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

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

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Contract No. DE-AC36-08GO28308

Management Report
NREL/MP-5B00-87147
Revised January 2024

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Suggested Citation
Advanced Research on Integrated Energy Systems (ARIES) User Call for Advanced Distribution Management System (ADMS) Test Bed Vehicle-Grid Integration Use Cases. 2023. Golden, CO: National Renewable Energy Laboratory. NREL/MP-5B00-87147. https://www.nrel.gov/docs/gen/fy23/87147.pdf.

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Errata

This report, originally published in August 2023, has been revised in January 2024 to reflect that the deadline for proposal submissions moved from October 27 to February 16, 2024.

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Timeline:

- **August 23, 2023**: Advanced Distribution Management System (ADMS) Test Bed User Call release date
- **September 22, 2023:** Questions are due to userprogram.esif@nrel.gov.
- **October 2, 2023:** Webinar and Q&A session to address submitted questions
- **February 16, 2024**: Deadline for proposal submission by 5 p.m. Mountain Daylight Time (MDT)
- **March 2024**: Selection and announcement of awards (anticipated)
- Cooperative research and development agreements must be fully negotiated (including the joint statement of work) and ready for submission to the U.S. Department of Energy for approval within 120 days of selection or the selected project may be canceled.

Contact/questions: Email communications and questions to userprogram.esif@nrel.gov. Please note that all questions that are submitted and the respective answers will be posted to https://nrel.gov/aries/user-call.html (except for questions deemed unresponsive to the call).

Proposal submissions: Qualified partners are eligible to submit a proposal to this targeted Energy Systems Integration Facility user call. (See Section 4: User Definition and Eligibility.) To apply, submit proposals to userprogram.esif@nrel.gov by 5 p.m. MDT on October 27, 2023. When a proposal is received, a confirmation email will be sent within 2–3 days stating the date and time of receipt. Note: Email submissions are restricted to 20 MB total, including all attachments. (See Section 6: Proposal Package.)

Notification of selection: Once selections are finalized, applicants will receive an email from the National Renewable Energy Laboratory (NREL), and NREL will assign a principal investigator to each selected proposal to collaborate with the applicant on a joint statement of work.

1 Introduction

The National Renewable Energy Laboratory (NREL), sponsored by the U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE), is dedicated to transforming energy through the research, development, commercialization, and deployment of renewable energy and energy-efficiency technologies. NREL's mission is to advance the science and engineering of energy-efficiency, sustainable transportation, and renewable power technologies. NREL does this by providing the knowledge to integrate and optimize energy systems.

The Energy Systems Integration Facility (ESIF) is a national user facility located on NREL's campus in Golden, Colorado. As a DOE user facility, state-of-the-art capabilities in the ESIF are available to the research community at large to conduct research that advances the missions of EERE and NREL. The mission of the ESIF is to accelerate the efficient transition to future energy systems that are secure, resilient, reliable, affordable, and clean. As a national user facility, the ESIF is equipped with an operations team that facilitates safe access to laboratory capabilities used for mission-aligned research experiments.

NREL is issuing this user call to external research partners to identify projects that require using NREL's Advanced Distribution Management System (ADMS) Test Bed for vehicle-grid integration (VGI) use cases. The ADMS Test Bed is a key capability of NREL's Advanced Research on Integrated Energy Systems (ARIES),[1] a national research capability at NREL that addresses the challenges associated with integrating distributed energy resources (DERs) into the broader power system. ARIES encompasses capabilities at both the ESIF and the Integrated Energy Systems at Scale at NREL's Flatirons Campus.[2] Research at the ESIF supports up to 2 MW, which covers distribution-level testing. NREL's Flatirons Campus allows for research at the 20-MW scale and beyond, representing the interface between the distribution and bulk power levels.

The ADMS Test Bed was developed by NREL and the DOE Office of Electricity Advanced Grid Research and Development program through DOE's Grid Modernization Laboratory Consortium as a vendor-neutral evaluation platform for advanced grid controls implemented on ADMS platforms. NREL's ADMS Test Bed works to advance the Biden-Harris Administration's goals of transforming utility electric distribution management systems to enable the integration and management of all assets and functions across the utility enterprise regardless of vendor or technology. Located in the ESIF, the ADMS Test Bed is an evaluation platform consisting of software and hardware elements that realistically represent a power distribution system to a commercial or precommercial ADMS and/or other utility managements systems.

1.1 Collaboration With NREL

NREL seeks qualified partners to participate in collaborative projects. Each selected collaborative project will be conducted under a cooperative research and development agreement

[1] See https://www.nrel.gov/aries/.
[2] NREL's recently renamed Flatirons Campus is located near Boulder, Colorado. The campus is also home to NREL's National Wind Technology Center, which provides unique capabilities that support experiments, innovation, and technology validation that advance U.S. leadership in wind energy technology.

(CRADA) between NREL and qualified partners working on the project. To be eligible for selection, a proposed project must include at least one qualified partner. (See Section 4: User Definition and Eligibility.)

1.2 Objective

Through this user call, NREL seeks proposals to support DOE's goals and ARIES goals through projects that use the ADMS Test Bed. This user call focuses on VGI use cases. Joint partnerships between NREL and qualified partners will enable the integration of high levels of electric vehicles (EVs) in future energy systems by addressing one or more of the research areas identified in Section 3: Research Areas for ADMS Test Bed VGI Use Cases.

1.3 Funding Summary

The funding for the selected use cases are summarized as follows:

- Period of performance: Up to 15 months
- Estimated DOE funding available (for use at national laboratories): Up to $750,000 per use case
- Cost share: Federal funding must be cost-shared at 40%, including at least 20% funds-in, based on the total project value. All federal funds must be costed at national laboratories.

2 ADMS Test Bed Overview

This section provides an overview of the ADMS Test Bed and use case definition and execution.

2.1 ADMS Test Bed Description

The ADMS Test Bed is an evaluation platform consisting of software and hardware elements that realistically represent a power distribution system to a commercial or precommercial ADMS or other utility management systems, such as a distributed energy resource management system (DERMS) or EV aggregator. Its main elements are simulation; controller and power hardware that can be interfaced with the software simulation through the use of hardware-in-the-loop (HIL) techniques; and industry-standard communications interfaces, as shown in Figure 1.

