2016 NORTH AMERICAN GRID MODERNIZATION TEST BED SURVEY

sgip

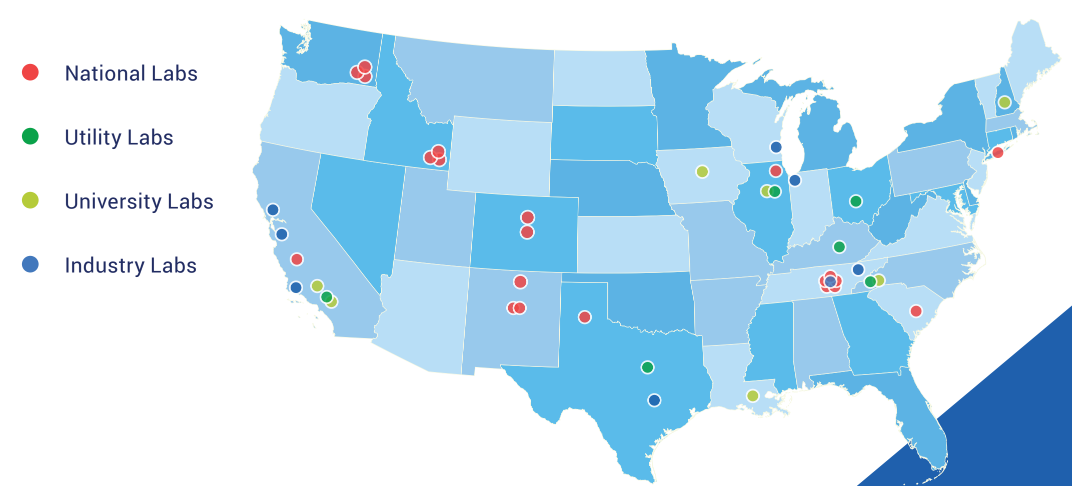
ABOUT THIS SURVEY

Smart grid test beds are a critical resource for developing and testing new technologies in a controlled and economic fashion. They help our industry avoid the consequences of deploying unproven technology at scale by a utility or grid operator.

SGIP's Grid Modernization Test Bed survey was created to foster collaboration among industry players who are engaged in such research and testing. What follows is a high-level look at who is doing what in this realm of study. This is not an inclusive look at all the research underway, but it does include some of the biggest, most important grid-modernization sites in North America.

CONTENTS

WHERE LABS ARE LOCATED



Not shown:
PowerTech Labs,
Surrey, BC, Canada

KEY FINDINGS

It's all about the grid edge

Test bed researchers named distributed generation and control as predominant areas of focus when responding to SGIP's 2016 Grid Modernization Test Bed Survey.

The survey collected data from some of the largest, best-known testing facilities in the nation. Nearly half – 49 percent of the researchers who participated – were from national labs. Academics made up 17 percent of the 41 test beds queried, industry labs accounted for 19 percent and utilities provided 15 percent of the sample.

Although grid-edge control itself was not a focus-area choice available to survey respondents, intelligent electronic devices, such as microprocessor-based controllers on things like circuit breakers or capacitor banks, was. Two-thirds of survey respondents had IEDs under study.

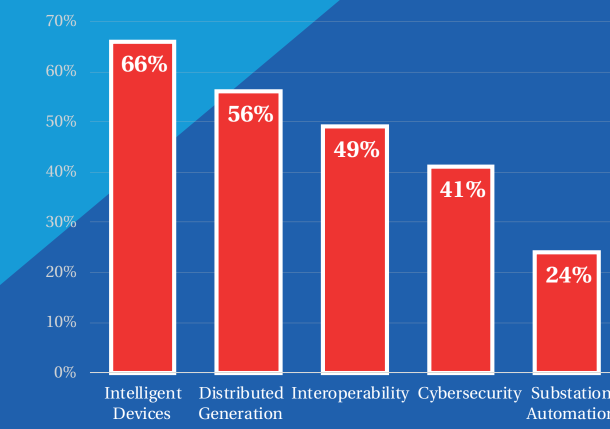
Distributed generation also is a leading focus area. More than half – 56 percent – of survey respondents name it as an investigative polestar.

