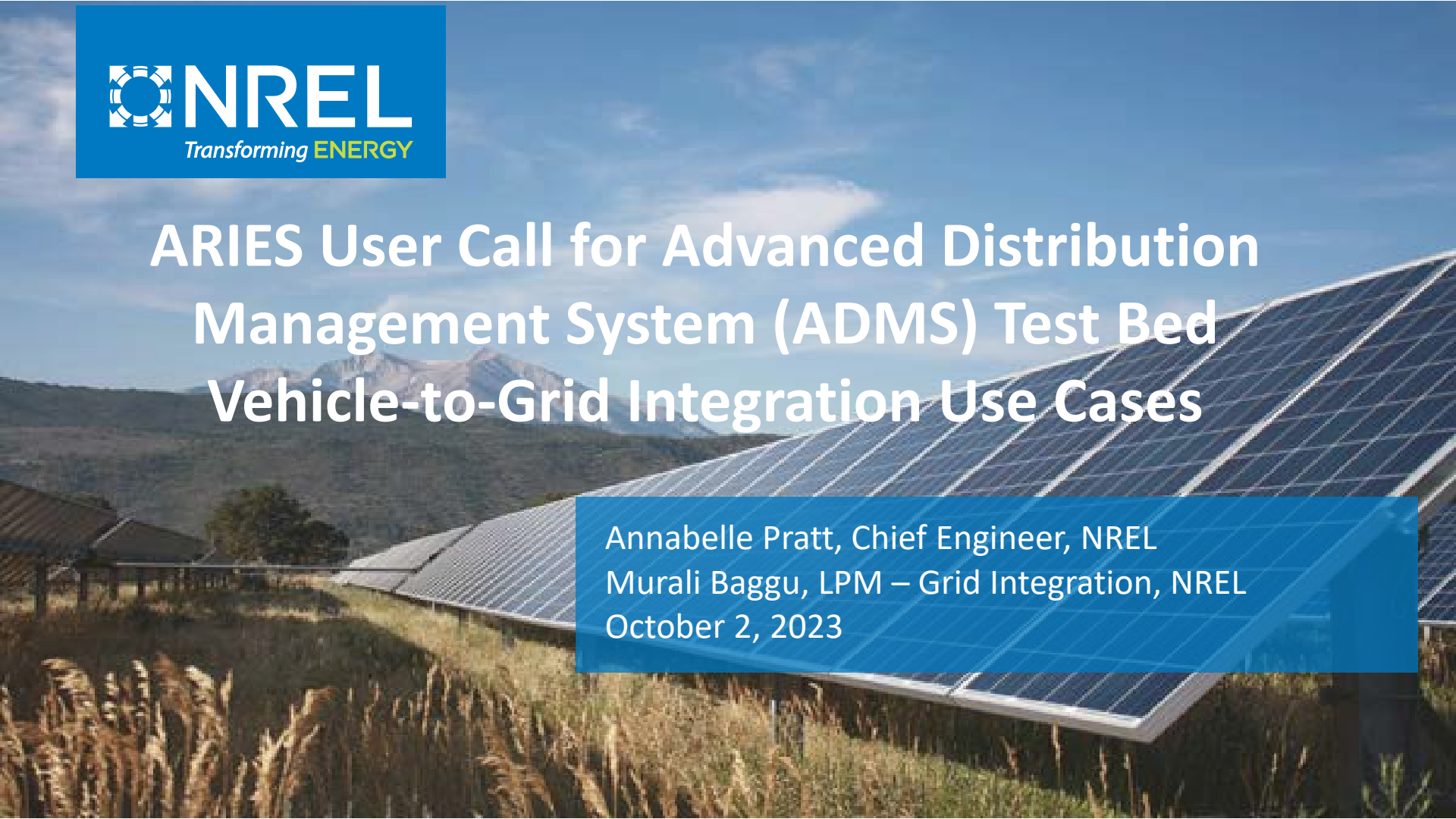


ARIES User Call for Advanced Distribution Management System (ADMS) Test Bed Vehicle-to-Grid Integration Use Cases

Annabelle Pratt, Chief Engineer, NREL
Murali Baggu, LPM – Grid Integration, NREL
October 2, 2023

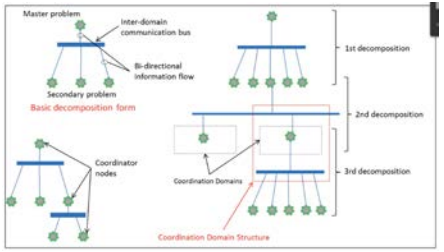
Outline

- Brief overview of the ARIES ADMS Test Bed capability
- User call summary
- Q&A.

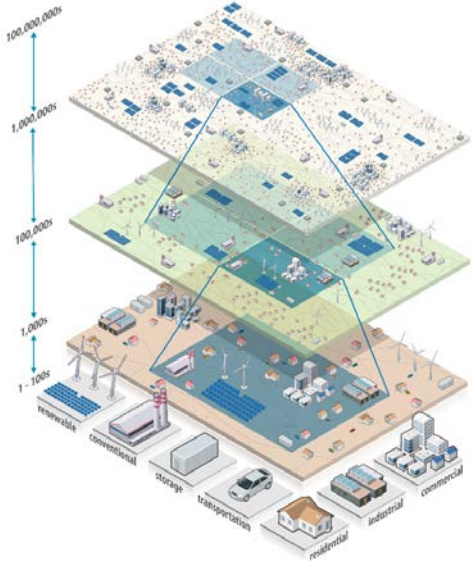
List of Acronyms
ADMS: Advanced Distribution Management System
ARIES: Advanced Research on Integrated Energy Systems
DER: distributed energy resource
DERMS: distributed energy resource management system
EV: electric vehicle
ESIF: Energy Systems Integration Facility
GMLC: Grid Modernization Laboratory Consortium
R&D: research and development

Motivation

- Higher DER penetration challenges grid controls.
  - High levels of EVs are of special concern.
- Industry is responding with new products:
  - ADMS that are DER-aware
  - ADMS with DERMS modules
  - Stand-alone DERMS products
  - Virtual power plants and aggregators.
- R&D organizations (national laboratories, universities) are responding with new grid control architectures, e.g.:
  - GMLC Grid Architecture
  - NREL's Autonomous Energy Systems concept.