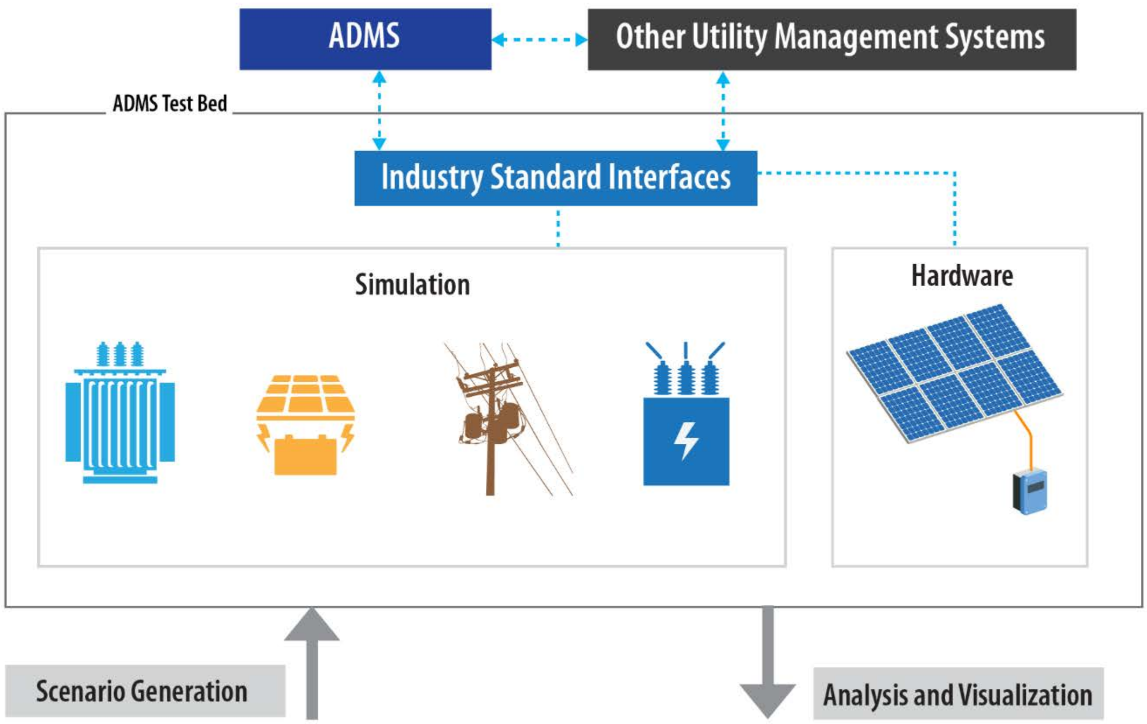

Figure 1. Overview diagram of the ADMS Test Bed

The software simulation environment acts as the real distribution system on which the ADMS or other utility management system operates. The simulation environment can combine quasi-steady-state simulations, phasor-domain simulations, and electromagnetic transient simulations. The Hierarchical Engine for Large-scale Infrastructure Co-Simulation (HELICS)[3] platform, developed by a consortium of DOE national laboratories, interconnects these simulation tools and integrates physical hardware.

Controller hardware and power hardware—such as photovoltaics (PV) and battery energy storage system inverters, grid-edge devices, EVs, and legacy utility control and automation equipment—can be linked to the simulated utility environment. Through integrating power

[3] See https://helics.org/.

hardware, researchers can evaluate how equipment interacts with the ADMS or other utility management system and validate software models for studies at scale.

Another essential element of the test bed is the ability for all simulated devices that interface with the utility management systems to communicate using an industry-standard communication protocol. Other energy management systems—such as microgrid controllers, home energy management systems, or building automation systems—can also be incorporated into the test bed, as needed, for specific use cases.

For each use case, a set of scenarios is generated that includes loading and solar insolation conditions, DER levels, and/or faults. These scenarios are then simulated and can be observed using real-time visualization tools developed for the test bed, and the data are also stored to enable analysis.

2.2 ADMS Test Bed Use Cases

NREL has previously partnered with different utilities, vendors, and other organizations to perform several use case studies. In one example, Holy Cross Energy partnered with NREL to use the ADMS Test Bed to test control algorithms that manage DERs to regulate distribution voltages, reduce peak demand, and provide more cost-efficient energy use for DER owners.

Following these experiments, the ADMS Test Bed was used to demonstrate the operation of NREL's real-time optimal power flow algorithms controlling DERs along with Holy Cross Energy's ADMS, provided by Survalent, controlling legacy equipment to reduce peak demand and, as a result, peak demand charges (Padullaparti et al. 2021).

Other use cases studied the impact of ADMS network model quality on Volt/Var optimization (Pratt et al. 2020); using advanced metering infrastructure data for grid operations (Wang et al. 2021; Netto et al 2021); the effect of DERs on fault location, isolation, and service restoration (Pratt et al. 2021); and DER controls strategies for transmission and distribution grid services. We are currently working on a federated DERMS approach use case. Through this user call, NREL seeks to identify future use cases of the ADMS Test Bed that will enable the integration of high levels of EVs in future energy systems.

We use a collaborative approach to define and execute the use cases in which we involve utility and vendor partners as stakeholders (Veda et al. 2017), as illustrated in Figure 2. The definition of a use case could start with a utility that defines an operational challenge that they want to address through an ADMS deployment. It could also start with a vendor that wishes to demonstrate the value of one of their applications under certain conditions. It could also be a combination of the two, i.e., a utility might be interested in evaluating whether a proposed vendor solution will address their operational challenge.