Interoperability grabs the attention of nearly half of the researchers – 49 percent. Cybersecurity is the other big winner. It's a focus area for 41 percent of the investigators.

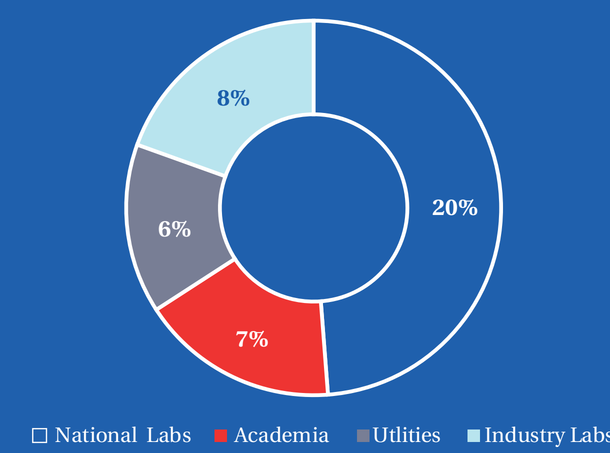
Research concentrations vary by type of institution. For instance, when it comes to interoperability, 40 percent of national labs say it's a key study area, versus 57 percent of academics, one-third of utilities and 75 percent of equipment vendors, a.k.a. industry labs.

More than half of respondents at three lab types cited distributed generation as a focus. Universities led the pack with 71 percent, followed by utilities (66 percent) and industry labs (62 percent), while only 45 percent of national labs named DG as a focus. However, 15 percent of national labs named transmission issues – a write-in option – as their key area of study.

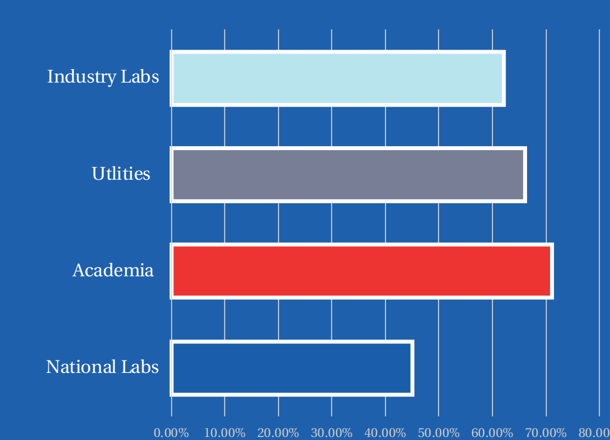
Top 5 Areas of Test Bed Focus



Who responded?



Who's focused on DG?



WHAT ARE THEY TESTING? AND HOW?

The importance of grid-edge technology shows up in the types of equipment under study. Eighty-three percent of the researchers are using sensors and monitors in their facilities. Generation resources, smart inverters and microgrids are each in use at more than half – 54 percent – of the test beds. Storage – usually battery energy storage – also is under review; 51 percent said they have storage devices at their sites.

Microgrid Nation

As noted earlier, more than half of survey participants have microgrid testing in progress. Solar PV is by far the largest sources of generation. It's in use at 41 percent of the sites. Close on its heels is storage, which is being evaluated by 39 percent of the test beds.

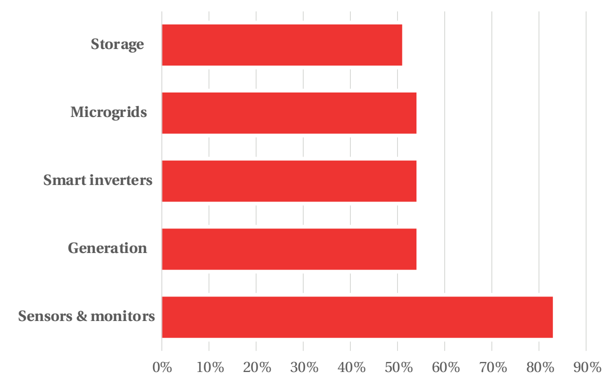
Only 5 percent of the testbeds are using combined heat and power generation in their microgrids, and 15 percent are testing microturbines and wind power as generation resources. A larger number – 22 percent – have diesel generation backup for intermittent energy sources. Interestingly, electric vehicles are part of the microgrid mix at one in five facilities, or 20 percent.

