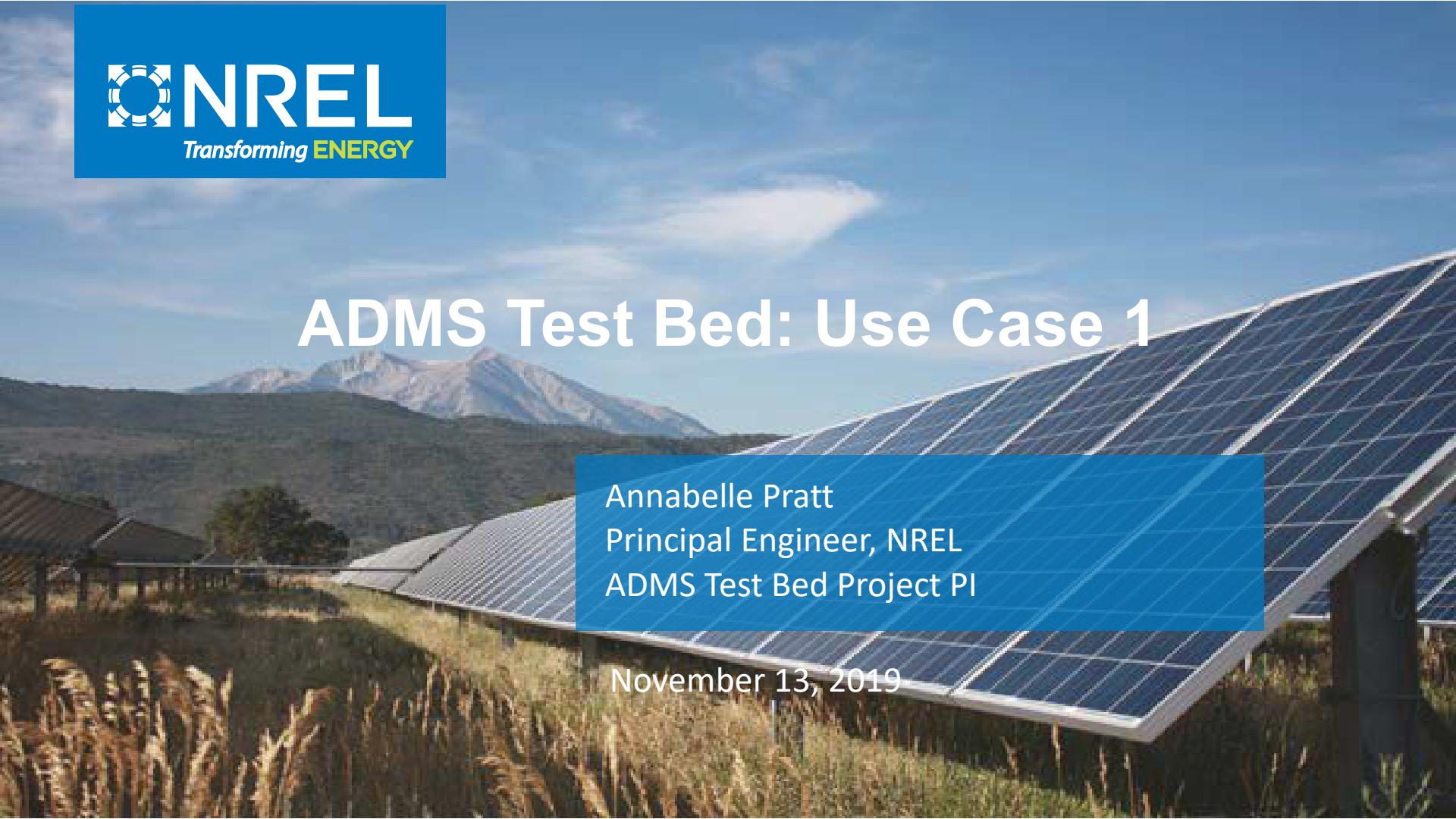

ADMS Test Bed: Use Case 1

Annabelle Pratt
Principal Engineer, NREL
ADMS Test Bed Project PI

November 13, 2019

- Use Case 1 objective
- Scenarios
- Simulation results
- ADMS test bed setup for Use Case 1
- Test plan
- Progress
- Summary

Use Case 1 Objective

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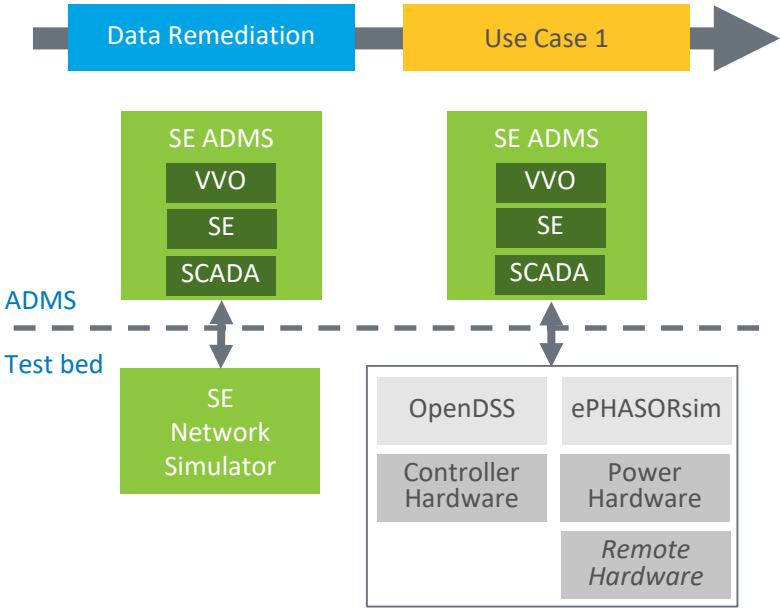
Evaluate performance of the advanced distribution management system (ADMS) VVO application for different levels of model quality and different levels of measurement density:

- Performance improvements from accurate model
- Offset model inaccuracies with additional telemetry
- Trade-off between model quality and telemetry density.



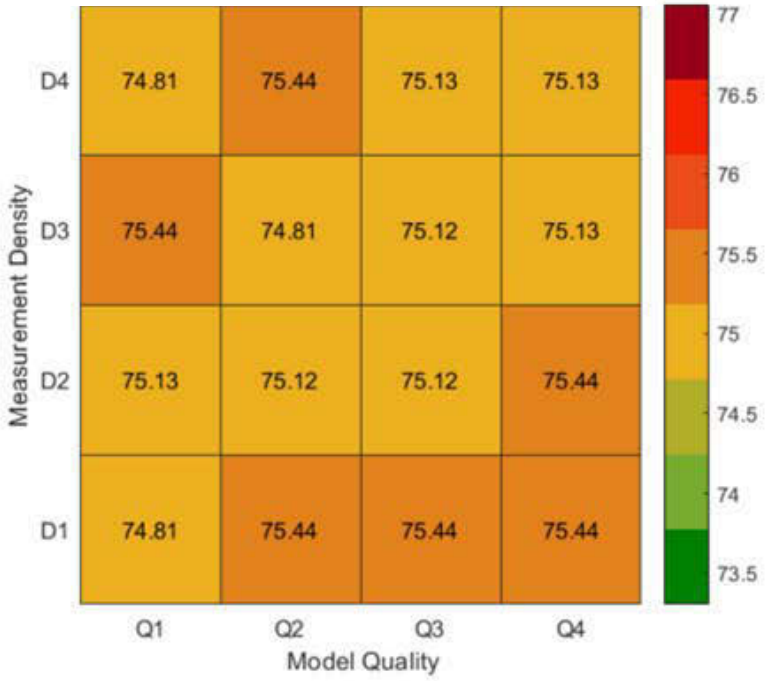
Scenarios

- Schneider's VVO is model-based:
  - Believed to be better for systems with high photovoltaic penetration.
- For simulation on test bed, selected:
  - Two data quality levels: changes network model within ADMS
  - Two measurement density levels: changes whether advanced metering infrastructure (AMI) measurements are considered.
- Based on Phase 1 (simulation only) results.