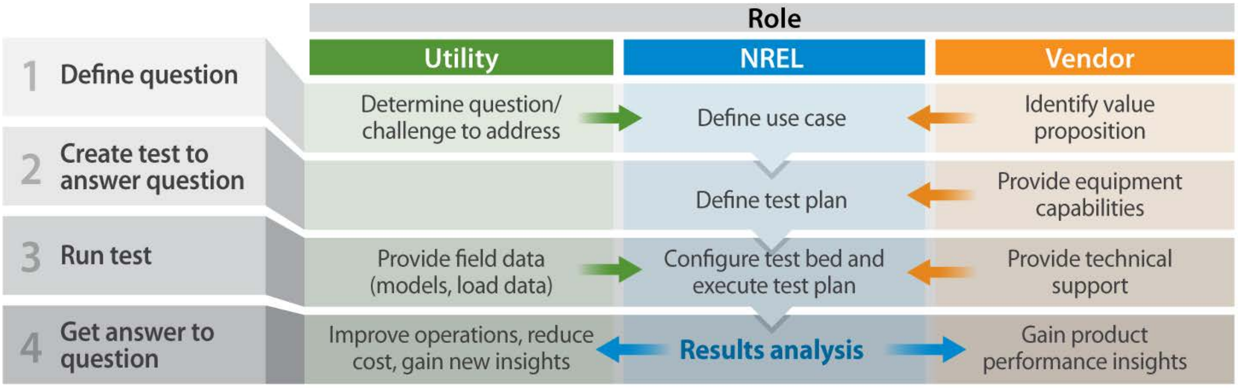

Figure 2. Use case definition and execution process

Once the use case is defined, we define a test plan and configure the test bed for the specific use case with inputs from the utility and vendor. These inputs typically include the ADMS platform, training on the use of the platform, and information on the equipment capabilities from the vendor, as well as distribution network models and historical field data from the utility. For a vendor-driven use case with the intent of showing the value of a new application, for example, we might choose to use synthetic feeders, i.e., anonymized, realistic feeders, such as those made available through the Advanced Research Projects Agency-Energy Generating Realistic Information for the Development of Distribution and Transmission Algorithms (GRID DATA) program,[4] or representative feeders provided by the Electric Power Research Institute. Upon execution of the test plan, we analyze the results and disseminate them to our partners and, to the extent possible, with proper anonymization in place, to the broader utility industry and academic power research community.

[4] See https://www.bettergrids.org/portfolio_category/griddata.

3 Research Areas for ADMS Test Bed VGI Use Cases

Applicants are encouraged to propose mission-aligned research that requires the use of the ADMS Test Bed at the ESIF that addresses the challenge of integrating high levels of EVs into the power system and incorporates at least one of four VGI research areas. Applicants may submit more than one proposal, and proposals may address more than one VGI research area. The four VGI research areas are:

- **VGI Research Area 1: Control architectures**—addresses control architectures and/or algorithms for systems with high levels of EVs and other DERs. The intent of this research area is to develop projects that evaluate emerging control architectures and/or algorithms on realistic power systems.
- **VGI Research Area 2: Role of DERMS and aggregators**—addresses ways to coordinate the operation of an ADMS with a DERMS and/or aggregators and the level of visibility that the ADMS requires into DERMS and/or aggregator operations to manage high levels of EVs and other DERs.
- **VGI Research Area 3: Integration with buildings**—addresses the evaluation of control and management solutions that specifically include vehicle integration with buildings (residential or commercial).
- **VGI Research Area 4: Communications architectures and cyber-secure data**—addresses the evaluation of EV control and management solutions that specifically include different communication architectures, protocols, and/or cyber-secure solutions.

Of specific interest are projects that align with the DOE Grid Modernization Initiative (GMI).[5] The GMI coordinates research and development across DOE to help set the nation on an affordable path to a resilient, secure, and reliable grid with a reduced environmental impact.

Proposals that address the following technical activities in the areas of system operations, power flow, and control are of specific interest:

- Architecture and control theory
- Coordinated system controls
- Enabling flexible generation
- Crosscutting initiatives.

3.1 Research Area 1: Control Architectures

Distribution operators need to prepare for a future electric grid with increased levels of EVs and other DERs, prosumers and microgrids, as well as new business models and services, some of which could be provided by third-party aggregators. This complex operating environment will require enhanced operating systems, platforms, and applications for the management of electricity. As the levels of EVs increase, distribution management system capabilities—including ADMS applications, DERMS, and EV aggregators—need to be updated to attain effective management of the electric power distribution system. This requires, at a minimum, visibility of the EVs and ideally some level (direct or indirect) of controllability. There is increasing consensus that a more distributed framework with a hierarchical control and

[5] See https://www.energy.gov/oe/downloads/gmi-updated-strategy-2020.

communication structure would provide more benefits toward the scalability of monitoring, control, and communications and the underlying computations for grid operation.

This research area addresses EV control architectures and/or algorithms for power systems with high levels of EVs and other DERs. The intent of this research area is to develop projects that evaluate emerging EV control architectures and/or algorithms on realistic (real or synthetic) power systems.

3.2 Research Area 2: Role of DERMS and Aggregators

EVs on distribution feeders typically have only local controls (such as delayed charging control) or are managed by EV aggregators. As the levels of EVs increase, a coordinated control strategy might be more appropriate between ADMS, DERMS, and third-party EV aggregators, some of which might provide virtual power plant services. Both DERMS and EV aggregators need to be integrated with utility distribution management systems when providing grid services to utilities.

This research area is intended to identify research that uses the ADMS Test Bed to address questions such as: What is the best way to coordinate the operation of an ADMS with a DERMS and/or EV aggregators? What level of visibility does the ADMS require into DERMS and/or EV aggregator operations? Systems with high levels of EVs also provide opportunities to use EVs to provide grid services, and projects in this research area could evaluate the management of EVs for the provision of bulk grid services.

3.3 Research Area 3: Integration With Buildings

Households and businesses are constantly installing new devices—e.g., EV chargers, rooftop solar, energy storage, smart appliances—onto the grid. As the number increases to the millions, new solutions and capabilities are needed to optimize distribution power management. There are also some disadvantaged communities that lag in their deployment of EVs and other smart devices; thus, use cases that address the benefits of technologies for future power systems in such communities are of high interest. As more of the transportation fleet is electrified, the impact on distribution systems will become significant. In addition to increased load and potentially generation, EVs are mobile and will move between different nodes within the distribution power system. Some commercial or industrial customers might also deploy fleets of EVs at the distribution level.

The intent of this research area is to develop projects that evaluate EV control and management solutions that specifically address vehicle integration with buildings (residential or commercial).

3.4 Research Area 4: Communication Architectures and Cyber-Secure Data

There is a complex industry-standard landscape for communications with EVs. Various standards have been used in this space, and communication standards can support different information models. The communication landscape gets even more complex when considering the various types of current and evolving communication network technologies and topologies and the associated protocols that could be used in a specific or new deployment, such as supervisory control and data acquisition, advanced metering infrastructure, and third-party networks. Interoperability is needed at all levels, and communication architecture advancements are needed to manage the complexity and to encourage interoperability while preserving data privacy.