Making it real

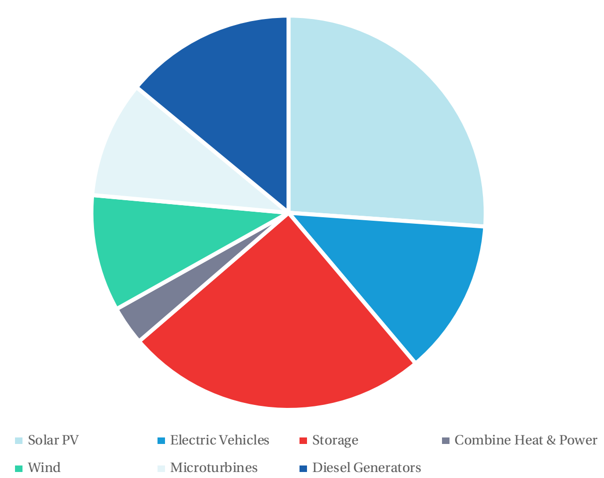
Most – 90 percent – of survey respondents have actual physical equipment in their labs. A smaller number, 78 percent, said "yes" to virtual testing of some kind.

Test beds also tend to be grid connected. Seventy-six percent are grid-connected. Only 24 percent are not.

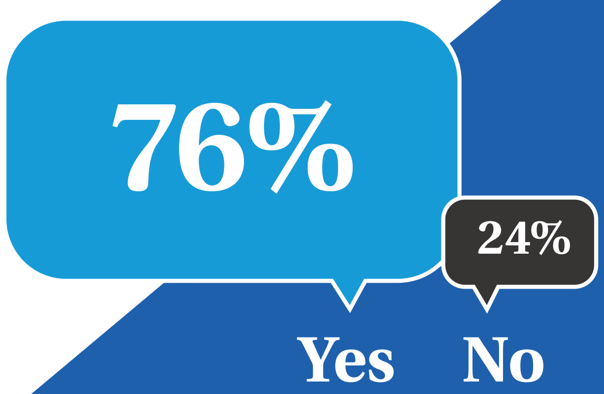
Top 5 Types of Equipment



Microgrid Energy Resources



Grid connected



NOTABLE ACHIEVEMENTS

SGIP asked researchers to briefly describe one or two key findings. Among the items submitted, investigators discovered ....

"It is possible to use an Internet of Things (IoT), open-source software approach to harmonize sensing, communication and control of various grid-connected devices."

Keith Hardy, Director, EV-Smart Grid Interoperability Center Argonne National Laboratory

"Understanding the mechanical constraints of a system is important for distributed control. Even if you can design a distributed controller that can converge in time, you can't meet high-speed service requirements if your mechanical control is too slow."

Thomas Edgar, Security Researcher, PowerNET Test Bed Pacific Northwest National Lab

"Complexity of environments is often under-estimated. Simple proof-of-principle experiments can help weed out ideas before larger scale, higher fidelity runs."

Paul Skare, Technical Group Manager, EIOC Grid Tools Test Bed Pacific Northwest National Lab

More reliable, resilient power lines

Researchers verified that a power-line coating can help utilities add capacity and control losses. "We tested the General Cable E3X coating in the test facility with findings of up to 30% decrease in operating temperature," said Philip Irminger, Principal Investigator for the Powerline Conductor Accelerated Test (PCAT) Facility at Oak Ridge National Lab. Such technology promises to increase capacity and lower line losses, thereby making the grid more efficient.

