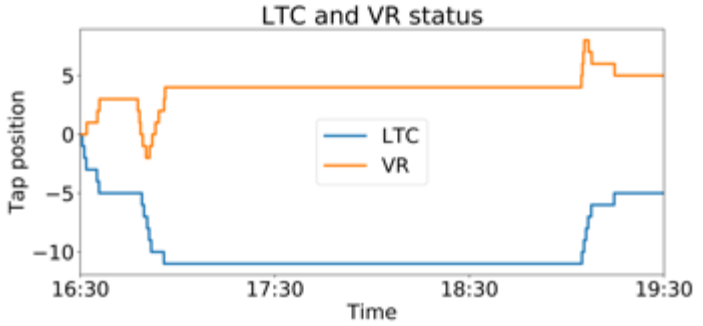
ADMS + DERMS : Power

- ADMS reduces voltage, which reduces feeder power consumption.
- DERMS dispatches energy storage to reduce peak demand.



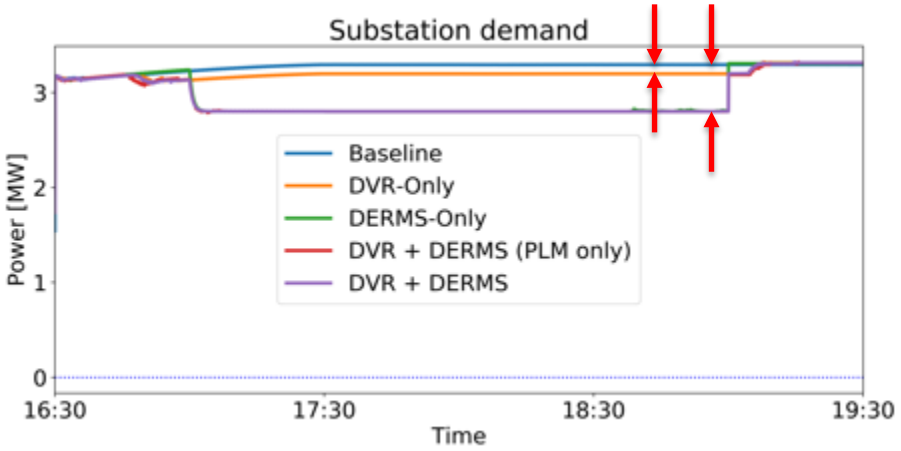


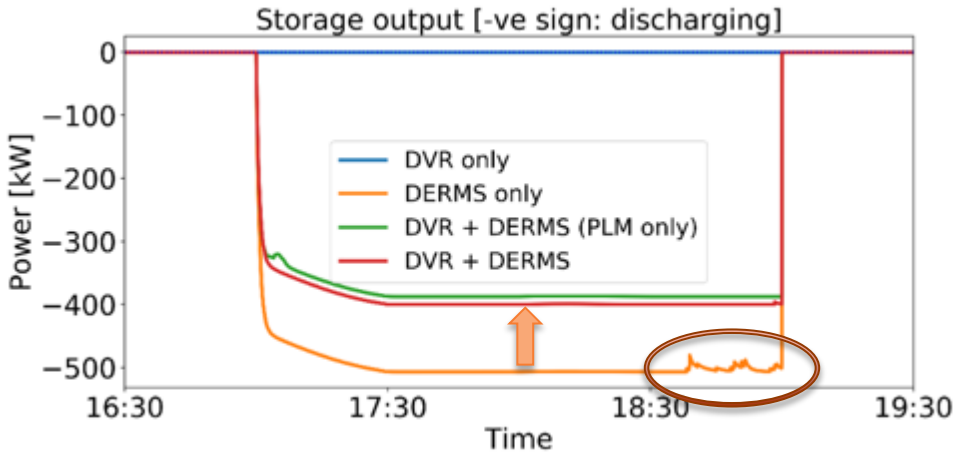




PLM Comparison

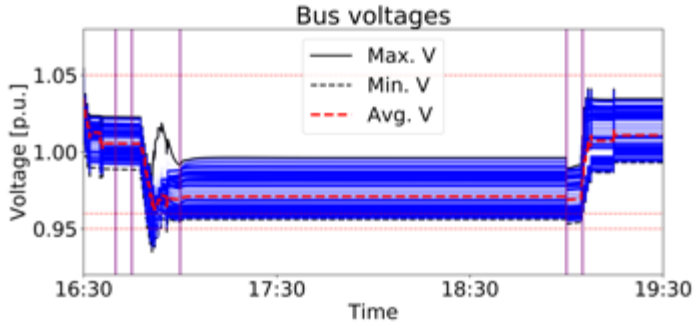
