NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

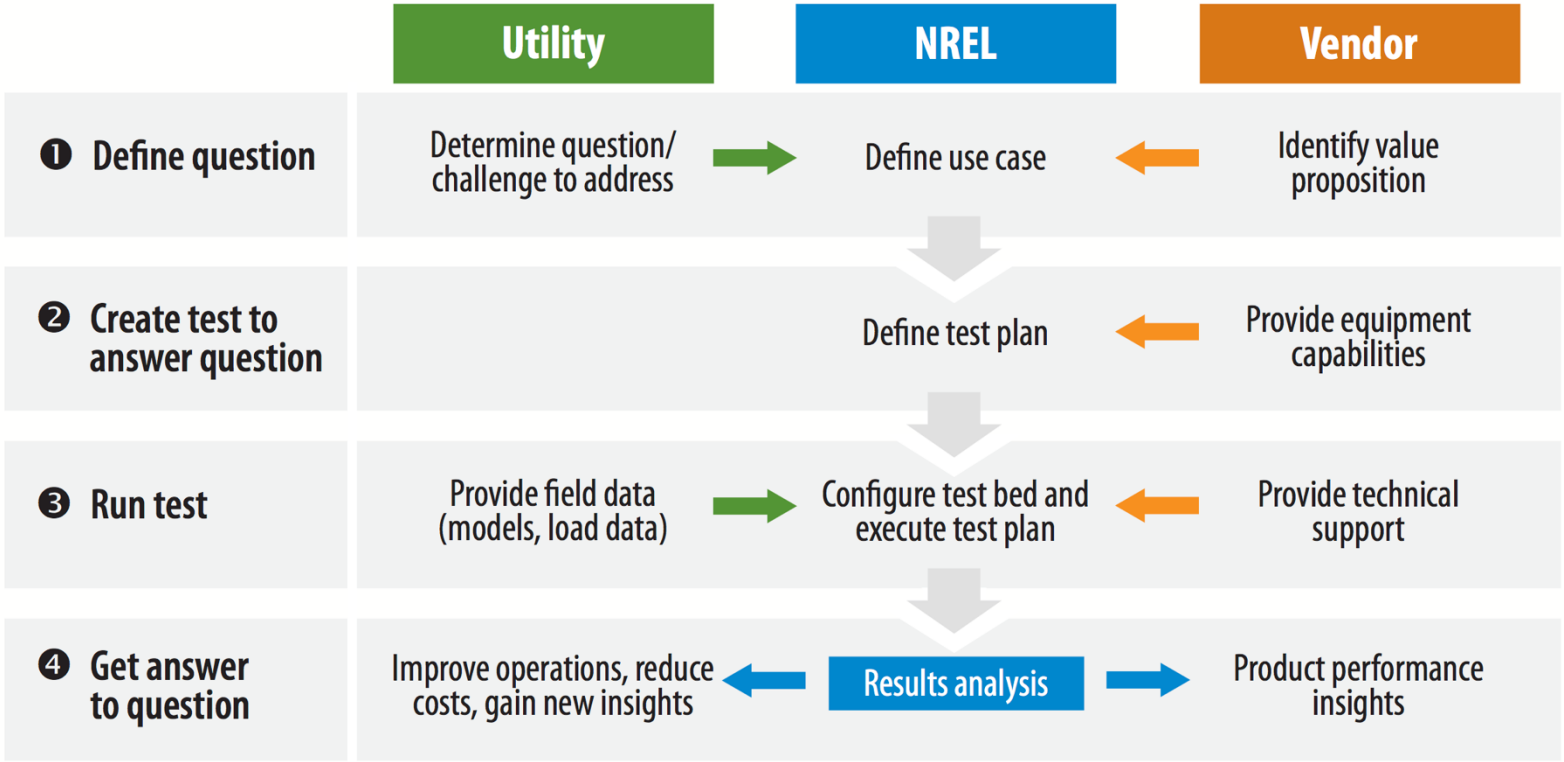
ADMS Testbed - Use Cases

Santosh Veda, Senior Researcher
September 26, 2018

ADMS Testbed Workshop, Sept. 25-26, NREL

ADMS Testbed Development

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY



ADMS Applications

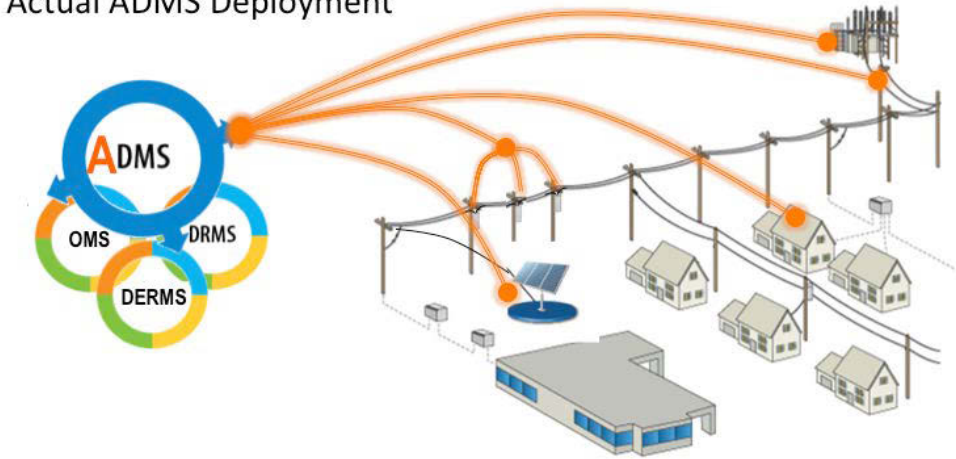
Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

- 15 advanced distribution management system (ADMS) applications considered for discussion
  - Demand response (DR)
  - Short circuit analysis
  - Distributed energy management system (DERMS)
  - Standard outdoor measurement (SOM)
  - Etc.

ADMS Applications Continued

- Volt-VAR Optimization (VVO)
- Fault Location Isolation & Service Restoration (FLISR)
- Online Power Flow (OLPF)/ State Estimation (DSSE)
- Market Participation

Actual ADMS Deployment



OLPF/DSSE Use Cases

- **Data Remediation**
  - **Data needs for feeder models; specifications and locations for adding new telemetry points; impact on ADMS applications**
- Calibrate OLPF/DSSE functions
  - Comparing the states' testbed measurements, tuning algorithms
- Evaluate performance of hierarchical distributed sensing
  - Integrating sensing technologies like advanced metering infrastructure (AMI), OpenFMB, OpenADR, grid-edge smart controls, distribution phasor measurement units (PMUs)
- Modeling loss of photovoltaic (PV) generation
  - Behavior of behind-the-meter components for PV, net load allocation, integrating forecasting, customer facility data, load models, etc.

