

ARIES2021

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Message from the ARIES Leadership Team

The world is embarking on an unprecedented energy transition, and every day brings a reminder that we must act fast. Another blackout from a storm or a sobering statistic about the global impacts of our energy use reminds us that change is here. We need clean and resilient energy systems right now, and that will require an accelerated path from breakthrough to real-world deployment. The Advanced Research on Integrated Energy Systems (ARIES) research platform at the National Renewable Energy Laboratory (NREL) is the United States' most powerful research capability to support the transition to a clean energy future. And in its first full year of operation, it is already delivering results.

To develop better transportation practices, ARIES has been at the center of an extensive collaboration to modernize ports, creating a virtual replica of transit hubs for owners to optimize energy efficiency and reliability. To support widespread renewable energy generation, ARIES is proving how multiple resources can work together as a hybrid power plant. Major manufacturers and power providers are using the results for their own hybrid energy activities. To improve energy storage options, ARIES is optimizing new designs for thermal and electrochemical behind-themeter storage systems.

Upcoming semiconductor technologies could open entirely new resilient architectures for power distribution at scale. With ARIES, researchers can drop such devices into a replica electric system, showing how they could be incorporated into modern operations. Likewise, as cybersecurity threats evolve in energy systems, ARIES provides an integrated physical-digital domain for next-generation specialists to hone advanced cyber defenses.

Results from early ARIES projects are only the tip of the iceberg. Although ARIES has achieved exciting demonstrations during the past year, we see greater opportunities and needs as we commit completely to the clean energy transition. As more groups partner with us, and as we further develop ARIES capabilities, we expect that this unique research-and-development platform will provide the guiding light for clean, efficient, and resilient energy everywhere.

Sincerely,

ennifer Kurtz, ARIES Director

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Johney Green, Associate Laboratory Director for Mechanical and Thermal Engineering Sciences

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Vision

The swift transition toward a clean and sustainable energy future demands new ways of generating, integrating, and delivering the energy we all rely on. The Advanced Research on Integrated Energy Systems (ARIES) research platform will validate the tools we need for a full-scale clean energy transition. As the U.S. Department of Energy (DOE) pursues ambitious clean energy goals, ARIES is conducting critical research that supports those goals.

ARIES is the nation's most advanced platform for clean electric grid integration research and validation. It is a digital-physical ecosystem that extends beyond the National Renewable Energy Laboratory (NREL), connecting other national laboratories and research partners globally.

ARIES research addresses these key challenges:

- Variability in the physical size of new energy technologies being added to energy systems
- · Securely controlling large numbers (millions to tens of millions) of interconnected devices
- Integrating multiple diverse technologies that have not previously worked together.

Making progress on these challenges will be critical to advancing future innovations and to making the energy grid of the future a reality. The five research areas studied collectively within ARIES are:

- Energy storage
- Power electronics
- Hybrid energy systems
- Cybersecurity
- Future energy infrastructure.

This report details the major accomplishments across all five research areas during ARIES' first year of operation. Learn more about the NREL facilities that make ARIES research possible:

Advanced Computing Annual Report

Energy Systems Integration Facility Annual Report



needs for clean and secure energy systems.

Clean Energy Goals

sector by 2035

ARIES supports DOE's clean energy goals, including putting the United States on a path toward a carbon-free electricity sector by 2035 and economy-wide, net-zero greenhouse gas emissions by 2050. ARIES research areas strongly align with and support decarbonizing the economy, with a focus on environmental justice, workforce development, and state and local partnerships.



sector

Who We Work With: Impact with DOE and Industry

under a single project. In Fiscal Year 2021, key partners

sector



4. Reducing the carbon footprint of buildings across the nation



5. Enabling a net-zero agricultural sector, proviing savings to farmers and rural communities across the country

ARIES RESEARCH HIGHLIGHTS

ENERGY STORAGE

Digital Twin Capability Provides Customized Approach to Port Modernization

Dallas/Fort Worth International Airport (DFW) is the fourth busiest airport in the world, and its air traffic is forecasted to double in the next 20 years. The airport is seeking strategies to update its infrastructure to become one of the world's cleanest and most energy-efficient hubs. NREL and DFW are engaged in a multitude of efforts that lean on the capacity of ARIES to render and to visualize that energy transition. With a digital twin of DFW operations, researchers have allowed the airport to carefully consider the effects of investments and decisions on passenger experience, energy use, and airport revenue before committing to a particular approach.