Source: PNNL



Source: NREL

Motivation (Cont.)

- We need realistic laboratory environments to evaluate new grid control products (and synergies among control products) and new control architectures for:
  1. De-risking—making field demonstration projects (pilots) more successful
  2. Proving ground—evaluating claims
  3. Future-proofing—performing evaluations on models of future power systems with even higher levels of DER.
- For this, we need a flexible combination of laboratory hardware and simulation tools to allow for a wide range of experiments.

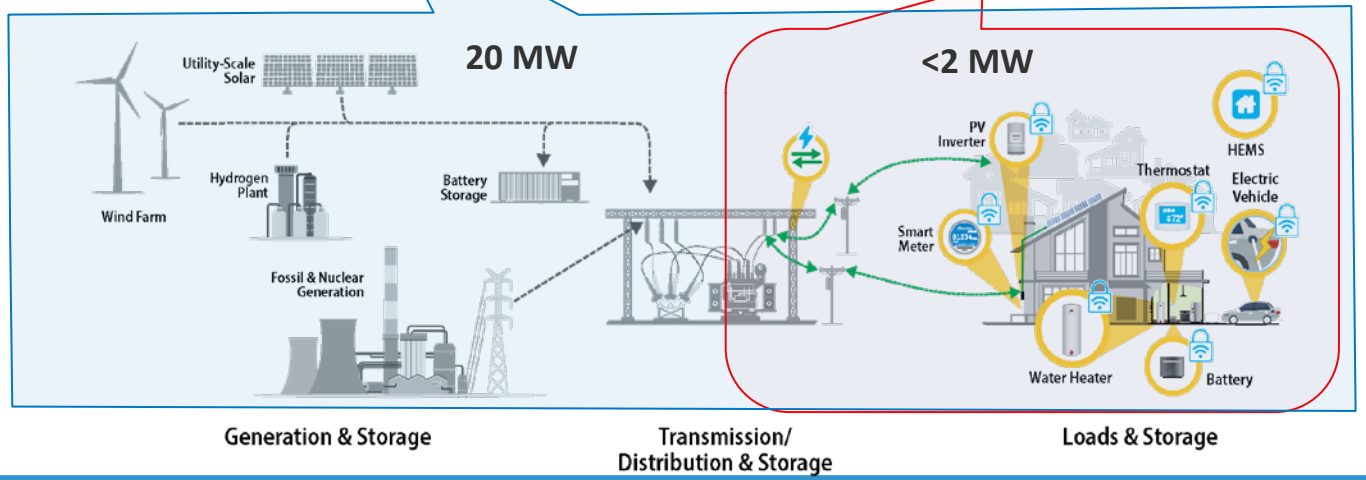
ESIF: NREL's largest R&D facility (182,500 ft^2/20,000 m^2)

Space for ~200 NREL staff and research partners.

Photos by NREL

NREL's ARIES Research Platform

Photos by NREL



Virtual Emulation

ARIES is a **globally unique research capability**, demonstrating that DERs can operate in real-time energy markets and provide reliable and resilient grid services.

Grid Controls Evaluation Capabilities

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- The ADMS Test Bed: Developed through GMLC/OE funding (2016)
- Originally focused on evaluations of ADMS; however, the foundational capabilities are the:
  1. Realistic, real-time representation of a real or representative distribution power system in a laboratory that includes behind-the-meter and utility-scale DERs
  2. Ability to interface the laboratory system with commercial or precommercial grid management software through industry-standard communication protocols.

https://www.nrel.gov/grid/advanced-distribution-management.html

ADMS Test Bed

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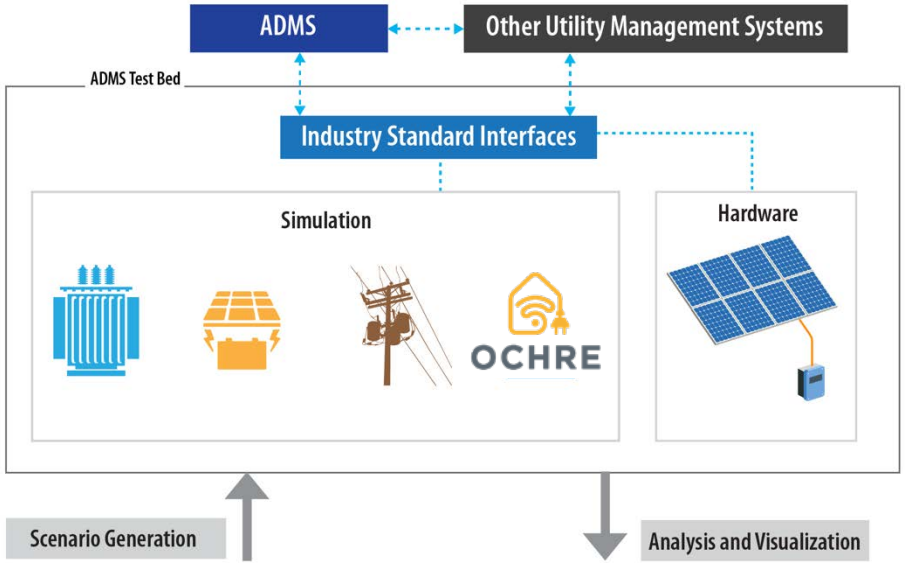
ADMS Test Bed capabilities include:

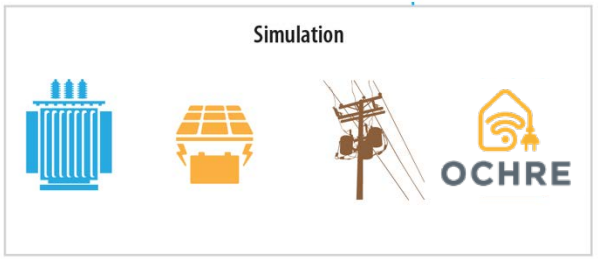
- Real-time co-simulation using HELICS:
  - Real or representative power system
  - Either QSTS (OpenDSS) or EMT (RTDS or OPAL-RT) for the power system
  - Current or future DER levels
  - Normal or abnormal grid conditions
  - OCHRE™ for residential buildings.