- Reduced feeder head power by 2.1% with ADMS performing DVR only and by 10% for ADMS + DERMS
- Less power required from batteries with ADMS performing DVR
  - State of charge limits not reached.

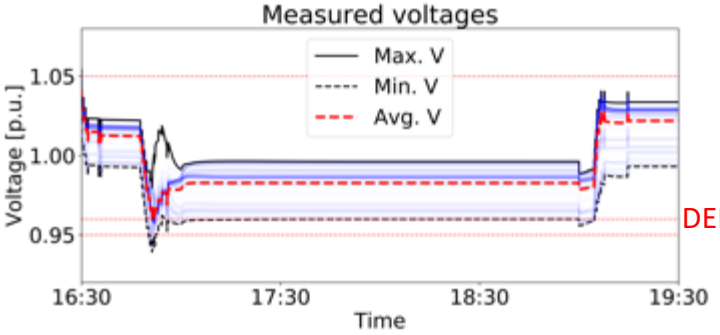




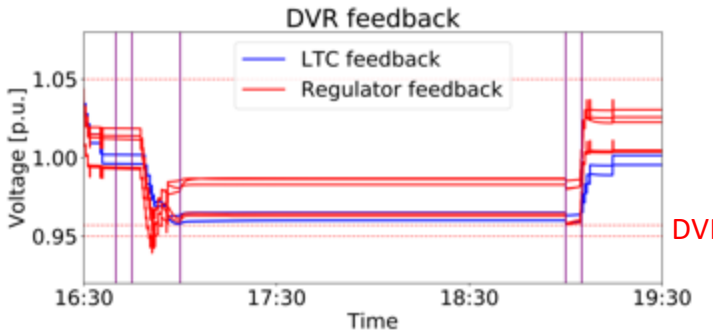
ADMS + DERMS: Voltages

- ADMS and DERMS regulate voltages based on different feedback voltages.