The DFW digital twin leverages a larger effort, called Athena, funded by the DOE Office of Energy Efficiency and Renewable Energy (EERE) Vehicle Technologies Office. Athena aims to create an interactive analysis environment powered by NREL's supercomputer and customized with data from actual airport activities. The virtual environment integrates models of traffic flow, socioeconomic behavior, and energy use so that ports can parse through the complexity of their own operations.

The initial application with DFW is helping to frame the topics that will influence future port operations, such as autonomous and electric vehicles (EVs), congestion, ride-hailing companies, building energy efficiency, and shuttle route optimization. The digital twin relates these factors to the overall impacts on energy, comfort, and costs. In one use case, NREL and partners

are identifying behind-the-meter storage options that blend building efficiency measures and vehicle fast charging to dramatically reduce energy costs. The strategy integrates thermal and battery energy storage solutions, in addition to all-system efficiency improvements, in an innovative approach for cost and energy savings.

Digital twin research with major U.S. ports is revealing that large transportation hubs can transition to clean energy without increasing passenger travel times or operating costs. In fact, NREL and DFW have found that making even small changes to existing transit routes can substantially reduce energy use. For the first time, data science and modeling and analysis are providing the world's busiest hubs clear insights to help guide 20-plus-year investments in clean energy and efficiency.



DOD Develops Renewable Microgrids Through ARIES Emulation

The ARIES platform is hosting participants in a technology acceleration program funded by the U.S. Department of Defense (DOD) Environmental Security Technology Certification Program (ESTCP). The program pairs startups and energy mainstays to advance storage and microgrid solutions from concept to industry application. ESTCP offers technical assistance in the form of rigorous sink-or-swim validation rounds.

This past fiscal year, 2021, involved the first ESTCP cohort—a The plug-and-play environment of ARIES allows industry mix of large energy research organizations (such as Ameresco, participants to quickly ramp up their real-world experience and Arizona State University, Cummins, S&C Electric Company, and vet their technologies against the challenges of true resilience Raytheon) paired with smaller, early-stage organizations that events. Results of the program are being released to the public, are proposing new technological energy storage approaches to allowing entities with critical loads to incorporate the latest energy resilience. Future cohorts will continue the program as solutions for energy resilience. current participants graduate to real-world deployment.

NREL hosted the program's first cohort, creating elaborate validation sites for multiple phases of experimentation. In the most rigorous phase, NREL created a mock military base modeled after DOD's Naval Air Station Patuxent River. On a scaled replica of the air base, participants plugged in their microgrid controllers, energy storage solutions, and other resilience-

Hydrogen Hardware Smooths **Demand from Electric Vehicle** Charging

Electrolyzers are less sensitive to changes in power supply than other loads, making them a potentially useful technology to balance more jumpy loads, such as EV charging stations. The DOE EERE Hydrogen and Fuel Cell Technologies Office is advancing pathways for electrolyzers to facilitate clean hydrogen production while balancing the variability of modern energy assets. In one approach, researchers are using a 750-kW electrolyzer integrated with other ARIES hardware to show that grid-scale electrolyzers can reduce the uncertainty of EV charging demand.

enhancing technologies to see whether the technologies could support the base through long-lasting outages. The participants who succeed in powering the ARIES system will stage their technologies at a real DOD base for live deployment.

DOD is not the only entity that stands to gain from improving

critical infrastructure resilience. Hospitals, universities, and first-

response organizations, among others, need technical guidance

to invest in the most resilient technologies for their sites-which

could make the difference between lives saved and lives lost.

the trials of a true emergency from the safety of the lab.

