# ADMS Testbed Capabilities


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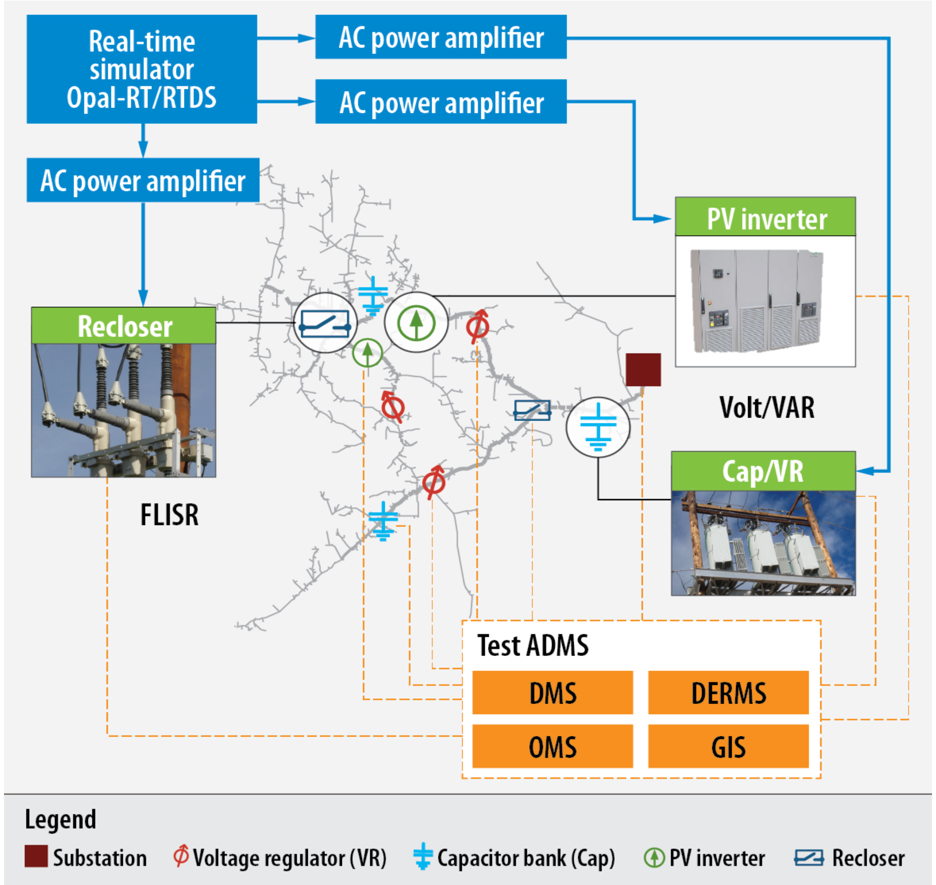
# ADMS Testbed development

### Project Description

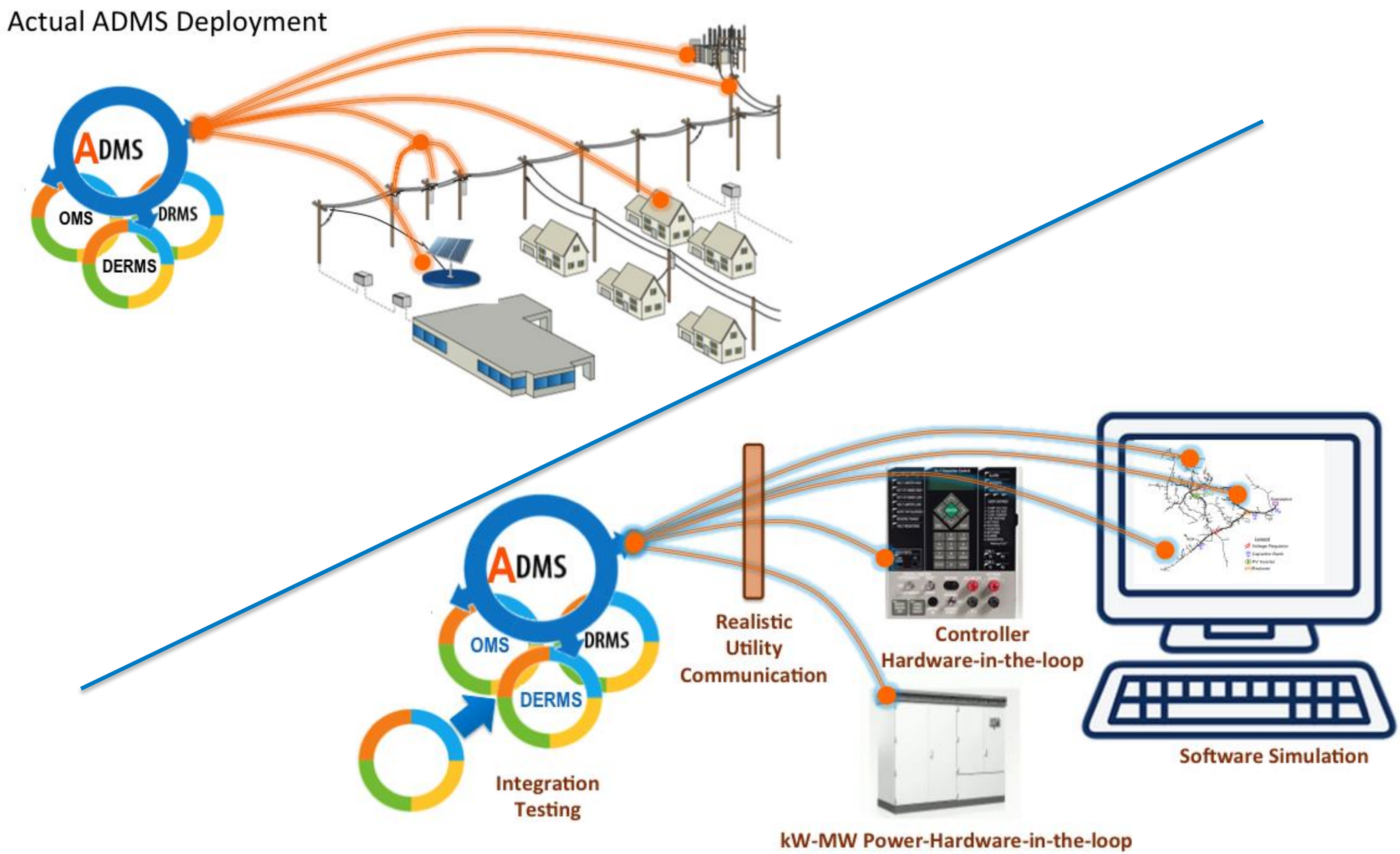
- Model large scale distribution systems for evaluating ADMS applications.
- Integrate distribution system hardware in ESIF for PHIL experimentation.
- Develop advanced visualization capability for mock utility distribution system operator's control room.




**Evaluation of advanced DMS functions**

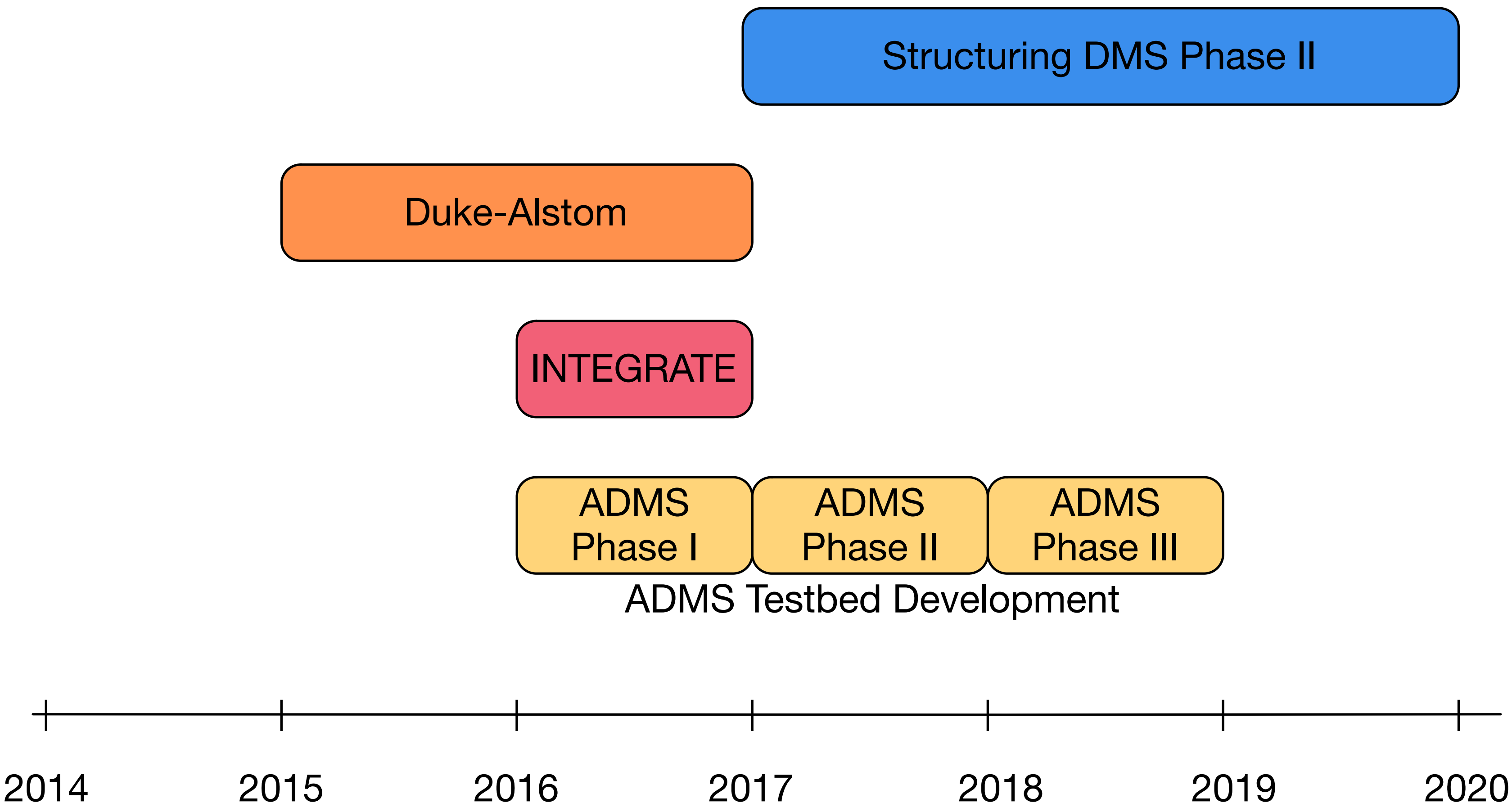
NREL is working with utilities and Vendors to evaluate advanced DMS applications like VVO, FLISR, OPF and market participation of distribution assets in a realistic environment developed during this project.