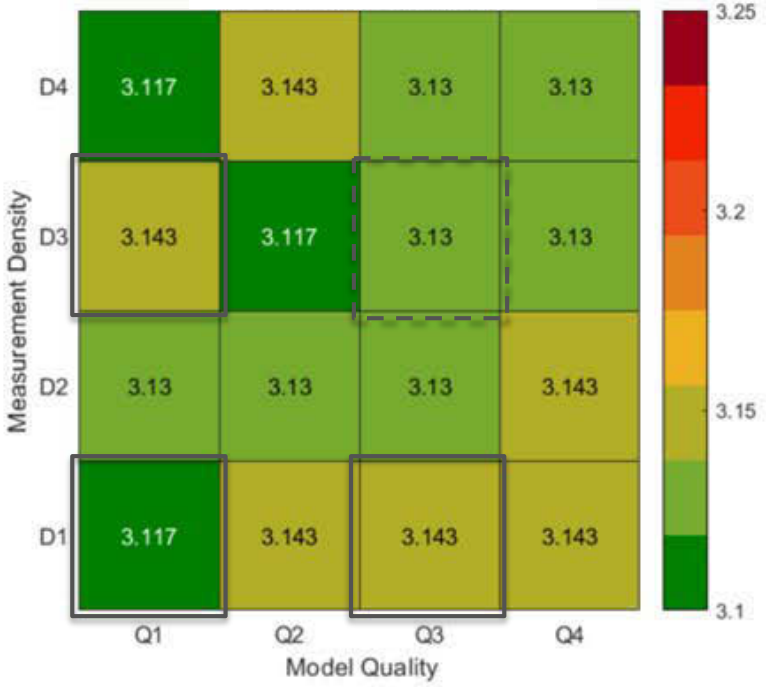
Use Case 1: Phase 1 Simulation Results

- No significant impact for this feeder
- Other Xcel Energy feeders show more change.

Energy consumption estimates (MWh)



Power (MW, daily median)



Use Case 1: Lab Setup

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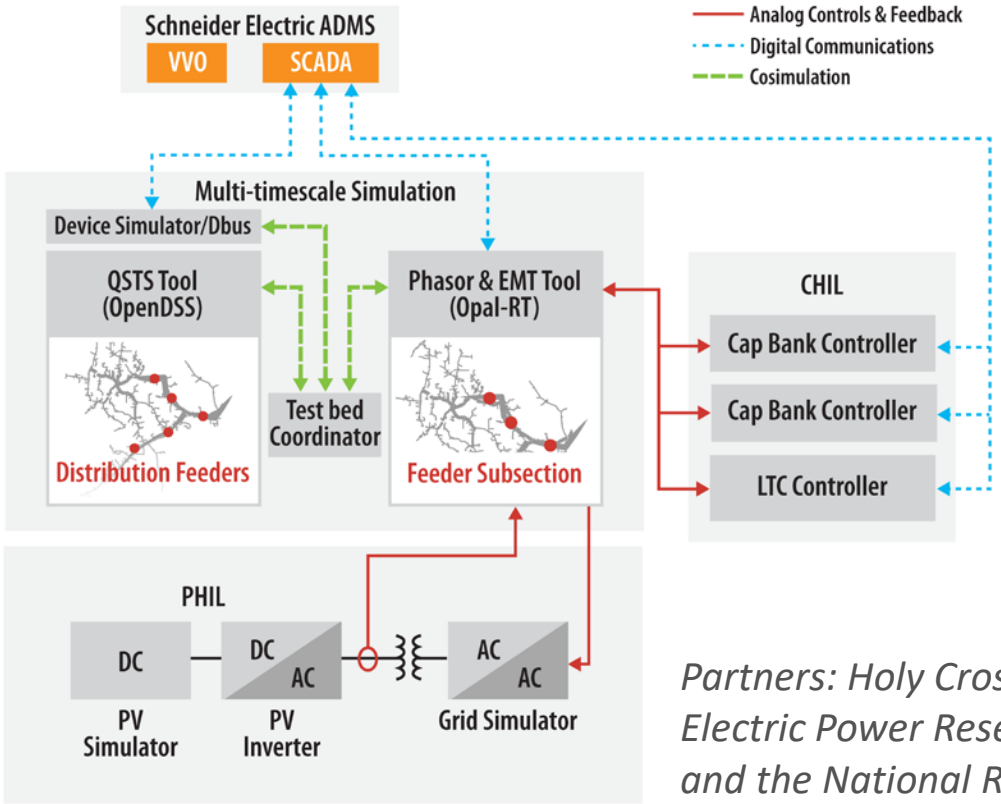


Partners: Holy Cross Energy, Survalent, the Electric Power Research Institute (EPRI), Opal-RT, and the National Rural Electric Cooperative Association