VVO Use Cases

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

- Voltage Regulation
  - Legacy voltage control assets, smart inverters, energy storage, autonomous controllers
- **Peak Load Management**
  - **Conservative voltage regulation (CVR) for peak load management and interaction with "aggregators" like a DERMS and Demand Response Management System (DRMS)**
- Performance evaluation
  - Multi-objective VVO, different control architectures
- **Interaction with Active Grid Edge Devices**
  - **Centralized VVO with grid-edge controllers**

FLISR Use Cases

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

- High penetration of distributed energy resources (DERs)
  - Upstream and downstream DERs; line loading before and after fault; intermittency and visibility challenges
- Interaction with microgrids
  - Impact of temporary fault, black start capability, need for direct communication
- Very high loading conditions
  - Unnecessary backup feeder trip; use of load forecasting
- Multiple simultaneous faults
  - Severe thunderstorms leading to multiple faults, feeder re-tripping and lockouts
- Widespread outages
  - Uncertain distribution configurations, assessment of communication status and feeder outages

Market Participation Use Cases

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

- Maintaining power quality while providing bulk grid services
- Distribution system operations (DSOs) providing market functions
- Estimating available capacity for bidding in energy markets

Simulation time scales

Application	Use Case	Simulation Time Scale
VVO (sub-second simulations with hardware)	Traditional VVO	1 second
	Inverter Controls	Milliseconds
FLISR	High resolution Electromagnetic Transients Program (EMTP) simulations to characterize protection system; second-scale for ADMS	
Market Participation	Frequency Regulation	1 second
	Demand Response	1 second
	Synthetic Inertia	Milliseconds
	Peak load management	A few seconds to minutes

ADMS Use Case 1

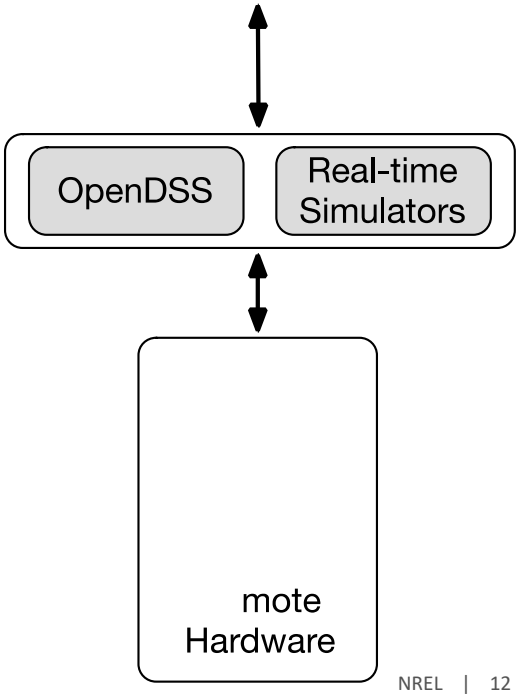
ADMS Testbed Capabilities

- Use Case 0
  - ADMS internal power flow with power hardware-in-the-loop (PHIL) with a PV inverter
- Use Case 1
  - Multitime scale simulation as external power flow
  - Integrated data collection and management system
- Use Case 2
  - Integrated application

Use Case 1 - Objective

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
- Tradeoff between model quality and telemetry density



Model Quality & ADMS Deployment

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

- Model quality is essential for accurate ADMS performance
- A geographical information system (GIS) is a typical source for ADMS
- Model and data cleanup = up to 25% of ADMS costs
- Upkeep of models during operation is a critical need

Important Questions

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

- What level of data cleanup needs to be performed for successful deployment?
- Can the need for data cleanup be offset by deploying additional sensors?
- Can sensors such as AMI be used in addition to supervisory control and data acquisition (SCADA) points to improve ADMS performance?
- What is the impact of the reduced data quality on the performance of ADMS and its applications?

Use Case Setup

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

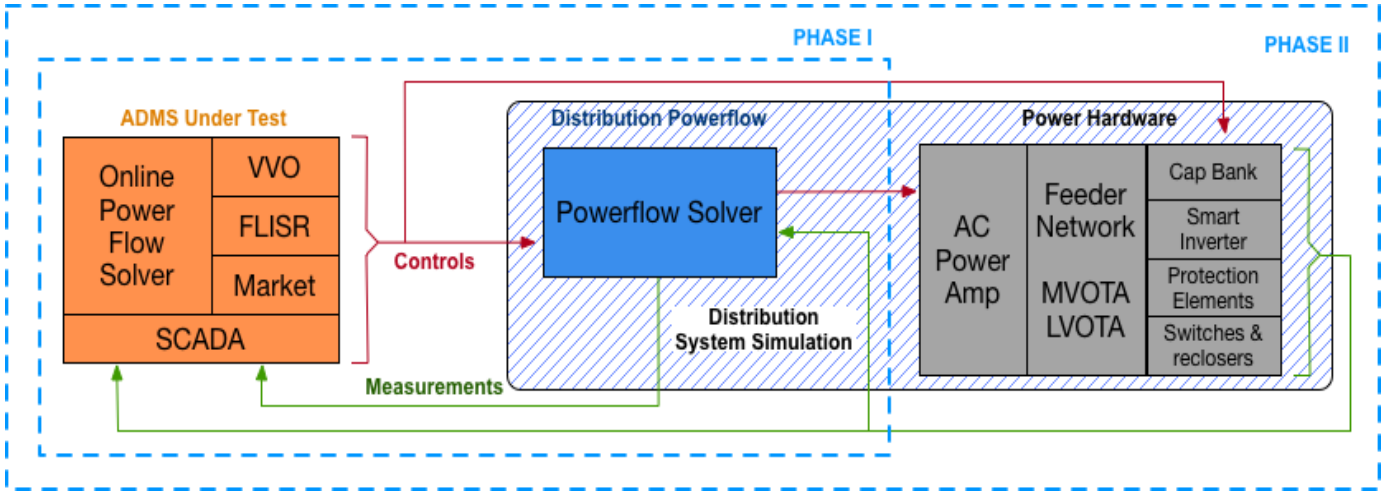
Levels of Model Quality

- **Level 1** – Base level GIS data
- **Level 2** – Field verification at select locations
- **Level 3** – Tap phase verifications
- **Level 4** – Field confirming each primary pole line

Levels of Measurement Density

- **Level 1** – Feeder head
- **Level 2** –Level 1 + utility assets + 1 tail-end AMI sensor
- **Level 3** – Level 2 + additional 9 AMI sensors
- **Level 4** – Level 3 + additional 20 AMI sensors