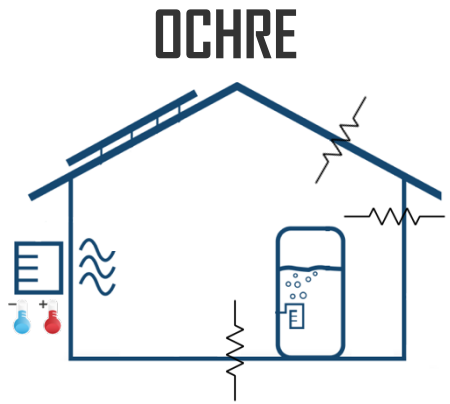


QSTS: quasi-steady state time series
EMT: electromagnetic transient

OCHRE

- OCHRE:
  - Object-Oriented Controllable High-Resolution Residential Energy Model (open source)
  - Residential building simulation suitable for co-simulation with power systems
  - Implementation on high-performance computing for many homes
  - https://ochre-docs-final.readthedocs.io/en/latest/.





ADMS Test Bed

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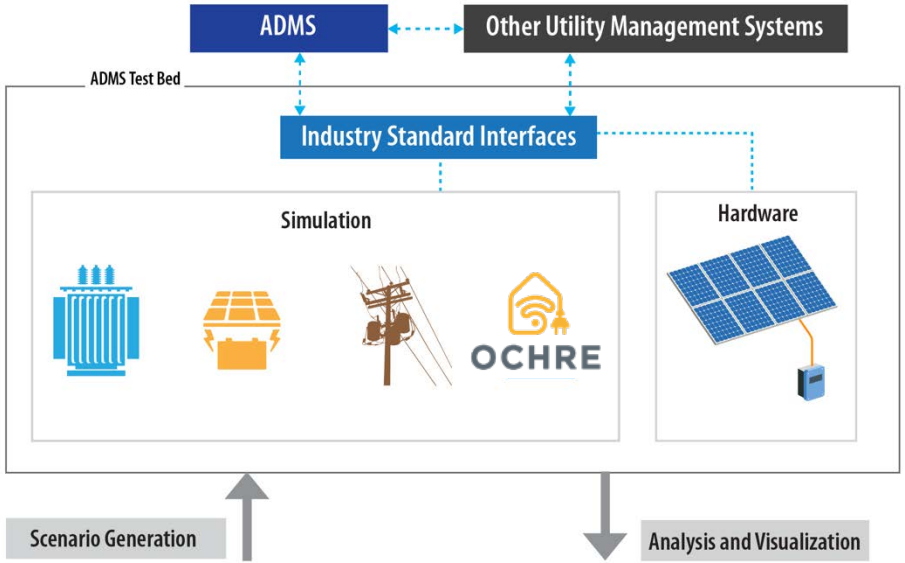
ADMS Test Bed capabilities include:

- Real-time co-simulation using HELICS:
  - Real or representative power system
  - Either QSTS (OpenDSS) or EMT (RTDS or OPAL-RT) for the power system
  - Current or future DER levels
  - Normal or abnormal grid conditions
  - OCHRE for residential buildings.
- Hardware integration:
  - Power or controller hardware, e.g., inverters, capacitor bank controllers.
- Communication interfaces
  - Mostly DNP3, some Modbus, IEEE 2030.5.



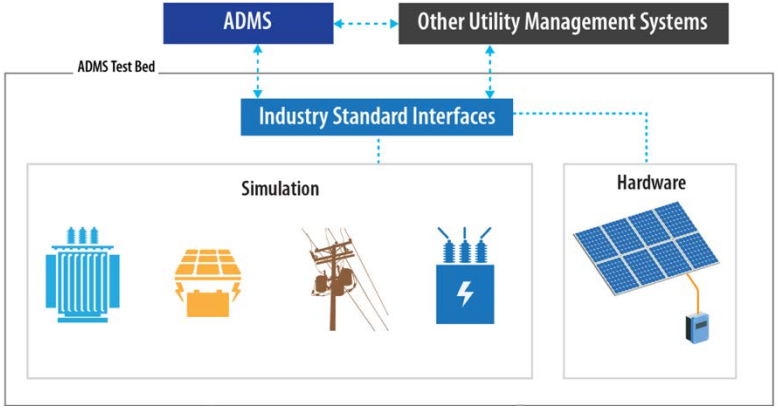
QSTS: quasi-steady state time series
EMT: electromagnetic transient

ADMS Test Bed

Photo by NREL

ADMS and Controls Interfaced

- Commercial ADMS by:
  - General Electric
  - Schneider Electric
  - Survalent
  - Oracle (current)
  - OSI (in progress).