Test Bed Setup

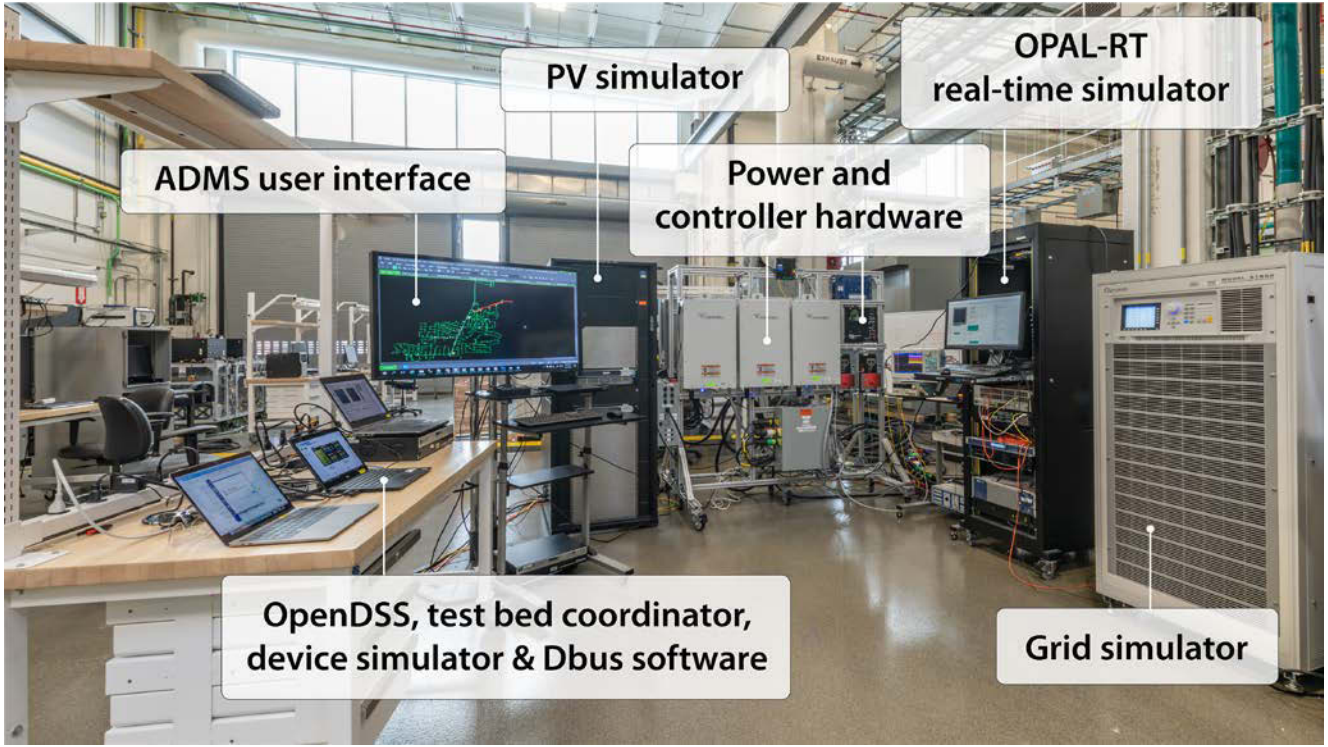
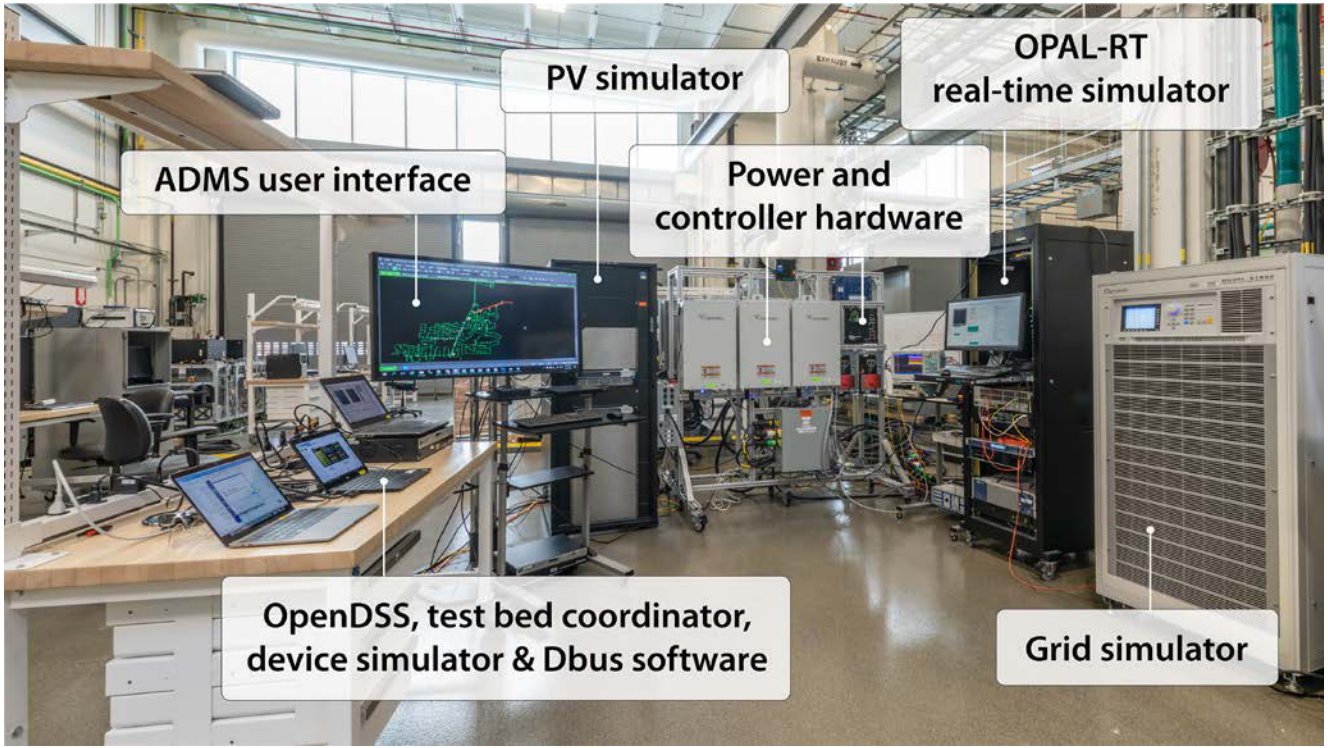


Photo by NREL

Test Bed Setup

ADMS test bed setup at NREL's Energy Systems Integration Facility

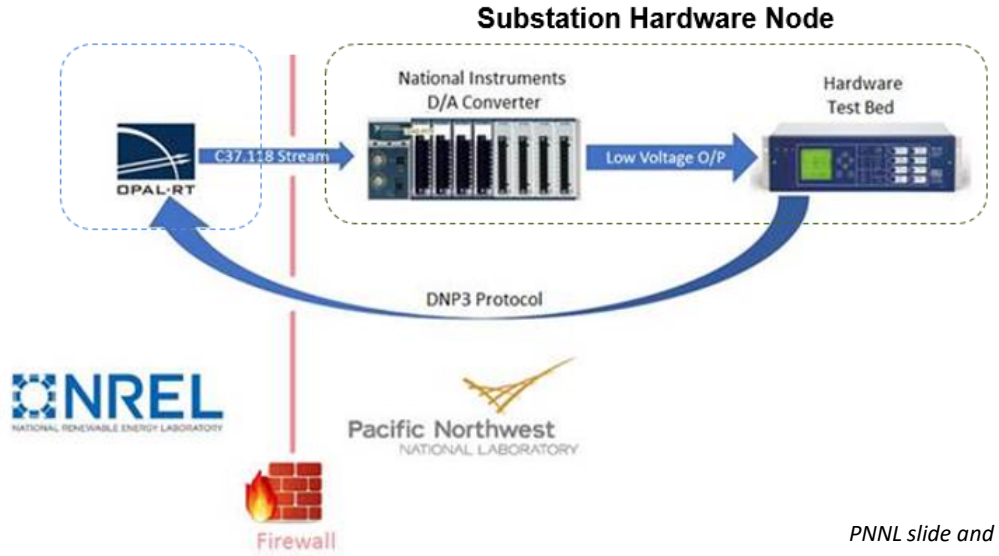


Remote HIL at PNNL

Photos by NREL

ADMS Testbed – Approach to drive RHIL (1)

- IEEE standard C37.118 protocol was used for streaming phasor data from the simulator to the remote hardware.
- DNP3 protocol was used to communicate relay/controller commands back to the simulator.



ADMS Test Bed Setup for Use Case 1

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- Xcel Energy feeder:
  - 61.59 miles; 2,880 customers; 73% underground; 27% overhead; built in 2001.
- Winter weekday load profile for light load:
  - ~6.5-MW peak; scaled to historical data for Feb. 7.
- Summer weekday for heavy load:
  - ~12.5-MW peak; scaled to historical data for June 26.
- Baseline run without VVO activated; then with VVO activated:
  - VVO objective = energy reduction.

