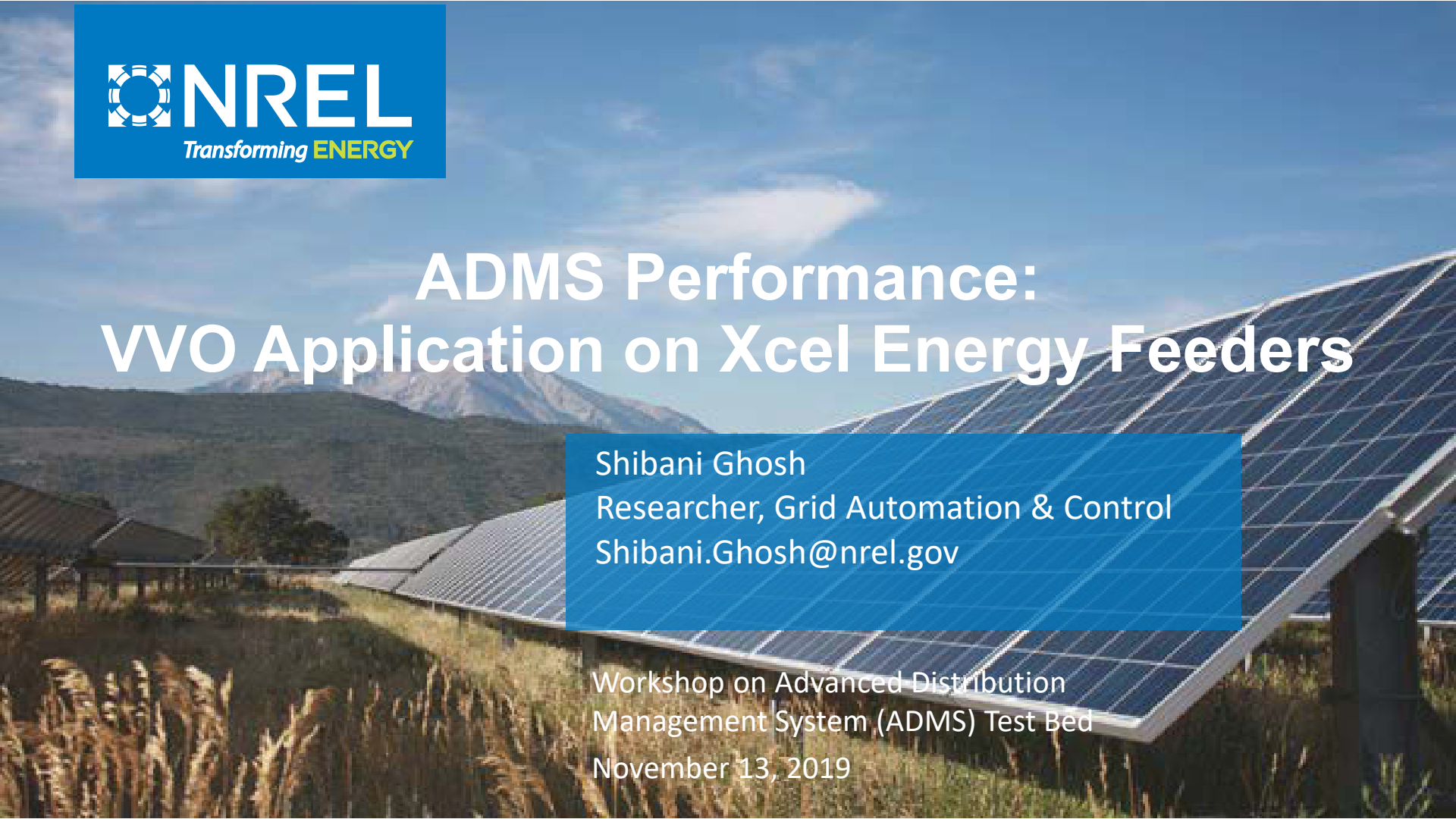

ADMS Performance: VVO Application on Xcel Energy Feeders

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Workshop on Advanced Distribution Management System (ADMS) Test Bed

