



INL's energy system testing integrates simulation, storage systems, a renewable energy microgrid, load control capabilities and full-scale testing.

Microgrids and Backup Power Systems

Field-scale integration of diverse energy resources

Today's electrical grid is built on a one-way delivery model of the past: power generation, transmission and distribution in response to user demand. Today's evolving grids and those of the future will look far different, however.

Numerous factors are driving these changes, including more renewable energy integration, use of smaller-scale, widely distributed energy resources, and the need for increased reliability and resilience. Such systems will blur the boundaries between suppliers and consumers — resulting in two-way power flow and demand that increasingly adapts to available supply.

Dynamic systems with 50 to 75 percent average renewable energy content can be technically and economically challenging to

stabilize. Not only do grids experience variability in loads (demand for electricity), but renewable sources such as wind are intermittent and can drop off without notice.

A number of advances will be critical for making the future grid reliable and resilient. For example, "shock absorbers" such as energy storage systems and dynamic communication will help minimize brownouts or power surges.

Idaho National Laboratory has the expertise and infrastructure to test numerous aspects of these modern energy systems. The lab's experts perform simulations using real-world data and hardware. They test dynamic storage and load-balancing options using a renewable energy microgrid test bed. On-site electric vehicle testing and a

full-scale power grid provide unmatched demonstration opportunities. Laboratory engineers are helping put these concepts into practice at U.S. military bases around the world.

DIGITAL REAL-TIME SIMULATION

Modeling and simulation provide powerful tools for rapid, cost-effective development and validation of new technologies, methods and devices before using them in the field. INL has advanced capabilities for modeling the power grid and cosimulating electrical, thermal and mechanical systems.

The lab's digital real-time simulation racks can accommodate both power hardware and controller hardware in the simulation loop. Combined with a grid emulator and operational



INL researchers consult at a concentrated solar energy installation at Utah's Tooele Army Depot.



data from actual utilities, INL can perform dynamic simulations using physical hardware and controllers.

INL also has the ability to connect grid simulations in real time with the National Renewable Energy Laboratory in Golden, Colorado. The connection enables the labs to simulate scenarios that neither lab could perform on its own. The two labs are collaborating to study how advanced vehicle charging stations could provide energy storage solutions for the grid of the future.

EVS AND OTHER STORAGE SOLUTIONS

Electric vehicle battery packs could prove to be optimal storage devices for energy produced when demand is light. As advanced vehicles become more widespread, they will add a growing and flexible component to the grid's overall load. INL's Electric Vehicle Infrastructure

Laboratory is co-located with energy systems researchers, providing the ability to test how numerous plugged-in vehicles interact with the grid under different scenarios.

For utilities, flow batteries offer a tool for shaping load: storing excess electrical power during off-peak hours and releasing it during peak demand periods. Somewhat like a combination between a traditional battery and a fuel cell, flow batteries are well-suited to long use durations and more recharge/ discharge cycles.

INL has two Z20-4 Zinc/Iron flow batteries that together are capable of generating 128 kilowatts at full power for 2.5 hours. Integrated with the grid and microgrid, the data collected in real-world conditions will allow INL researchers to model and demonstrate energy use and storage scenarios.

Since usage and charging patterns impact a storage system's performance and lifetime, INL studies a variety of large-scale energy storage systems (including flywheels and supercapacitors) to understand which is best suited to a particular scenario. The ideal combination of energy source and backup system depends on the electricity demands of each particular end user.

MICROGRID TEST BED

Microgrids are power distribution systems with distributed energy sources, storage devices and controllable loads. They can operate connected to the grid, but can disconnect and function as an independent island as needed.

A microgrid can be powered by distributed generators, batteries or renewable resources. Integrating several resources (i.e., wind and concentrated or photovoltaic



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solar) with the right storage option can result in a system of variable and controllable resources that is both flexible and manageable.

The microgrid test bed at INL includes solar panels, energy storage devices, load banks, smart inverters, a power distribution system and multiple switchgear sets. It also includes "smart home" components such as appliances and other loads that can dynamically adjust their electricity demand.

The system's load control capabilities and grid interaction algorithms allow researchers to study demand response, peak shaving and ancillary services, and to test component interactions, performance, controls and integration challenges.

REAL-WORLD DEMONSTRATIONS

Military bases require reliable power with backup systems that can take over if the primary grid is interrupted. Diesel generators can provide such backup. However, as bases incorporate more renewable sources such as wind and solar, the resulting swings in usage can stress generators and shorten their life spans.

Such bases look to INL's experts for solutions. The lab has expertise in renewable resource assessment, grid integration and resilient power systems. INL's engineers welcomed the opportunity to move those concepts from the lab setting to real-world demonstrations.

To date, INL researchers have assisted in the development and integration of more than 1,000 MW of hybrid power, solar and wind energy systems at Department of Defense and industry/utility sites around the world. Examples include:

- Development, design and implementation support for the Pantex Wind Project, the largest federally owned wind project to date. The 11.5-MW project supplies more than half of the facility's electrical energy use (U.S. Department of Energy).
- Technical input and guidance for more than 25 Energy Conservation Investment Program (ECIP) projects (U.S. Army).

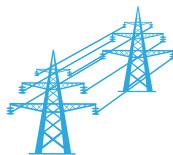
Selected Capabilities

Modeling/Simulation



- Chroma 61860 grid emulator that can output single- or three-phase voltage and current
- Ability to simulate High Voltage Alternating Current (HVAC) and High Voltage Direct Current (HVDC) networks
- Cybersecurity simulation capabilities

Microgrid



- 275 kW microgrid
- Three smart inverters, multiple string and microinverters
- Microgrid control and communications systems
- 165 kW of flexible load banks
- Smart home devices and circuit controls
- Gas generator, additional generation to include wind and concentrated solar
- 30 kW of PV, including 5 kW of flexible solar PV
- 335 kWh of storage

Electric Vehicles



- 60 kVA Regenerative Grid Simulator
- Custom LabVIEW host control and data acquisition
- Level 1, level 2, wireless and DC fast charging systems
- Smart grid-enabled EVSE
- 400 kVA of lab supply ranging from 120 V single phase to 480 V AC three-phase

Industrial Scale



- 61-mile, 138-kV dual-fed power loop
- Loop includes seven substations, and a control center
- State-of-the-art communications and instrumentation capabilities
- Portions of the power loop can be isolated and reconfigured for specialized testing

FOR MORE INFORMATION

Technical contact

Kurt Myers

208-526-5022

kurt.myers@inl.gov

General contact

Abby Todd

Communications Liaison

208-526-6166

abby.toddbloxham@inl.gov

www.inl.gov

- Feasibility assessment and design/development support for 2-5 MW of wind energy in Sasebo, Japan, as well as multiple other wind energy feasibility/development assessments (U.S. Navy).
- Design and testing for solar and Li-ion storage microgrid system in Guam (U.S. Navy).
- Analysis and design for hybrid island/grid system improvements including three new 900-kW wind turbines at San Clemente Island (U.S. Navy).

- Grid/system development and integration guidance for new 700-kW wind energy, and testing of potential battery storage systems for San Nicolas Island (U.S. Navy).
- Design review and system integration planning for 2-MW solar project at Dugway Proving Ground (U.S. Army).
- Assist design review, planning and analysis for 1.7-MW wind project, 1.5-MW concentrated solar project upgrades, power system study and microgrid at Tooele Army Depot (U.S. Army).

In addition to experience and expertise developing and designing microgrids made up of renewable resources, INL has industrial-scale testing capabilities including a 138-kV isolatable dual-fed power loop.

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