Test Setup

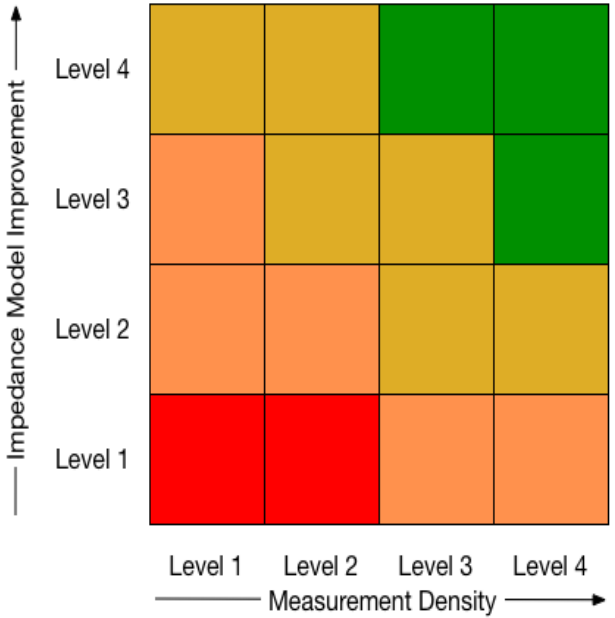


Phase I: Software-based simulations

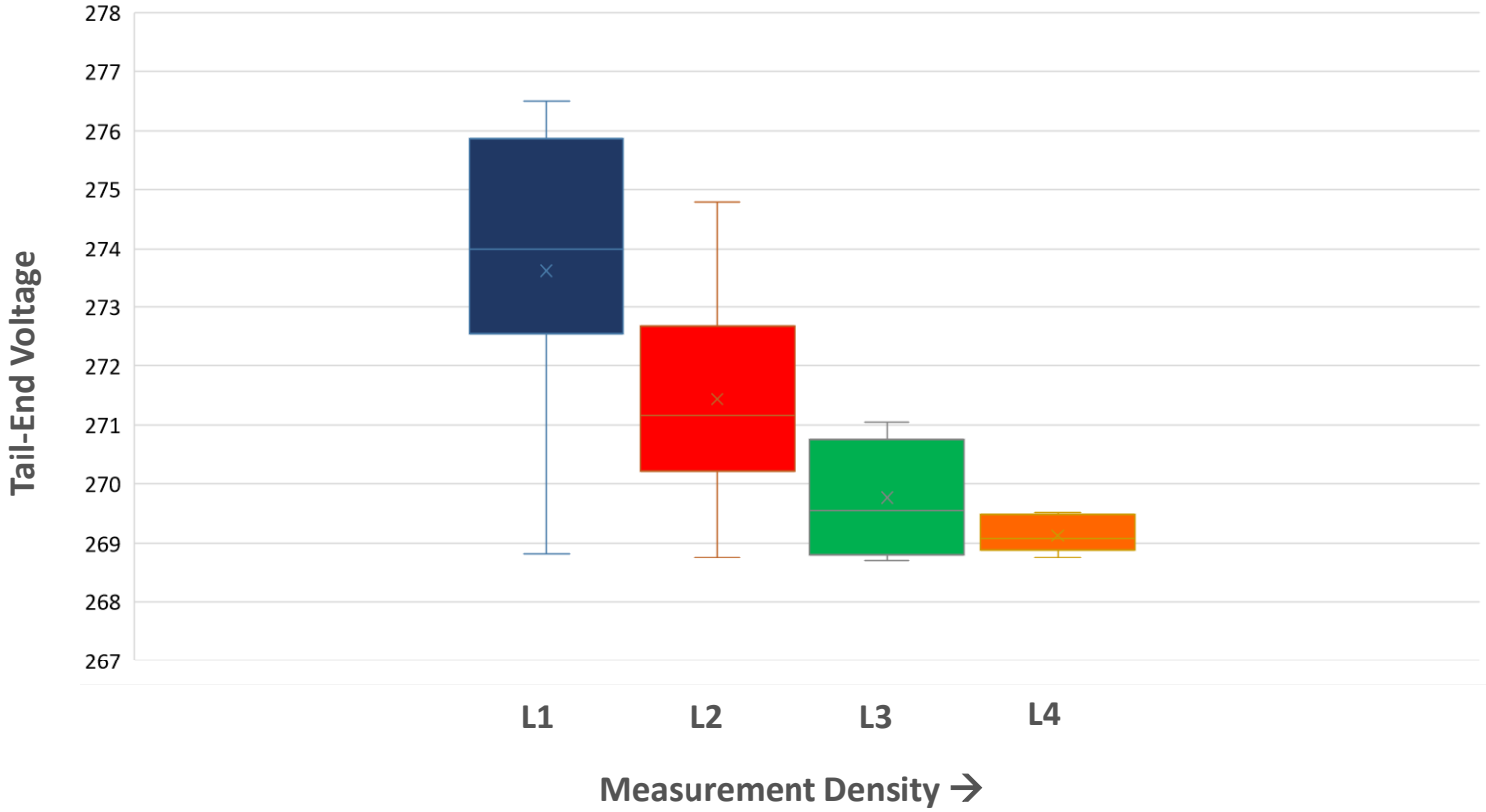
Phase II: Hardware-in-the-loop (HIL)-based evaluation

Test Metrics

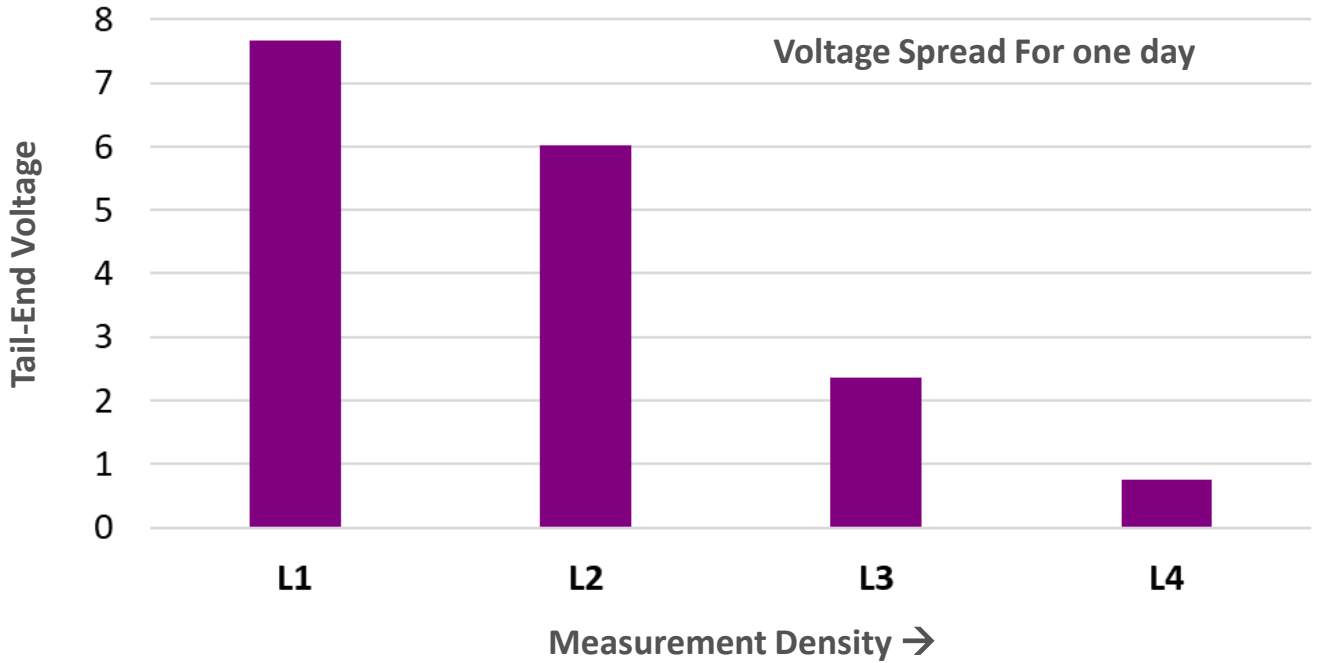
Test Metric	Description
CVR Energy Reduction	Feeder energy consumption before and after application of CVR
System Average Voltage Fluctuation Index	Average voltage fluctuations for all nodes within the time period. Represents the flatness of the voltage profile.
System Control Device Operation Index	Number of times the capacitor banks were turned on or off
Capacitor bank operations, load-tap changing (LTC) or voltage regulator operations	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