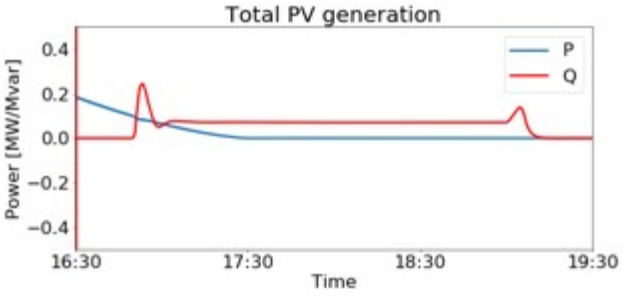


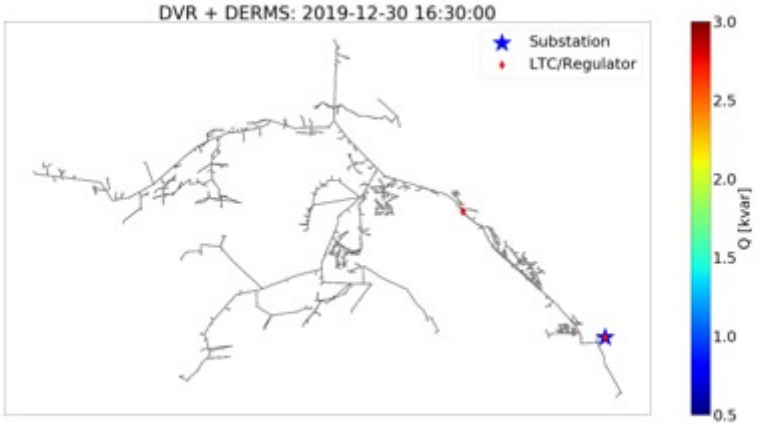
DERMS Limit

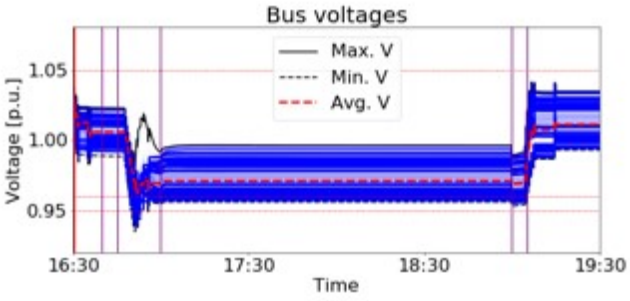


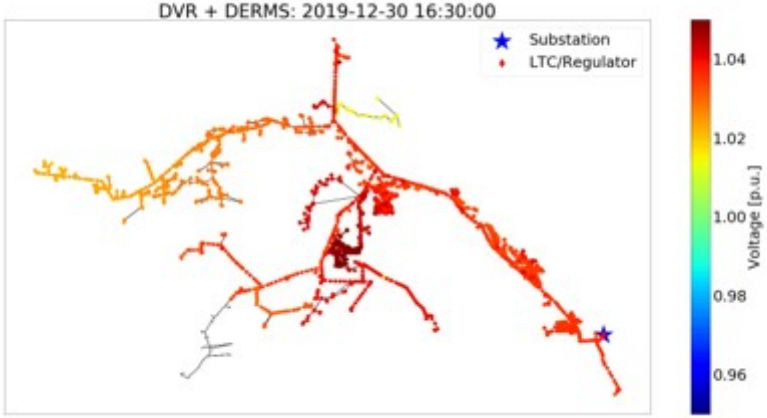
DVR Limits

DERMS Uses Smart Inverters for Voltage Support