November 13, 2019

Data Remediation

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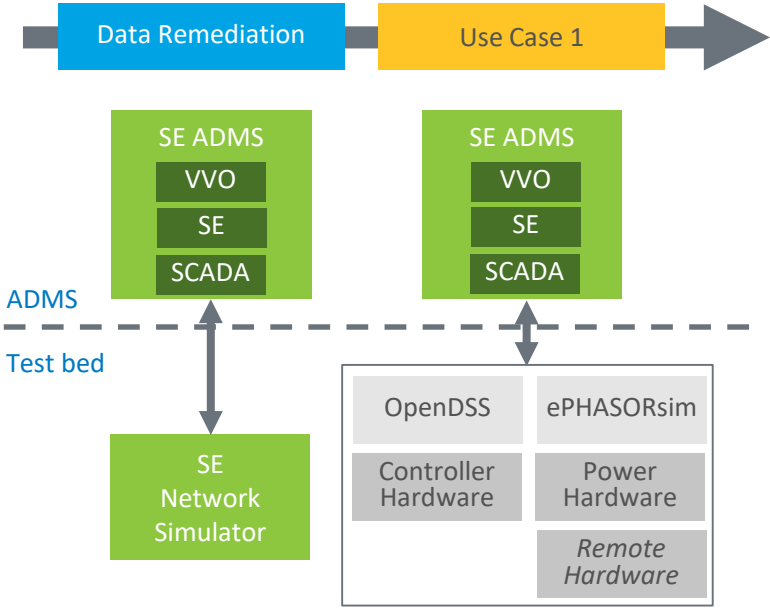
Evaluate performance of the ADMS VVO* application for different levels of model quality and different levels of measurement density:

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

- Results from this project inform ADMS Test Bed Use Case 1.



*Advanced distribution management system volt/VAR optimization

ADMS Deployment

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- What level of data remediation does the utility need for a successful deployment?
- How many and which type(s) of sensors need to be installed for optimal ADMS performance?
- What is the impact of the lower data remediation level on the performance of ADMS and its applications?
- How much will additional remediation improve the ADMS performance?

Levels of Model Quality

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- **Level 1 (Q1)**: Base-level data extracted from the Xcel Energy Geographic Information System (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 (advanced metering infrastructure [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.

Test Setup

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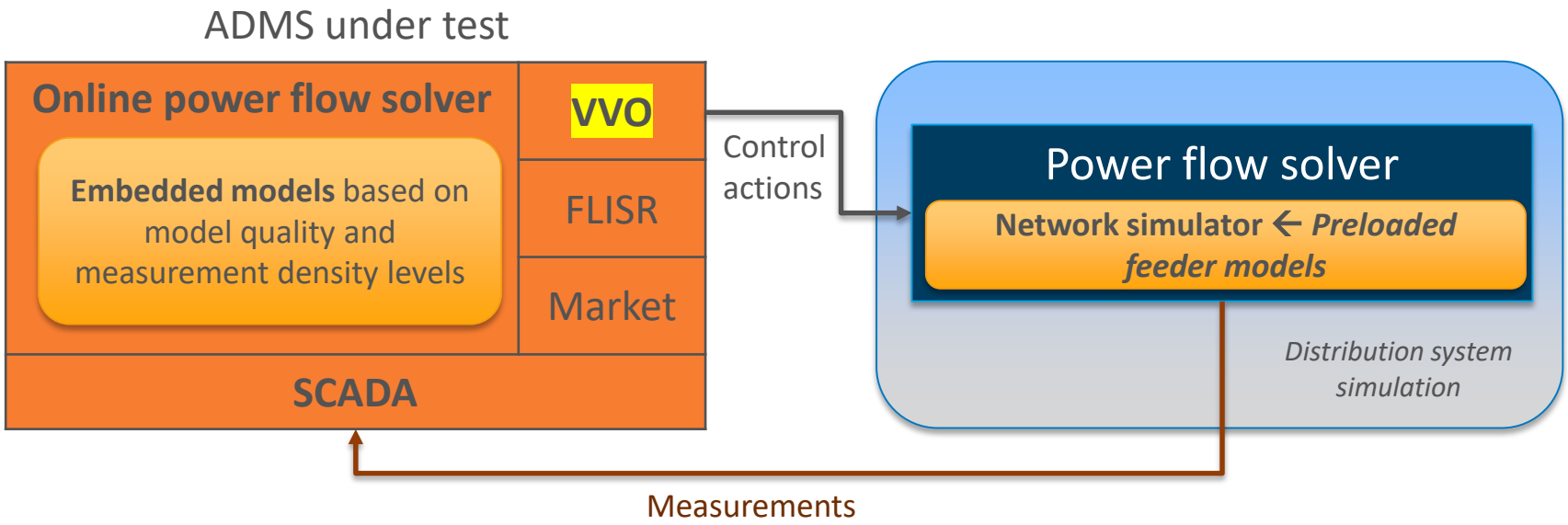