Grid support from storage

Rob Hovsapian, manager of the Idaho National Lab Microgrid Test Bed, reported that his team completed a proof of concept for "multi-timescale control of behind-the-meter energy storage with forecast scheduling and second-stage adaptive algorithms for peak shaving, demand reduction and load/generation smoothing." The team also worked on economic modeling of case studies for this type of energy storage use as well as security and life cycle considerations.

PRIMARY FOCUS
NATIONAL LABS

Respondent And Test Bed Name	Location	Distributed Generation	Intelligent Devices	Cybersecurity	Substation Automation	Interoperability	Integration	Storage	How are you testing?	Physical	Virtual	Test bed is grid-connected?	Yes	No
Argonne National Laboratory Electric Vehicle-Smart Grid Interoperability Center	Chicago IL		✓			✓	✓			✓	✓		✓	
Brookhaven National Laboratory Northeast Solar Energy Research Center (NSERC)	Upton NY	✓	✓	✓			✓			✓			✓	
Idaho National Laboratory Battery Test Center	Idaho Falls ID							✓		✓	✓			✓
Idaho National Laboratory INL Microgrid	Idaho Falls ID	✓	✓	✓		✓				✓	✓		✓	
Lawrence Berkeley National Lab FLEXLAB®	Berkeley CA	✓	✓			✓	✓			✓	✓		✓	
National Renewable Energy Laboratory National Wind Technology Center (NWTC)	Boulder CO	✓								✓	✓		✓	
National Renewable Energy Laboratory Energy Systems Integration Facility (ESIF)	Golden CO	✓	✓	✓		✓	✓			✓	✓		✓	
Oak Ridge National Laboratory Distributed Energy Comms. and Controls (DECC)	Oak Ridge TN	✓	✓	✓		✓				✓	✓		✓	
Oak Ridge National Laboratory SI-GRID	Oak Ridge TN	✓	✓	✓		✓			✓	✓			✓	
Oak Ridge National Laboratory Powerline Conductor Accelerated Test (PCAT) Facility	Oak Ridge TN									✓				✓
Oak Ridge National Laboratory AMI Test Bed	Oak Ridge TN			✓						✓			✓	
Oak Ridge National Laboratory Cable Test Facility	Oak Ridge TN		✓							✓				✓
Pacific Northwest National Laboratory EIOC Grid Tools Test Bed	Richland WA		✓	✓	✓	✓				✓	✓			✓
Pacific Northwest National Laboratory Lab Homes Test Bed (HAN oriented)	Richland WA									✓			✓	
Pacific Northwest National Laboratory PowerNET IED Test Bed	Richland WA		✓								✓			✓
Sandia National Laboratories Microgrid Test Bed	Albuquerque NM		✓	✓	✓	✓				✓	✓		✓	
Sandia National Laboratories DER Test Bed	Albuquerque NM	✓		✓						✓	✓			✓
Sandia National Laboratories Scaled Wind Farm Test (SWiFT) Facility	Lubbock TX	✓								✓	✓		✓	
Savannah River National Laboratory Electrical Grid Research Innovation and Development (eGRID) Center	Charleston SC		✓		✓					✓	✓		✓	