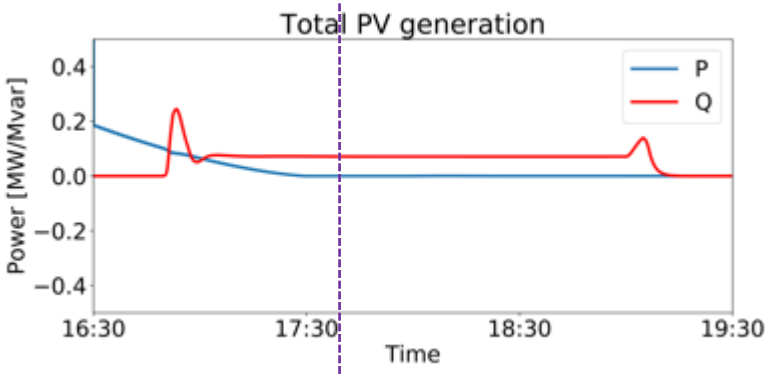


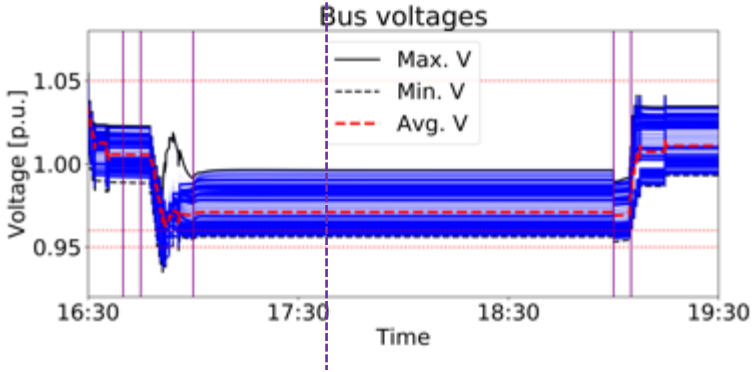


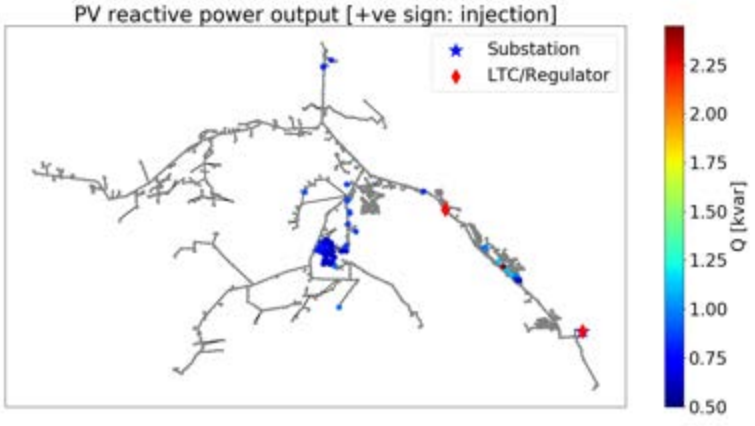


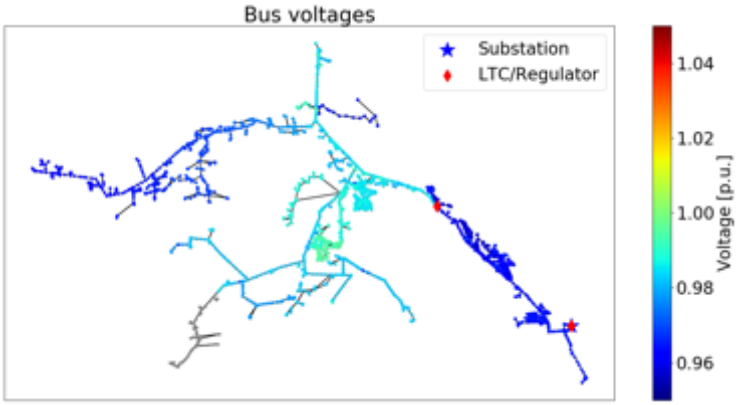


DVR + DERMS: Voltages



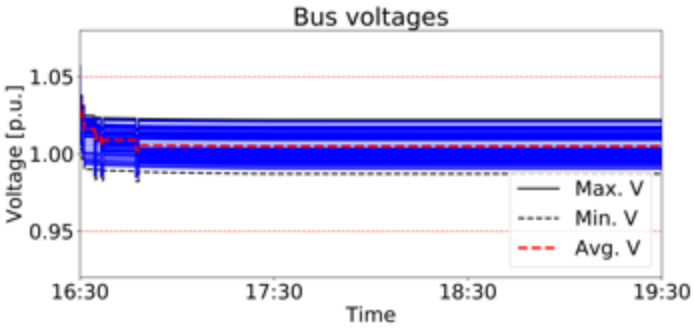