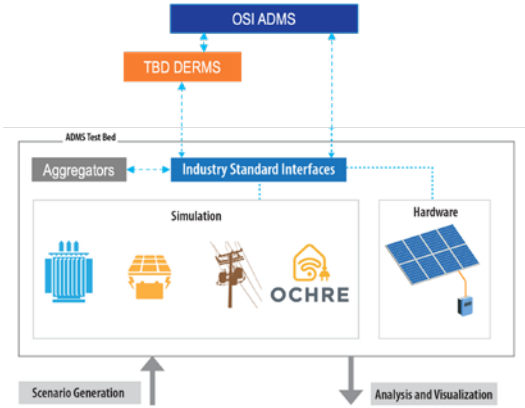


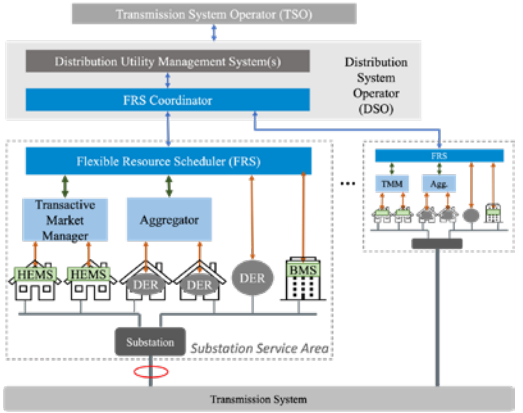
- Other utility management systems:
  - Varentec GEMS (now Sentient Energy).

- Research control algorithms:
  - Applications on GridAPPS-D, an OE-funded open-source platform for ADMS application evaluation https://www.gridapps-d.org/
  - Python code.

What About DERMS?

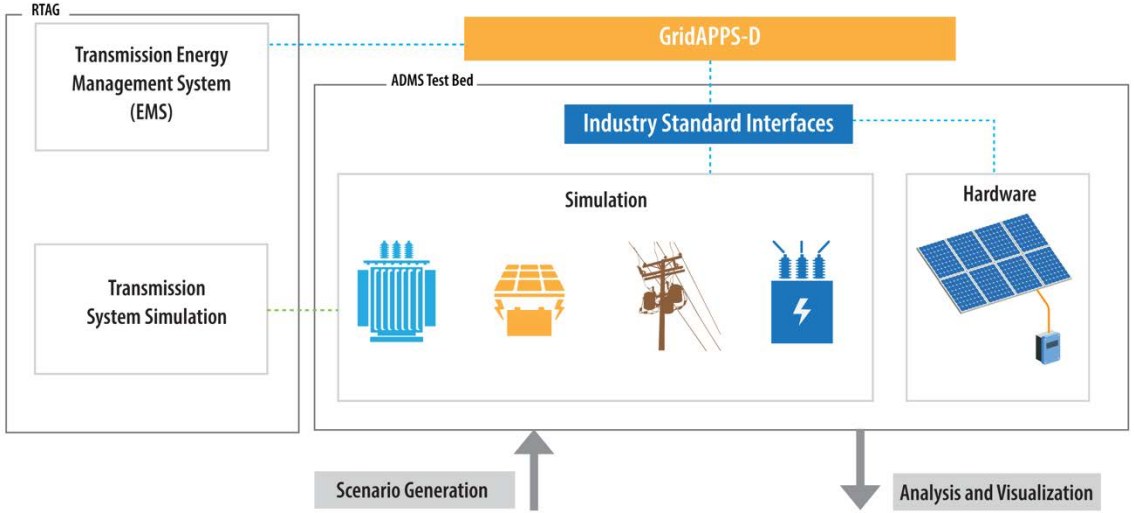
- One active project that uses the test bed (SALMON) will include a DERMS:
  - Has not yet been selected
  - Expect a decision in October.
- The ESIF has invested in a Smarter Grid Solutions DERMS
  - A representative, state-of-the-art solution
  - Reservable asset at the ESIF.
- Research “DERMS” solutions have been/are being interfaced:
  - NREL’s real-time optimal power flow (RTOPF)
  - Flexible resource scheduler (FRS) application on GridAPPS-D.





Bulk System Co-Simulation

- Real-Time Analytics for Bulk Grid (RTAG):
  - https://www.nrel.gov/grid/control-room.html
  - Transmission power system simulation
  - Transmission energy management system.



ADMS Test Bed Use Cases

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- ADMS network model quality impact on VVO
  - Xcel Energy/Schneider Electric
- Peak load management with ADMS and DERMS
  - Holy Cross Energy/Survalent
- AMI-based, data-centric grid operations
  - SDG&E + GridAPPS-D
- FLISR in the presence of DERs
  - Central Georgia EMC/Survalent
- DER controls strategies for T&D grid services
  - Xcel Energy + GridAPPS-D
- Federated DERMS for high PV system
  - Southern Company/Oracle + GridAPPS-D → Feb 2024
- Co-optimizing grid and facility operations
  - Shell + Spirae → Jul 2024
- System restoration with improved fault tracking
  - Israel Electric Company + EGM → June 2024

Previous user call

ADMS Test Bed capabilities used by:

- Non-wires alternatives
- ECO-IDEA
- GO-SOLAR
- SolarExpert
- Resilient Operation of Networked Microgrids (RONM)
  - SDG&E, Cobb EMC
- FAST-DERMS
  - SDG&E, Oracle, EPRI + GridAPPS-D → April 2024
- REORG
  - Holy Cross Energy, Minsait ACS → Mar 2024
- PV Integration using a Virtual Airgap (PIVA)
  GridBright, SDG&E → Sep 2023
- SALMON
  - Portland General Electric, OSI + TBD DERMS → Aug 2027

ARIES User Call for ADMS Test Bed Future Use Cases

- NREL is issuing this user call to external research partners to identify projects that require using NREL's ADMS Test Bed for vehicle-to-grid integration use cases.