With ARIES, critically resilient technologies can now experience

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Watch: Step inside this project to learn more.

In the validation, the ARIES electrolyzer was powered by simulated scenarios in which EV charging units were operating in the same distribution network. The electrolyzer's function was to fill in the gaps of EV charging so the utility sees a smooth, consistent load coming from the combined electrolyzer-EV charging system. In experiments that varied the number and power demand of EV chargers, researchers showed that the commercial electrolyzer could follow the erratic demand of EV charging, effectively smoothing the overall demand while generating hydrogen for other applications.

Findings from the project are important for the emerging topic of hydrogen-grid integration: If an electrolyzer can accommodate EV charging, it could be used alongside other resources that have dynamic power demand or supply, such as nuclear power, alternative fuel production, and wind.

POWER **ELECTRONICS**

ARIES Assets Support First-Ever Example of Grid-Forming Wind Turbines

As renewables comprise an increasingly larger share of the power supply, they are also taking a larger share of responsibility as stewards of grid stability, a service traditionally provided by fossil-fueled generators. NREL is helping to make the transition to renewably sourced stability seamless by designing and demonstrating new controls for renewable technologies. In a wind industry breakthrough, NREL and partner General Electric (GE) have shown grid-forming controls—the capability to supply fundamental stability and stand-alone power to the grid-for Type 3 wind turbines, an especially common turbine technology.

NREL operated the grid-forming turbine on its campus using controls from GE and simulated power flow from ARIES assets. The demonstration was part of the DOE EERE Wind Energy Technologies Office project WindVSG: Wind as a Virtual Synchronous Generator, which aims to equip wind and storage power inverters with controls that electronically imitate the stabilizing features of conventional generators. Incoming energy devices—such as wind, solar, and battery energy storage—are interfaced with power electronics, which can be programmed for a variety of more versatile operations. WindVSG is working to establish next-generation controls, which include grid-forming capabilities, so power systems can more quickly achieve stability from renewable resources.

Grid-forming controls could allow wind turbines to fulfill a much wider role on the electric grid, including the ability to blackstart following an outage, to set the underlying grid frequency and voltage, and to provide fundamentally critical stabilizing services—all of which open new value streams for wind and hybrid power plants. Further work using ARIES to validate the grid-forming operation is underway; NREL and GE are now assessing the mechanical stress on the turbine.

WindVSG is one chapter of a DOE-wide focus to redefine the role of power electronic devices, drawing on the full capabilities of these new, advanced technologies. ARIES offers a space for both prototyping and real-system proofs. One additional ARIES capability developed in FY 2021 is a tool kit to rapidly characterize power electronic technologies so researchers can understand their detailed electronic behavior and, as a result, design more reliable interfaces with the electric grid.

ARIES Sparks Forward-Thinking Alternative to Power Distribution with Compact Medium-Voltage **Converters**

An ARIES initiative is spearheading a technology that could fundamentally redesign the electric grid. With support from the DOE EERE Advanced Manufacturing Office, NREL is working with several partners to develop medium-voltage, back-to-back converters. The project is called Grid Application Development, Testbed, and Analysis for Medium-Voltage Silicon Carbide (GADTAMS), and it is targeting a game-changing solution for renewable integration, grid resilience, and adaptability.

GADTAMS proposes a hardware solution to reliably integrate more distributed energy resources: compact power converters separating areas of the medium-voltage grid so that independent sections can flexibly become microgrids as needed. But instead of the heavy, impractical converters on offer today, the GADTAMS converters will be one-fifth the size and onetenth the weight, and they will allow advanced controllability. The power electronic devices could provide a new underlying



structure to distribution grids, enabling networked microgrids that strengthen and stabilize power flow. Once ready for real-world deployment, GADTAMS converters could intersect distribution sections, creating unprecedented flexibility and controllability.