Test Setup: VVO Settings

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Conservation voltage reduction (CVR)

Objective functions

- ***Power consumption reduction***
- Power factor improvement
- Active power losses reduction
- Consumer voltages improvement
- VAR control

Constraints

- Consumer voltage
- Medium voltage
- AMI voltage
- Power factor measurements
- Voltage unbalance index

Test Setup: VVO Configuration

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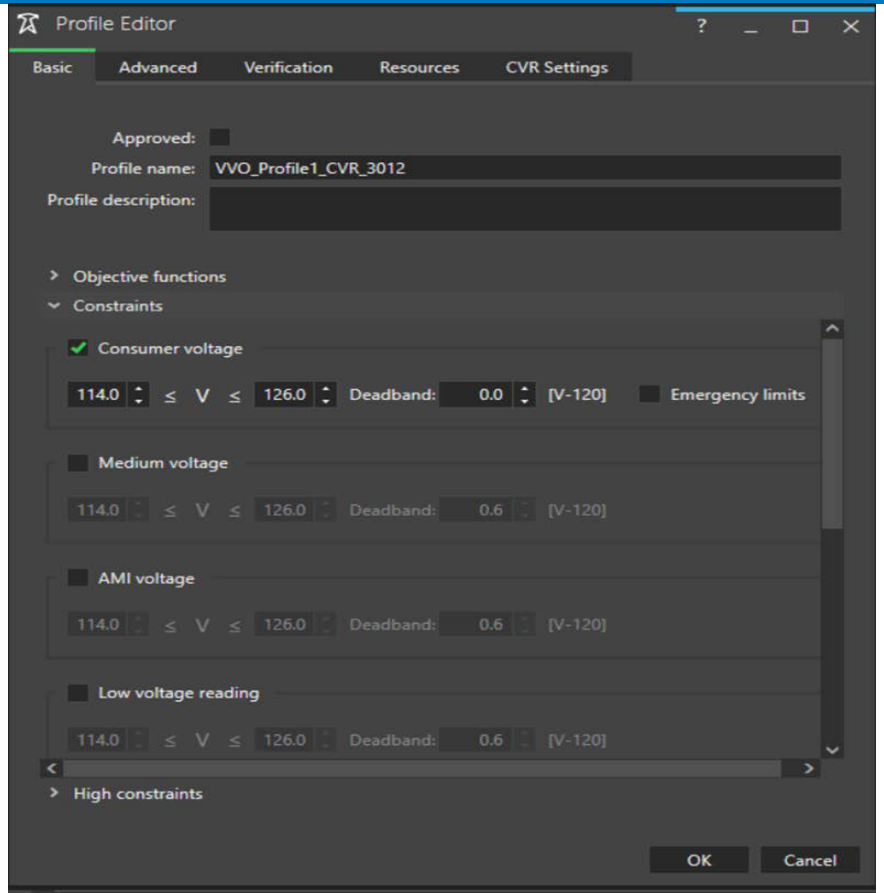

Test Setup: Daily Simulations

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- **VVO configuration**: Select objective/constraints
- **Feeder**: Select feeder to perform VVO (CVR)
- **Days**: Select days (load profiles, loading levels)
- **Data**: Collect required data for post-processing

Selected Feeders

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Feeder	Type	Circuit Miles (apprx.)	Customers (#)	Underground (UG %) / Overhead (OH %)	Peak Load (MW, apprx.)
Feeder 1	Rural	80	1571	54/46	1.07
Feeder 2	Rural	125	2143	70/30	7.13
Feeder 3	Semi-urban	47	2799	87/13	6.73
Feeder 4	Urban	22	477	13/87	12.34
Feeder 5	Urban	14	351	25/75	11.3
Feeder 6	Urban	61	2880	73/27	12.46