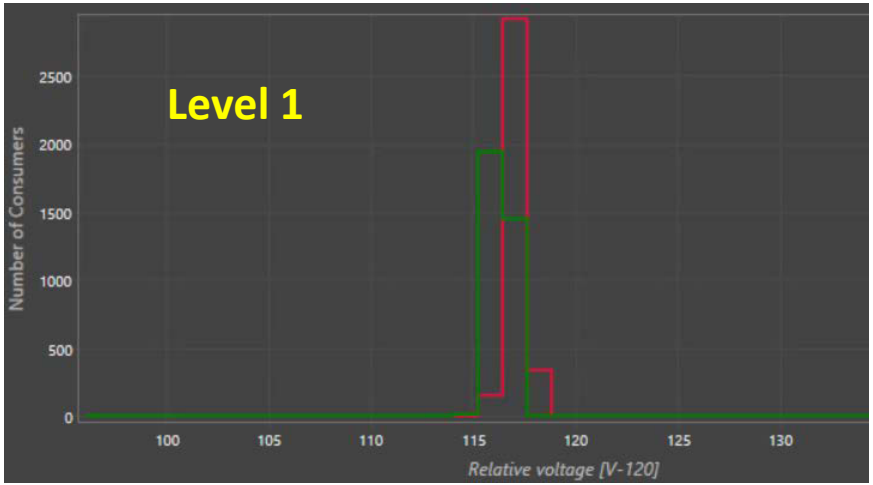
Phase I - Initial Results

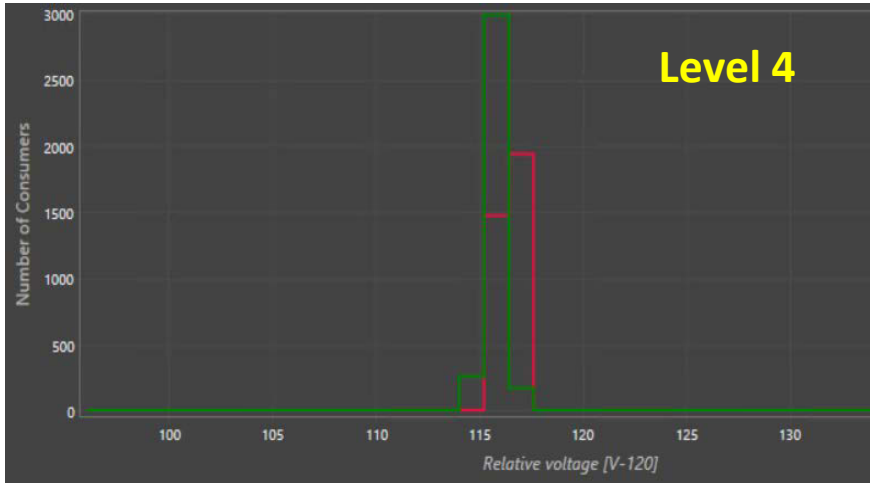


Phase I – Initial Results

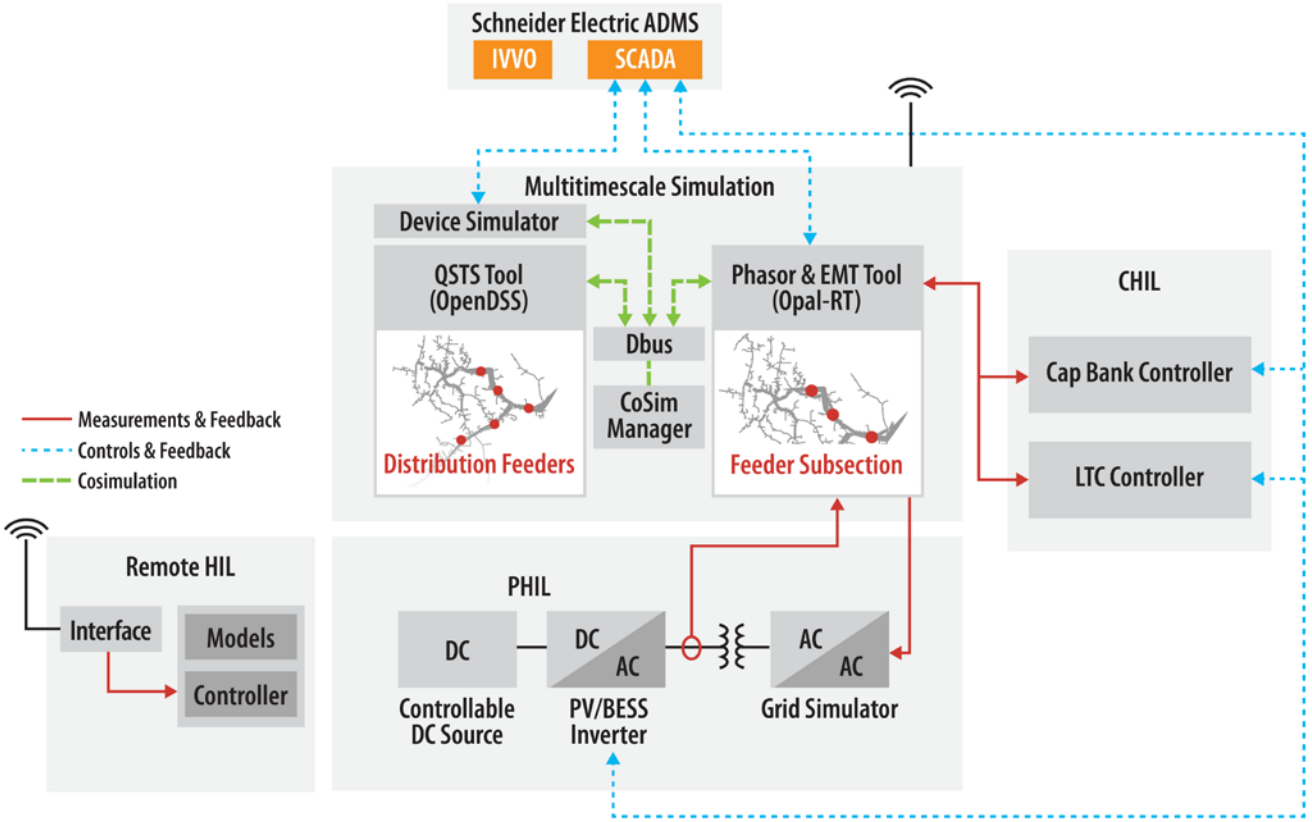


Performance Against Model Quality



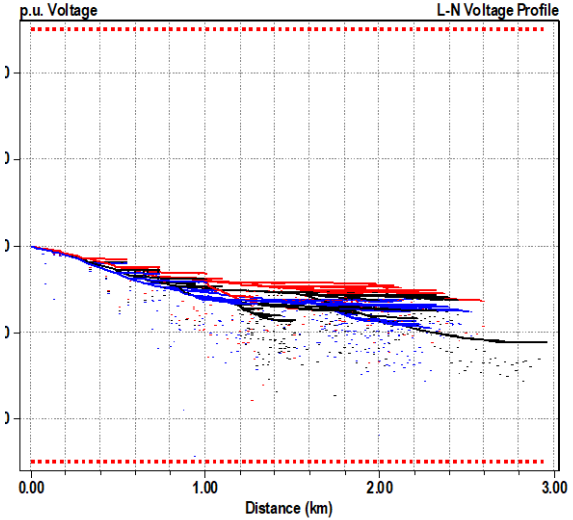


Test Setup

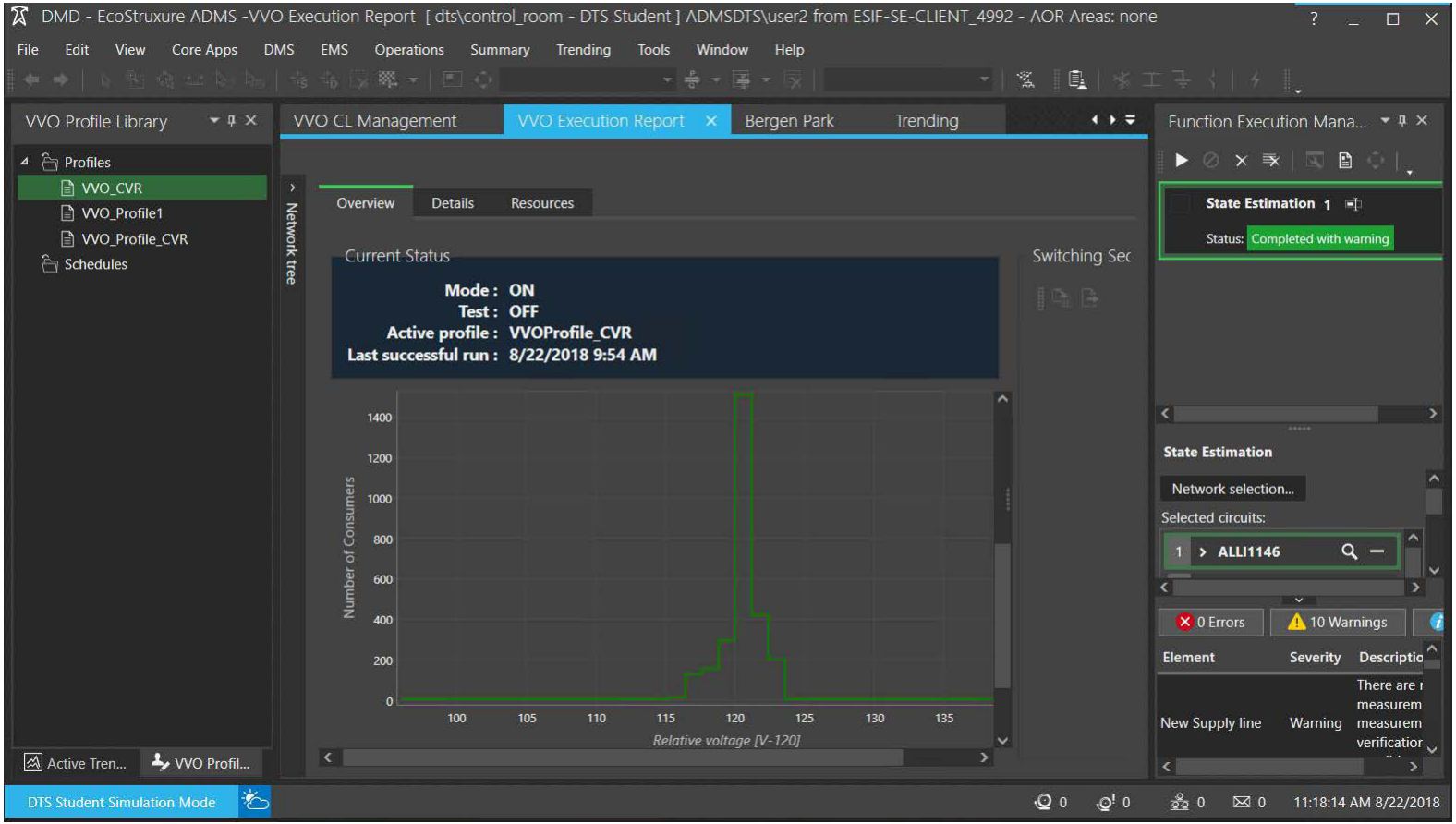

Schneider Electric ADMS
IVVO
SCADA
Multitimescale Simulation
Device Simulator
QSTS Tool (OpenDSS)
Phasor & EMT Tool (Opal-RT)
Dbus
CoSim Manager
Distribution Feeders
Feeder Subsection
CHIL
Cap Bank Controller
LTC Controller
Measurements & Feedback
Controls & Feedback
Cosimulation
Remote HIL
Interface
Models
Controller
PHIL
DC
DC
AC
AC
AC
Controllable DC Source
PV/BESS Inverter
Grid Simulator

Model Conversion

- Xcel Energy feeder converted from CIM to OpenDSS
  - Validating against Synergi model from Xcel
  - Tool to convert from OpenDSS to ePHASORSIM completed



Configuring the ADMS



Use Case 1 - Summary

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

Test Metric	Description	Measurement
CVR Energy Reduction*	Feeder energy consumption before and after application of CVR	Feeder head voltage and current measurements
Average Absolute Deviation*	Sum of absolute voltage deviation at each node divided by number of nodes.	RMS voltage at every node collected from software-based simulation platforms
Voltage Excursions	Number of voltage violations (beyond the acceptable range of 0.95-1.05pu)	RMS voltage at every node collected from software-based simulation platforms
Capacitor bank operations	Number of times the cap banks were turned on or off	Cap operations as recorded from the cap bank controller
Voltage Regulator operations	Number of times the voltage regulators were operated	Regulator operations as recorded from regulator controller
Cost of operation	Cost of voltage regulation; incurred from operation of cap banks, regulators, etc.	ADMS output
Power factor	Power factor will be computed at selected nodes	Voltage and current or power measurements collected from software-based simulation platforms

* primary test metrics

Next Steps

- Completing Phase I simulation studies
- Identify two scenarios from Phase I for validation with HIL Evaluation
- Develop methodology to enable equitable comparison of Phase I and Phase II results

Use Case 2: Integrated Use Case

ADMS Testbed Capabilities

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

- Use Case 0
  - ADMS internal power flow with PHIL (PV inverter)
- Use Case 1
  - Multitime scale simulation as external power flow