# Vision for the ADMS Testbed




ESIF ADMS Testbed

# ADMS Testbed Projects - Overview



# Operational Impacts of High Penetration of PV on a Representative Distribution Feeder in Duke Energy's Territory

## TECHNOLOGY ADDRESSED

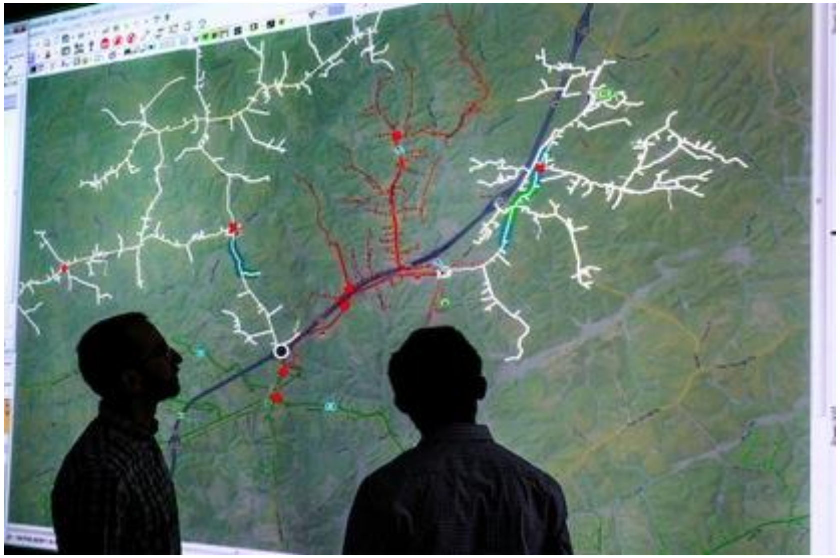
Understand impacts of smart inverters on distribution systems and advanced distribution management systems

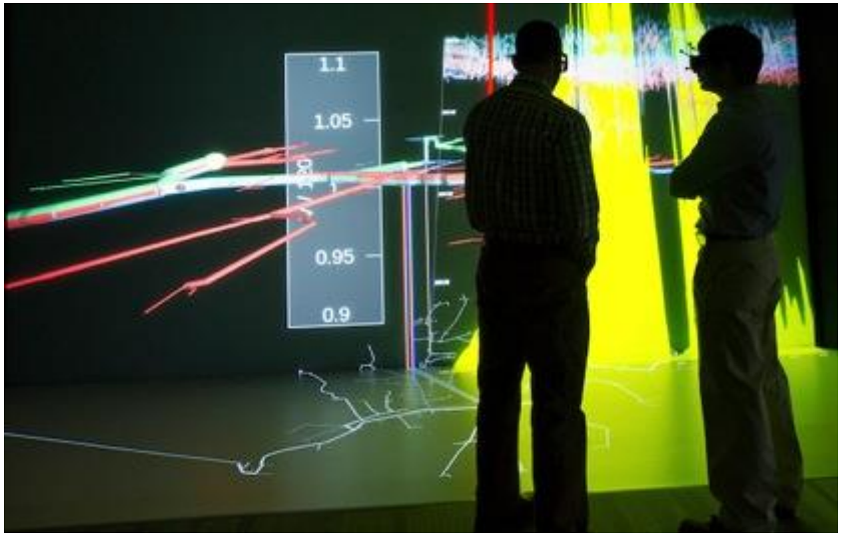
## R&D STRATEGY

NREL is working with GE Grid Solutions to implement a comprehensive modeling, analysis, visualization and hardware study using a representation of Duke Energy's utility feeder.

## IMPACT

Enable greater adoption of smart inverters at utilities by addressing the challenges of integrating them with GIS, DMS, OMS and SCADA systems.





# Feeder Voltage Regulation with High Penetration PV using Advanced Inverters and a Distribution Management System

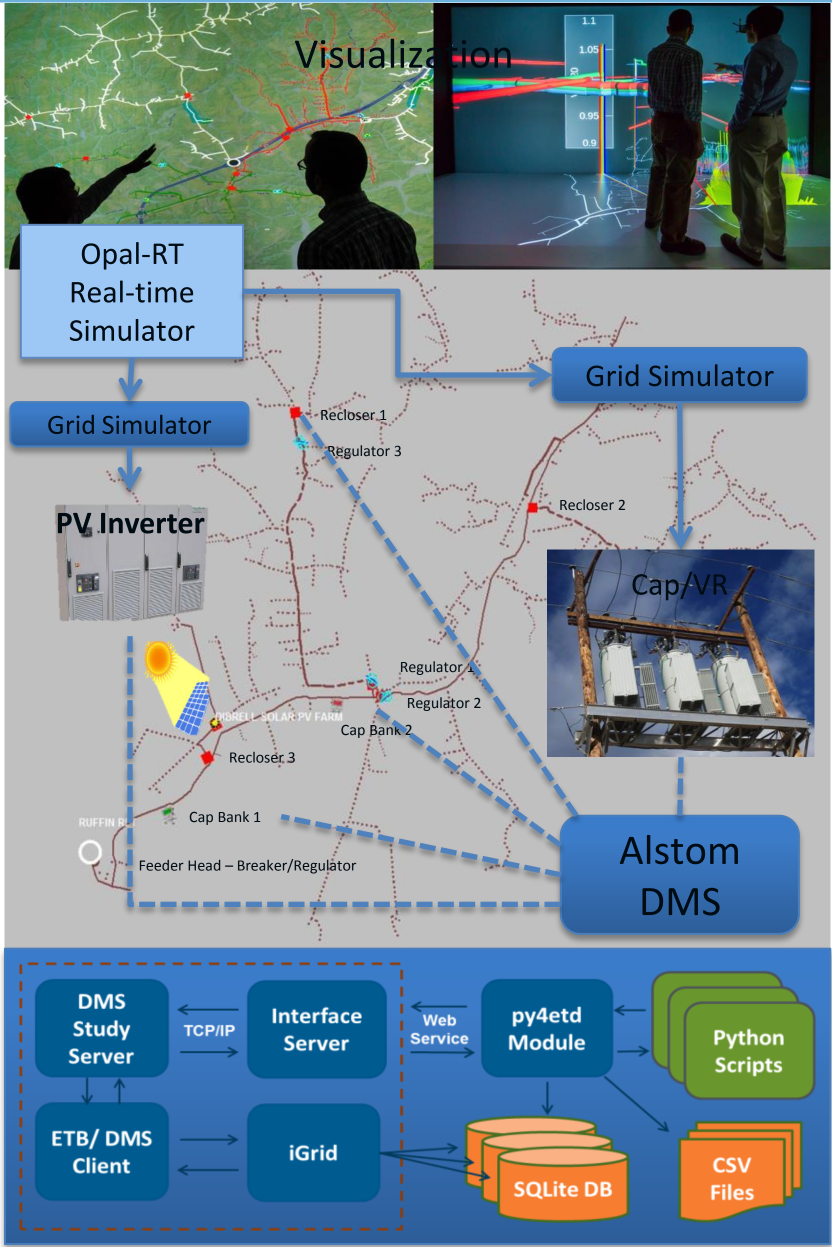
**Objective:**

Understand advanced inverter and distribution management system (DMS) control options for large (1–5 MW) distributed solar photovoltaics (PV) and their impact on distribution system operations for:

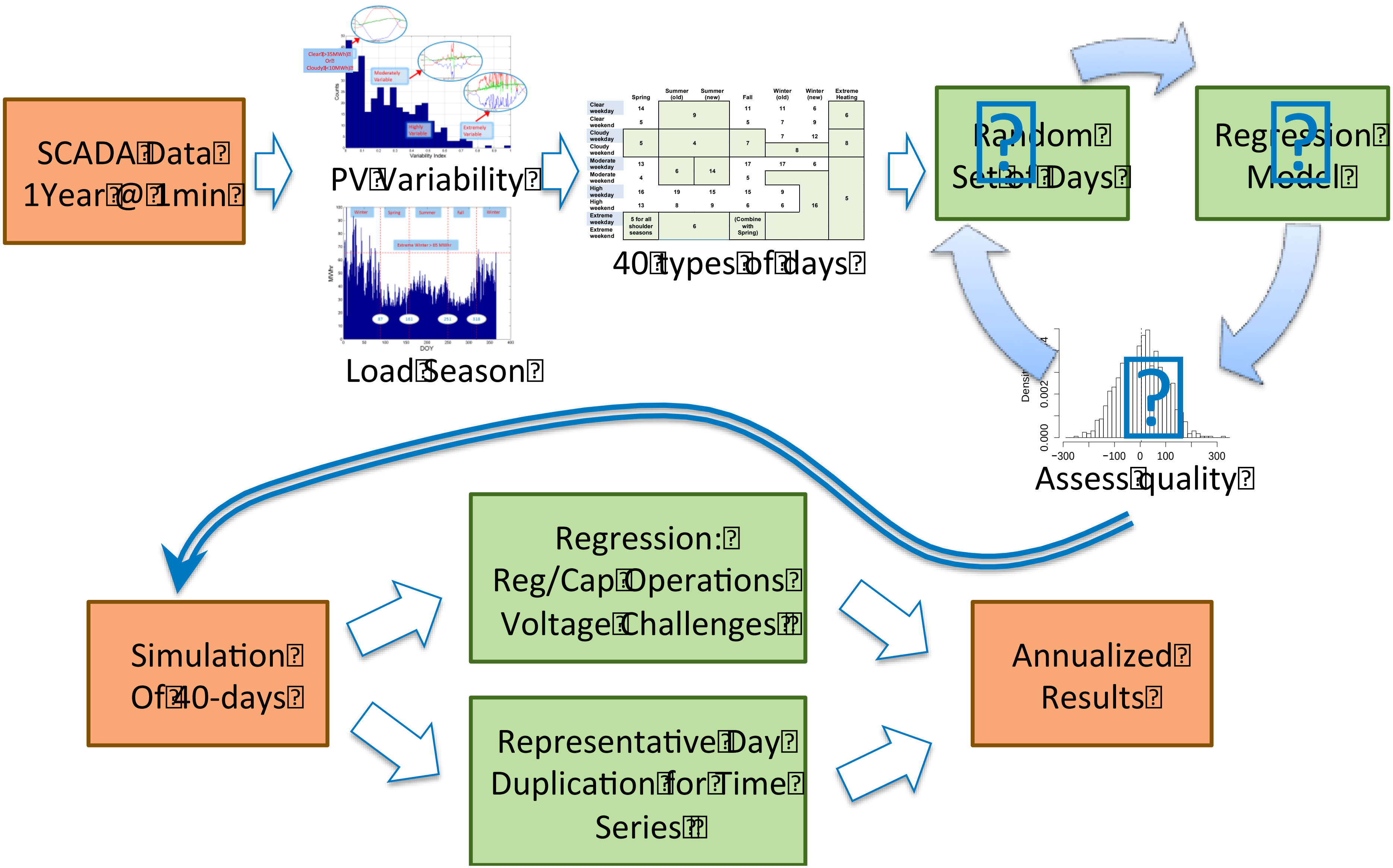
- Active power only (baseline);
- Local autonomous inverter control: power factor (PF) ≠1 and volt/VAR (Q(V)); and
- Integrated volt/VAR control (IVVC)

**Approaches:**

- Quasi-steady-state time-series (QSTS)
- Statistics-based methods to reduce simulation times
- Advanced visualizations
- Power hardware-in-the-loop (PHIL) and Co-simulation
- Cost-benefit analysis to compare financial impacts of each control approach.