Test Metrics

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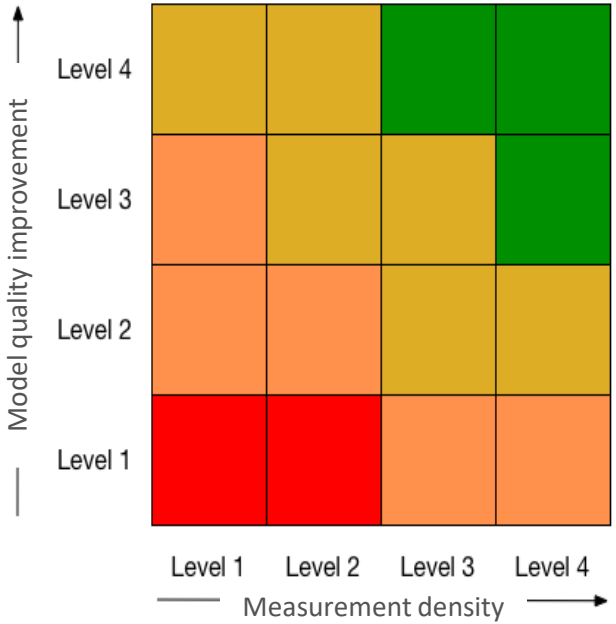
Test Metric	Description
CVR energy reduction	Feeder energy consumption before and after application of CVR
System average voltage fluctuation index	Average voltage fluctuations for all nodes within the time period. Represents the flatness of the voltage profile
System control device Operation index **Capacitor bank operations, load tap changer (LTC), or voltage regulator operations**	i. Number of times the capacitor banks were turned on or off ii. Number of times the LTC/voltage regulators were operated
System energy loss index	Ratio of total energy loss during the entire simulation time to the total load
Power factor	Power factor computed at selected nodes

Expected outcome



Results: Voltage Reduction

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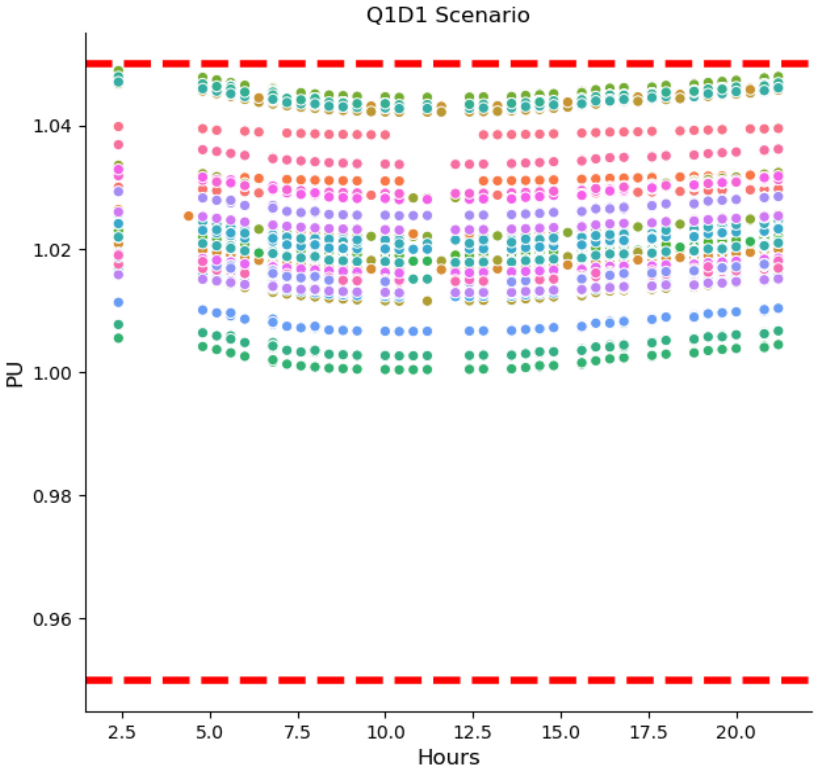
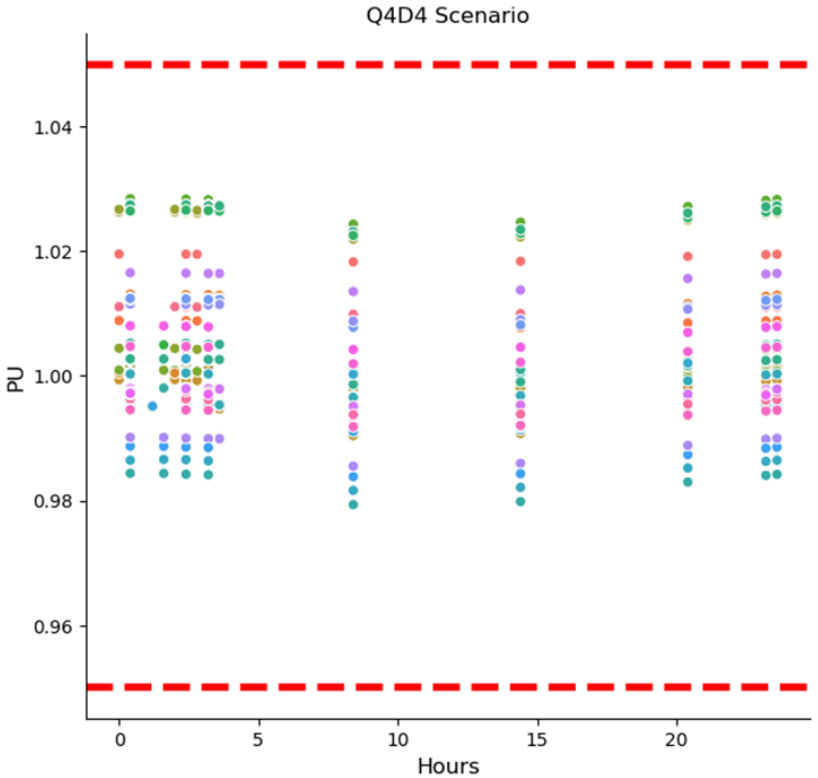
Feeder 1 (rural, even mix of underground and overhead assets)