ADMS Test Bed Setup for Use Case 1

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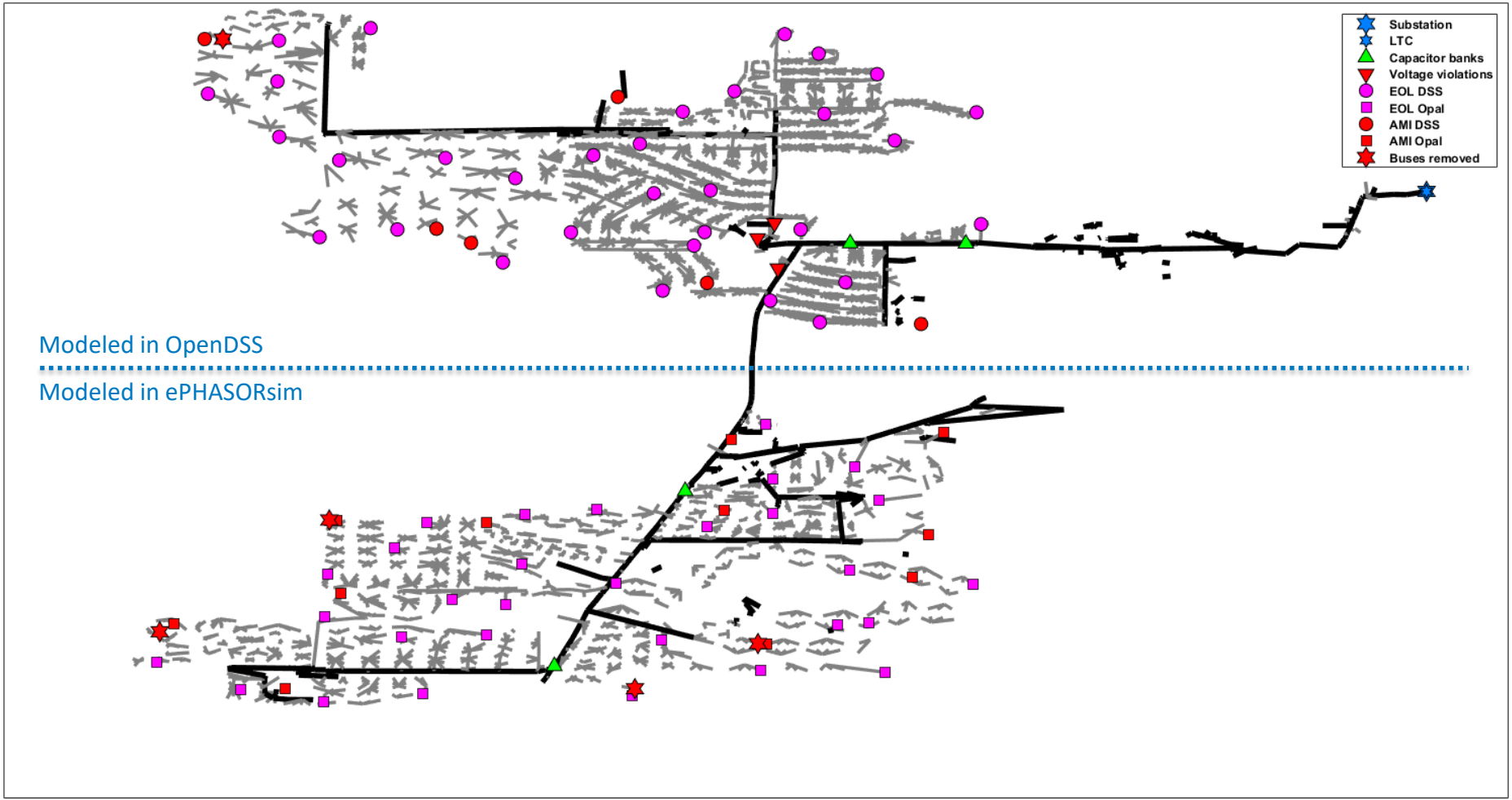
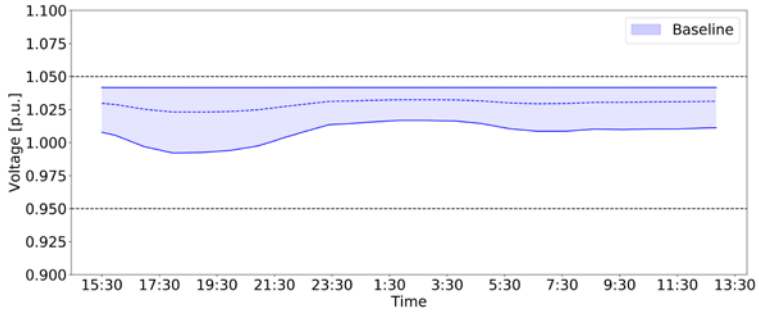
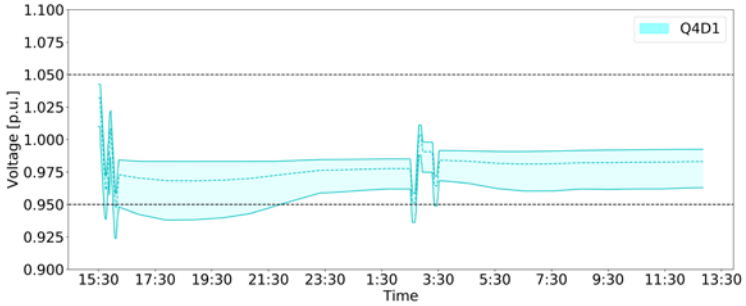
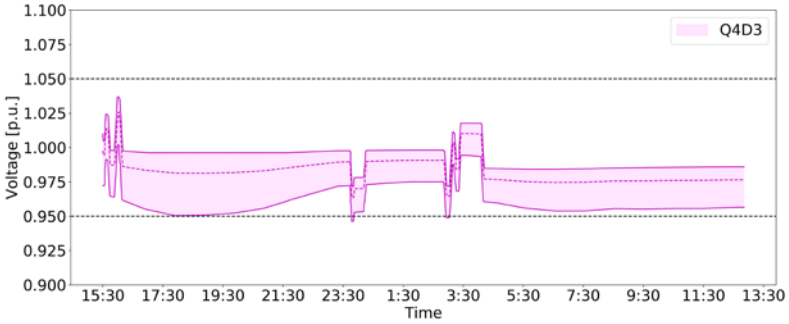
- Experiments run from 15:30 to 13:30 p.m. to allow almost 24-hour simulation and changeover time.
- ADMS can control load tap changer (LTC) and four capacitor banks:
  - LTC in OpenDSS, using LTC controller-hardware-in-the-loop (CHIL)
  - Two in OpenDSS, using device simulator software
  - Two in Opal-RT, one using capacitor bank controller CHIL and one simulated in ePHASORSIM (can run second as remote-hardware-in-the-loop (RHIL) to the Pacific Northwest National Laboratory (PNNL)).