The ability to handle the sheer number of communications and the massive amount of data also becomes a challenge; and as home, commercial building, and industrial energy management systems control energy consumption by managing EVs and other DERs (e.g., rooftop PV and local storage), and by shaving, shifting, and modulating loads, customer participation will increase through reliance on networked sensors and controls. These management systems also need to interface with power system service providers to optimize asset utilization for lower cost while maintaining reliability and resilience; therefore, with this increased access, cyber-secure solutions to new control strategies are critical to maintaining overall grid infrastructure reliability and resilience.

The intent of this research area is to develop projects that use the ADMS Test Bed to evaluate EV control and management solutions that specifically include different communication architectures and/or protocols and address questions such as: How do the proposed EV communications perform for different types of control and under different adverse system conditions? What is the impact of EV communication latency?

4 User Definition and Eligibility

Users are researchers who conduct experiments at or provide collaboration for an approved experiment in a DOE user facility. The primary type of user is an on-site, badged user (i.e., a researcher who conducts experiments that use laboratory capabilities in the facilities). Users are either NREL staff (including interns and postdoctoral researchers) or external users, such as industry partners, university researchers, and other DOE national laboratory or independent research facility staff.

External users can work in NREL facilities either independently or in collaboration with NREL researchers.

4.1 Eligible Applicants

- **Domestic entities:** For-profit entities, educational institutions, and nonprofits that are incorporated (or otherwise formed) under the laws of a particular state or territory of the United States and have a physical location for business operations in the United States are eligible to apply. Federally funded research and development centers (DOE/National Nuclear Security Administration and non-DOE/National Nuclear Security Administration entities) and federal agencies and instrumentalities are eligible to apply.
- **Foreign entities:** Foreign entities, whether for-profit or otherwise, are eligible to apply. All non-U.S. applicants, users, and funding sources must be approved by DOE before NREL will grant access to foreign entities or users.
- **Individuals:** Individuals are not eligible to apply.

4.2 Other Eligibility Requirements

- **Funding requirement:** Federal funding must be cost-shared at 40% of the total value of the project, including at least 20% funds-in. All federal funds will be provided to national laboratories, i.e., no federal funds will be provided to project partners. Required cost- share percentages are calculated based on the total value of the project, which is the sum of the DOE funds and the partner contribution provided to national laboratories. Cost shares may include cash or in-kind contributions, but for this user call, at least 20% of the total value of the project must be in the form of funds-in to national laboratories. For example, if the total project value is $500,000, 40% (or $200,000) must come from nonfederal sources, and at least $100,000 of that must be funds-in (i.e., cash contributions). In this example, DOE would provide $300,000 to the project. Cost shares from other DOE offices are not permitted.
- **Site security and safety:** All users must be qualified to conduct work in the ESIF and adhere to all onboarding and training requirements before access to the laboratory will be granted. Learn more about NREL's site security procedures, and review the *ESIF User Guide*.
- **Partnership agreement for applicants:** Please see NREL's Technology Partnership Program page for additional information regarding the CRADA and agreement process.
- **Requirement to share results:** Nonproprietary projects are eligible under this user call. Nonproprietary results and information must be shared for each project accepted through the user call.

5 Submission Information

Proposal packages for the user call will be accepted through February 16, 2024.

5.1 Applicants

Applicants must submit a proposal package that contains two (2) files:

1. An application that includes all sections described in Section 6: Proposal Package and adheres to all formatting requirements.
2. PowerPoint slide deck.

Email completed proposal packages to userprogram.esif@nrel.gov by **5 p.m. Mountain Daylight Time (MDT) on February 16, 2024**. The subject line of the email should read: ADMS Test Bed User Call - Organization, Contact Last Name (e.g., ADMS Test Bed User Call - NREL, Taylor). There is no limit to the number of proposals that an applicant may submit.

6 Proposal Package

The proposal package consists of two (2) files:

1. Application
2. Summary slide deck.

Templates are provided for the summary slide deck.

6.1 Proposal Format

Proposals should be no more than five (5) single-spaced pages (not including resumes and references) using 11-point font (Times New Roman preferred), should be in single PDF file format, and must include the following components under headings corresponding to:

- **Title page:** Include proposal title, co-principal investigator (co-PI), brief company description, and nonproprietary summary. Include name, nationality, address, phone number, and email address of the primary contact(s) for both contracting discussions and technical discussions (limited to 1 page, not counted in the 5-page limit).
- **1.0 Abstract:** Describe the specific product, component, algorithm, or process being developed, refined, or evaluated. Include how NREL's ADMS Test Bed is essential to execute the work.
- **2.0 Project description:** Describe the project in enough detail that it can be evaluated for feasibility; research impact; relevance to DOE, NREL, and ADMS Test Bed objectives; and appropriate use of national laboratory capabilities. Indicate the desired laboratory start date and duration of the experiments to be conducted.
- **3.0 Research & development approach:** Describe the approach, design of activities, and methods that will be used. Identify the research and development challenges that, if successfully addressed, will result in significant advances. Be clear about how the project will advance the state of the art.
- **4.0 Expected benefits & deliverables:** Describe the expected benefits to the research community, DOE, NREL, and the electric utility industry that would result from successful implementation of the project. List the deliverables and indicate whether there is an expectation to generate intellectual property or publication(s).
- **5.0 Equipment & resources:** Briefly state which critical equipment, resources, and ADMS Test Bed capabilities are required for the project. Include a description and specifications of any non-NREL equipment that would need to be brought to the ESIF.
- **6.0 Funding:** Provide a table describing all funding sources, amounts, and whether the funding has been confirmed/awarded or is pending an award decision. Clearly indicate what funding will be provided to national laboratory staff to support the project.
- **7.0 References & technical specifications:** In addition to references, proposals may include technical data sheets for devices, products, or software platforms planned to be brought to/deployed at the ESIF (not counted in the 5-page limit).
- **8.0 Team:** Single-page resumes of key project participants should be included (not counted in the 5-page limit).

6.2 Summary Slides

All proposal packages must include a summary slide deck that adheres to the template provided. The summary slide template files are provided as part of the document package attached to the solicitation on https://sam.gov.