Results: Voltage Violations

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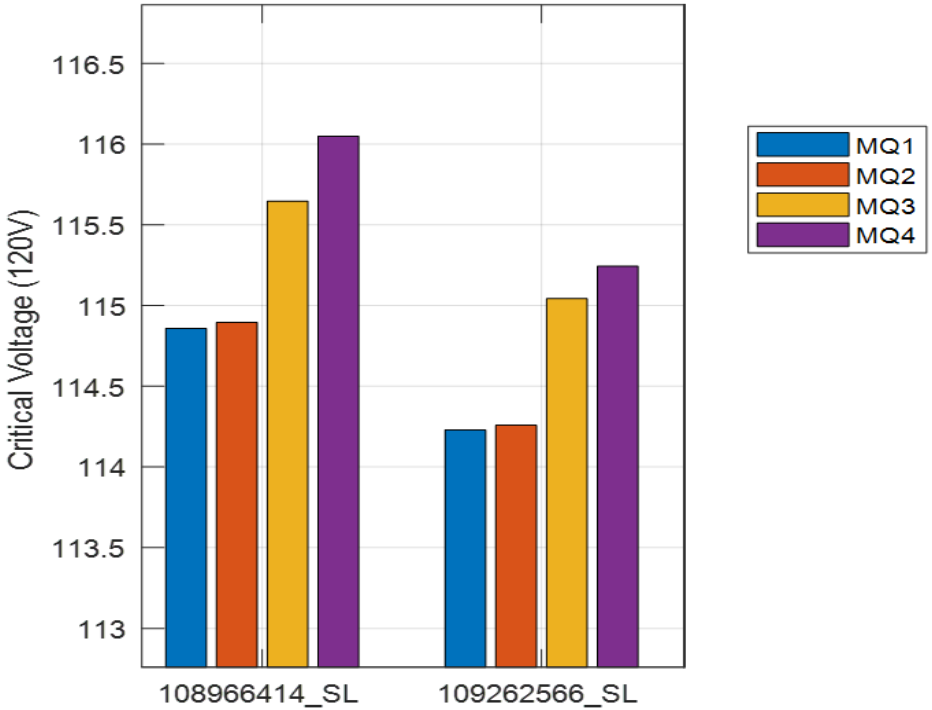
Feeder 1 (rural, even mix of underground and overhead assets)