Substation
LTC
Capacitor banks
Voltage violations
EOL DSS
EOL Opal
AMI DSS
AMI Opal
Buses removed
Modeled in OpenDSS
Modeled in ePHASORsim

Light Load Results







Light Load

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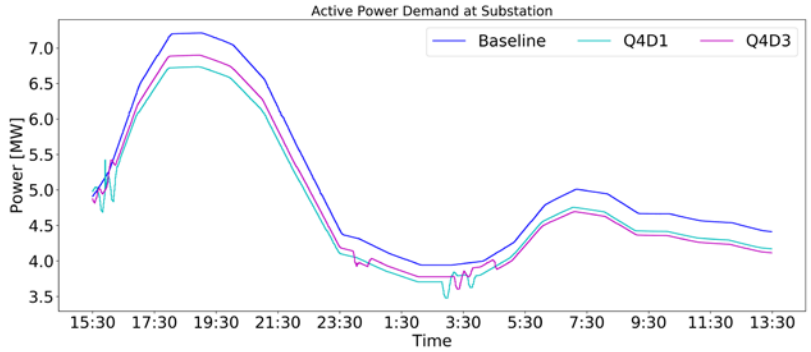

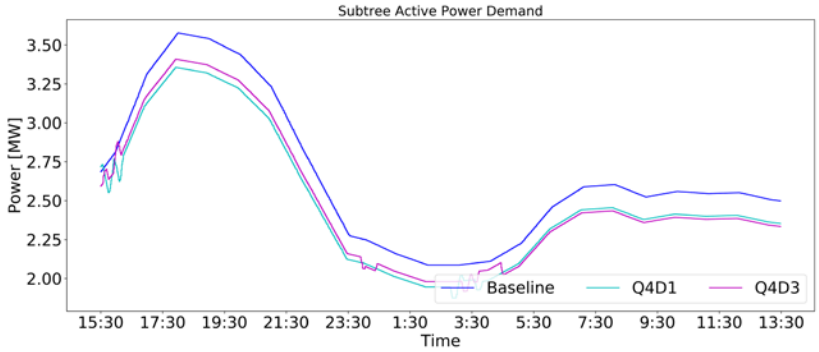

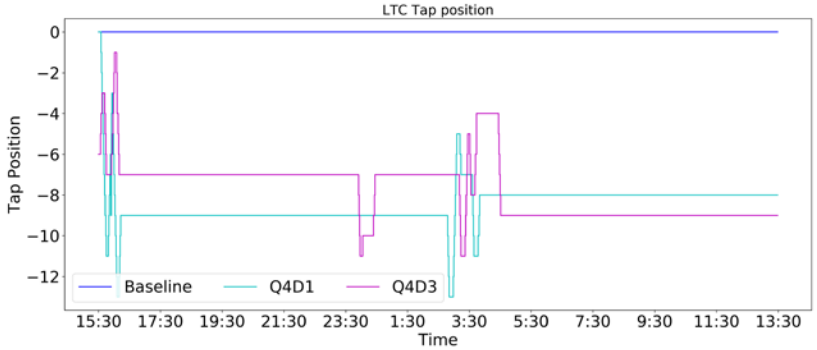

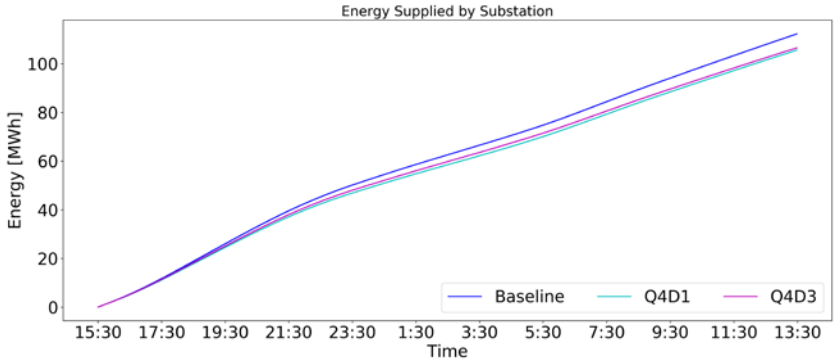

Light Load: Metrics

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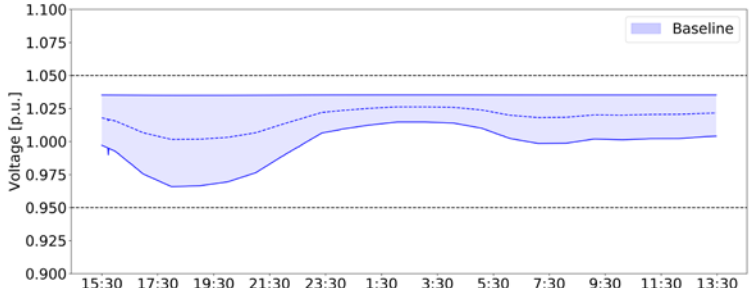
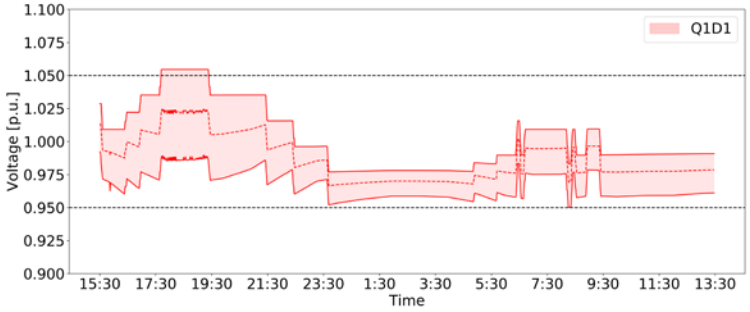
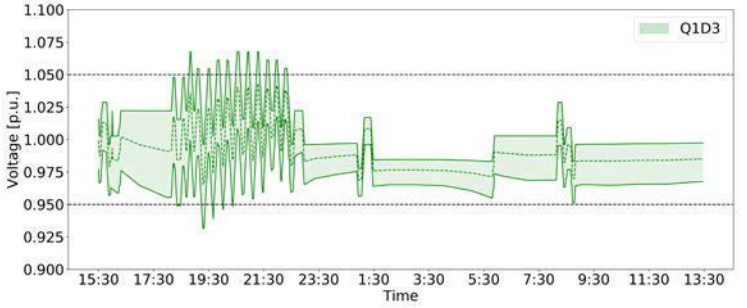
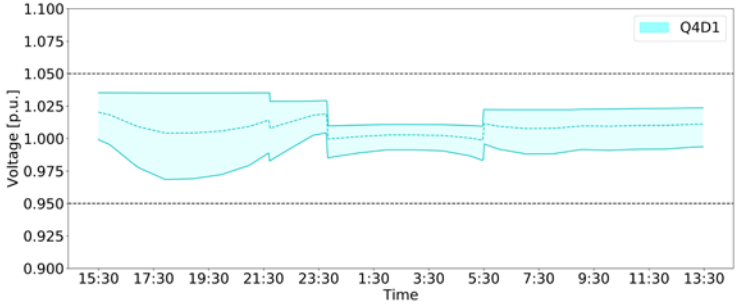
	Number of Capacitor Changes	Number of LTC Tap Changes	Energy Savings (%)	Number of Voltage Violations
Baseline	0	0	N/A	0
Q4D1	0	54	6.1	1702
Q4D3	0	47	4.6	12

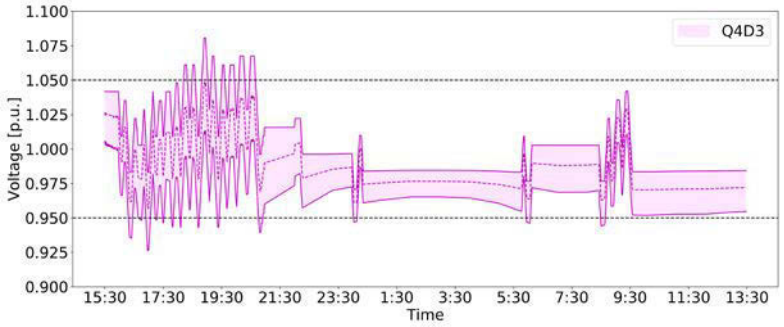
Heavy Load: Preliminary











Summary and Thoughts on Future Directions

- Operational test bed for Use Case 1 allows study of data quality and measurement density impacts
- Working with Schneider to fine-tune VVO configuration for this feeder
- Results show impact of both data quality and measurement densities
- Plan to address “hunting” to not distract from main study area.