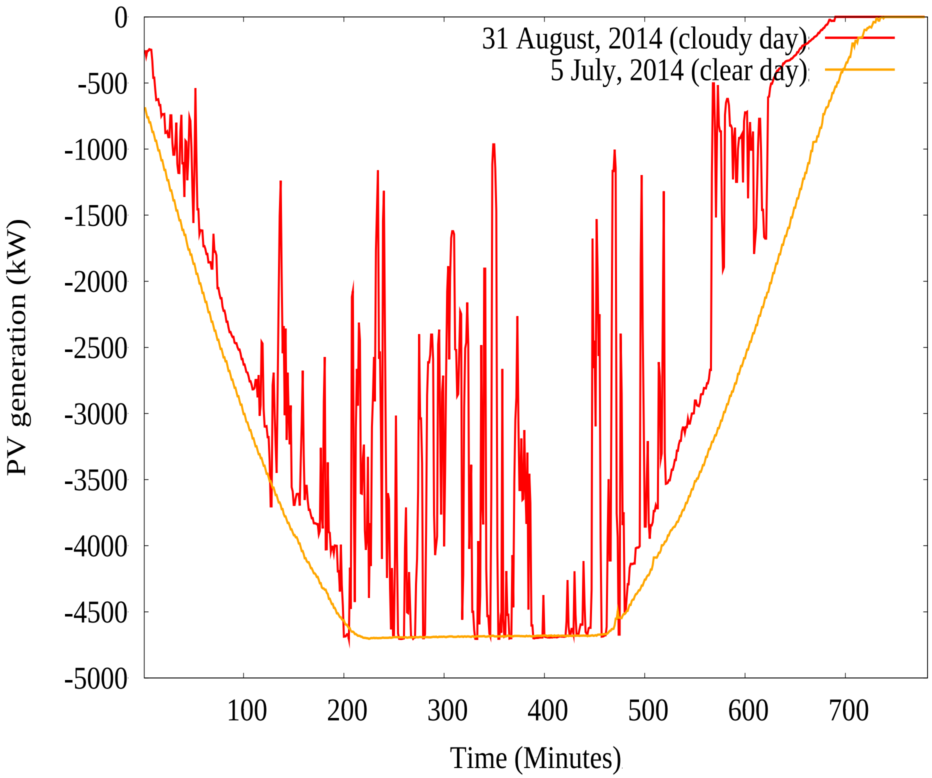
# Data Analysis: 1 Year → 40 Days → 1 Year



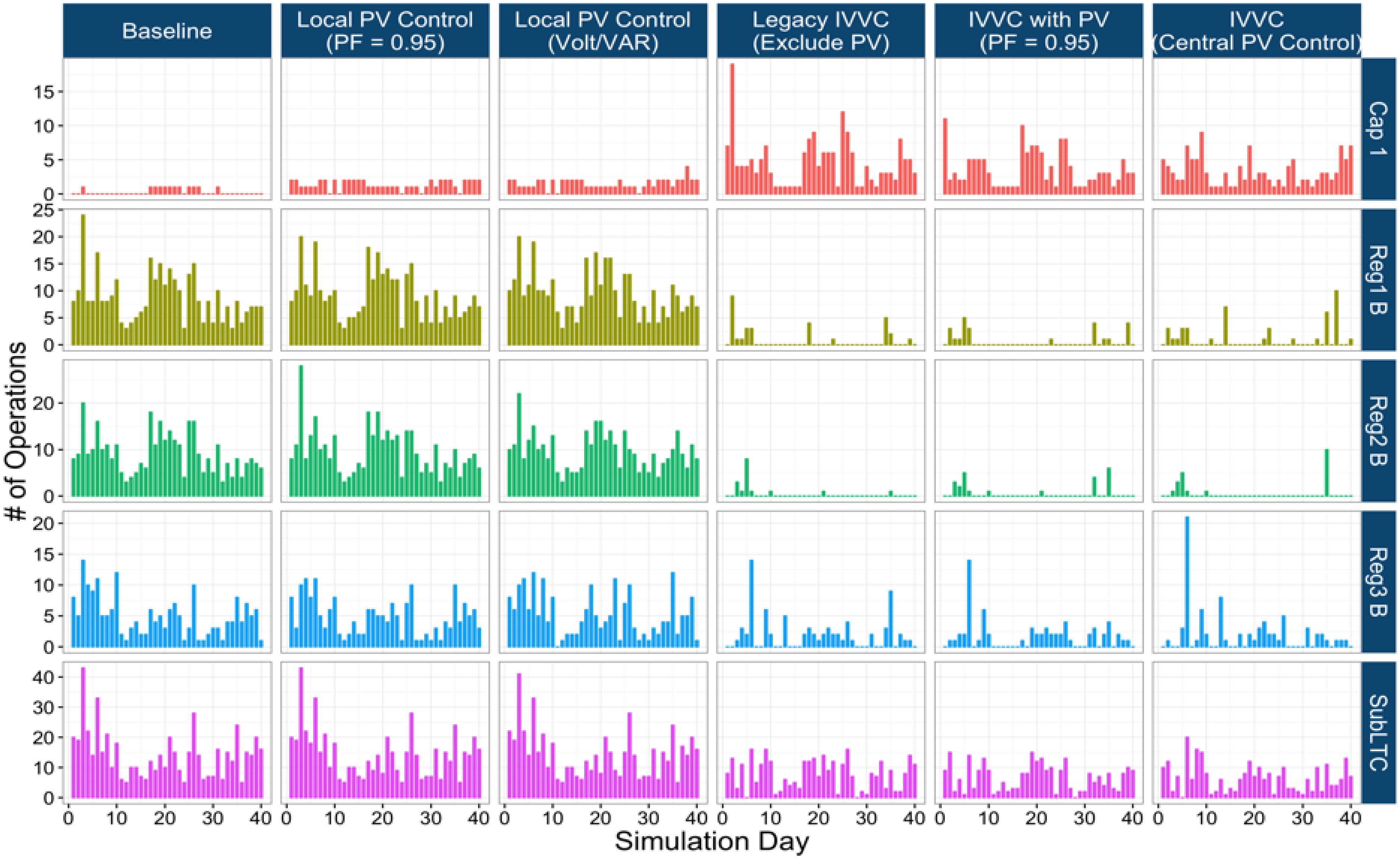

| | Spring | Summer (old) | Summer (new) | Fall | Winter (old) | Winter (new) | Extreme Heating |
|---|---|---|---|---|---|---|---|
| Clear weekday | 14 | 9 | | 11 | 11 | 6 | 6 |
| Clear weekend | 5 | | | 5 | 7 | 9 | |
| Cloudy weekday | 5 | 4 | | 7 | 7 | 12 | 8 |
| Cloudy weekend | | | | | 8 | | |
| Moderate weekday | 13 | 6 | 14 | 17 | 17 | 6 | 5 |
| Moderate weekend | 4 | | | 5 | | | |
| High weekday | 16 | 19 | 15 | 15 | 9 | | |
| High weekend | 13 | 8 | 9 | 6 | 6 | 16 | |
| Extreme weekday | 5 for all shoulder seasons | 6 | | (Combine with Spring) | | | |
| Extreme weekend | | | | | | | |

# Simulations Cases

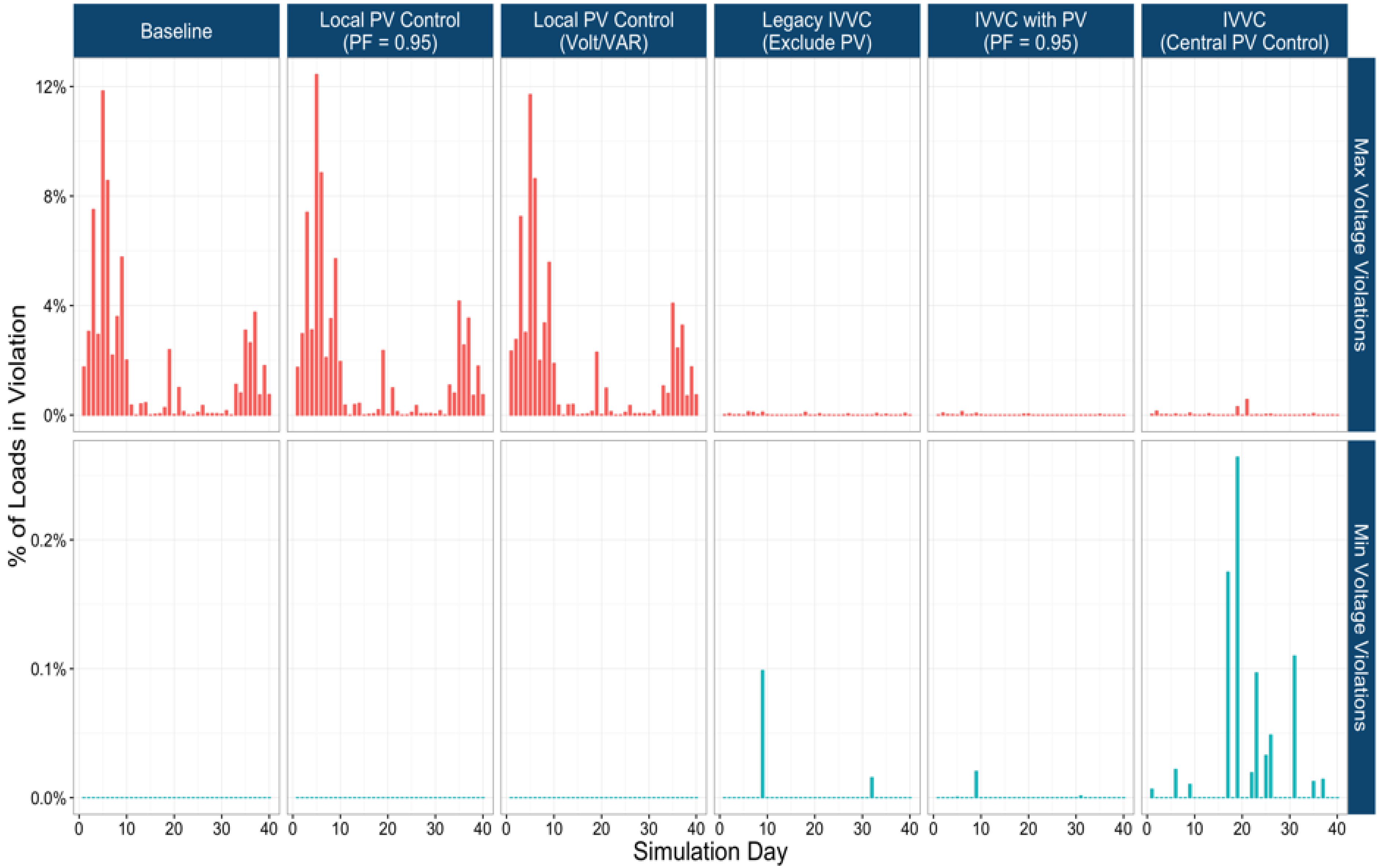
- Baseline
- Local PV Control (PF = 0.95)
- Local PV Control (Volt/VAR)
- Legacy IVVC (Exclude PV)
- IVVC with PV @ PF 0.95
- IVVC (Central PV Control)