DIFFERENT EQUIPMENT USED IN TEST BEDS
NATIONAL LABS

Respondent And Test Bed Name	Location	Generation	SCADA	Sensors & Monitors	Smart Inverters	Storage	Substation Equipment	Volt/VAR	Automation devices	Electric Vehicles	Microgrids	Metering	HAN &/or Building Systems	Communications
Argonne National Laboratory Electric Vehicle-Smart Grid Interoperability Center	Chicago IL	✓		✓		✓				✓	✓			✓
Brookhaven National Laboratory NE Solar Energy Research Center	Upton NY	✓	✓											
Idaho National Laboratory Battery Test Center	Idaho Falls ID					✓								
Idaho National Laboratory INL Microgrid	Idaho Falls ID	✓	✓	✓	✓	✓	✓		✓	✓	✓			
Lawrence Berkeley National Lab FLEXLAB®	Berkeley CA	✓	✓	✓	✓	✓		✓	✓		✓		✓	
National Renewable Energy Laboratory National Wind Technology Center (NWTC)	Boulder CO	✓					✓				✓			
National Renewable Energy Laboratory Energy Systems Integration Facility (ESIF)	Golden CO	✓	✓	✓	✓	✓		✓	✓	✓	✓			
Oak Ridge National Laboratory Distributed Energy Comms. and Controls (DECC)	Oak Ridge TN	✓	✓	✓	✓	✓		✓	✓		✓			
Oak Ridge National Laboratory SI-GRID	Oak Ridge TN			✓	✓	✓					✓			
Oak Ridge National Laboratory Powerline Conductor Accelerated Test (PCAT) Facility	Oak Ridge TN			✓										
Oak Ridge National Laboratory AMI Test Bed	Oak Ridge TN											✓		
Oak Ridge National Laboratory Cable Test Facility	Oak Ridge TN			✓										
Pacific Northwest National Laboratory EIOC Grid Tools Test Bed	Richland WA		✓	✓			✓		✓	✓			✓	
Pacific Northwest National Laboratory Lab Homes Test Bed (HAN oriented)	Richland WA												✓	
Pacific Northwest National Laboratory PowerNET IED Test Bed	Richland WA		✓	✓								✓		
Sandia National Laboratories Microgrid Test Bed	Albuquerque NM		✓	✓	✓	✓		✓			✓			
Sandia National Laboratories DER Test Bed	Albuquerque NM	✓		✓	✓	✓			✓		✓			
Sandia National Laboratories Scaled Wind Farm Test (SWiFT) Facility	Lubbock TX		✓	✓	✓		✓		✓					
Savannah River National Laboratory Electrical Grid Research Innovation and Development (eGRID) Center	Charleston SC		✓	✓			✓		✓					

PRIMARY FOCUS UNIVERSITY LABS

Respondent And Test Bed Name	Location	Distributed Generation	Intelligent Devices	Cybersecurity	Substation Automation	Interoperability	Integration	Storage	How are you testing?	Physical	Virtual	Test bed is grid-connected?	Yes	No
University of California UCI Microgrid	Irvine CA	✓	✓			✓				✓	✓			
UCLA Smart Grid Energy Research Center	Los Angeles CA	✓	✓			✓				✓	✓		✓	
University of Illinois Cyber Physical Systems Test Bed	Urbana IL	✓	✓	✓	✓	✓	✓			✓	✓		✓	
Iowa State University PowerCyber Test Bed	AMES IA			✓							✓			✓
University of New Hampshire Interoperability Laboratory	Durham NH	✓	✓			✓				✓	✓		✓	
University of New Orleans Power & Energy Research Laboratory	New Orleans LA		✓								✓			✓
University of North Carolina Duke Energy Smart Grid Laboratory	Charlotte NC	✓	✓	✓	✓					✓	✓		✓	

PRIMARY FOCUS UTILITY LABS

Respondent And Test Bed Name	Location	Distributed Generation	Intelligent Devices	Cybersecurity	Substation Automation	Interoperability	Integration	Storage	How are you testing?	Physical	Virtual	Test bed is grid-connected?	Yes	No
Ameren Illinois (Ameren) Technology Applications Center	Champaign IL		✓	✓						✓	✓		✓	
American Electric Power Walnut Test Site	Groveport OH	✓	✓					✓		✓	✓		✓	
Powertech Labs, a division of BC Hydro Powertech Labs	Surrey BC Canada	✓	✓	✓	✓	✓	✓			✓	✓		✓	
CPS Energy CPS Microgrid	San Antonio TX	✓						✓		✓	✓		✓	
Southern California Edison SCE Advanced Technology Controls Lab	Westminster CA	✓								✓	✓		✓	