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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.

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Levels of Model Quality

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- **Level 1 (Q1) –** Base-level data extracted from the Xcel Energy GIS adjusted just enough for power flow convergence.
- **Level 2 (Q2) –** In addition to Level 1, field verification at select locations to obtain wire size/material (if unknown), capacitor, regulator, recloser, and step transformer attributes (locations noncontiguous).
- **Level 3 (Q3) –** In addition to Level 2 remediation, phasing information collected through field verification at select locations.
- **Level 4 (Q4) –** In addition to Level 3, field confirmation performed for each primary circuit to obtain distribution transformer attributes, identifying new assets not shown in the GIS data and identifying assets that no longer exist in the field.

Levels of Measurement Density

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Level 1 (D1) – Feeder head and tail-end measurements.

Level 2 (D2) – Measurements from Level 1, voltage regulators, capacitor banks, reclosers, and one tail-end voltage sensor (AMI sensor) per feeder with communications.

Level 3 (D3) – Measurements from Level 2 and a total of 10 AMI sensors per feeder.

Level 4 (D4) – Measurements from Level 2 and a total of 20 AMI sensors per feeder.

Heavy Load: Latest

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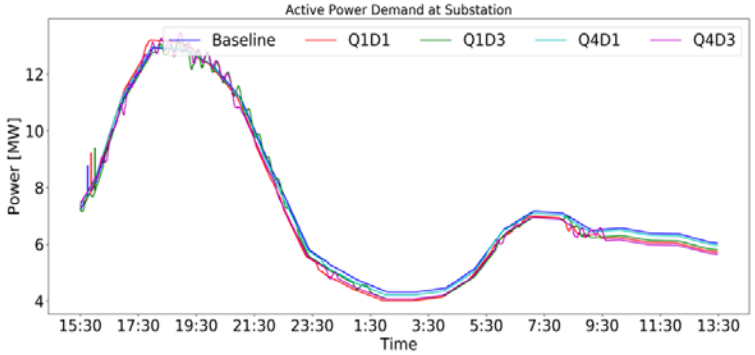
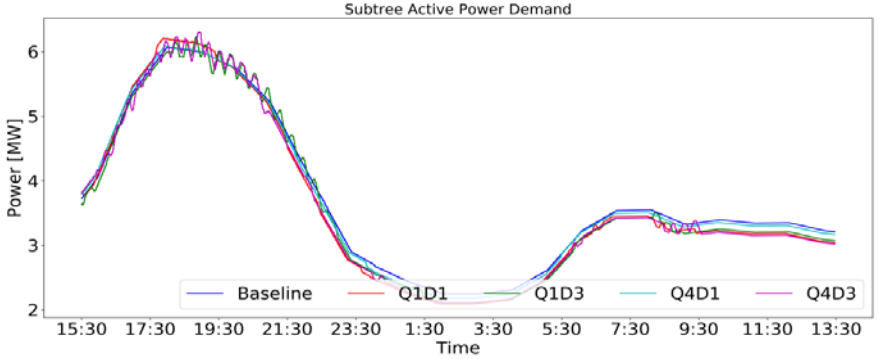
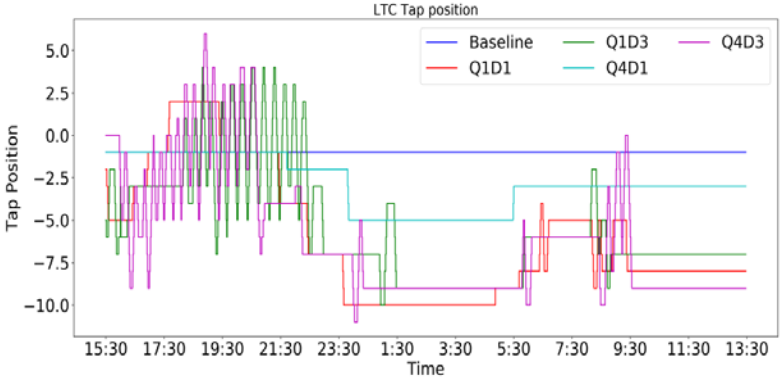
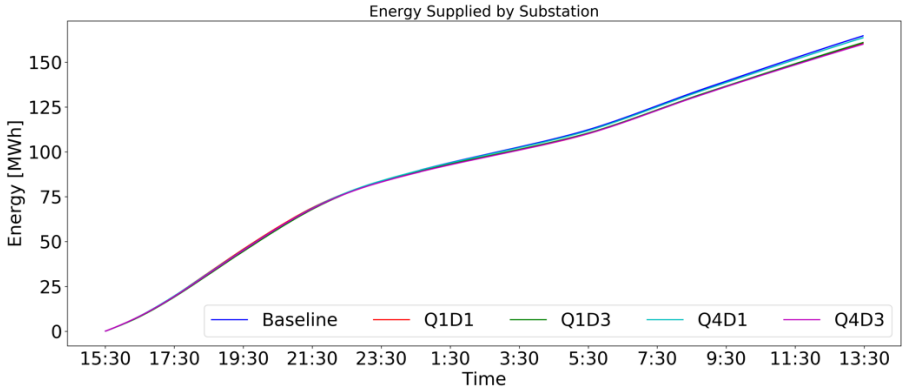
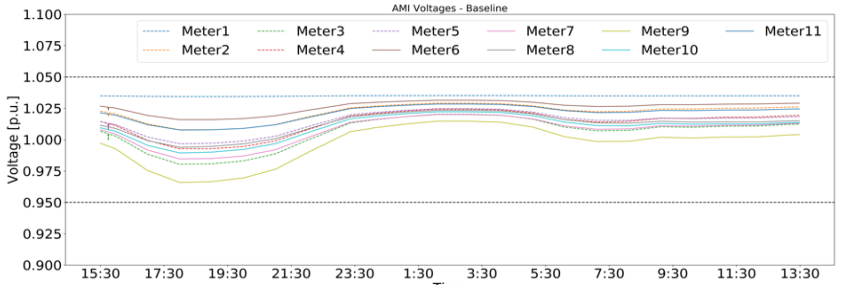