# Feeder 40-day results of number of operations of voltage regulation equipment



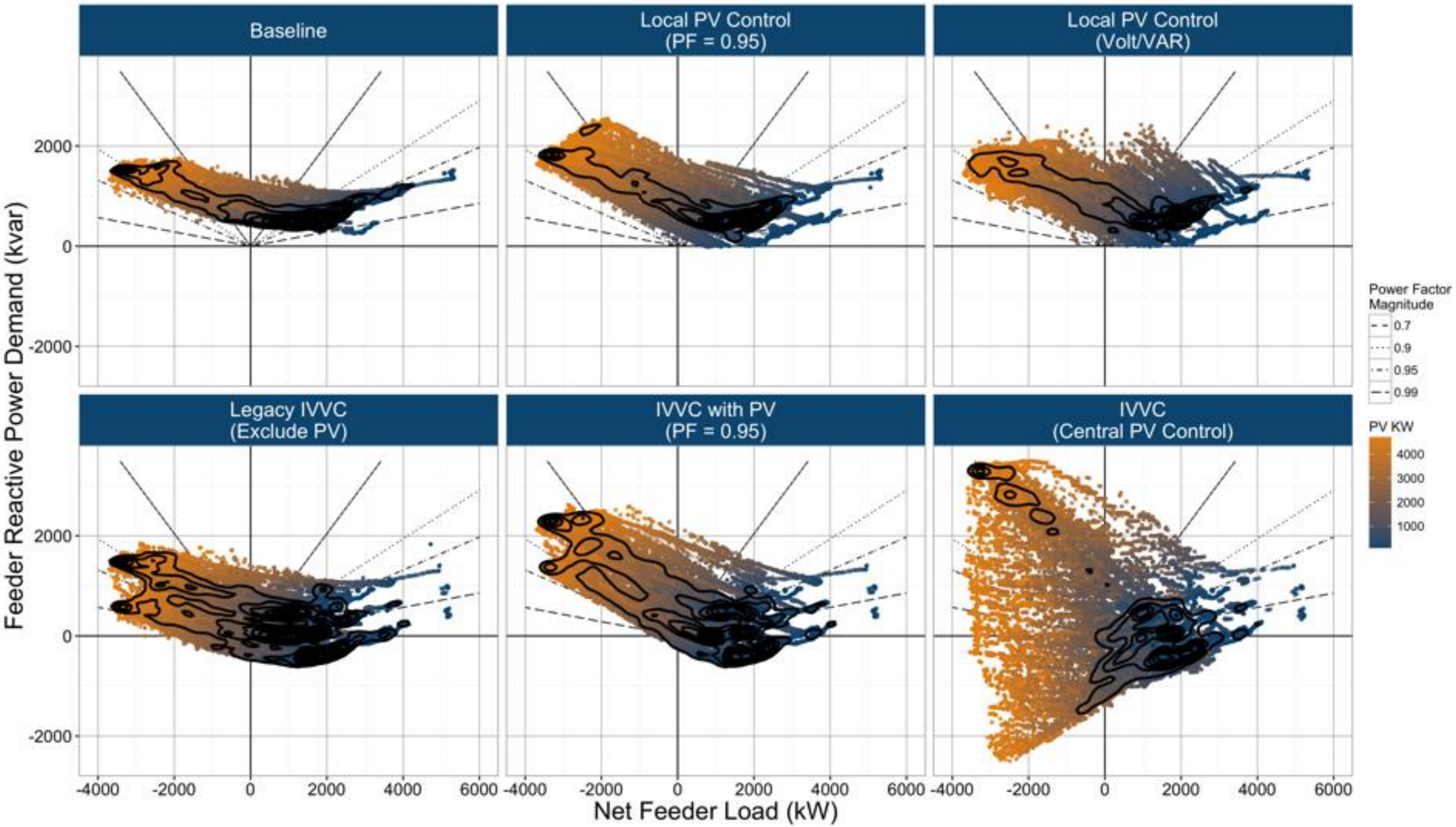
# Feeder 40-day results of number of load-voltage violations



# Summary Comparison of Annualized Scenarios

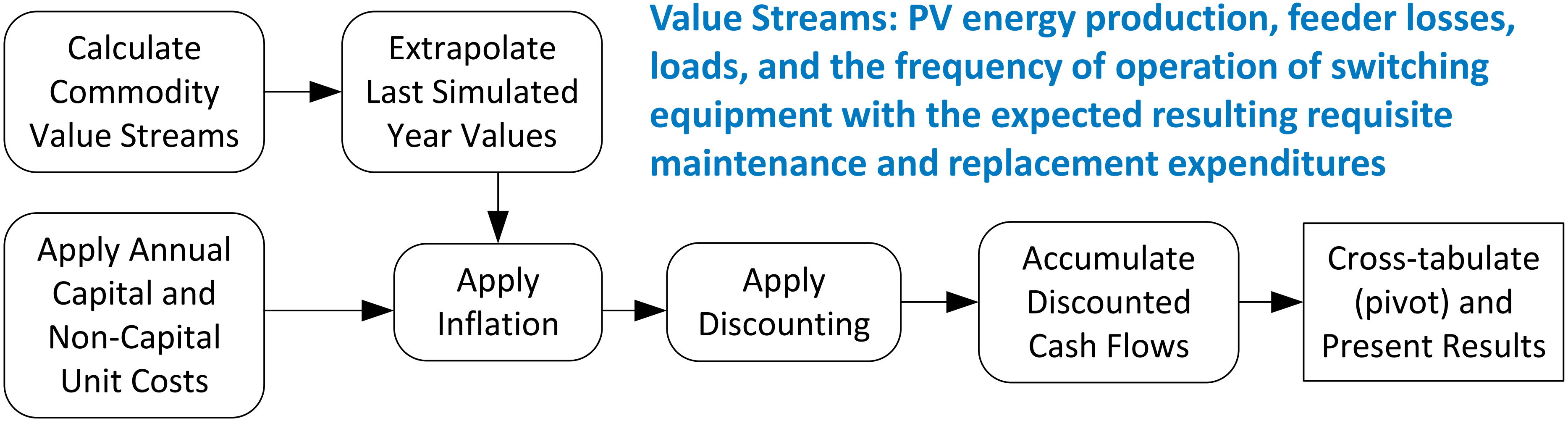
| | | IVVC Control | | | | Annualized Equipment Operations | | | | Voltage Challenges | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Scenario** | **PV Mode** | **LTC** | **Regulators** | **Capacitors** | **PV** | **LTC** | **Regulators** | **Capacitors** | **Total** | **Over** | **Under** |
| **Baseline** | Default | - | - | - | - | 5,043 | 19,160 | 125 | 24,328 | 1.47% | 0.00% |
| **Local PV Control (PF = 0.95)** | PF=0.95 | - | - | - | - | 5,063 | 19,943 | 505 | 25,511 | 1.48% | 0.00% |
| **Local PV Control (Volt/VAR)** | Q(V) | - | - | - | - | 5,087 | 19,857 | 541 | 25,485 | 1.44% | 0.00% |
| **Legacy IVVC (Exclude PV)** | Default | Y | Y | Y | - | 2,869 | 2,943 | 1,863 | 7,675 | 0.02% | 0.00% |
| **IVVC with PV (PF = 0.95)** | PF=0.95 | Y | Y | Y | - | 2,498 | 1,888 | 1,409 | 5,795 | 0.01% | 0.00% |
| **IVVC (Central PV Control)** | IVVC for reactive power | Y | Y | Y | Y | 2,312 | 2,698 | 1,151 | 6,161 | 0.05% | 0.02% |