Advanced Research on Integrated Energy Systems (ARIES) User Call for Advanced Distribution Management System (ADMS) Test Bed Vehicle-Grid Integration Use Cases

Table 1. Review and Allocation Timeline

User call solicitation announced, posted to SAM.gov	Aug. 23, 2023
Questions are due to userprogram.esif@nrel.gov	Sept. 22, 2023
Q&A session to address submitted questions	Oct. 2, 2023
Submission deadline	~~Oct.~~ ~~27~~ Dec. 1, 2023, 5:00 p.m. MDT
Review period	~~Nov.~~ Dec. 2023
Expected time frame for decisions	~~Dec. 2023~~ Jan. 2024
Expected time frame for agreement negotiations	90–120 days
Allocation period of performance	Up to 15 months

ARIES User Call for ADMS Test Bed Future Use Cases

- Proposals need to address at least one of the four research areas.
- Applicants may submit more than one proposal, and proposals may address more than one vehicle-to-grid integration (VGI) research area.

Vehicle-to-Grid Integration (VGI) Research Areas:

- **Control architectures**—addresses control architectures and/or algorithms for systems with high levels of EVs and other DERs
- **Role of DERMS and aggregators**—addresses ways to coordinate the operation of an ADMS with a DERMS and/or aggregators to manage high levels of EVs and other DERs
- **Integration with buildings**—addresses the evaluation of control and management solutions that specifically include vehicle integration with buildings (residential or commercial)
- **Communications architectures and cyber-secure data**—addresses the evaluation of solutions that specifically include different communication architectures, protocols, and/or cyber-secure solutions.

ARIES User Call for ADMS Test Bed Future Use Cases

- Federal funding must be cost-shared at 40% of the total value of the project, including at least 20% funds-in.
- Required cost-share percentages are calculated based on the total value of the project:
  - Sum of the DOE funds and the partner contribution provided to national laboratories.
- Cost shares may include cash or in-kind contributions.
- At least 20% of the total value of the project must be in the form of funds-in to national laboratories.
- Example:
  - Total project value of $500,000
  - 40% (or $200,000) must come from nonfederal sources.
  - At least $100,000 of that must be funds-in (i.e., cash contributions).
  - DOE would provide $300,000 to the project.
- Cost shares from other DOE offices are not permitted.
- All federal funds will be provided to national laboratories, i.e., no federal funds will be provided to project partners.

Proposal and Summary Slide Requirements

- Proposals should be no more than five (5) single-spaced pages (not including resumes and references) in a single PDF file using 11-point font (Times New Roman preferred):
  - Title page
  - Abstract
  - Project description
  - R&D approach
  - Expected benefits and deliverables
  - Equipment and resources *(NREL staff can help with this.)*
  - Funding
  - References and technical specifications
  - Team.
- PowerPoint slide deck (template provided)
- Email completed proposal packages to userprogram.esif@nrel.gov .

Equipment and Resources

- Simulators:
  - QSTS: OpenDSS for power systems; OCHRE for residential buildings (*EnergyPlus® for commercial)*
  - EMT: RTDS and OPAL-RT *(Typhoon).*
- Hardware (<2 MW):
  - Capacitor bank, voltage regulator, and load tap changer controllers
  - PV inverters + PV panel emulators
  - Battery inverters (include grid-forming) + battery emulators
  - Electric vehicles, EV emulator, EVSEs, fast chargers
  - Residential building appliances (A/C, electric water heater, washer/dryer, etc.)
  - Commercial building equipment (RTU, thermal storage).
- Controllers:
  - foresee home energy management system code
  - Three different commercial building management systems
  - Smarter Grid Solutions DERMS and DOE's flexible resource scheduler application on GridAPPS-D.

Review Process

- Requests that pass the initial compliance screening are subject to review by NREL's review committee.
- Reviewers rate the projects on a scale from 1 (lowest score) to 5 (highest score) according to the following criteria:
  - Research impact
  - Mission alignment
  - Whether the project contributes to the stewardship and overall strategy of the ADMS Test Bed.
- A table with a detailed description of the review criteria is included in the user call.

Questions?

Thank You

www.nrel.gov

Annabelle.Pratt@nrel.gov

NREL/PR-5D00-87701

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For Further Reading

- DER Control Strategies for T&D Grid Services—ADMS Test Bed Use Case. NREL/PR-5D00-84379, Nov 2022 (Presentation)
- 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.
- ADMS Test Bed Use Case: FLISR in the Presence of DERs, NREL/PR-5D00-84408. Nov 2022. (Presentation)
- 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," *IEEE ISGT*, 2021.
- Harsha Padullaparti, Santosh Veda, Jiyu Wang, Martha Symko-Davies, and Tom Bialek, "Phase Identification in Real Distribution Networks with High PV Penetration Using Field AMI Data," *IEEE PES General Meeting*, July 2022.
- L. Strezoski, H. Padullaparti, F. Ding and M. Baggu, "Integration of Utility Distributed Energy Resource Management System and Aggregators for Evolving Distribution System Operators," *Journal of Modern Power Systems and Clean Energy,* vol. 10, no. 2, Mar. 2022.
- J. Wang, H. Padullaparti, S. Veda, M. Baggu, M. Symko-Davies, A. Salmani, and T. Bialek, "A Machine Learning-based Method to Estimate Transformer Primary-Side Voltages with Limited Customer-Side AMI Measurements," in *IEEE Power & Energy Society General Meeting (PESGM)*, July 2021.
- M. Netto, J. Hao, H. Padullaparti, and V. Krishnan, "On the Use of Smart Meter Data to Estimate the Voltage Magnitude on the Primary Side of Distribution Service Transformers," in *IEEE Power & Energy Society General Meeting (PESGM)*, July 2021.
- 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.

For Further Reading

- 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 GreenTech, March 2017.
- S. Veda, M. Baggu, and A. Pratt, “Defining a Use Case for ADMS Testbed: Data Quality Requirements for ADMS Deployment,” IEEE ISGT, February 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.