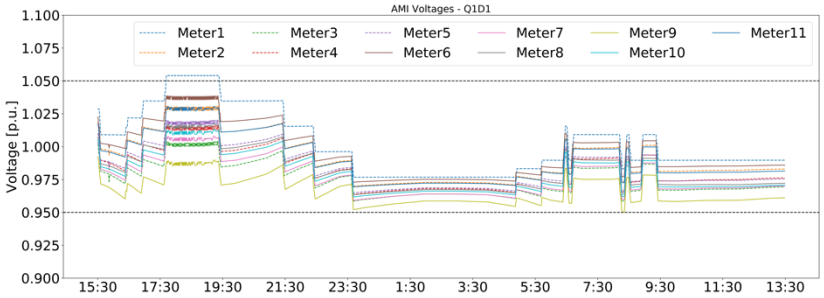


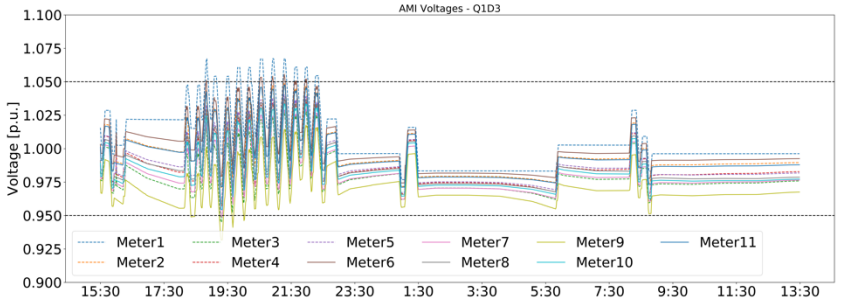


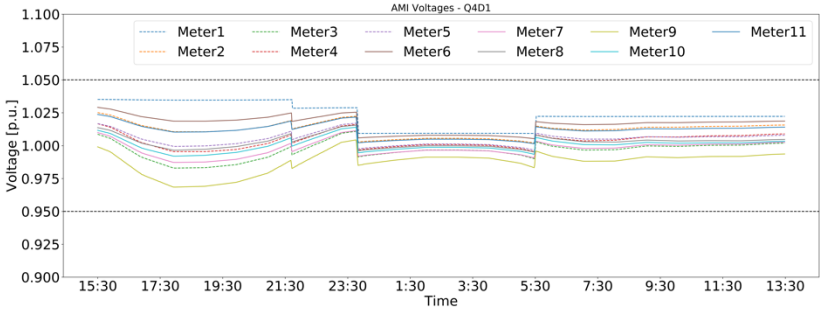


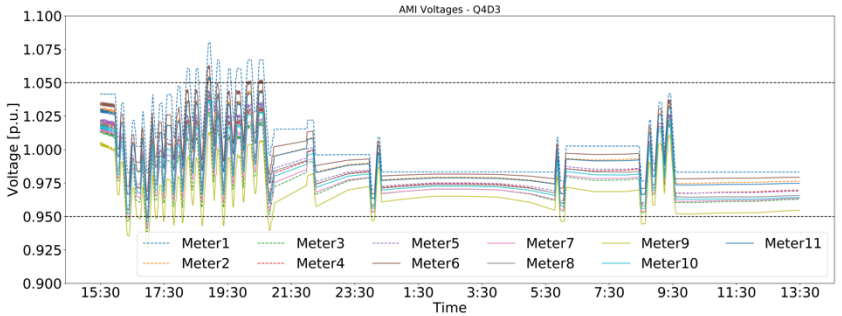
Heavy Load: AMI Voltages



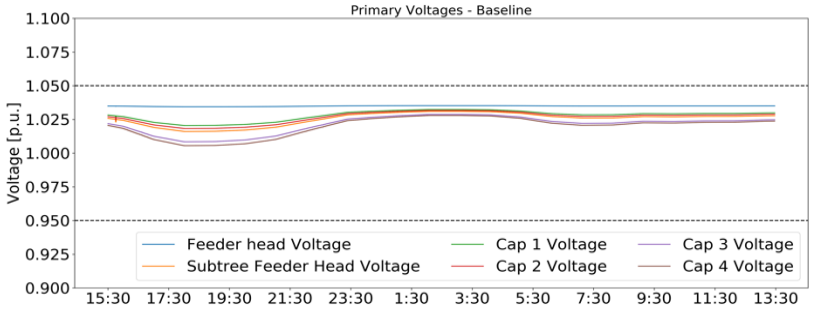


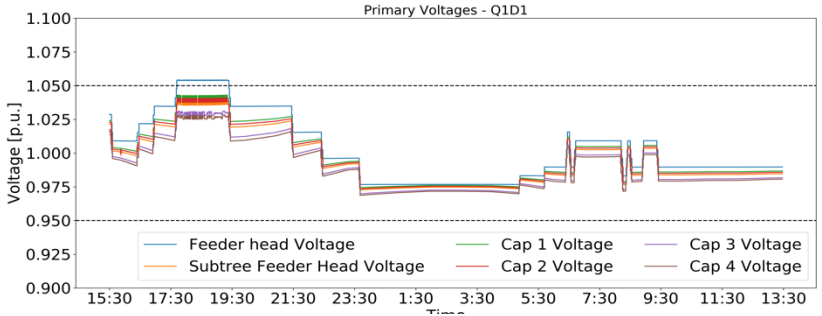


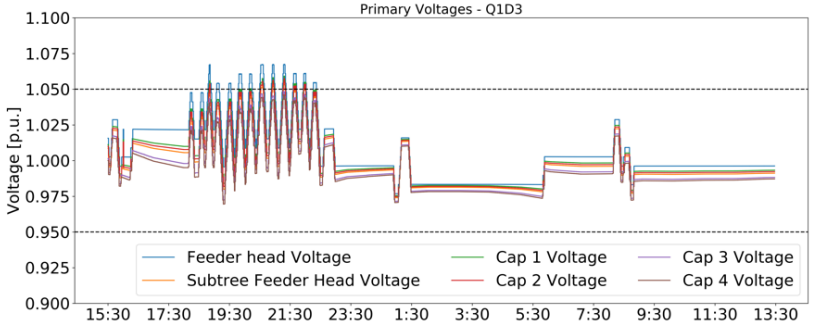


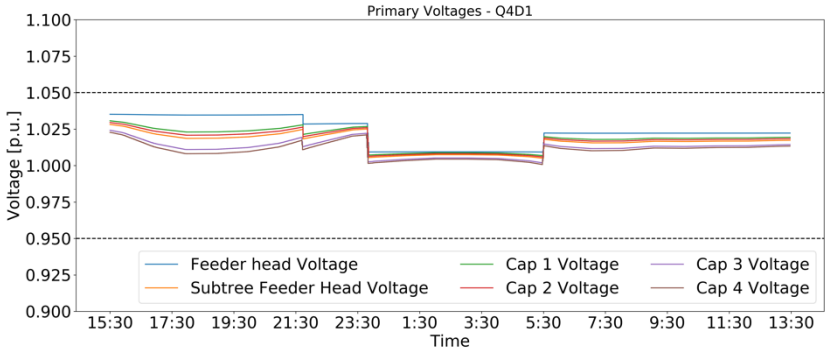