# Substation P/Q Plots



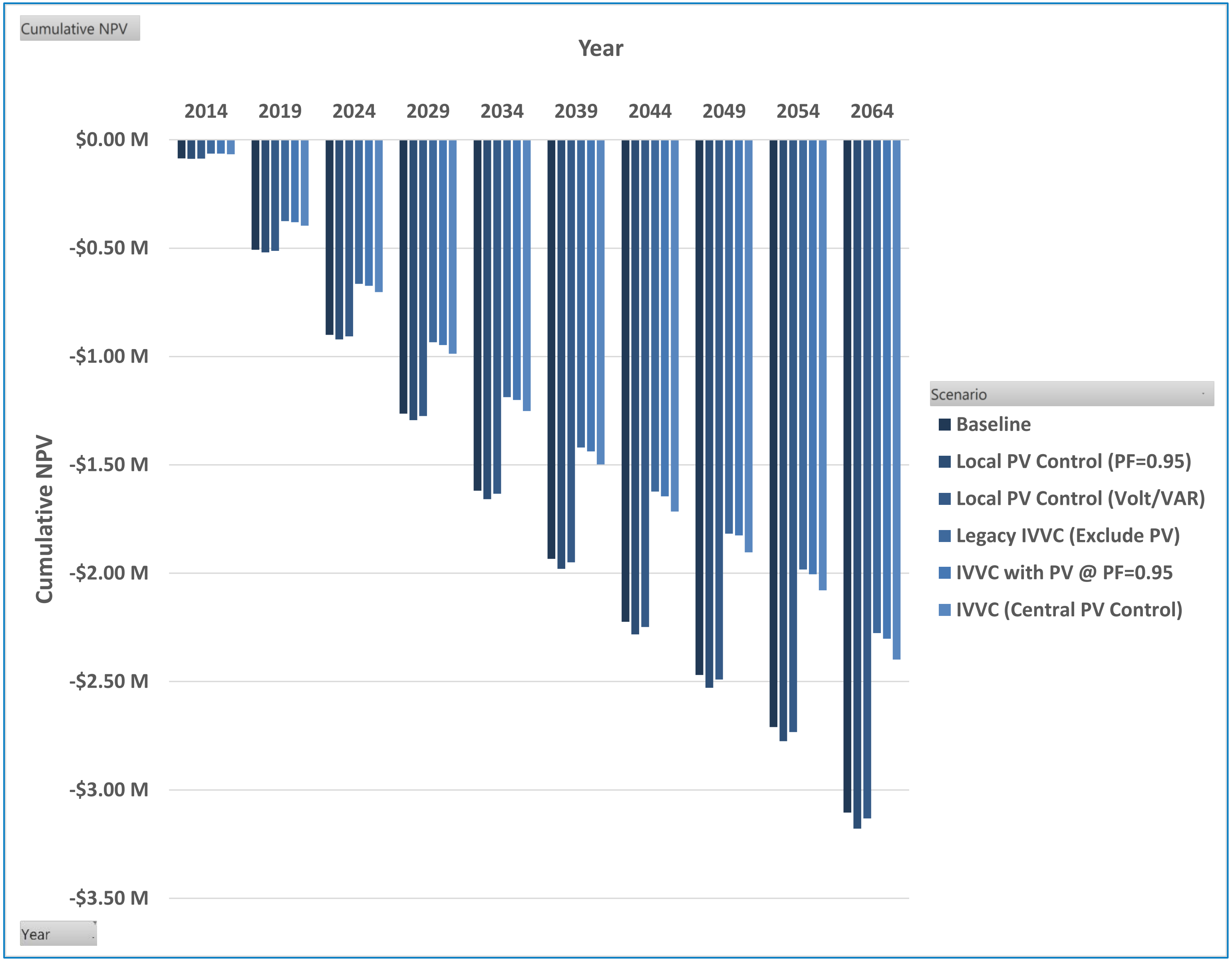
# Cost Benefit Analysis Assumptions

**Value Streams: PV energy production, feeder losses, loads, and the frequency of operation of switching equipment with the expected resulting requisite maintenance and replacement expenditures**

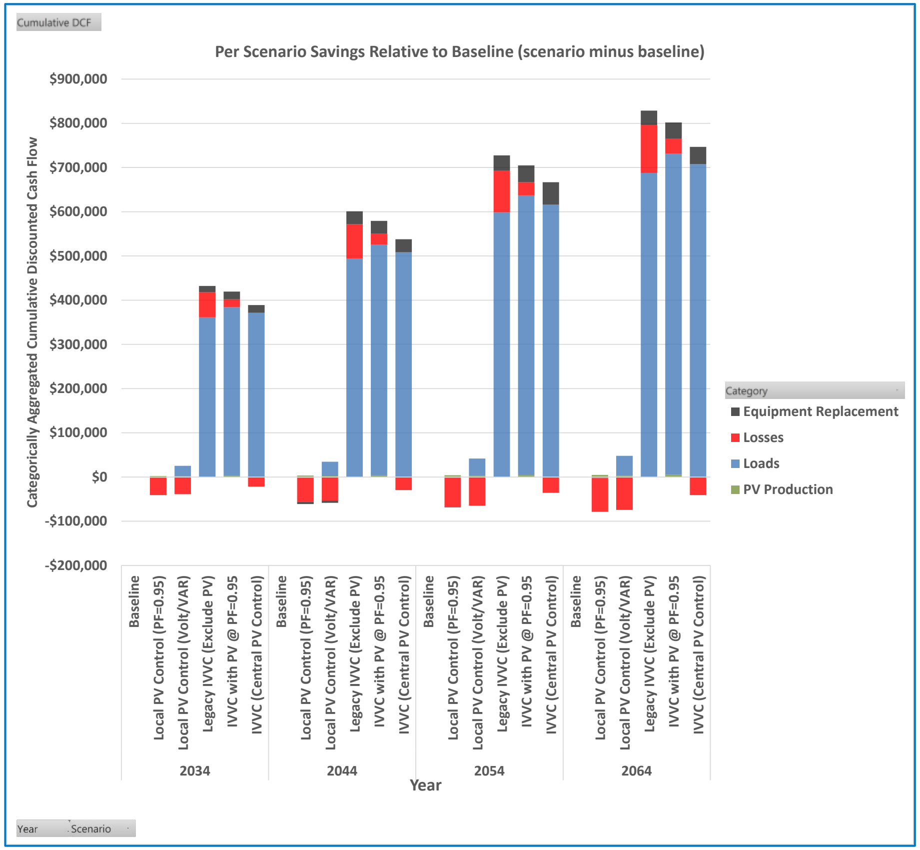


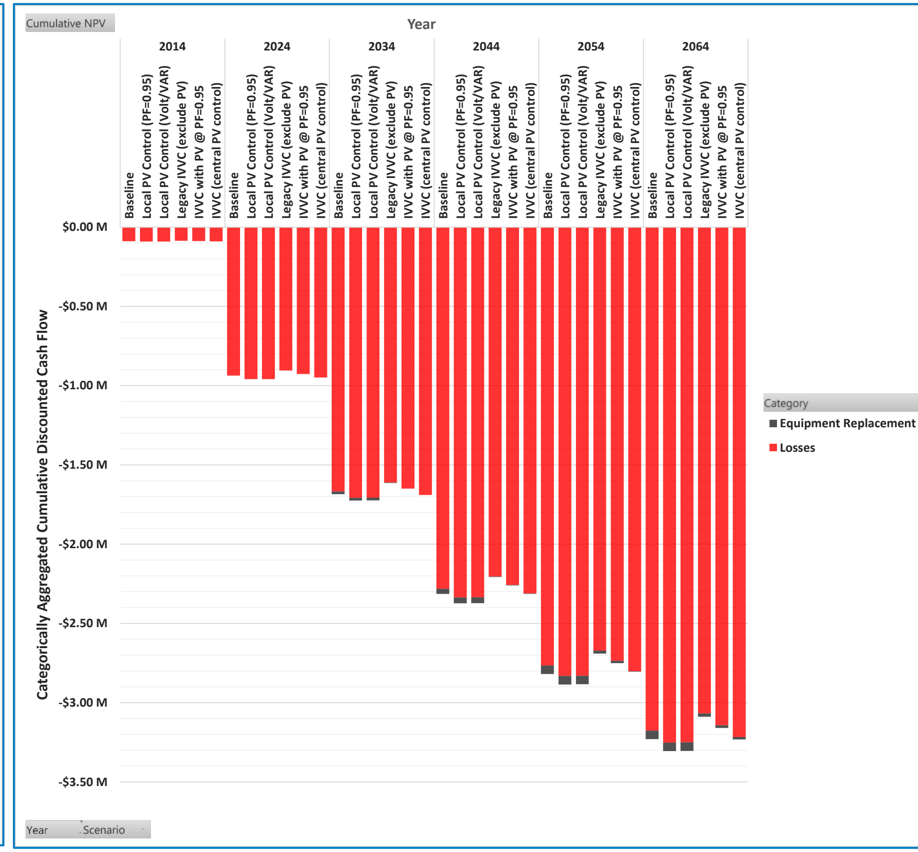

| Dates | Days of Week | Times | Value of Energy (¢ per kWh) | |
|---|---|---|---|---|
| | | | Capacity Credit | Energy Credit |
| **June 1–Sept. 30** | M–F | Summer on-peak: 1 p.m.–9 p.m. | 6.00 | 3.87 |
| | | Summer off-peak: 9 p.m.–1 p.m. | | 3.33 |
| | Sun. & Sat. | Summer off-peak: All | | 3.33 |
| **Oct. 1–May 31** | M–F | Winter on-peak: 6 a.m.–1 p.m. | 2.19 | 3.87 |
| | | Winter off-peak: 1 p.m.–6 a.m. | | 3.33 |
| | Sun. & Sat. | Winter off-peak: All | | 3.33 |