DIFFERENT EQUIPMENT USED IN TEST BEDS UNIVERSITY LABS

Respondent And Test Bed Name	Location	Generation	SCADA	Sensors & Monitors	Smart Inverters	Storage	Substation Equipment	Volt/VAR	Automation devices	Electric Vehicles	Microgrids	Metering	HAN &/or Building Systems	Communications
University of California UCI Microgrid	Irvine CA	✓	✓	✓	✓	✓	✓				✓	✓		
UCLA Smart Grid Energy Research Center	Los Angeles CA	✓		✓	✓	✓				✓	✓			
University of Illinois Cyber Physical Systems Test Bed	Urbana IL	✓	✓	✓	✓		✓		✓		✓			
Iowa State University PowerCyber Test Bed	AMES IA		✓	✓			✓		✓					
University of New Hampshire Interoperability Laboratory	Durham NH				✓	✓			✓		✓			
University of New Orleans Power & Energy Research Laboratory	New Orleans LA			✓			✓							
University of North Carolina Duke Energy Smart Grid Laboratory	Charlotte NC	✓	✓	✓	✓	✓	✓	✓	✓		✓			

DIFFERENT EQUIPMENT USED IN TEST BEDS UTILITY LABS

Respondent And Test Bed Name	Location	Generation	SCADA	Sensors & Monitors	Smart Inverters	Storage	Substation Equipment	Volt/VAR	Automation devices	Electric Vehicles	Microgrids	Metering	HAN &/or Building Systems	Communications
Ameren Illinois (Ameren) Technology Applications Center	Champaign IL		✓	✓			✓	✓	✓			✓	✓	
American Electric Power Walnut Test Site	Groveport OH	✓		✓					✓		✓			
Powertech Labs, a division of BC Hydro Powertech Labs	Surrey BC Canada	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
CPS Energy CPS Microgrid	San Antonio TX	✓		✓										
Duke Energy Mount Holly	Mount Holly NC	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	
Southern California Edison SCE Advanced Technology Controls Lab	Westminster CA			✓					✓	✓	✓			

PRIMARY FOCUS INDUSTRY LABS

Respondent And Test Bed Name	Location	Distributed Generation	Intelligent Devices	Cybersecurity	Substation Automation	Interoperability	Integration	Storage	How are you testing?	Physical	Virtual	Test bed is grid-connected?	Yes	No
AES Energy Storage AES Energy Storage Deployment Center	Long Beach CA			✔		✔		✔		✔	✔		✔	
EnerNex EnerNex Smartgrid Labs	Knoxville TN		✔	✔	✔	✔				✔				✔
Enphase Concerto	Petaluma CA	✔	✔			✔				✔	✔		✔	
EPRI EPRI Test Bed	Knoxville TN	✔	✔	✔	✔	✔	✔	✔		✔	✔		✔	
Fronius Fronius USA HQ Test Bed	Portage IN	✔								✔			✔	
NEC NEC Laboratories America	Cupertino CA	✔	✔			✔				✔	✔		✔	
Pecan Street Mueller Neighborhood	Austin TX		✔	✔						✔			✔	
S&C Electric S&C Electric Co Test Bed	Chicago IL	✔	✔		✔	✔				✔	✔		✔	

INDUSTRY LABS COLLABORATION

Respondent And Test Bed Name	Will Collaborate?	Potential Partners: Utilities	Potential Partners: Vendors	Potential Partners: Academia	How Do You Handle Costs?: Fee	How Do You Handle Costs?: Shared Cost	How Do You Handle Costs?: No Cost
AES Energy Storage AES Energy Storage Deployment Center	Y		✔				
EnerNex EnerNex Smartgrid Labs	Y	✔	✔	✔	✔		
Enphase Concerto Lab	Y	✔	✔	✔		✔	
EPRI EPRI	Y	✔	✔	✔	✔		
Fronius Fronius USA HQ Test Bed	Y	✔	✔	✔		✔	
NEC NEC Laboratories America	N						
Pecan Street Mueller Neighborhood	Y	✔	✔	✔	✔	✔	
S&C Electric S&C Electric Co Test Bed	Y	✔		✔	✔	✔	✔