ADMS Test Bed

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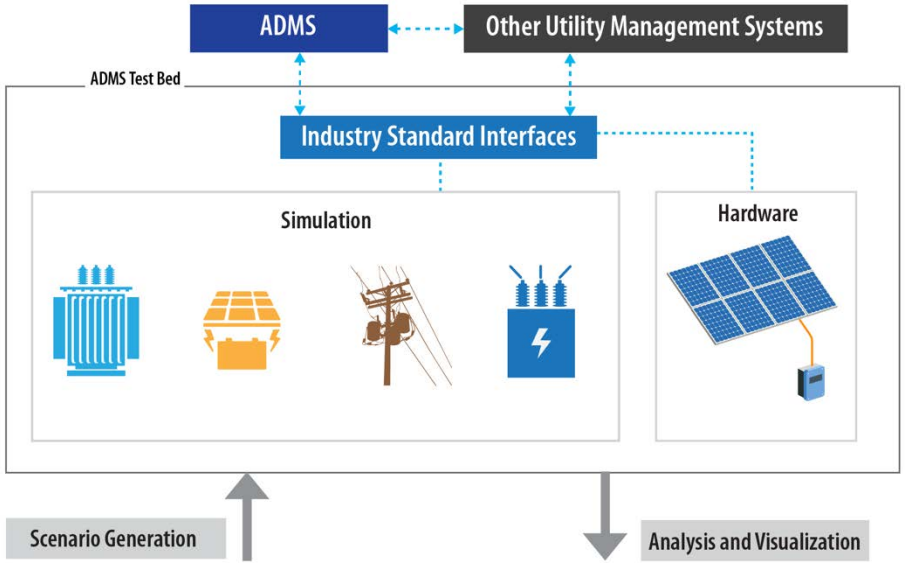
Goal: Accelerate industry adoption of ADMS to:

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

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

- Set up a realistic laboratory environment.
- Simulate real distribution systems.
- Integrate distribution system hardware.
- Use industry-standard communications.
- Create advanced visualization capability.



https://www.nrel.gov/grid/advanced-distribution-management.html

ADMS Test Bed

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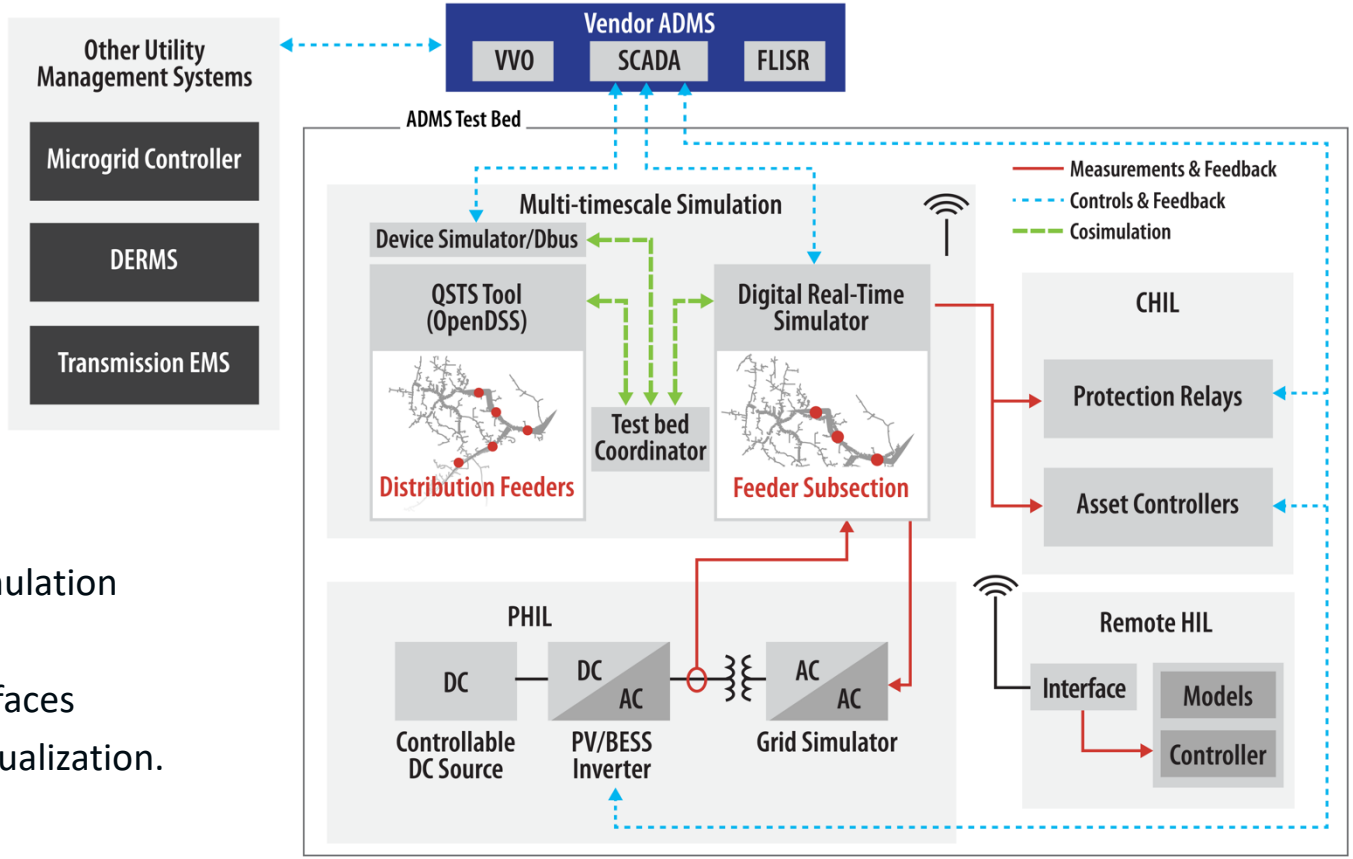
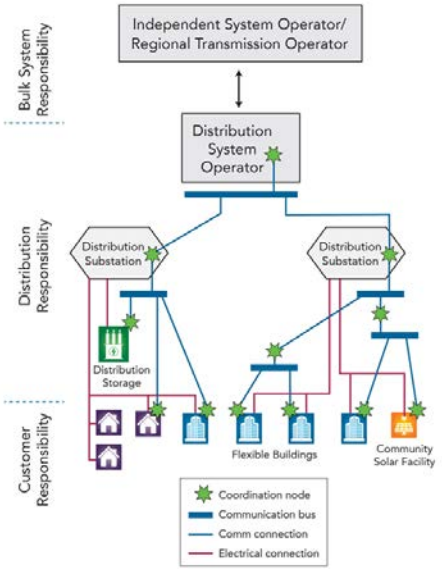
ADMS Test Bed capabilities include:

- Multi-timescale co-simulation
- Hardware integration
- Communications interfaces
- Data collection and visualization.



A Few Words About Scale

- The grid is a tightly coupled system and therefore control should be developed and implemented with a holistic, end-to-end system view.
- Do we need to simulate the entire Western Interconnection, for example, to arrive at any conclusions about grid control solutions?
- No because electric grid infrastructure has a natural hierarchy with key aggregation points:
  - Transmission price nodes
  - Distribution substations.
- We consider the distribution substation service area an appropriate scale for evaluations of DER management solutions.
  - Even with centralized ADMS and DERMS, key functions such as voltage management are implemented at the substation level.
- We can connect a small number of distribution substations to a transmission price node to evaluate data exchange.
- Only after a specific control is successfully demonstrated at the distribution substation level do larger-scale simulations make sense.



Source: *Interoperability Strategic Vision*, March 2018

Multi-Timescale Simulation

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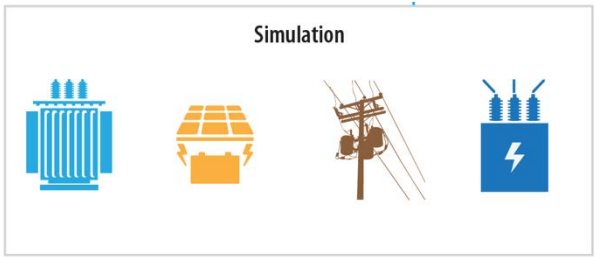
- Can select one or more simulators to fit the use case
- We have used/are using:
  - OpenDSS by the Electric Power Research Institute (EPRI):
    - QSTS
    - 1-s minimum time step; minutes typical.
  - ePHASORSIM by OPAL-RT:
    - Dynamic phasor, 1- to 10-ms time step.
  - eMEGASIM by OPAL-RT:
    - EMT simulation
    - 50- to ~200-µs time step.
  - RSCAD by RTDS:
    - EMT simulation.



Model Conversion

- NREL's open-source Distribution Transformation Tool (DiTTo) can convert between various distribution system modeling formats: https://github.com/NREL/ditto.
  - *Developed a stand-alone OpenDSS to ePHASORSIM conversion tool*, https://github.com/NREL/DSS2ePHASOR.
- Different real-time simulators can import different software formats.
- Model reduction is often required for real-time simulators—we have used NREL and commercial tools.