# Cumulative NPV's



# Categorical Cost and Savings

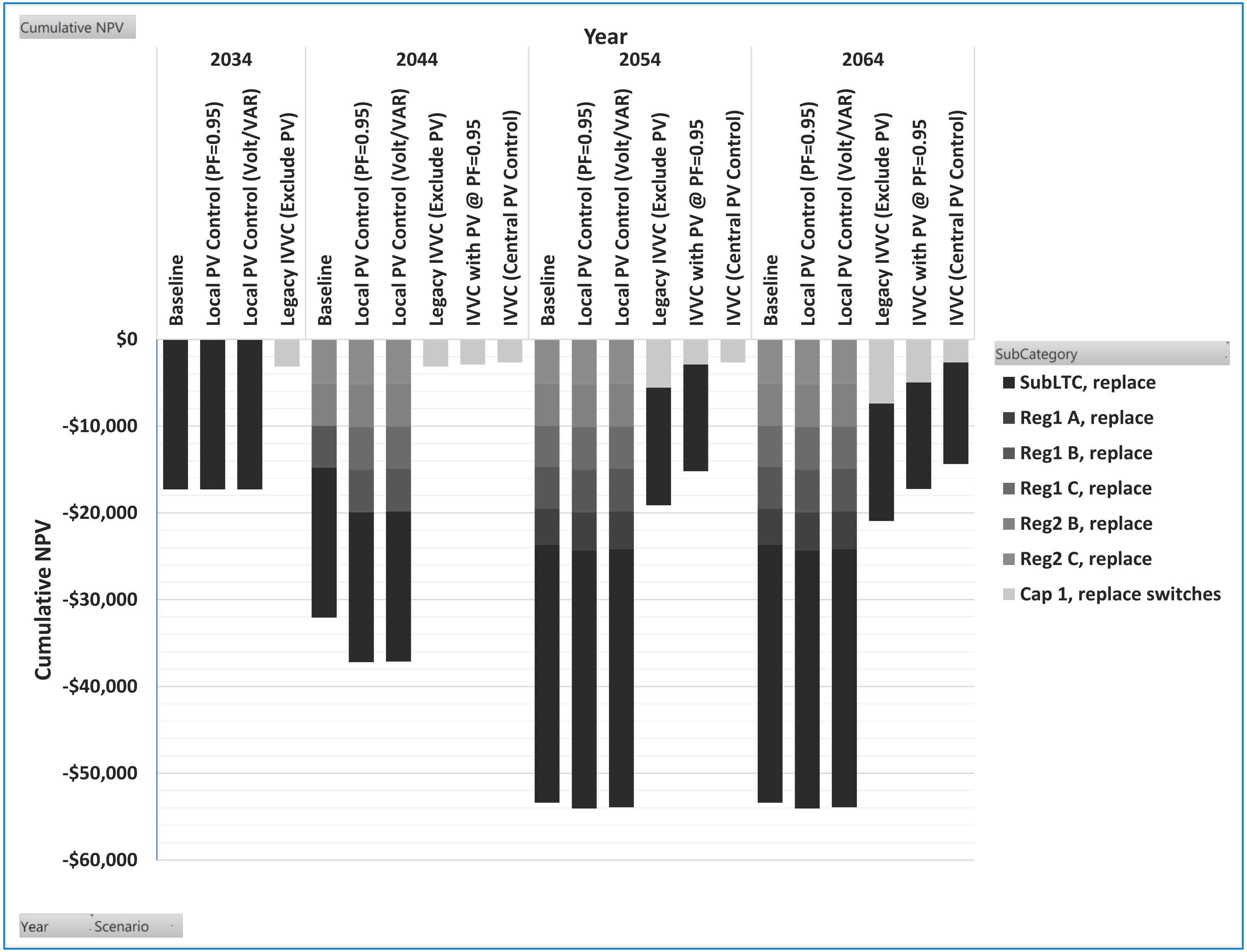



Categorical cost and savings compared to baseline

Categorically aggregated cumulative discounted cash flows for costs of feeder losses and equipment replacement

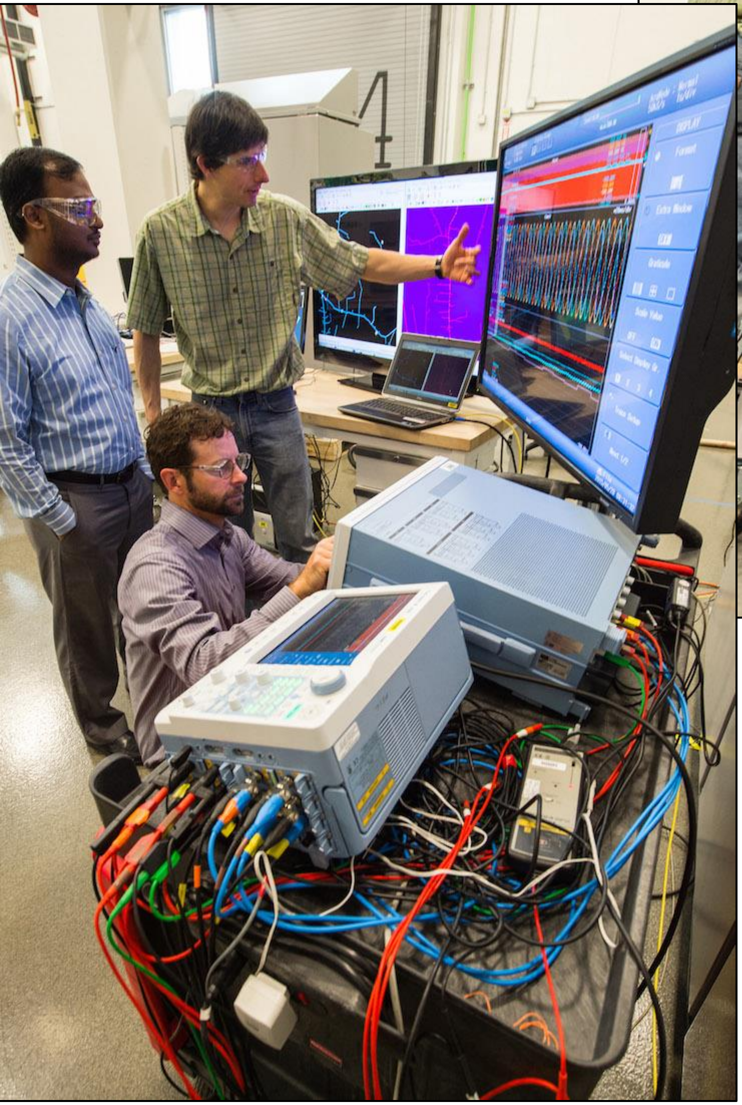
# Aggregated cumulative discounted cash flows for equipment replacement

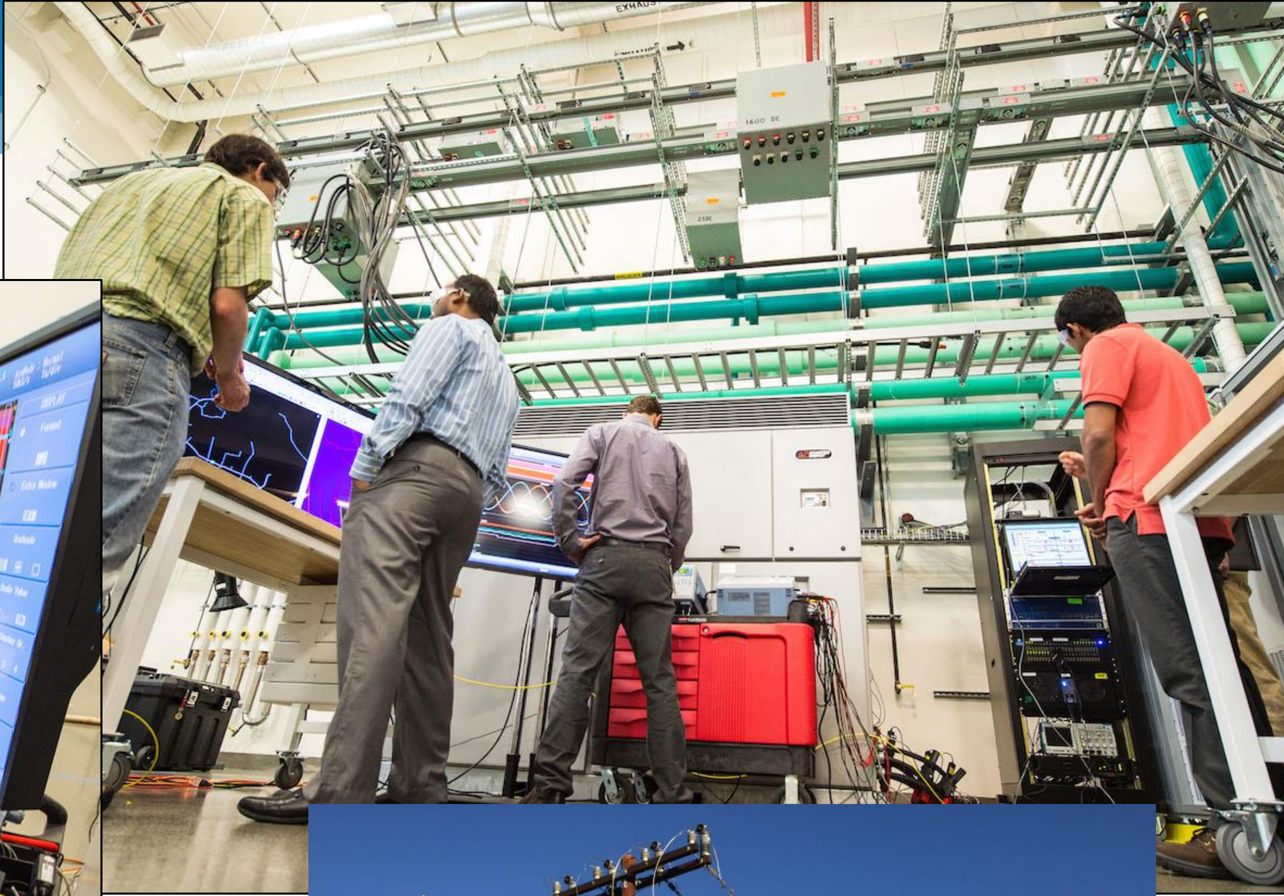


# Summary

- Illustrates the potential for coordinated control of voltage management equipment and the central DMS IVVC by:
  - Providing substantial improvement in distribution operations with large-scale PV
  - Reducing regulator operations
  - Decreasing the number of voltage challenges
- The preliminary cost-benefit analysis showed operational cost savings for the IVVC scenarios that were:
  - Partially driven by reduced wear and tear on utility regulating equipment,
  - but dominated by the use of CVR/Demand reduction objective
- Work needed in the area of integrating advanced inverters as controllable resources into IVVC optimization strategies
  - Event triggered operation of DMS IVVC
  - Power factor set point in place of reactive power set point