  - Integrated data collection and management system
- Use Case 2
  - Integrated application (EMS + ADMS + DERMS)

Integrating DERMS with ADMS – Opportunities

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

- Controls aggregation
  - ✓ ADMS can exercise control over additional assets
- Model and data abstraction
  - ✓ Limit what details are needed to model/observe the DERs
- Performance improvement
  - ✓ Allow grid-edge control for improved performance
- Advanced capabilities
  - ✓ DSO-type functionalities with multiple DER aggregators

Integrating DERMS with ADMS – Challenges

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

- Model abstraction
  - Extent of abstraction can very based on application
- Data exchange
  - How often and what data needs to be exchanged?
  - Communication speed is a constraint when designing applications
- Interfaces and messages
  - Lack of mature standards
- Customer participation
  - Value case, incentives, multiple controllers at home level
- Measurement vs model-based DERMS
  - Different needs based on the DERMS technology

Potential Applications

- Service Restoration (FLISR + DERMS)
  - Passive: FLISR uses DERMS-estimated group DER capacity to plan reconfiguration
  - Active: DERMS provides requested group DER capacity for specified duration
  - FLISR is restricted; other assets used for reconfiguration; load relief
- Peak Management (dynamic voltage regulation (DVR) + DERMS)
  - ADMS uses DVR to clamp voltages at 114 V; DERMS dispatches DERs to lower peak demand

Other Potential Integrated Applications

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

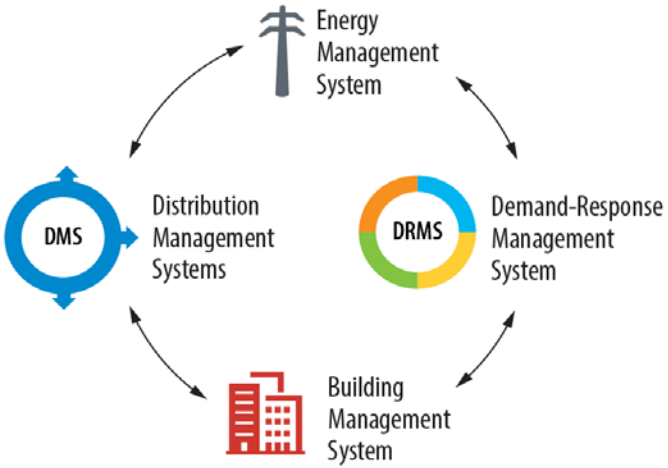
- Adaptive relay protection: Issue adaptive settings for relays based on DERMS forecast.
- Load Shedding/Emergency Response Service (ERS) programs: DER assets as first resort before load shedding through DERMS; some programs are a requirement while some are incentivized; DERMS can improve operations for both.
- DERMS for maintaining grid reliability: Under Frequency Load Shedding (UFLS), Under Voltage Load Shedding (UVLS), Emergency Voltage Reduction (some voltage violations acceptable for deeper MW cut).
- Instabilities (angular, voltage) from the transmission side: DERMS as a lever for bulk grid operators; DERMS for increasing Available Transfer Capacity (ATC) along transmission corridors by addressing instability criteria.
- Market applications: Ancillary markets; large area restoration; black start.