Multi-Timescale Simulation

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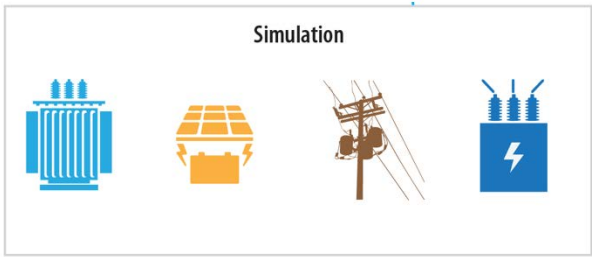
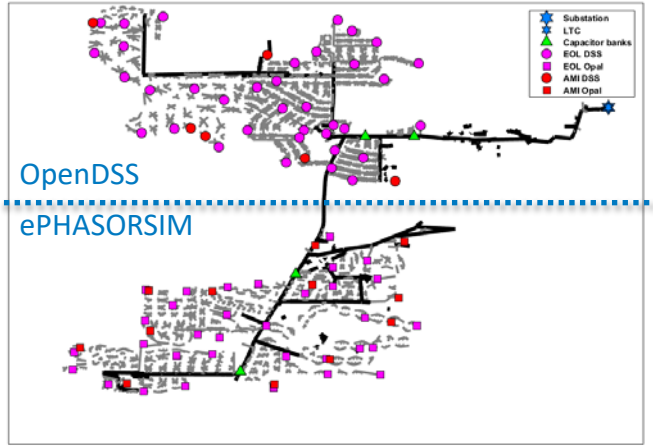
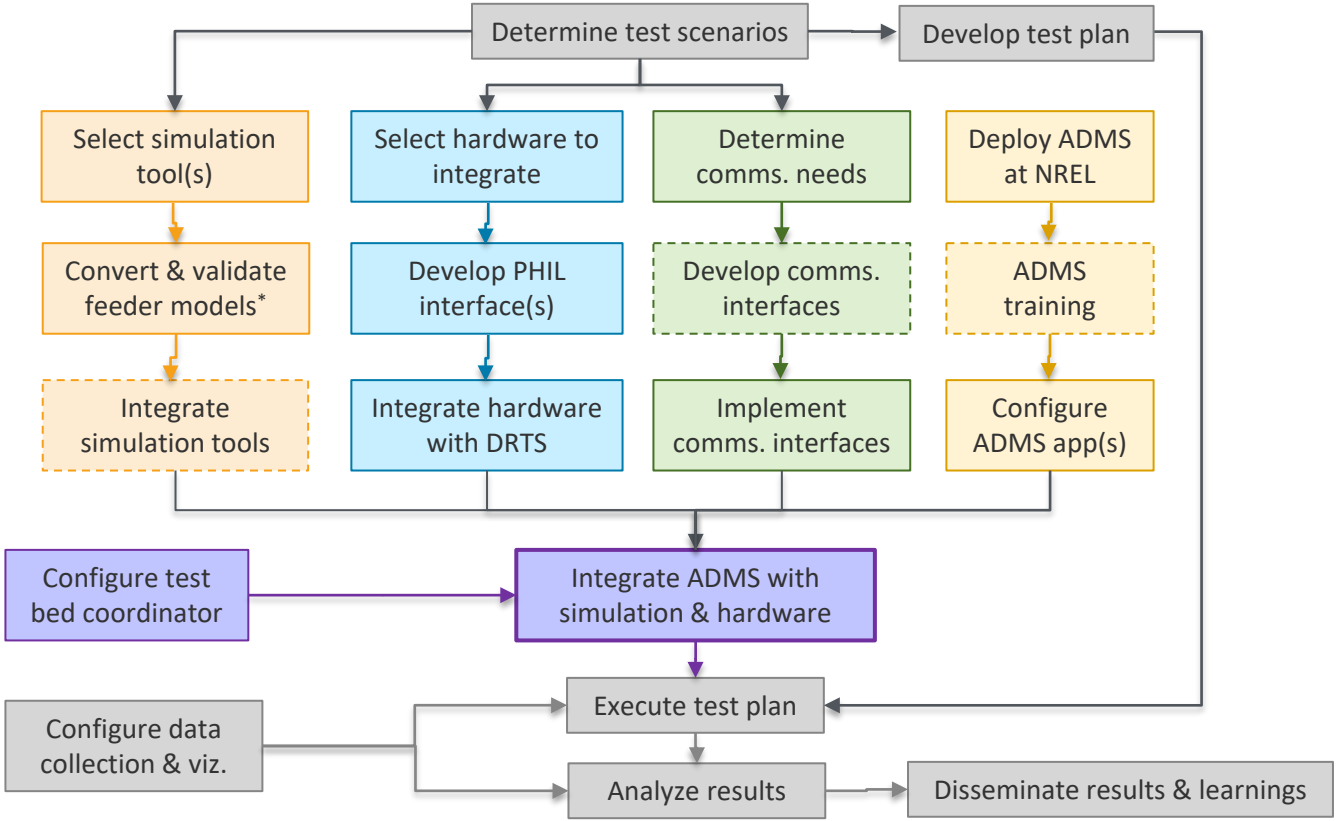
- Can run parts of a feeder in different simulators. Demonstrated:
  - OpenDSS and ePHASORSIM
  - OpenDSS and eMEGASIM.
- Orchestrated by test bed coordinator software:
  - Written in Python.
- Uses the Hierarchical Engine for Large-Scale Infrastructure Co-Simulation (HELICS) framework:
  - U.S. Department of Energy (DOE) investment through the Grid Modernization Initiative
  - www.helics.org.

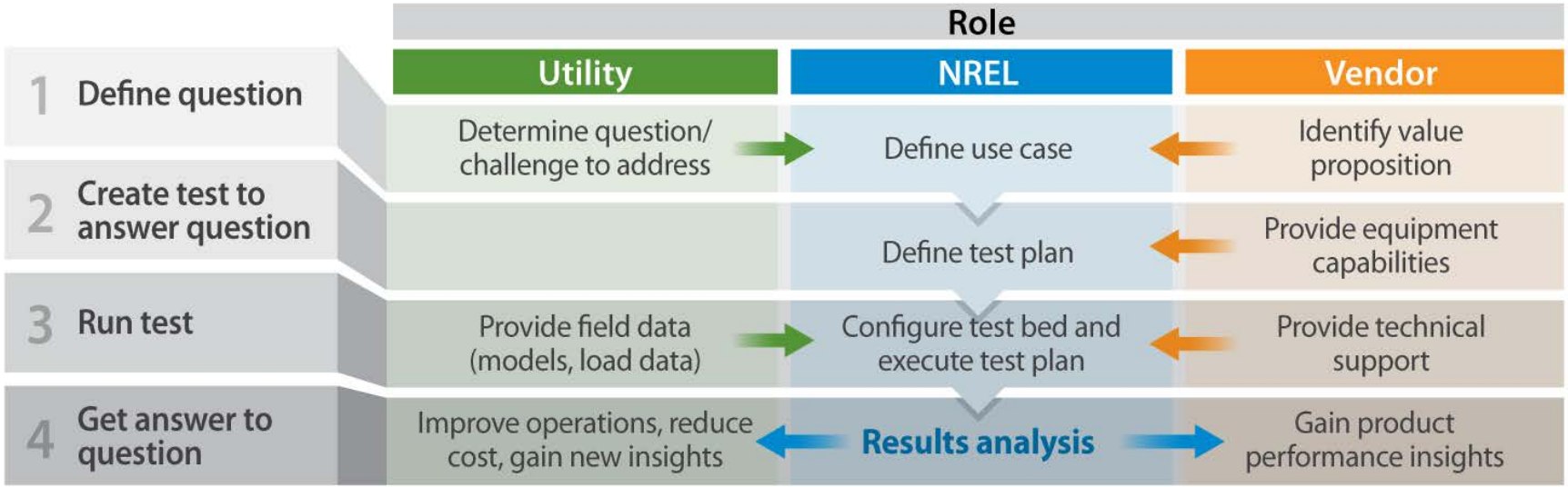




Configuring the Test Bed



* NREL's Distribution Transformation Tool (DiTTo): https://github.com/NREL/ditto.

ADMS Test Bed
Use Case Development

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