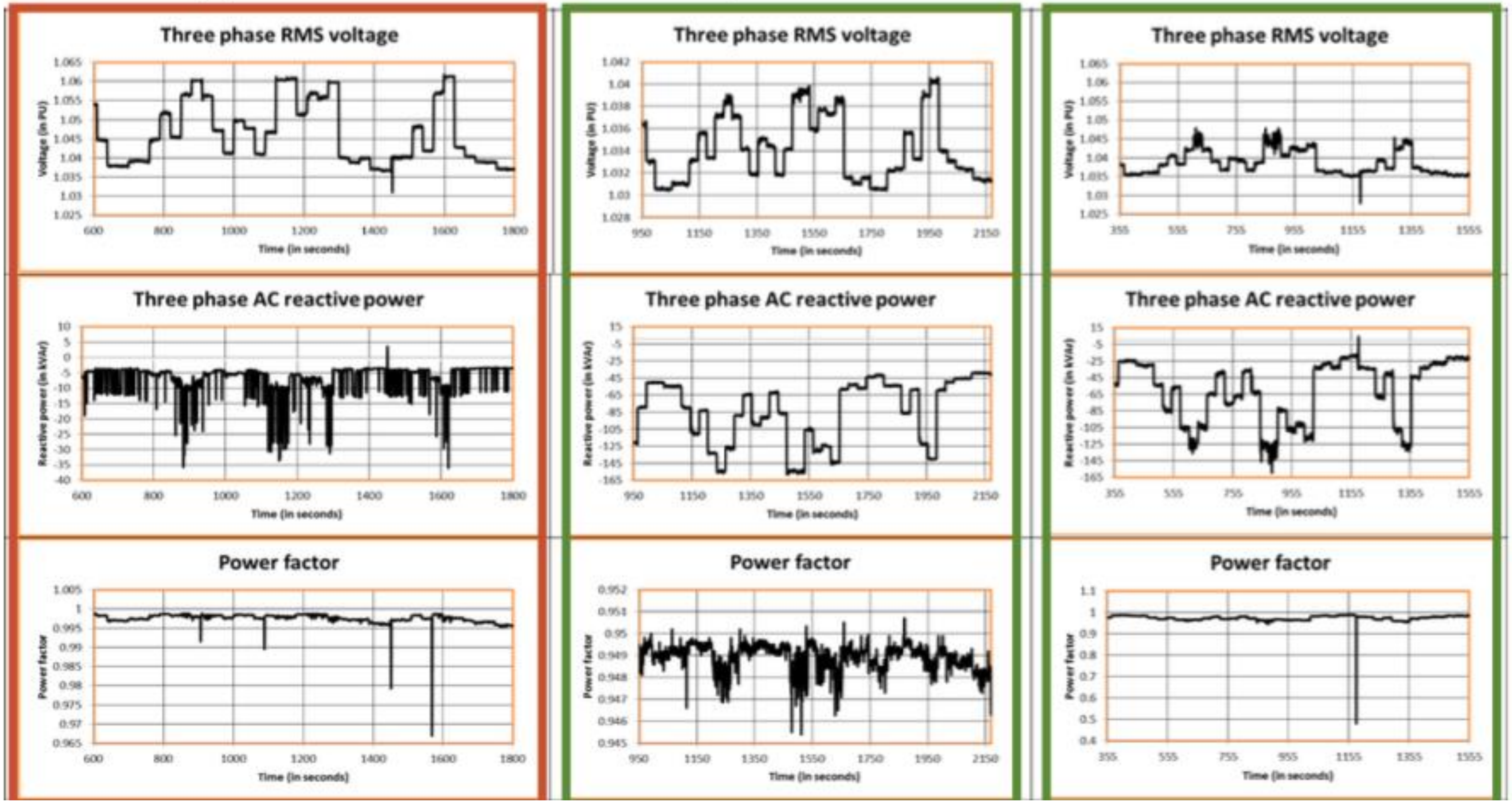
# Lab Setup





# ADMS Testbed Use Case 0 - Results

| Inverter operation at unity power factor | Inverter operation at 0.95 power factor | Inverter operation at Volt-VAR |
|---|---|---|



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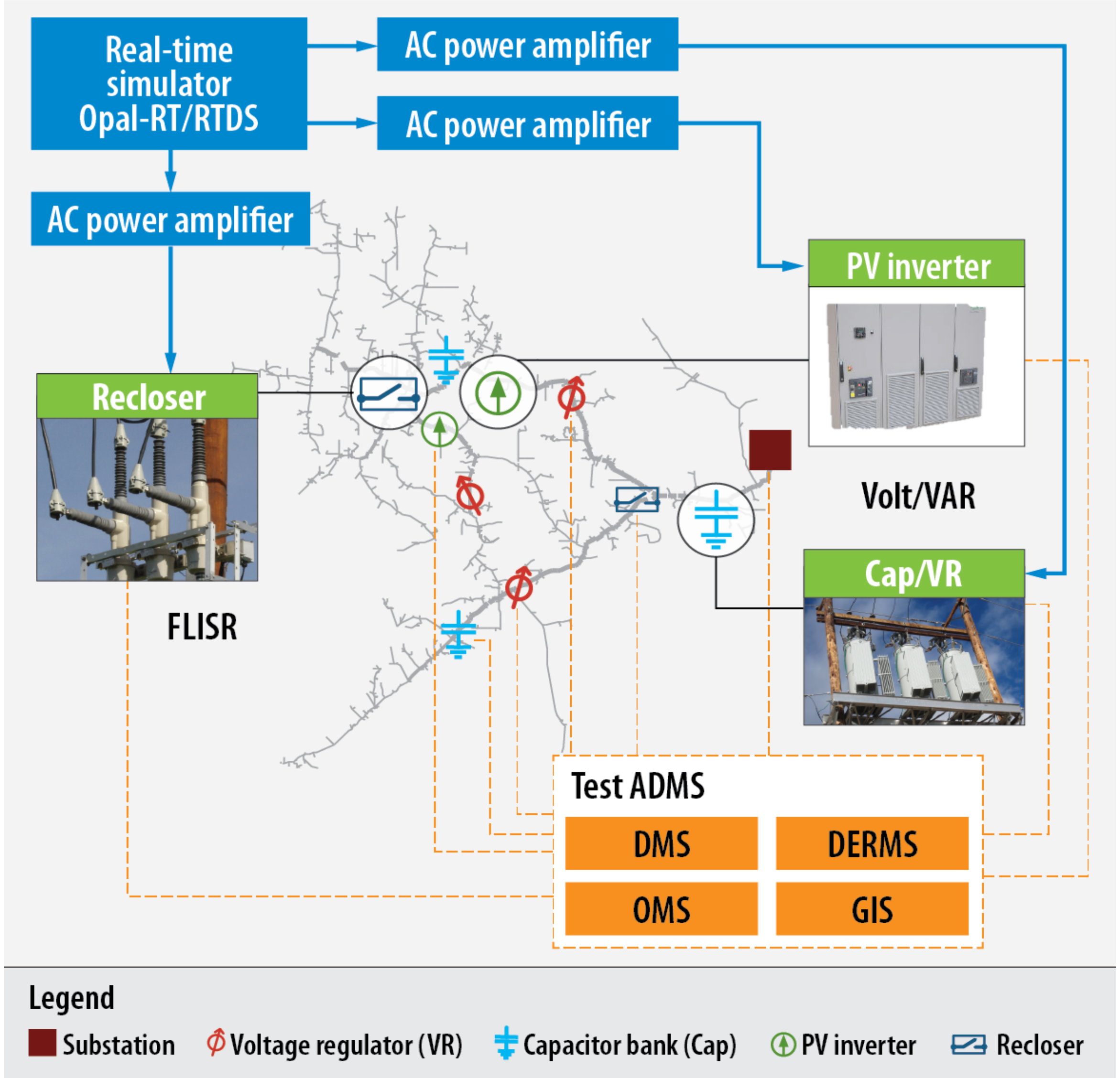


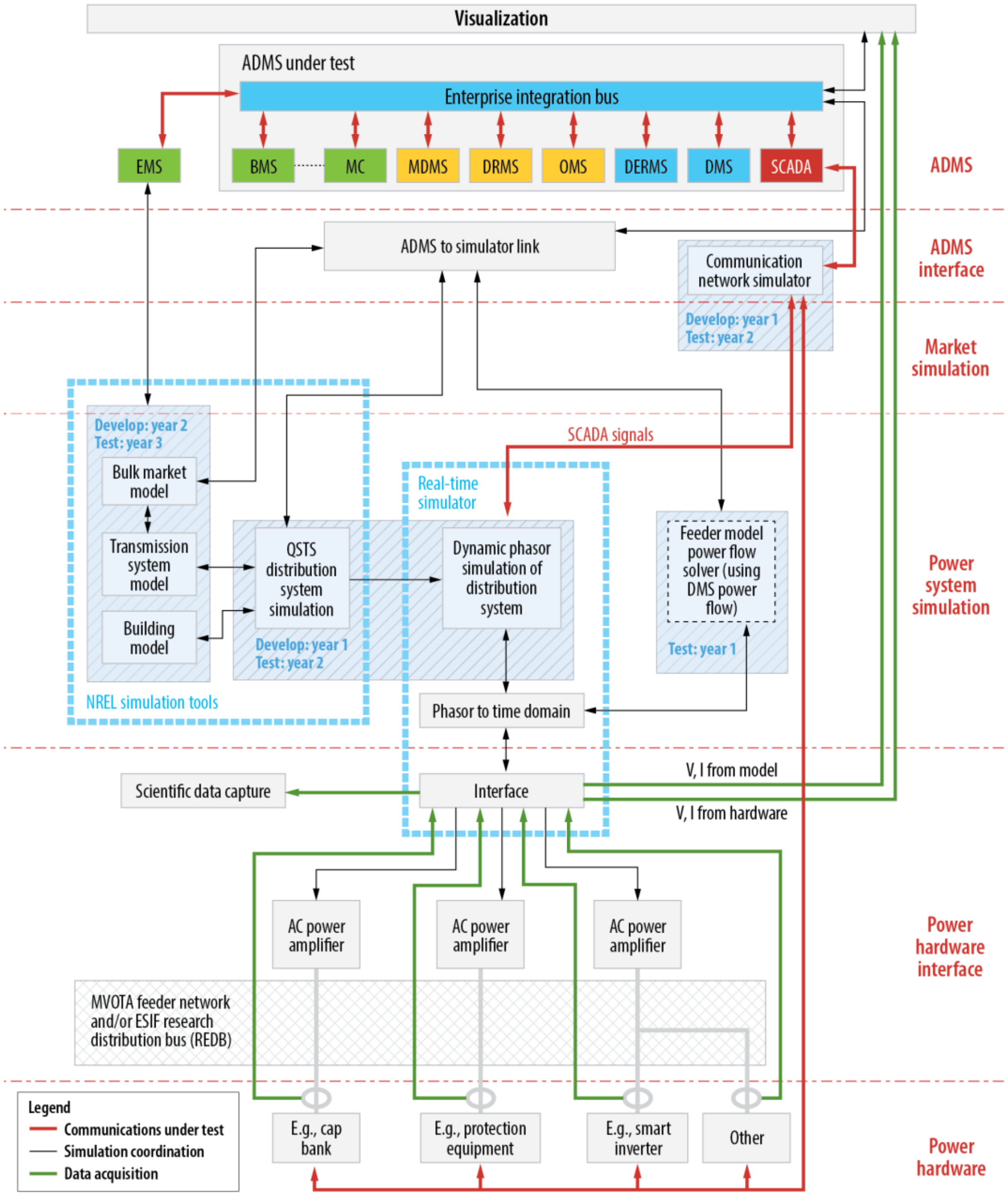

**KEY APPLICATION:**

**Evaluation of advanced DMS functions**

NREL is working with utilities and Vendors to evaluate advanced DMS applications like VVO, FLISR, OPF and market participation of distribution assets in a realistic environment developed during this project