Results: Energy Savings with VVO

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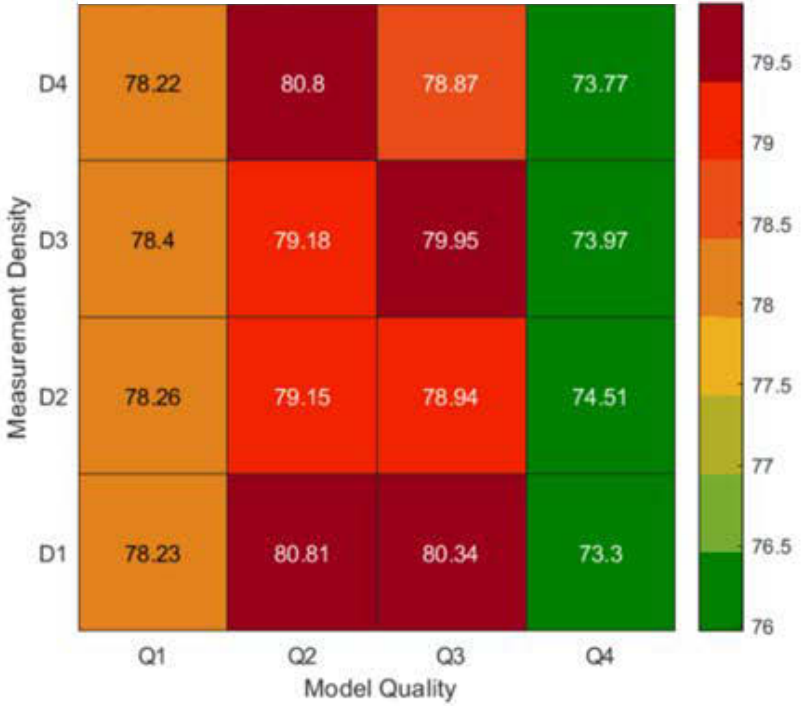
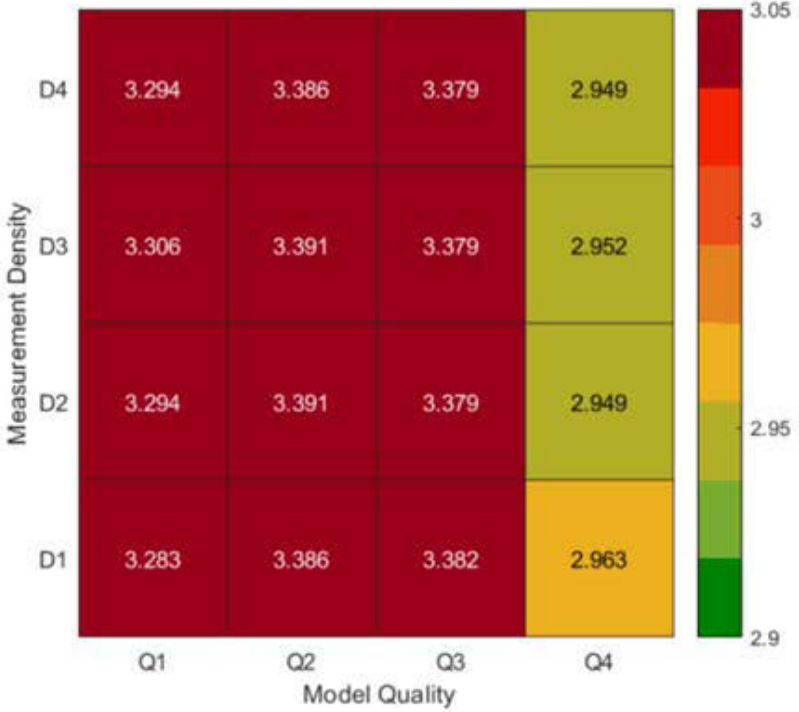
Feeder 1 (rural, even mix of underground and overhead assets)

Energy consumption estimates (MWh)



Power (MW, daily median)