NREL is working with an industry manufacturer and two university research teams to engineer a prototype device. Once complete, the converter can be plugged into an ARIES power electronic test bed to evaluate its anticipated flexibility. With ARIES, the GADTAMS project team will collect baseline operational data to jump-start the conversation around using medium-voltage converters for future grid designs.

GADTAMS will rely on ARIES to implement a concept that does not yet exist anywhere else. Along the way, project results will inform industry standards related to microgrids and distributed energy resource integration. If successful, the compact converter technology could lead a dramatic change in grid infrastructure, creating an electric distribution system that is designed for the advanced capabilities of modern power electronic devices rather than the legacy products of the past.

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HYBRID ENERGY SYSTEMS

ARIES Validates Hardware for National Initiative on Hybrid **Renewable Power Plants**

NREL is leading a coalition of national laboratories and industry partners in creating the next generation of power plants: hybrid plants that combine renewable and conventional resources. The project, called Clusters of Flexible PV-Wind-Storage-Hybrid Generation, or FlexPower, is part of the DOE Grid Modernization Initiative.

FlexPower is using ARIES infrastructure to validate hybrid controls on the full range of energy resources, including hydroelectric and thermal generation, and on novel technologies spanning energy storage and power-to-gas. In one example, researchers implemented a fast-response controller for managing various forms of power injection from hybrid plants. The fast controls were designed to be functional for almost any mix of generation and storage technologies, and they are undergoing validation in a wide variety of hybrid power plant configurations that are made possible by ARIES. These advancements allow hybrid power plants to provide greater functions on the grid, beyond the abilities of traditional generation.

Results from the project could allow industry to increase the value of renewable investments by bestowing modern resources with the flexibility to participate in new ways on the electric grid. Rather than being simple sources of power generation, renewables and hybrid power plants can now offer more complex grid support, such as frequency stability and standalone resilience.

FlexPower reflects an expanding role for new energy resources: With the right controls, renewables—or a blend of renewables and other technologies—can access new value streams as sources of grid stability and power conditioning. Already, FlexPower strategies to expand the role of solar have been used in Chile for procuring power reserves. As regulations and policies promote more versatility from renewable and hybrid power plants, FlexPower is readying the necessary controls for quick and reliable deployment on real systems.



ARIES Is Helping Maui Prepare for 100% Renewable Energy

Through 2024, the Hawaiian island of Maui is scheduled to bring more megawatts of renewable power online than ever before. With such high proportions of solar photovoltaics (PV), wind, and battery energy storage, Maui will operate without any conventional synchronous generation for some hours of the day, a probable first for interconnected electric transmission systems anywhere.

In support of the island's 100% renewable energy transition, and with support from the DOE EERE Solar Energy Technologies Office, NREL and Hawaiian Electric Corporation are developing operational tools as well as designing and implementing a replica Maui system with ARIES assets. The goal is to understand the effects of transitioning to high- and allrenewables operation.

One such tool is MIDAS, the Multi-Timescale Integrated Dynamic and Scheduling framework, allowing the local utility to manage dispatch on energy systems with higher shares of renewables. The MIDAS framework will bolster inverter-based resources, such as wind, solar, and storage, in providing frequency and voltage stability for low-inertia electric

Scalable Method for 100% **Renewables Systems Emerges from Surprise NREL Outage**

Not long after upgrading its ARIES infrastructure to allow higher-power research, NREL experienced an equipment failure that caused a campuswide blackout on the Flatirons Campus. With NREL research showing that renewable resources can provide fundamental power system resilience, the blackout offered an opportunity to prove it.