6.3 Formatting

The page format for the application document comprises margins of 1 inch around the text (top, bottom, left, right), with the text at 11-point, single-spaced font in Times, Times New Roman, or appropriate symbol font (for math script). The provided PowerPoint template should be used for the summary slide deck.

- **Headers and footers:** To ensure that your proposal is clearly identified, please include header and footer information (within the top and bottom 1-inch margins) as follows:
  - Left header: proposal title
  - Left footer: Co-PI's name and organization
  - Right footer: page number.
- **Other notes:** Applications may contain embedded figures, but the entire document should be legible when printed. The inclusion of figures must not result in exceeding the page limit. The file name on each document should match and follow this format:
  - Organization name_co-PI last name.Project title
  - (i.e., NREL_Taylor.NextGenDERMS.pdf and NREL_Taylor.NextGenDERMS.ppt)

7 Review and Allocation Process

All eligible proposals will be evaluated by NREL technical research staff and management. To be considered, an applicant must meet all eligibility criteria and have an application package comprising all required materials.

Allocations of laboratory space, equipment, and other necessary resources will be made for up to 15 consecutive months from the laboratory start date. Extensions may be granted based on individual cases.

Table 1. Review and Allocation Timeline

User call solicitation announced, posted to SAM.gov	August 23, 2023
Questions are due to userprogram.esif@nrel.gov	September 22, 2023
Q&A session to address submitted questions	October 2, 2023
Submission deadline	February 16, 2024, 5:00 p.m. MDT
Review period	February 2024
Expected time frame for decisions	March 2024
Expected time frame for agreement negotiations	90–120 days
Allocation period of performance	Up to 15 months

8 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.

8.1 Criteria

Reviewers assess proposal packages and assign scores based on research impact, mission alignment, and whether the project contributes to the stewardship and overall strategy of the ADMS Test Bed.

8.2 Ratings and Weighted Scores

Table 2 provides a detailed description of the review criteria. Scores are weighted based on criteria and summed to generate an overall score for each proposal package.

Table 2. Review Criteria

Score	Mission Alignment	Research Impact	ADMS Test Bed Stewardship & Strategy
	20%	**40%**	**40%**
5 Excellent	Aligns with multiple specific GMI technical activities and clearly articulates how the project will advance the objective(s)	Likely of interest to most of the research community. Will change a paradigm with effects on multiple disciplines and/or market sectors. Very likely to produce intellectual property or lead to peer-reviewed publication	Effective crosscutting usage and addresses research areas as outlined. Uses multiple ADMS Test Bed capabilities. Very likely to enhance or expand ADMS Test Bed capabilities. Clearly builds on prior research outcomes, data, models, or lab configurations. Likely to engage a strategic partner for many years.
4 Very Good	Aligns with a single GMI technical activity and clearly articulates how the project will advance the objective(s)	Likely of interest to most of the research community. Will change a paradigm with effects on a single discipline and/or market sector. Likely to produce intellectual property or lead to peer-reviewed publication	Effective laboratory usage: Uses multiple ADMS Test Bed and crosscutting capabilities and addresses research areas as outlined. Very likely to enhance or expand ADMS Test Bed capabilities. Likely to build on prior research outcomes, data, models, or configurations. Likely to engage a strategic partner for the duration of the project
3 Good	Aligns broadly with NREL/DOE mission areas but does not articulate how the project will advance specific GMI technical activities	Likely of interest to a single discipline in the research community. Will change a paradigm with effects on a single discipline and/or market sector. Might produce intellectual property or lead to peer-reviewed publication	Uses a single ADMS Test Bed capability and addresses research areas as outlined. Might enhance or expand ADMS Test Bed capabilities. Might build on research outcomes, data, models, or configurations developed through prior projects. Might bring in a strategic partner
2 Fair	Relates to the NREL/DOE mission area but not to a specific GMI technical activity	Likely of interest to a single discipline in the research community. Will not change a paradigm with effects on any discipline and/or market sector. Not likely to produce intellectual property or lead to peer-reviewed publication	Uses a single ADMS Test Bed capability and addresses research areas to some extent. Not likely to enhance or expand ADMS Test Bed capabilities, build on prior research outcomes, data, models, or configurations. Not likely to engage a strategic partner
1 Poor	Does not relate to the NREL/DOE mission	Not likely of interest to the research community. Not likely to change a paradigm with effects on a discipline and/or market sector. Not likely to produce intellectual property or lead to peer-reviewed publication	Does not effectively use ADMS Test Bed capabilities and/or does not address research areas. Will not enhance or expand ADMS Test Bed capabilities, build on prior research outcomes, data, models, or configurations. Will not engage a strategic partner

8.3 Conflicts of Interest and Confidentiality

Every effort is made to avoid conflicts of interest. Reviewers are required to identify potential conflicts of interest on any projects they are requested to review. If a co-PI is concerned about a potential conflict of interest, the applicant should provide a summary of the potential conflict in the body of the submission email.

No proprietary information should be included in the proposal package.

9 Notification

Staff from NREL's ESIF User Program will communicate resource allocation decisions to all applicants. The identities of reviewers are kept confidential, but reviewer comments and composite scores might be available upon request.

10 Principal Investigator Responsibilities

The primary point of contact for the research project will be the PI, who will be an NREL staff member identified upon selection. Applicants should identify a co-PI who will be the primary non-NREL contact for the project. No limit is placed on the number of team members or potential laboratory users associated with a particular project.

Responsibilities of the co-PI during the proposal and review period are to:

- Submit a completed proposal package by the submission deadline.
- Ensure the accuracy of the proposal content.
- Respond in a timely manner to any requests or questions from NREL regarding the proposal.

Upon selection, the NREL PI will work with the co-PI to develop, negotiate, and agree on a detailed baseline execution plan.

Responsibilities of the co-PI after selection are to:

- Provide the necessary documentation to NREL's Technology Transfer Office to enable them to establish the appropriate agreement associated with the project.
- Support the PI in the development of an execution plan.

After receiving approval to use NREL's resources, the co-PI's responsibilities are to:

- Ensure that all users complete the necessary training to use the resources safely and securely.

During the project execution, the co-PI's responsibilities are to:

- Communicate changes in schedule, resource needs, or user access to the PI in a timely manner. The PI will then communicate with the ESIF User Program.
- Support the PI in providing a summary of results.
- Complete a user survey.
- Support the PI in sharing nonproprietary results publicly after the conclusion of the project.