# Plan

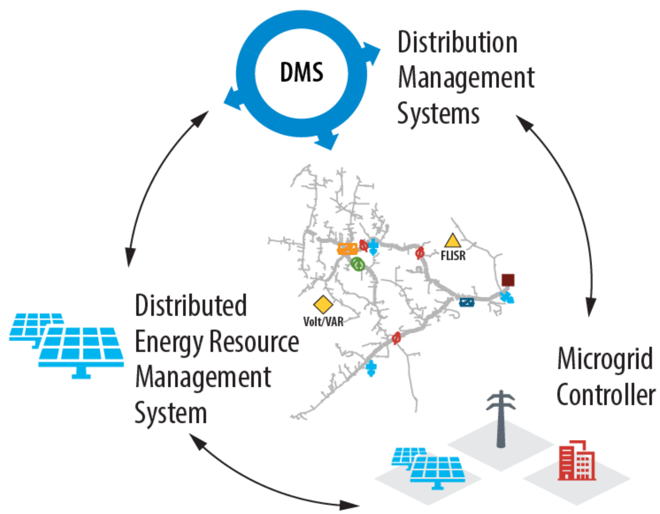
- Year 1: ADMS Internal Power Flow Solver implementation as Distribution Grid with PHIL
- Year 2: multi-timescale software model evaluation with external power flow solution (OpenDSS/Opal-RT ePHASORSim) with PHIL
- Year 3: Integrated application demonstration with remote nodes PHIL Implementation



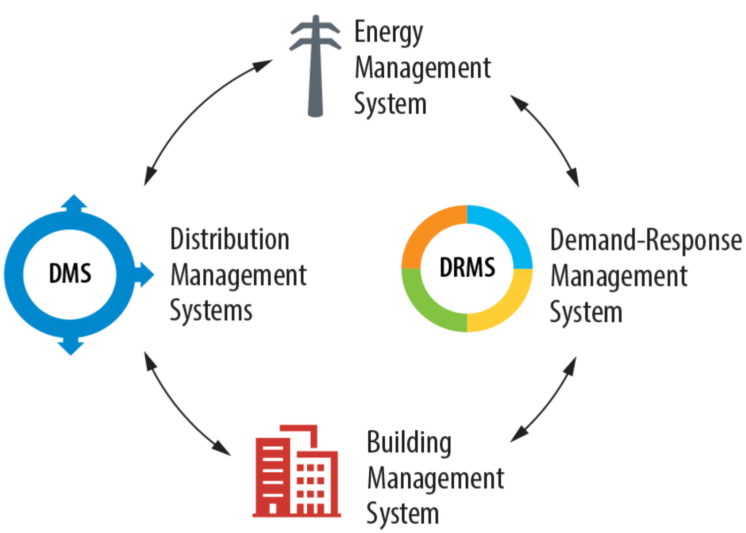
# Purpose and Benefits

- Test and understand the **impact of ADMS functionality**
- **Low-cost pre-pilot testing** ground for ADMS functionality
- evaluate **what-if hypothetical scenarios**
- Identifying the **right use-case** and technical parameters
- **interoperability and vulnerability** of the ADMS and connected devices.
  1. **Interactions with hardware devices**;
  2. **Integration challenges** of ADMS with legacy systems
- **Develop and evaluate new functions**
- Facility for **operator training** of utility engineers

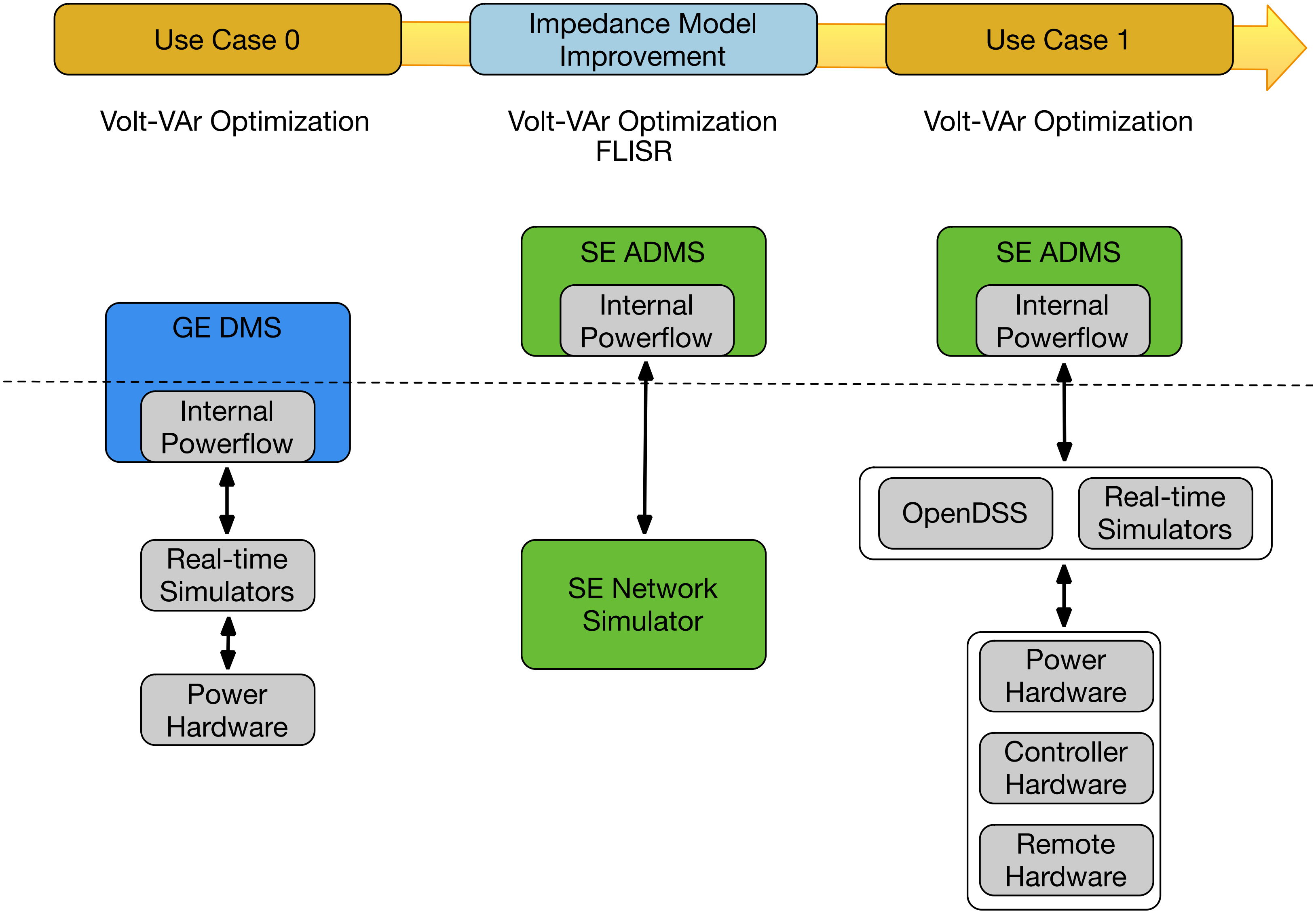
Use Case 1




Use Case 2



# ADMS Testbed Capability Development



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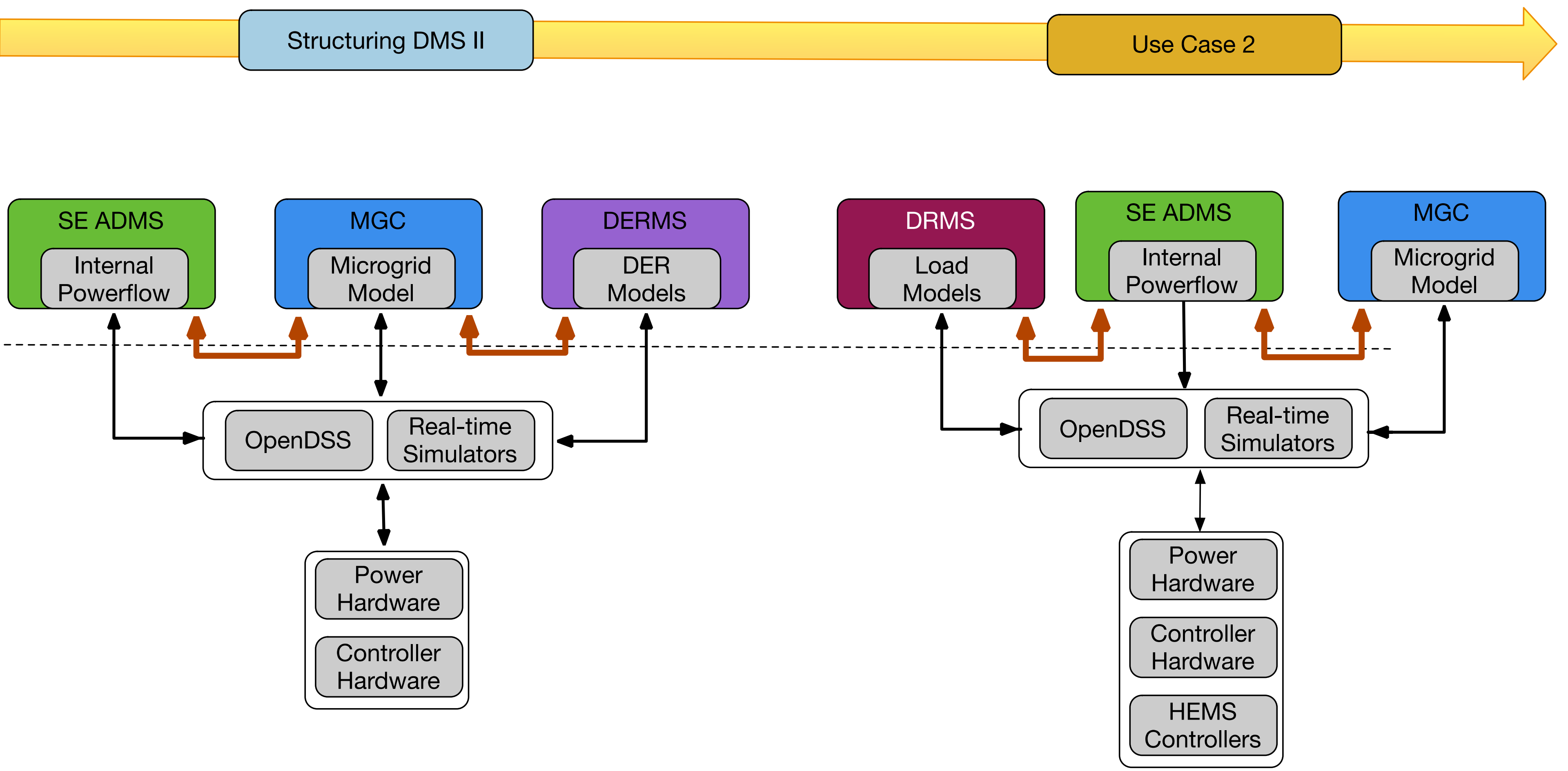

What other use cases can be tested using this capability?