Within 1 week of the blackout, NREL researchers customized a guickand-ready microgrid configuration using an on-site wind turbine, a utility-scale solar PV array, and a large lithium-ion (Li-ion) battery. In the interest of time, and because of the lack of a preconfigured microgrid controller, the researchers installed simple, reproducible controls on each renewable device—controls that could be easily implemented on most modern devices. With the distributed controls, NREL's renewable microgrid managed to black-start the campus and maintain stable power until the failed equipment could be replaced. Though unplanned, the demonstration proved that an all-renewables system could provide fundamental resilience and stability for future grids, and it presented one example of how this is possible.

grids—services that are becoming more important as renewables displace traditional sources of grid stability. For Maui and many other grid operators, MIDAS can help to evaluate the trade-offs of dispatching renewable (and nonrenewable) assets-trade-offs such as the cost of electricity and the need for stability, which are relevant for sub-second operations, day-ahead scheduling, and years-ahead planning.

As part of this project, NREL has modeled Maui in detail, defining the entire island's transmission system at a sub-second scale. NREL also developed several future scenarios that capture different concentrations of renewables, eventually reaching 100%. By running the scenarios, researchers affirmed that PV, wind, and batteries alone, with grid-forming battery controls, could provide fundamental stability on the island at any concentration of renewables. MIDAS surfaced other concerns related to protection system operation and resource adequacy, which still need to be addressed.

As Maui's objective to achieve 100% renewables approaches reality, MIDAS and ARIES demonstrations will provide a useful tool kit to derisk planning and operations for other utilities shifting to renewable resources.

Following the 100% renewables recovery, NREL researchers showed the broader potential of the distributed controls of renewables. On a simulated system thousands of times larger, using the same renewable resources (wind, solar, battery energy storage) and controls, the NREL researchers ran scenarios of high renewables and 100% renewables operation, demonstrating how the makeshift microgrid controls could scale to much larger systems and be adapted to different resource mixes. Importantly, NREL's method required no communications and no centralized coordination—an approach that could substantially reduce exposure to cyber threats and could be easily ported to other systems.

NREL's fast-thinking fix to restore power with renewables was an early example of a larger ARIES research effort—the Universal Interoperability for Grid-Forming Inverters consortium, announced in FY 2021-which is developing methods for renewables to provide all-around stability and resilience on the electric grid. The consortium will combine input and capabilities from dozens of public, private, and academic organizations to demonstrate solutions for large and small power systems that are reaching higher penetration levels of renewable generation.



Watch: See how ARIES is demonstrating power system resilience with 100% renewable grids.

CYBERSECURITY

Clean Energy Cybersecurity Accelerator Speeds Cyber Innovation

In October 2021, NREL and DOE announced the launch of the Clean Energy Cybersecurity Accelerator (CECA), a technology partnership comprising federal experts, industry partners in the energy sector, and innovators to accelerate the deployment of new cybersecurity solutions for the nation's evolving grid.

As the United States works toward a zero-emissions future, innovators and industry must tackle the increasing number of cyber threats to the U.S. energy sector. New grid devices are rapidly being connected, and although this benefits consumers through choice, opportunity, and clean energy resources, such innovations can expose risks and vulnerabilities that are not yet well understood. With private and public support, CECA is helping to identify the most urgent security gaps in the modern electric grid and expedite disruptive solutions to the market. Using NREL's cyber range in the ARIES platform, CECA provides an environment where innovative cybersecurity technologies can be evaluated with realistic power, control, and network layers against threat scenarios without putting customers or utility networks at risk. CECA cohorts are selected for their solutions to today's highest-priority cyber threats, and the technologies are evaluated on the cyber range using an emulated electric utility environment. This representative environment allows for sharing information across utilities without inadvertently sharing sensitive information on specific utility infrastructure designs. Startups from each cohort cycle exit the accelerator program with competitive experience, new partnership opportunities, and professional evaluations of their technologies.

Strategic direction and cost-sharing for CECA is provided by an industry-led executive steering committee and an operations advisory board comprising federal experts from DOE's Office of Cybersecurity, Energy Security, and Emergency Response and EERE.



Watch: Hear more about the Clean Energy Cyber Accelerator.