ADMS Testbed - Use Case 2

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

Objective

- Evaluate performance of peak load management use case coordinated across ADMS, DERMS & EMS
  - Communication interface between ADMS & DERMS
  - Reference controls architecture for interoperability
  - Effectiveness of DERMS in complementing ADMS operations
  - Focus on municipal and cooperative utilities



Peak Load Management - Questions

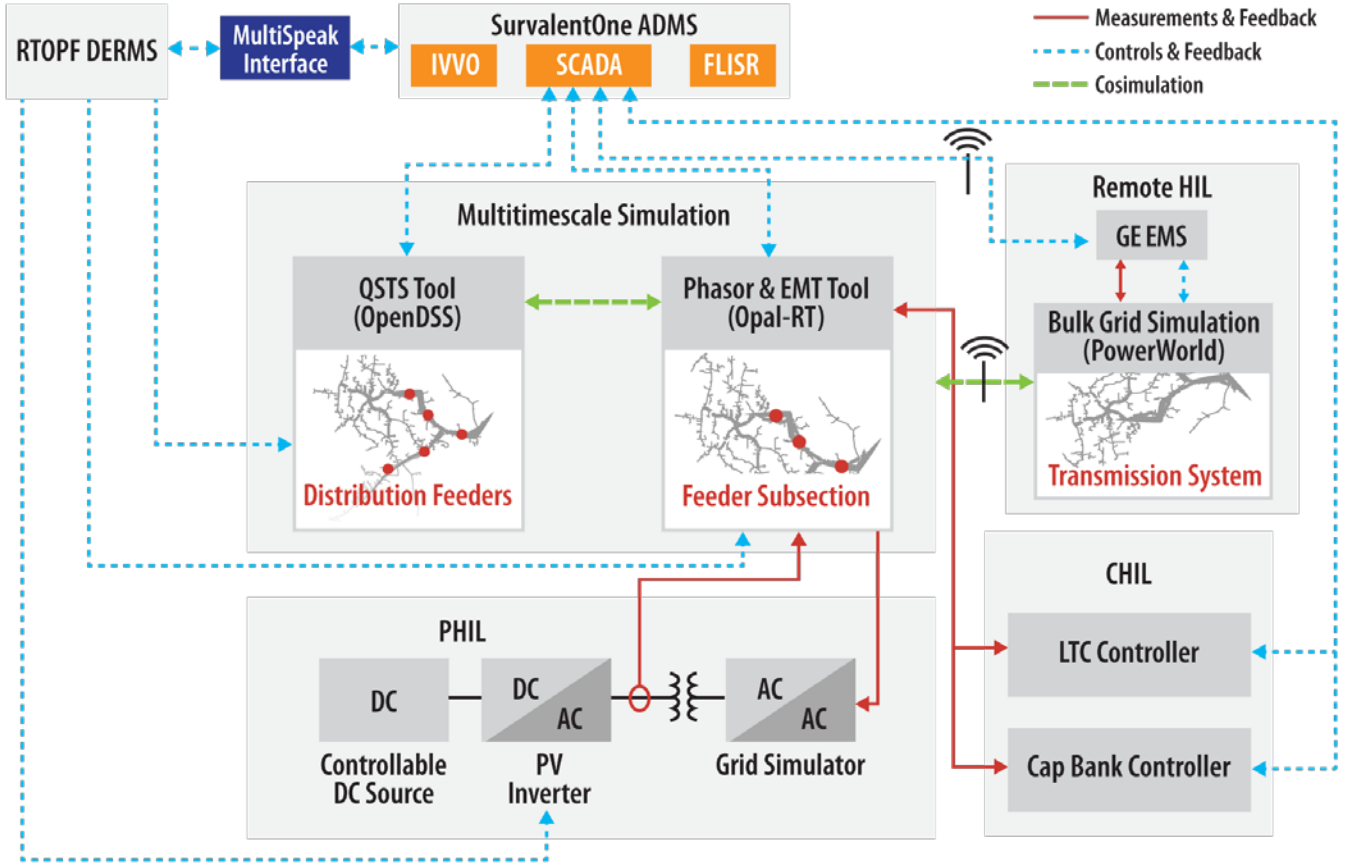
Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY

- How effective is DERMS in augmenting ADMS performance? (Performance evaluation: DVR only; DERMS only; DVR + DERMS)
- Are certain types of DERs better for this application? (types of DER: PV only, PV+ES, PV+ES+DR, etc.)
- How much controllable DER assets are needed to make a difference? (% controllable DER penetration)
- What information needs to be exchanged, and how often?

Use Case 2 Summary

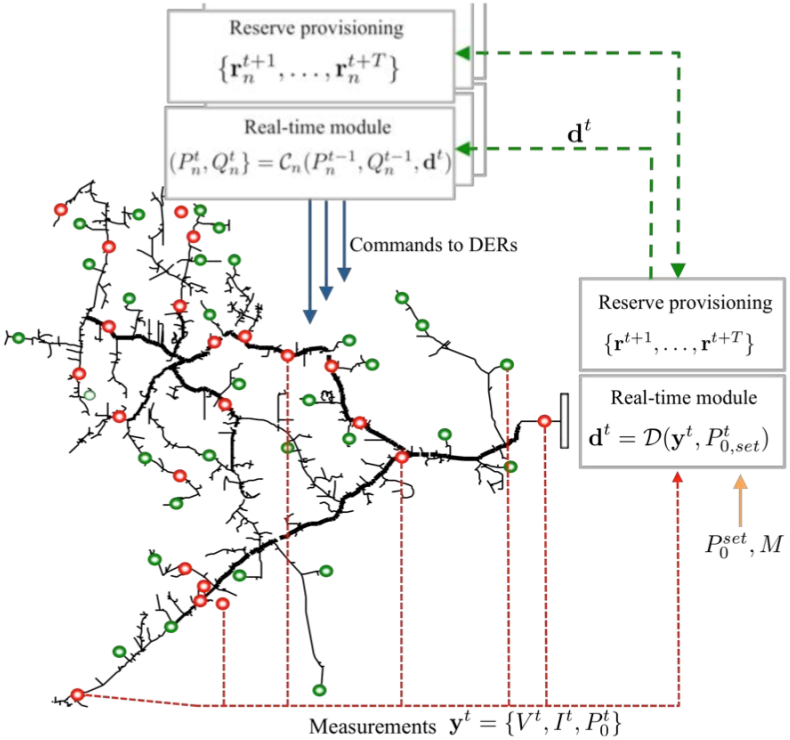
- General Electric's EMS initiates peak load management
- Survalent's ADMS controls legacy assets to lower voltage
- DERMS dispatches the DER assets (PV, Energy storage and load) to reduce load
- Utility partner: Holy Cross Energy (HCE)
- ADMS/DERMS enterprise-level interface: National Rural Electric Cooperative Association's (NRECA's) MultiSpeak