Results: Energy Savings with VVO

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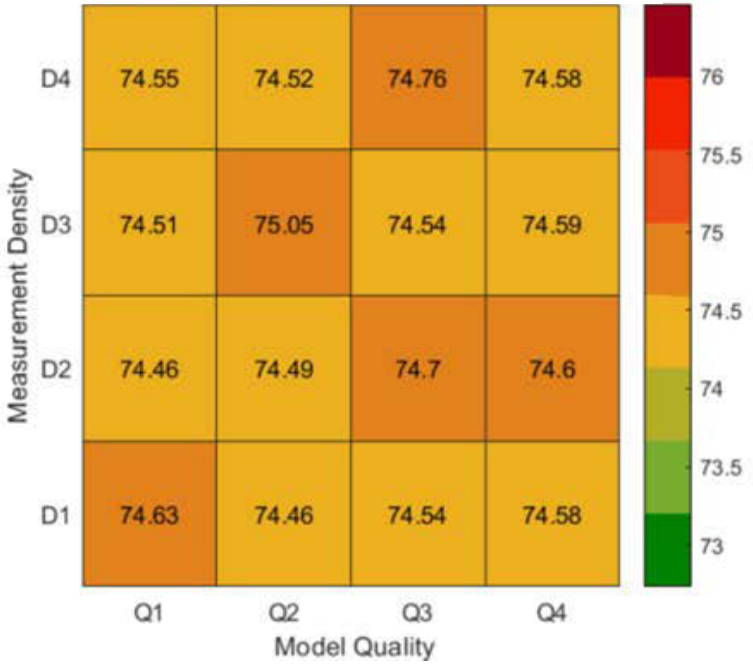
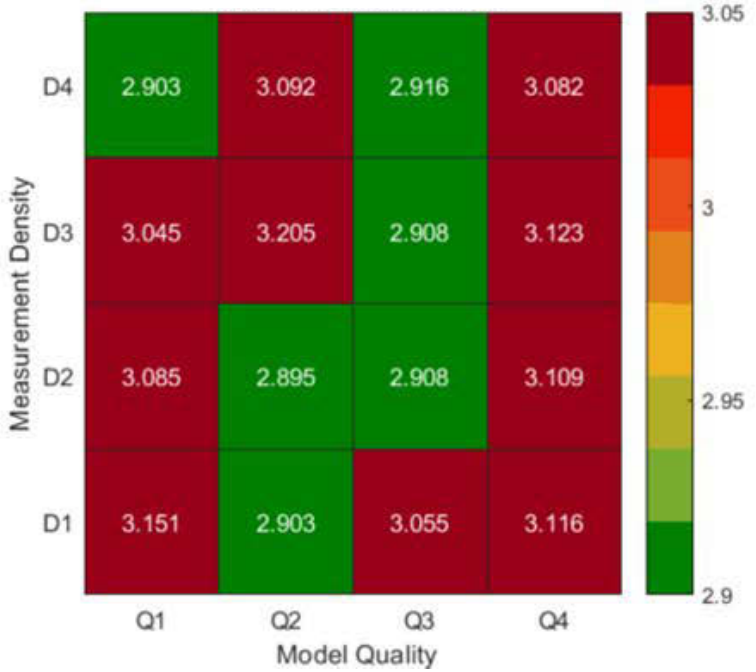
Feeder 2 (rural, mostly underground assets)

Energy consumption estimates (MWh)



Power (MW, daily median)



Results: Energy Savings with VVO

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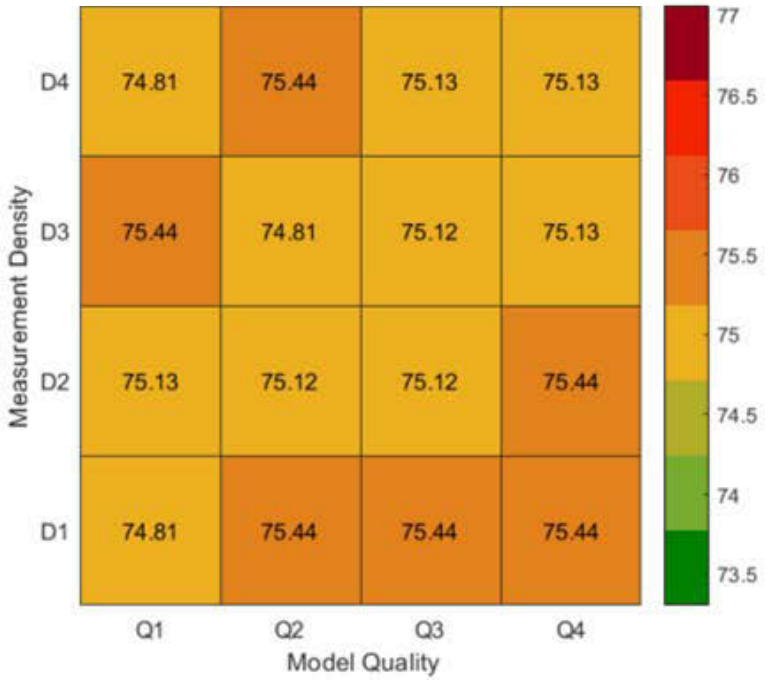
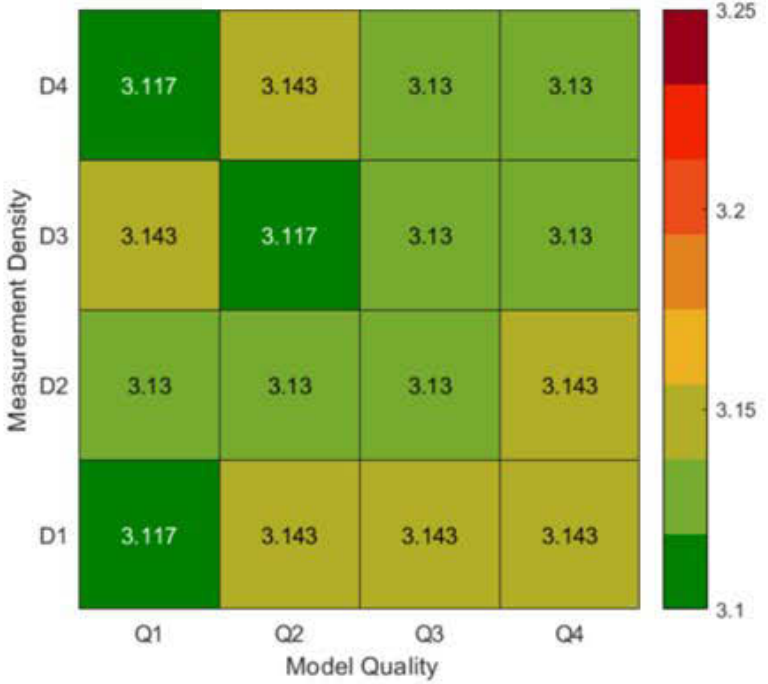
Feeder 6 (longest urban, 73% underground assets)