Host: Upload X



FUTURE ENERGY INFRASTRUCTURE

Modeling Subsea Microgrid Links for Alaskan Archipelago

Southeastern Alaska is dotted with coastal fishing communities that are electrically isolated, each relying on local generation, such as diesel or run-of-river hydropower. A DOE Office of Electricity project, named marine hydrOkinetic-based reliable and Resilient eleCtrification in Alaska (ORCA), has modeled possible configurations for the region that link cities with undersea cables and provide a resilience-enhanced renewable energy portfolio for the area's harsh weather and dynamic grid conditions.

The ORCA project used ARIES to build an electric model of the Alaskan archipelago that features medium-voltage DC connections to generators, creating a networked microgrid system for added resilience and reliability at a reduced cost. ARIES allowed the project team to model the networked microgrids at real power in a replica environment to understand the feasibility of such a grid design.

By validating technologies first on ARIES assets, remote Alaskan communities can make bold and informed decisions that enhance energy resilience, reliability, and efficiency for important commercial sites.

Scalable Stability with Grid-Forming Controls

Upcoming power electronic devices could unlock new approaches to transmission-scale grid control, involving new forms of stabilizing and improving power flow. DOE and industry are exploring creative configurations of these modern resources, including renewable energy devices, to have a more supportive role on the electric grid.

NREL has developed a concept that uses mature grid technologies to enhance the reliability of electric grids and to address pressing grid integration challenges for variable generation. The proposed solution, part of the DOE Office of Electricity-funded project SuperFACTS (Super-Flexible and Robust AC Transmission System), is a scalable concept that combines grid-forming battery energy storage and synchronous condenser capabilities in a single system that can be controlled to provide fully dispatchable and flexible operation. The combined assets can provide a full range of ancillary and reliability services to the grid that are similar to or better than conventional sources. They can also maintain adequate levels of grid strength and inertia and provide fault current for the proper operation of protection systems.

The SuperFACTS concept is an innovative, scalable, and highly reliable solution that can be sized and deployed in numbers to function in a variety of system designs and sizes, with the potential to become a key reliability enabler for 100% carbonfree smart grids. ARIES will be the proving ground for the SuperFACTS concept, with multi-MVA grid assets forming an experimental platform to validate the flexible system design.



LAB CAPABILITIES AND BUILDOUTS

Platform to Explore Integration and Impact of Power Electronics

The buildout of a **Power Electronic Grid Interface** (PEGI) is enabling a plug-and-play environment for the next generation of grid technologies. PEGI provides medium-voltage, megawattscale testing for incoming energy system integration solutions users can drop in technologies such as a microgrid controller, a novel battery technology, or an EV fast charger and evaluate how the product performs under live power on real grid infrastructure. As the electric grid transitions to more electronic, controllable devices, PEGI creates a unique space where new technologies can be exhaustively characterized, interconnected, and understood in a comprehensive range of future grid scenarios.

Developing High-Speed Internet Connections to Create a "SuperLab"

We can currently link models and simulations across the national laboratory complex, but imagine connecting these models with equipment, devices, and scientists so they can work together as if side by side instead of thousands of miles apart. In a future like this, researchers could run experiments that leverage thousands of devices to model the millions of devices that comprise our increasingly complex energy systems.

Watch: To learn more, see this short video on the SuperLab experiments.

In June, ARIES took an important step toward that future by completing a high-speed network connection between NREL's Flatirons Campus and South Table Mountain Campus. The network went from a single 10-GB connection to dual 100-GB connections, a 10-fold improvement.

Additionally, ARIES researchers worked with DOE's Energy Sciences Network (ESnet) to establish an On-Demand Secure Circuits and Advance Reservation System (OSCARS) circuit between NREL and the Pacific Northwest National Laboratory (PNNL). Established in July, this fixed-route, low-latency connection allows researchers to leverage the resources of two national labs to conduct real-time simulations.

Using both the new 100-GB connection and the OSCARS circuit, ARIES demonstrated the exchange of test data between research equipment at PNNL and NREL's Flatirons Campus.

Together, these are the first steps to developing a federated lab complex that can conduct research that no single lab or entity could achieve on its own.