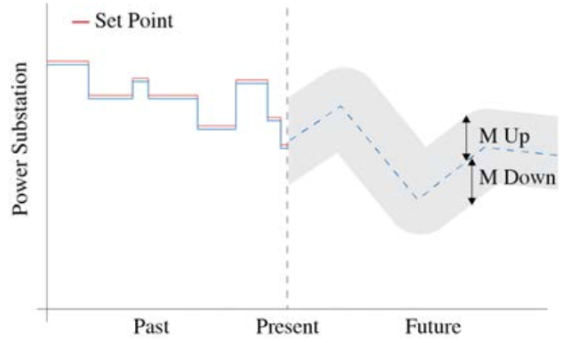
Use Case 2 – Test Setup



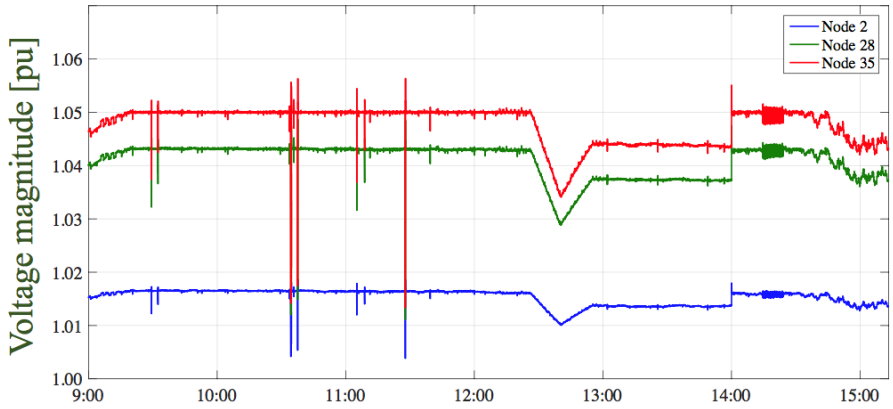
NREL's Real-Time Optimal Power Flow DERMS

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY





Regulating reserves: Dynamic provisioning and dispatch

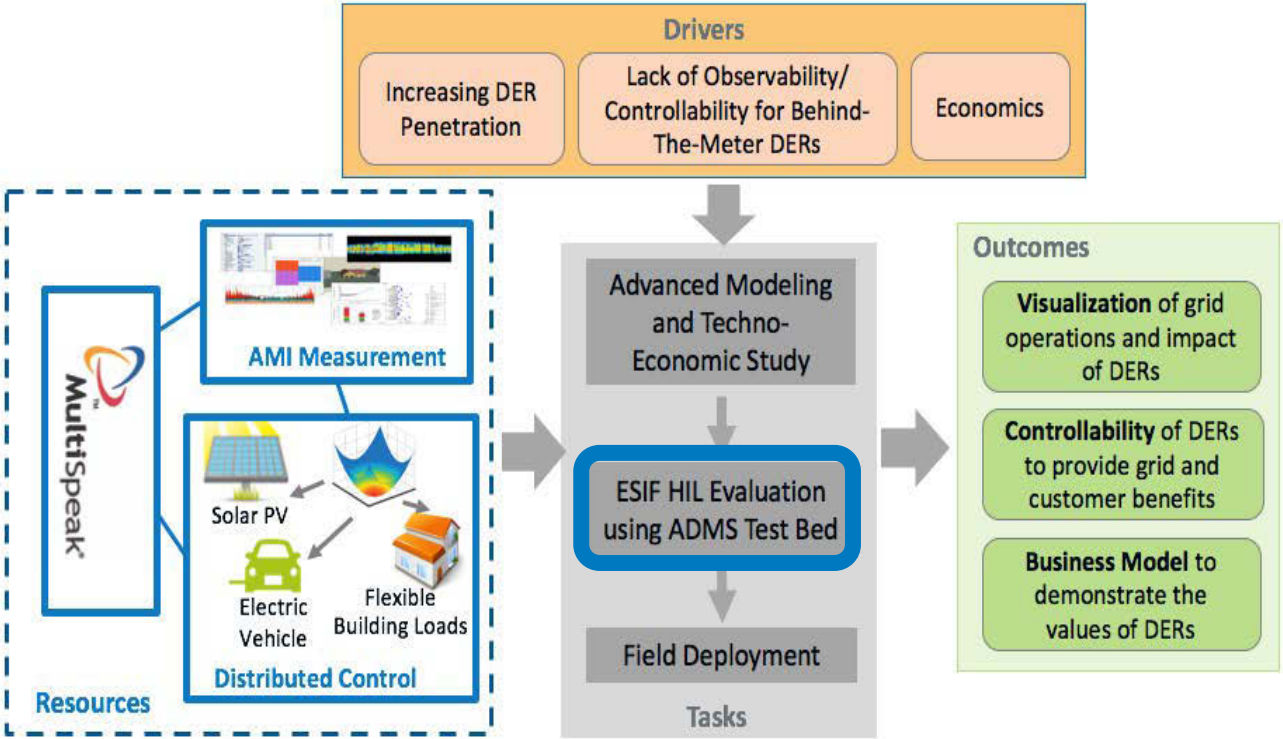


Use Case 2 Status

- ✓ CRADA between NREL and utility partner Holy Cross Energy; data received from Holy Cross Energy
- ✓ Multi-party NDA between the project partners
- ✓ Multiple cooperative/municipal advisory partners identified
- • Subcontracting underway with Survalent Inc, NRECA & Heila
- • Scoping discussions with partners

Synergistic Efforts around Use Case 2

Advanced Grid Research
OFFICE OF ELECTRICITY
US DEPARTMENT OF ENERGY



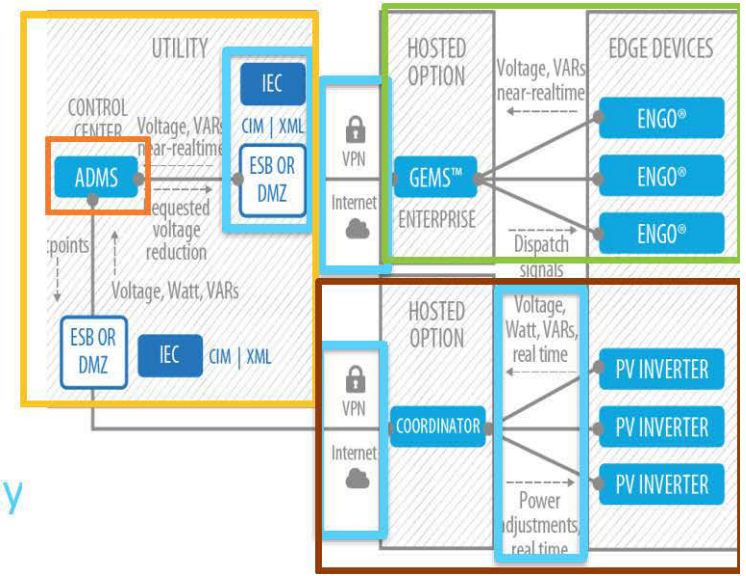
Grid Modernization via non-wires alternatives