11 Laboratory Operations Information

11.1 Resource Availability

NREL's resources are closely monitored, and every effort is made to minimize disruptions and maximize availability to users; however, regular maintenance, unanticipated issues, and failure of equipment might cause downtime. NREL's Laboratory Operations staff takes all precautions to minimize the impact of such events and communicates with users regarding these situations.

11.2 Business Hours

Laboratory Operations staff are available to monitor and manage systems and assist users during standard business hours, from 8:00 a.m.–5:00 p.m., Monday–Friday, except on holidays or special campus closures.

11.3 After Hours

Laboratory Operations staff also monitors systems outside of standard business hours; however, the center does not maintain an on-call rotation. If hardware or software breaks outside of standard business hours, resolution is not expected to start until the next business day.

Unattended operation is granted on the basis of individual cases and only after thorough safety and operational discussions.

12 Points of Contact

- ESIF user program: userprogram.esif@nrel.gov.

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Appendix. ESIF Overview and Capabilities

The U.S. Department of Energy (DOE) has established the Energy Systems Integration Facility (ESIF) on the campus of the National Renewable Energy Laboratory (NREL) in Golden, Colorado. The ESIF is a unique national asset that has the capability to catalyze the public- and private-sector research and development necessary to accelerate the commercialization and adoption of renewable energy and energy-efficiency technologies into today's energy systems where they can operate synergistically with other energy resources and technologies. A focus of this research is to demonstrate how advanced energy systems technologies can improve the overall reliability, resilience, and security of energy systems at an affordable cost.

ESIF Capabilities

The ESIF[6] provides integrated energy research capabilities across six indoor high-bay laboratories, three outdoor test areas, and associated control and visualization rooms. ESIF research is propelled by a novel electrical bus for controlled experimentation with both AC and DC lab assets and real devices. Covering power systems, grid controls, thermal systems, residential and commercial building applications, advanced vehicle interfaces, hydrogen storage and use, and power electronics and grid technologies, the ESIF offers one of the world's most diverse concerted energy technology integration portfolios. Electric power systems and devices up to 2 MW (AC and DC) are supported, including 13.2-kV distribution research connections, 1-MW electrolysis, +600-kg hydrogen storage, hydrogen vehicle fueling, and combined heat and power turbines. Communication and cyber technologies at the ESIF leverage expertise and advanced emulation tools for true system operation scenarios, helping to move technology toward the secure, efficient, and affordable energy system of the future. Further discussion of the ESIF's capabilities can be found in the ESIF annual reports.[7]

ADMS Test Bed

The Advanced Distribution Management System (ADMS) Test Bed is a national, vendor-neutral evaluation platform funded by the DOE Office of Electricity Advanced Grid Research and Development Program to accelerate industry development and the adoption of ADMS capabilities. The test bed enables utility partners, vendors, and researchers to evaluate existing and future ADMS, distributed energy resource management systems (DERMS), and other utility management system applications in a realistic laboratory environment.

The ADMS Test Bed consists of software simulations of distribution systems and field equipment integrated through hardware-in-the-loop (HIL) techniques that realistically represent a power distribution system to a commercial or precommercial ADMS, as shown in Figure A-1.

[6] See https://www.nrel.gov/esif/integrated-energy.html.
[7] See 2017: https://www.nrel.gov/docs/fy18osti/70906.pdf; 2018: https://www.nrel.gov/docs/fy19osti/73025.pdf; 2019: https://www.nrel.gov/docs/fy20osti/75862.pdf; and 2020: https://www.nrel.gov/docs/fy21osti/79354.pdf.