Higher-Power Grid Interface for Configuring City-Scale Power Flow Scenarios

ARIES is leveling up its capacity to customize power flow scenarios: A new **20-MVA controllable grid interface (CGI)** will soon connect incoming power to the NREL campus. The CGI passes utility power through an elaborate hardware network that allows researchers to program any imaginable power dynamic, such as an emergency outage, a grid with 100% renewable energy, or an islanded microgrid.

The CGI is an overarching capability of ARIES, enabling the customizable power flow that characterizes ARIES experiments. Compared to its lower-power predecessor, the 7-MVA CGI, this new interface allows partners to de-risk higher-power devices and operations with a high degree of confidence. Both CGI devices can be used in concert to simulate a more diverse set of distribution grid scenarios.



Directing Grid Integration Research Through the Control Center Facility

The Control Center Facility will provide centralized control of grid energy integration research-and-development activities at the Flatirons Campus. This facility will offer real-time monitoring and control of interconnected power devices, including multiple types of power generation, hydrogen production and utilization, as well as loads from multiple technology sectors including vehicle charging/fueling, energy storage technologies, etc. (renewable and conventional electricity generation, loads from multiple technology sectors, energy storage, etc.), with full data collection and archive functionality. Plus, researchers will be able to manage hardware-in-the-loop activities with off-site partners and provide robust analysis and data visualization.

Real-Time Simulator Ties Virtual Environments to Physical Validation

Alongside assets that physically shape power flow for ARIES experiments, a digital real-time simulator (DRTS) allows researchers to upload grid scenarios onto the hardware environment. DRTS systems can expand the number of interconnected devices researchers can use in experiments, enabling system-scale fidelity. Whether users are interested in simulating an urban neighborhood or a bustling container port, the DRTS can inject real or emulated data of loads, weather, demand, and more into experiments, using the CGI to express the modeled grid conditions at real power. The DRTS bridges cyber and physical capabilities at ARIES by sending low-latency information between virtual environments and hardware infrastructure, enabling "distribution grid-in-the-loop" research.

Cyber Range and Communications Assets to Manage Vast, Virtual Connectivity

The virtual environment that spans ARIES is useful for addressing a major trend in power systems: increasing connectivity and communications among distributed devices. The buildout of the ARIES cyber environment made significant advances in FY 2021, allowing researchers to visualize

and interact with data flow among devices in an immersive cyber range. Users can simulate cyberattacks or other threats to data in flight and assess the impact on real devices and power flow.

The ARIES cyber environment expands research well beyond the boundaries of NREL's campus to enable integration with other labs and partners. The cyber environment is both an asset for visually understanding data exchange and communications and a cutting-edge resource to train partners in managing cybersecurity risks.

Power Line and Infrastructure Upgrade to Study Transmission-Distribution System Dynamics

ARIES can now access the voltages that exist when transforming from transmission- to distribution-level systems. A new DOE-owned, 34.5-kV transmission line now links ARIES assets to the local utility. Substation infrastructure, such as transformers and medium-voltage power converters, are allowing researchers to experiment at the boundary of transmission and distribution systems.

The infrastructure buildout is essential for evaluating new technologies that interface with the bulk grid. It also allows researchers to explore novel electric grid architectures, such as flexible AC transmission systems and all-DC microgrids, at different timescales.

When properly tuned, these algorithms can provide results within 1% of the current system voltage using sensor data from only 30% of the system nodes. Grid Optimization with Solar (GO-Solar) also showed only a 1% error in the forecasting state 15 minutes ahead of the traditional estimation method with the same fraction of nodes.



ENGAGEMENT AND OUTREACH

ARIES is engaging with communities, industry leaders, academic partners, and more to ensure that research capabilities and projects meet the real-world needs of the evolving energy system. Outreach and engagement activities included presenting at more than 35 speaking engagements, convening two advisory groups, soliciting a user call and request for information, engaging communities in supporting their energy transition strategies, and more.