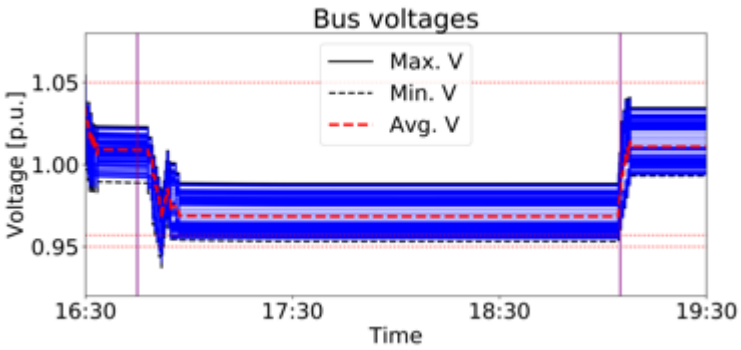


Comparison of Voltages

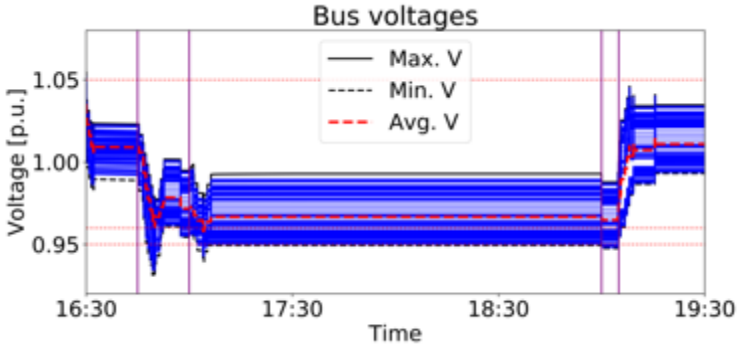
Baseline



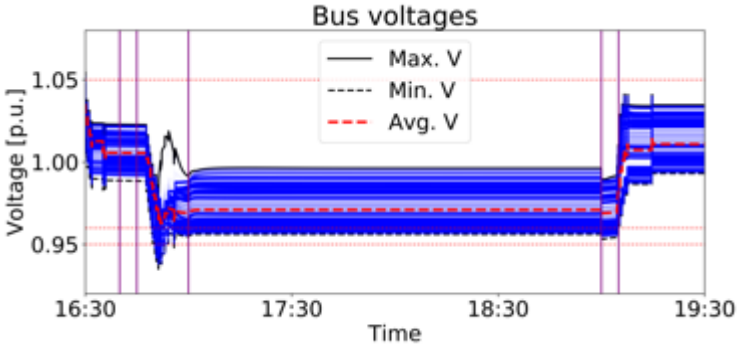
ADMS Only



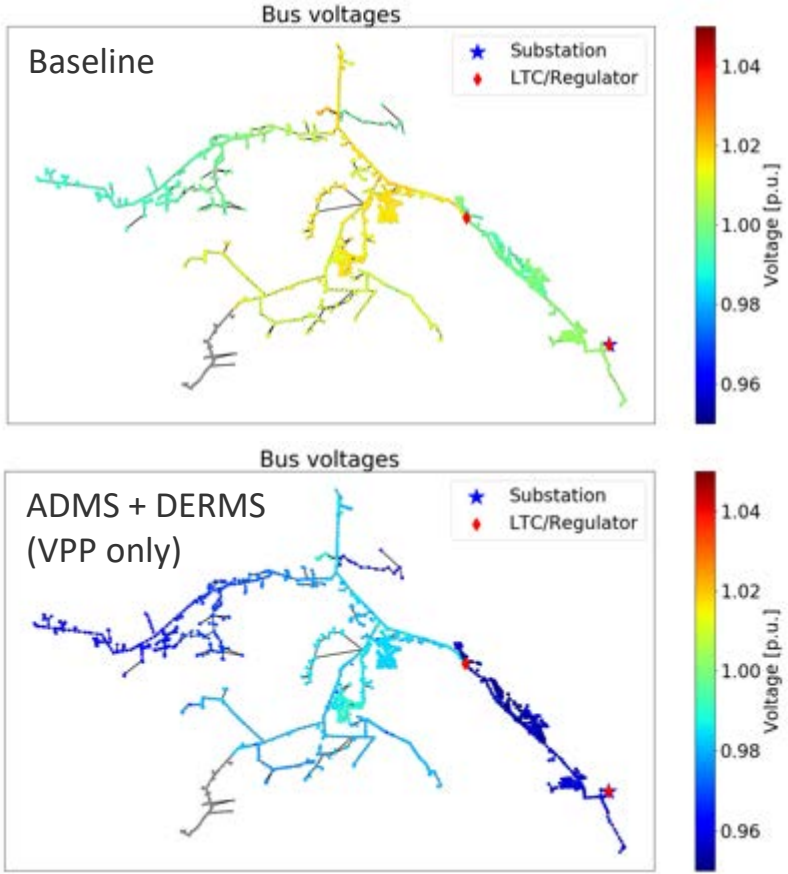
ADMS + DERMS (VPP only)