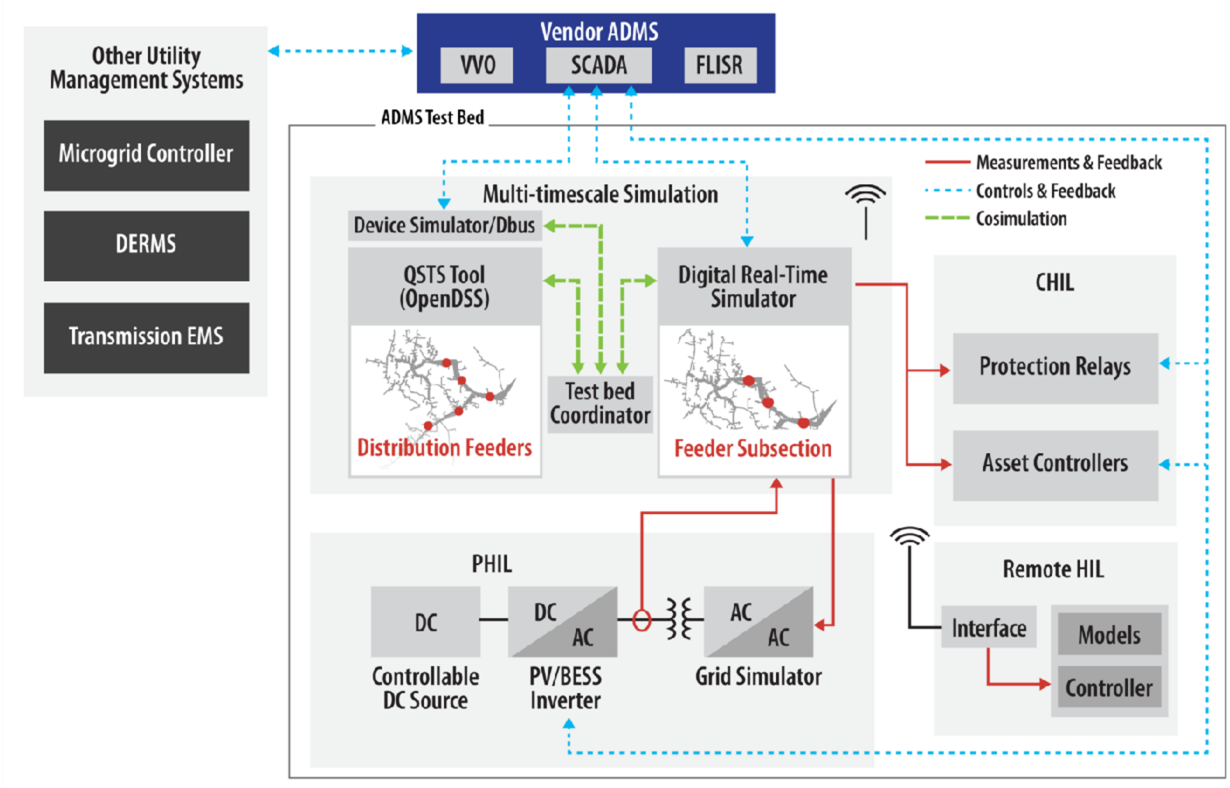

Figure A-1. ADMS Test Bed capability

An ADMS is interfaced to the test bed using industry-standard communication protocols—such as Distributed Network Protocol 3 (DNP3), International Electrotechnical Commission (IEC) 61850, and the Institute of Electrical and Electronics Engineers (IEEE) 2030.5—so it can be deployed as it would be in a utility environment. Other utility management systems—such as a microgrid controller, DERMS, or transmission energy management system—can also be integrated through protocols such as MultiSpeak and Inter-Control Center Communications Protocol (ICCP).

The multi-timescale simulation environment will act as the real distribution system on which the ADMS operates. The simulation environment is capable of performing quasi-steady-state time-series (QSTS) simulations, phasor-domain simulations, and/or electromagnetic transient (EMT) simulation studies. We use OpenDSS for QSTS simulations of systems with tens of thousands of nodes and several substations, and we can use either RTDS or OPAL-RT digital real-time simulators for phasor or EMT simulations of hundreds to several thousand nodes. Different simulation tools are coordinated through a test bed coordinator using the Hierarchical Engine for Large-scale Infrastructure Co-Simulation (HELICS), an open-source, cyber-physical energy co-simulation framework for electric power systems. The test bed can also integrate simulations of end-use loads in buildings using NREL's Object-oriented Controllable High-resolution Residential Energy (OCHRE™) (Blonsky et al. 2021) tool as well as home energy management system controllers with the distribution system simulation.

Controller-hardware-in-the-loop makes it possible to evaluate controller hardware—including legacy equipment (such as capacitor bank, load tap changer (LTC), and line voltage regulator controllers) and newer devices (such as smart meters)—when testing at actual scale or power levels is not required or possible. Power-hardware-in-the-loop (PHIL) links actual power system equipment—such as photovoltaic (PV) and battery energy storage system inverters, grid-edge devices, and legacy utility control and automation equipment—to a lab-simulated utility environment. With PHIL, researchers can test how equipment interacts with the ADMS at scale and validate software models. The megawatt-scale PHIL capability at the ESIF allows NREL researchers and partners to integrate multiple hardware devices, each with a separate simulated point of common coupling using multiple bidirectional AC grid emulators. Each point of common coupling has independent phase control that enables the recreation of a variety of grid scenarios, such as voltage sags/surges and the complete loss of a single phase or multiple phases. The AC grid emulators are interfaced with either OPAL-RT/RT-Lab or RTDS/RSCAD real-time simulation platforms. NREL has also developed approaches to conduct HIL experiments in real time with commercially available power systems simulation software, such as OpenDSS. The picture of the ADMS Test Bed in Figure A-2 shows a couple different ADMS user interfaces, a digital real-time simulator, and controller and power hardware.

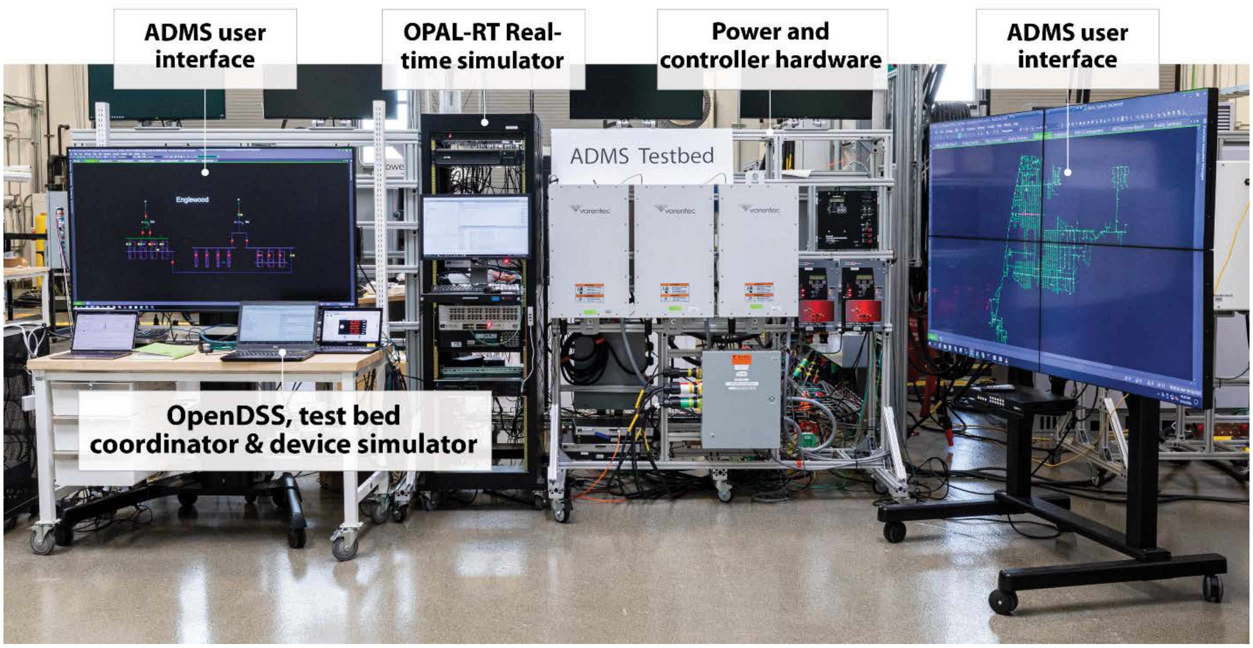

Figure A-2. Photograph of ADMS Test Bed setup

Researchers and partners can make use of NREL's advanced visualization capabilities, including 3D visualization, to analyze and present results from the test bed.