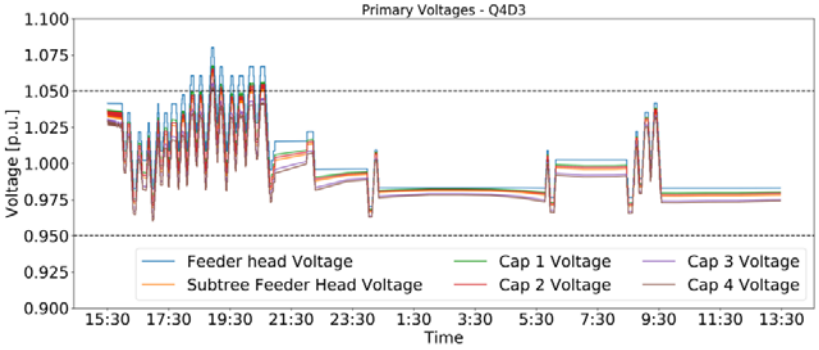
Heavy Load: Primary Voltages



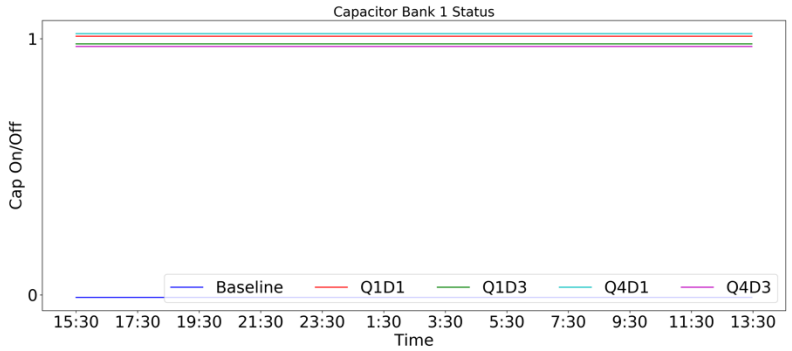


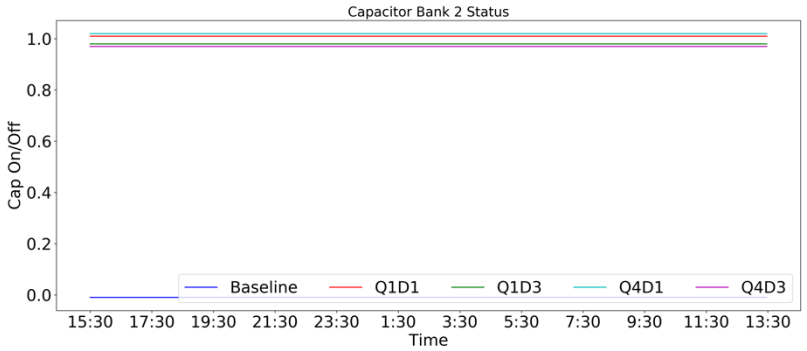


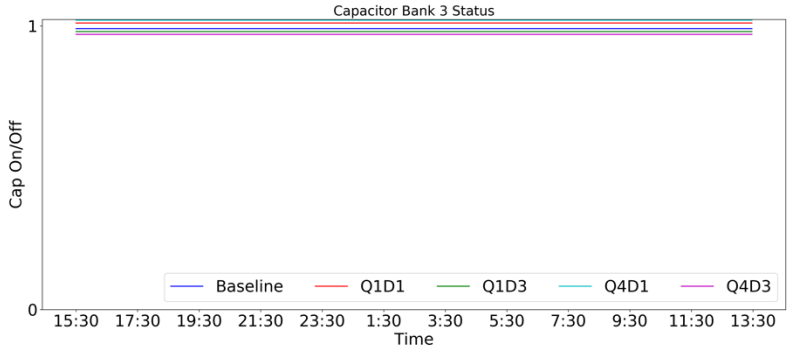


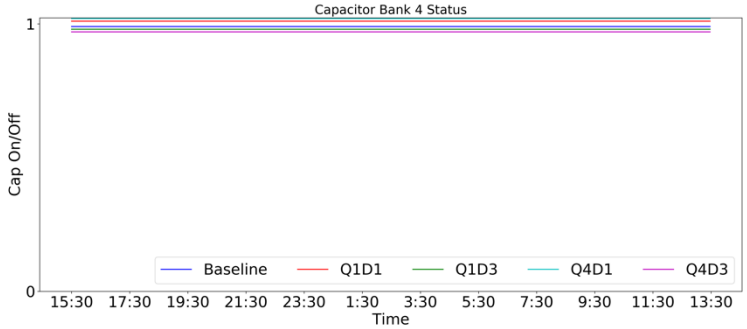


Heavy Load: Capacitor Banks

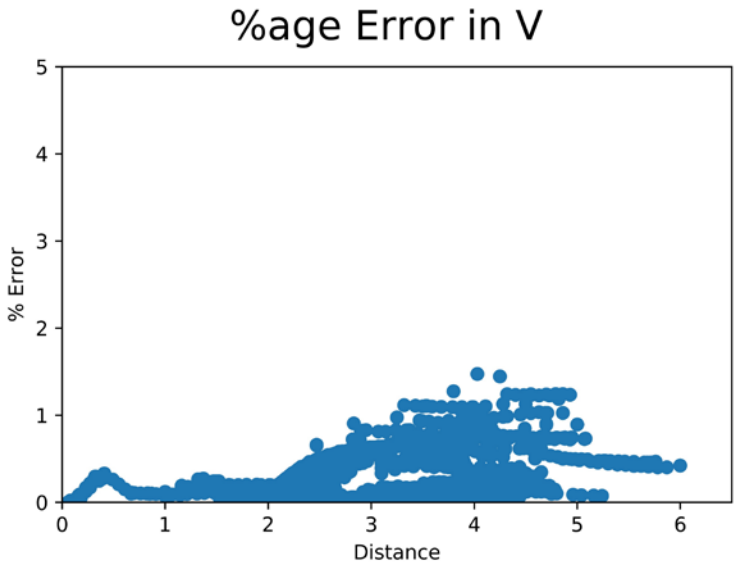


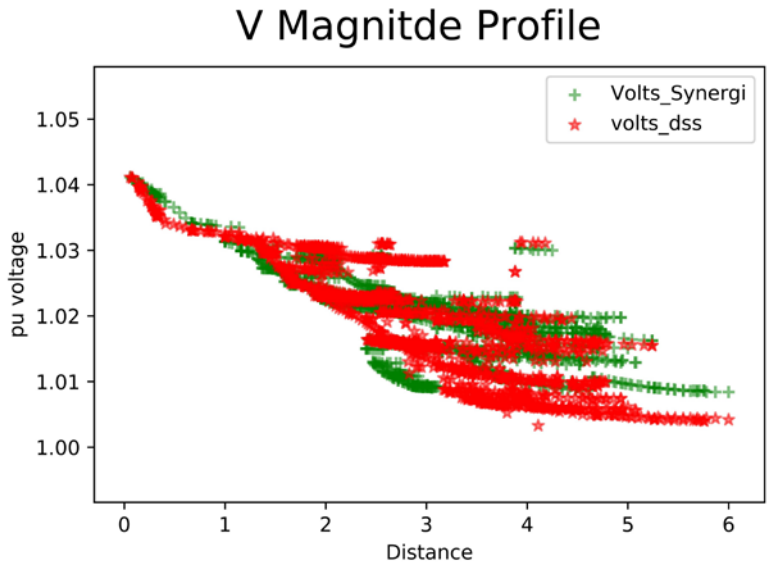






Feeder Validation





Load ~4.5 MW