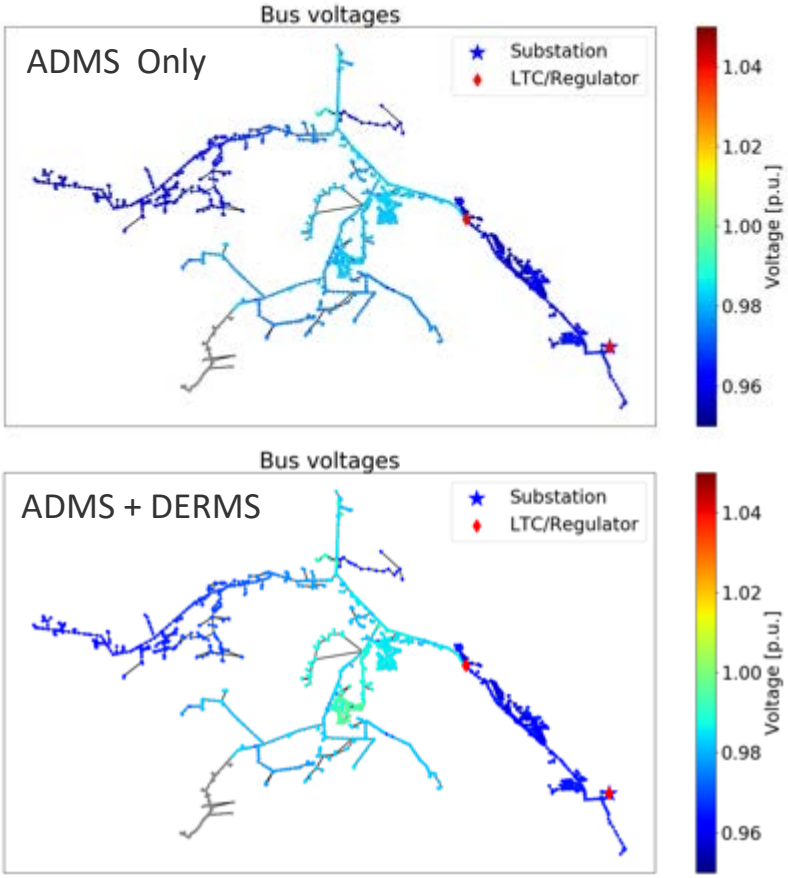


ADMS + DERMS



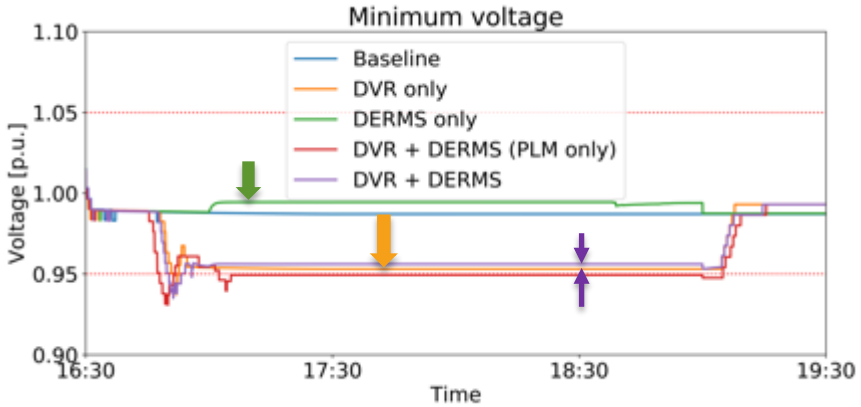
Comparison of Voltages





Voltage Comparison

- DERMS discharging batteries increases voltages.
- ADMS performing DVR reduces voltages.
- DERMS performing voltage regulation boosts lowest voltages.