Open-Source Platform and Applications for ADMS

NREL partnered with the Pacific Northwest National Laboratory to build an open-source ADMS platform, GridAPPS-D[8], that will accelerate the deployment of ADMS technologies to address the operational challenges faced by distribution utilities. GridAPPS-D has been designed to provide a services-based platform that supports the development of applications. GridAPPS-D

[8] See https://www.gridapps-d.org/.

provides a reference architecture and implementation that can be used by others to implement similar application development tools or to adapt existing systems or create new ones for the operational deployment of applications that comply with standards. Researchers, utilities, and vendors can use this open-source platform to develop, test, and adopt functionalities tailored to their needs without the burden of implementing full-scale ADMS systems.

GridAPPS-D has been integrated with the ADMS Test Bed to evaluate the performance of a novel ADMS voltage regulation application, as described earlier. The GridAPPS-D platform and some of its open-source, advanced distribution applications are available for future use cases.

Existing applications include real-time distributed energy resource dispatch, short-term grid forecasting, and intra-hour solar forecasting.

High-Performance Computing

The ADMS Test Bed can also take advantage of the high-performance computing capability at the ESIF[9] to emulate larger systems. One example is the federated DERMS for high-PV systems use case, where high-performance computing is used to enable real-time co-simulation of the power system with many homes that have home energy management systems. Kestrel is the newest high-performance computing system at NREL, and it is configured to run compute-intensive and parallel computing jobs. It is a cluster comprising 2,436 nodes (servers), and user-facing log-in and data analysis and visualization nodes will use Red Hat Enterprise Linux. Compute nodes will use Rocky Linux. The system uses a high-speed, 200-gigabit (Gb)/s Hewlett Packard Enterprise (HPE) Slingshot interconnect. All compute nodes will be connected to the high--performance HPE Slingshot 11 fabric in a dragonfly topology. In the case of the accelerated nodes, each node will have two 200-Gb/s network interface cards to the interconnect.

The parallel file system (PFS) ProjectFS and ScratchFS on Kestrel is a ClusterStor Lustre file system intended for high-performance input/output. ScratchFS uses a Lustre file system in a hybrid flash-disk configuration providing a total of 27 petabytes (PB) of capacity with 354 GB/s of IOR bandwidth. ProjectFS will provide 68 PB of capacity with 200 GB/s of IOR bandwidth. The Home File System (HFS) on Kestrel is part of the ClusterStor used for PFS, providing highly reliable storage for user home directories and NREL-specific software. HFS will provide 1.2 PB of capacity. Snapshots of files on the HFS will be available up to 30 days after change/deletion.

Communication Network Emulation

The ADMS Test Bed can be interfaced with a communication network emulation, originally developed for NREL’s Cyber-Energy Emulation Platform (CEEP), to allow researchers to model the telecommunications network and to visualize and evaluate the interdependencies of power systems and network communication flows. A conceptual diagram of such a setup is shown in Figure A-3.

NREL is also developing a research-focused network communication capability, Grid Research End-to-End Network Communications (GREEN-C), within the ESIF that aims to facilitate the interconnectivity and accessibility of virtual and physical assets at the communication layer.

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[9] See https://www.nrel.gov/hpc/.

GREEN-C will serve as a management plane (fabric/underlay) for asset administration as well as a user plane (experiment/overlay) for user-defined networks. GREEN-C leverages cyber network emulation capabilities that include virtual machine environments, protocol translation, cloud interfaces, and remote connectivity. The physical network connections are in place, and connectivity to hardware could be established and the virtual environments set up as needed for integration with the ADMS Test Bed for selected use cases.

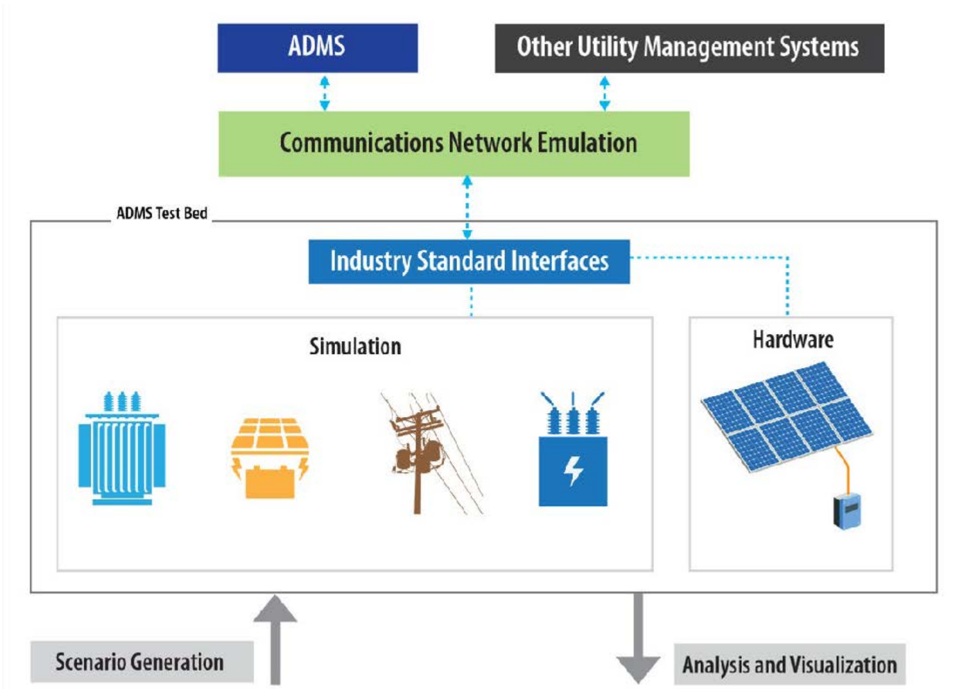

Figure A-3. ADMS Test Bed interfaced with NREL's communication network emulation

Cyberattack Simulation

Analysts can perform threat and consequence attack scenarios for distribution-level cybersecurity evaluations to safely explore cyber vulnerabilities and mitigation effectiveness. Researchers can launch attacks in the virtual world on both emulated and actual physical devices, such as a remote terminal unit that is linked to a residential solar system inverter, and evaluate how they would respond to an attack in the real world. Researchers defending the virtual world can then try to identify the cyberattack and implement mitigations, both manual and autonomous, to keep the system running. From there, researchers can assess the large-scale implications of an attack on an emulated electric grid. Some use cases might also benefit from NREL application developers that work to continually improve the security, analysis, and detection tools needed to better analyze and respond to attack scenarios on our current and future energy systems.