September 14, 2021

President Biden visits NREL's Flatirons Campus to announce his Build Back Better Plan. The president is briefed on ARIES capabilities during his visit

September 8–9, 2021 Deputy Secretary of Energy David Turk

visits NREL's South Table Mountain Campus and Flatirons Campus and learns about ARIES

AUG

JUL

JUN



September 15, 2021 U.S. Department of Energy Acting Assistant Secretary and Principal Deputy Secretary for Energy Efficiency and Renewable Energy Kelly Speakes-Backman visits NREL

August 25, 2021 Inaugural Executive Advisory Board meeting

August 23, 2021

SEPT

Alaska Senator Lisa Murkowski visits NREL's South Table Mountain campus and learns about ARIES

August 2021

Advanced Distribution Management System (ADMS) Test Bed request for information closes with 13 submissions, leading team to develop a user call later in the year

July 21, 2021 -Alaska Governor Mike Dunleavy visits NREL and learns about ARIES

February 24, 2021

JAN

FEB

Energy Storage Workshop—180 attendees from industry, NREL, DOE, and other national labs

October 13, 2020 Power Electronics Grid Interface (PEGI) Workshop—140 attendees

DEC

September 30, 2020

ОСТ

ARIES User Call—191 total user requests for FY 2021 resources, including 128 continuing projects and 63 new projects

NOV

July 15, 2021

MAY

U.S. Secretary of Energy Jennifer Granholm virtually tours NREL and learns about ARIES



APR

MAR



Community Engagement

support local clean energy transitions. This

Communities to Clean Energy (C2C): More communities, utilities, and other stakeholders toward their clean energy plans, many will use de-risking large-scale deployments.







LOOKING AHEAD

In the coming years, ARIES will continue to develop capabilities that will advance leading-edge energy integration research. Using ongoing capital investments driven by DOE priorities, industry collaboration, and the ARIES Research Plan, ARIES will build from existing capabilities to meet the energy research demands of the future. Efforts for multi-office research into FY 2022 and beyond include but are not limited to:

- DOE partnership to develop hydrogen at scale: DOE announced nearly \$8 million for nine cooperative projects that will complement existing H2@Scale efforts and support DOE's Hydrogen Shot goal to reduce the cost of clean hydrogen by 80% within the decade. The selected projects will leverage the ARIES platform to enable the integration of hydrogen technologies in future energy systems, including energy storage and a specific focus on safety and risk mitigation. These projects will begin in the Pacific Northwest coming years.
- ADMS user call: NREL's ADMS research helps utilities meet customer expectations of reliability, power quality, renewable energy use, data security, and resilience to natural disasters and other threats. NREL is accepting proposals from external research partners to identify projects that require the ADMS Test Bed, which will support industry and other partners that are developing energy system solutions for the real world.

Real-time distributed simulation demonstration **using ESnet:** By demonstrating real-time energy simulations between two national labs thousands of miles apart, NREL and PNNL researchers proved the concept of a "SuperLab." Next, ARIES will connect more national labs until they achieve the six-lab interconnection called "SuperLab 2.0." In doing so, ARIES can blur the line between NREL and the outside—connecting to physical and virtual research tools at other campuses.

NREL works with organizations—large and small—to expand the clean energy economy. How can you partner with ARIES to accelerate the movement of renewable energy and energy-efficient solutions into practical applications? Watch for opportunities to work with us, and learn more on the ARIES web page.



ADVISORY COMMITTEES

ARIES Steering Committee

The ARIES Steering Committee comprises EERE and NREL executive leadership. This committee meets quarterly and has oversight of and responsibility for ARIES research-and-development management, research impact, and financial and business practices.

ARIES Executive Advisory Board

The ARIES Executive Advisory Board provides an external perspective to NREL, DOE, and EERE on the research direction, development, and deployment of the ARIES research platform.

ARIES External Advisory Board

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In a state of the state of the

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Director, Threat Intelligence & National Se Engagements Berkshire Hathaway Energy

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