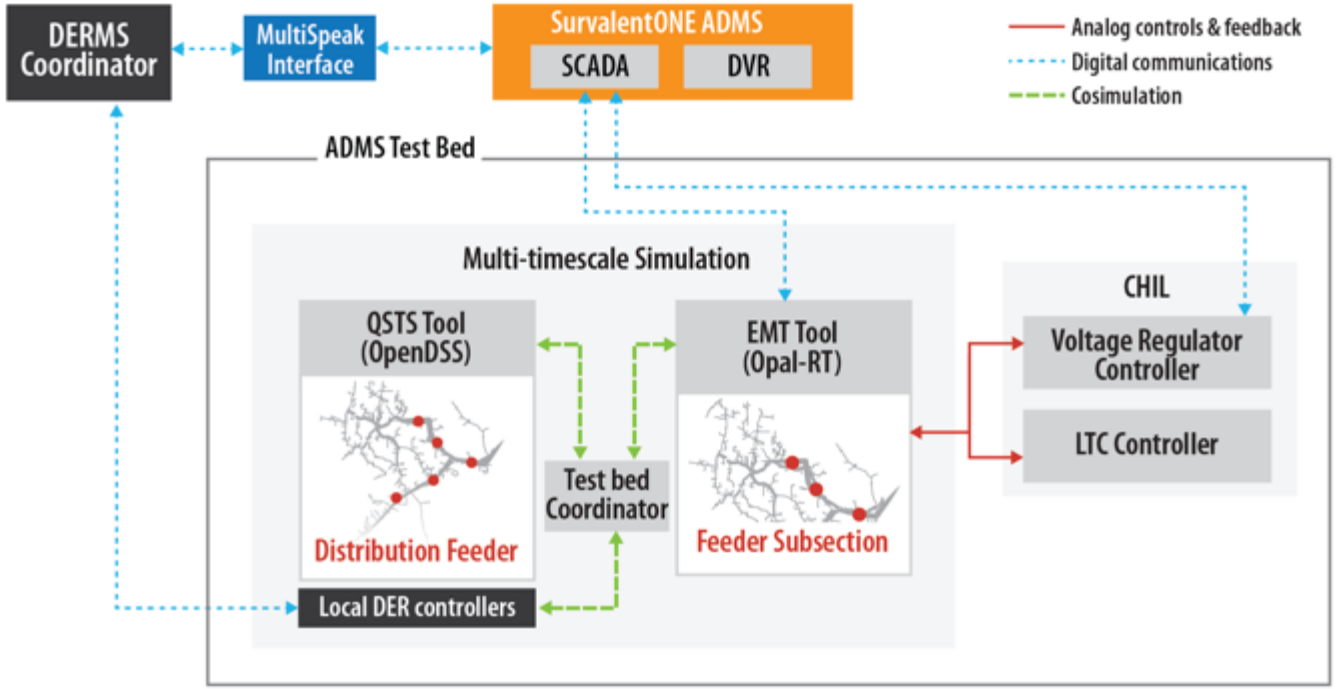


Outcomes

- Demonstrated combined operation of an ADMS and a prototype DERMS for PLM
- Demonstrated use of distributed battery storage to reduce substation demand
- Demonstrated ability of DERMS to regulate voltages within ANSI standards
- Extended industry-standard interface (NRECA's MultiSpeak standards) for ADMS-DERMS integration.

Next Step: Remote HIL

- PLM request from bulk energy management system (EMS) at PNNL
- Could be leveraged to demonstrate the impact of PLM on the bulk grid.



Future Use Cases and Events

Future Use Cases

- Request for information (RFI) on future use cases
- Target release in June 2021
- RFI responses requested ~6 weeks after release.

Future Events

Webinar: ECO-IDEA, Aug. 18, 2021

ADMS test bed workshop: Nov. 3–4, 2021

Tentatively planned for in-person at NREL

This work was authored in part 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. 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.

Thank you

www.nrel.gov

annabelle.pratt@nrel.gov

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

NREL/PR-5D00-80151

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

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," 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 Green Technologies Conference (GREENTECH), March 2017.
- S. Veda, M. Baggu, and A. Pratt, "Defining a Use Case for ADMS Testbed: Data Quality Requirements for ADMS Deployment," IEEE Conference on Innovative Smart Grid Technologies (ISGT), February 2019.
- J. Wang, B. Lundstrom, I. Mendoza, and A. Pratt, "Systematic Characterization of Power Hardware-in-the-Loop Evaluation Platform Stability," IEEE Energy Conversion Conference and Exhibition (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.

Other Project Outputs

- PyDBus: https://github.com/NREL/pydbus
- Model conversion tool: https://github.com/NREL/DSS2ePHASOR
- Visualization software: https://github.com/NREL/rts-vis-app and https://github.com/NREL/rts-data

- A video to highlight the ADMS test bed: https://www.youtube.com/watch?v=FBALnednTIE&feature=youtu.b
- A video that provides an overview of the test bed and Use Case1: https://www.youtube.com/playlist?list=PLmIn8Hncs7bGfqrW-G_A9JHVSbQk4BFc0