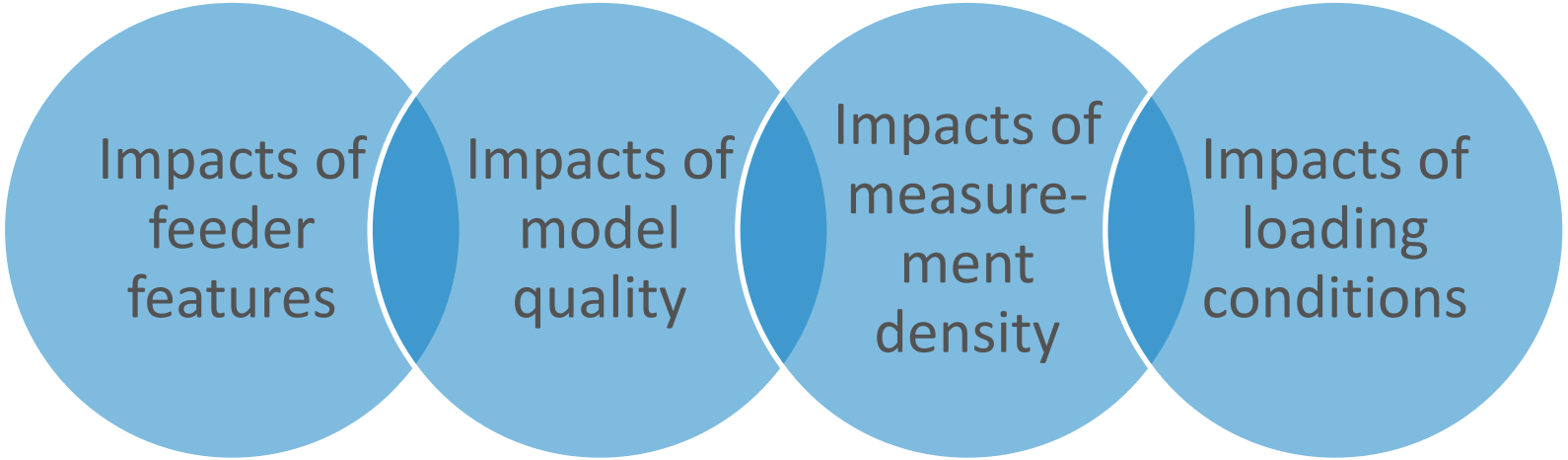
Energy consumption estimates (MWh)



Power (MW, daily median)



Findings


Impacts of feeder features
Impacts of model quality
Impacts of measure-ment density
Impacts of loading conditions

Findings: Summary

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- **Model quality** impacts are less evident on urban feeders because they are relatively new and have been field-verified in recent years.
- **Rural feeders** show better improvement on energy savings under VVO application with different levels of model improvement.
- For a **long feeder**, VVO function might not perform CVR well enough because of narrow margin to reduce voltage/energy consumption at feeder-end locations.
- **Measurement density levels** generally have less pronounced impact than model quality levels.
- With same VVO settings, **high-loading conditions** might create more voltage violations than **low-loading** conditions with same model quality.

Thank you

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