Other ADMS Projects

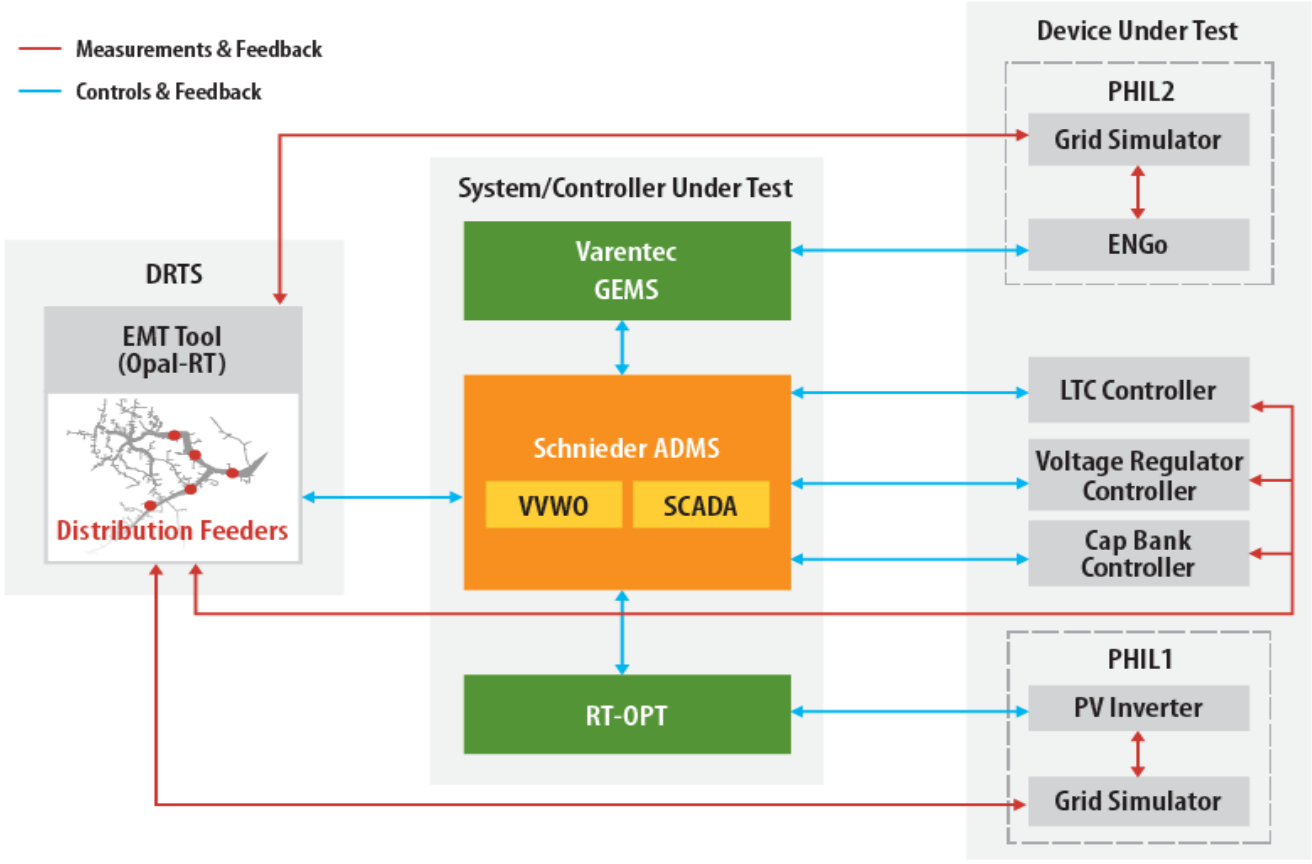
Use Case 3: ENERGISE ECOIDEA

Data-enhanced architecture for integration of centralized and distributed controls for VVO

- Utility enterprise
- Varentec ENGO® devices
- Real-time optimal power flow
- State estimation, forecasting
- Cybersecurity and interoperability



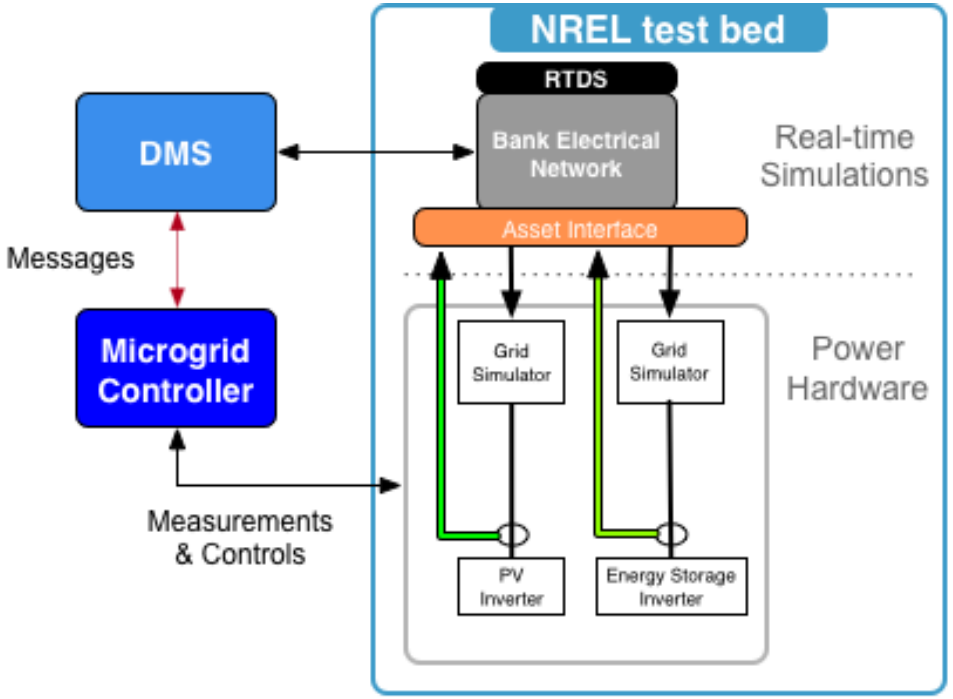
Use Case 3: ENERGISE ECOIDEA



Use Case 4: Integrated DMS

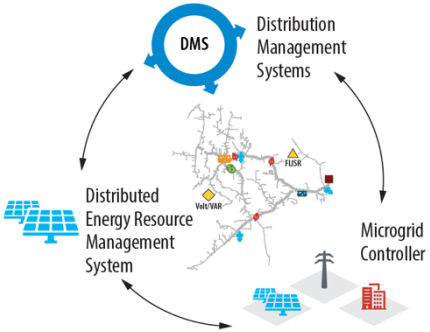
Use Case 4: PHIL Evaluation of Microgrid Energy Management System Integration with DMS: Interaction of µEMS, DERMS, and DMS/OMS via Field Verification.

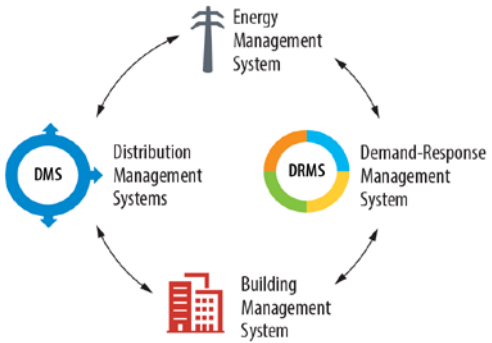
Test plan execution starting June 2019



Use Case 5: Controls coordination between centralized & distributed FLISR

- **Use Case 5**: Evaluation of centralized and decentralized FLISR using Flexible DER and Microgrid Assets Enabled by OpenFMB
  - **Test plan execution starting April 2020**





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 the U.S. Department of Energy Office of Electricity Delivery and Energy Reliability. 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

NREL/PR-5D00-72739

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.