DIFFERENT EQUIPMENT USED IN TEST BEDS INDUSTRY LABS

Respondent And Test Bed Name	Location	Generation	SCADA	Sensors & Monitors	Smart Inverters	Storage	Substation Equipment	Volt/VAR	Automation devices	Electric Vehicles	Microgrids	Metering	HAN &/or Building Systems	Communications
AES Energy Storage AES Energy Storage Deployment Center	Long Beach CA		✔	✔	✔	✔					✔			
EnerNex EnerNex Smartgrid Labs	Knoxville TN			✔			✔		✔			✔	✔	
Enphase Concerto	Petaluma CA	✔		✔	✔	✔		✔			✔		✔	
EPRI EPRI Test Bed	Knoxville TN	✔		✔	✔	✔			✔	✔	✔			
Fronius Fronius USA HQ Test Bed	Portage IN	✔		✔	✔									
NEC NEC Laboratories America	Cupertino CA	✔		✔	✔	✔					✔			
Pecan Street Mueller Neighborhood	Austin TX	✔		✔	✔	✔				✔		✔	✔	✔
S&C Electric S&C Electric Co Test Bed	Chicago IL	✔	✔	✔	✔	✔	✔		✔					

UNIVERSITY LABS COLLABORATION

Respondent And Test Bed Name	Will Collaborate?	Potential Partners: Utilities	Potential Partners: Vendors	Potential Partners: Academia	How Do You Handle Costs?: Fee	How Do You Handle Costs?: Shared Cost	How Do You Handle Costs?: No Cost
University of California UCI Microgrid	Y	✔	✔	✔	✔	✔	
University of Calif., Los Angeles Smart Grid Energy Research Center	Y	✔	✔	✔			
University of Illinois Cyber Physical Systems Test Bed	Y	✔	✔	✔	✔	✔	✔
Iowa State University PowerCyber Test Bed	Y	✔	✔	✔	✔	✔	
University of New Hampshire Interoperability Laboratory	Y	✔	✔	✔	✔	✔	
University of New Orleans Power & Energy Research Laboratory	Y	✔	✔	✔	✔	✔	
University of North Carolina Duke Energy Smart Grid Laboratory	Y	✔	✔	✔		✔	

NATIONAL LABS & **COLLABORATION**		Potential Partners			How Do You Handle Costs?		
Respondent And Test Bed Name	Will Collaborate?	Utilities	Vendors	Academia	Fee	Shared Cost	No Cost
Argonne National Laboratory Electric Vehicle-Smart Grid Interoperability Center	Y	✓	✓	✓	✓	✓	✓
Brookhaven National Laboratory Northeast Solar Energy Research Center (NSERC)	Y	✓	✓	✓		✓	
Idaho National Laboratory Battery Test Center	Y	✓	✓	✓	✓	✓	
Idaho National Laboratory INL Microgrid	Y	✓	✓	✓		✓	
Lawrence Berkeley National Lab **FLEXLAB®**	Y	✓	✓	✓		✓	
National Renewable Energy Laboratory National Wind Technology Center	Y	✓	✓	✓	✓	✓	
National Renewable Energy Laboratory Energy Systems Integration Facility	Y	✓	✓	✓	✓	✓	
Oak Ridge National Laboratory Distributed Energy Comms. and Controls (DECC)	Y	✓	✓	✓	✓	✓	✓
Oak Ridge National Laboratory SI-GRID	Y	✓	✓	✓	✓	✓	
Oak Ridge National Laboratory Powerline Conductor Accelerated Test (PCAT) Facility	Y	✓	✓	✓	✓	✓	
Oak Ridge National Laboratory AMI Test Bed	Y	✓	✓	✓	✓	✓	
Oak Ridge National Laboratory Cable Test Facility	Y	✓	✓	✓	✓	✓	
Pacific Northwest EIOC Grid Tools Test Bed	Y	✓	✓	✓	✓	✓	✓
Pacific Northwest National Laboratory Lab Homes Test Bed (HAN oriented)	Y	✓	✓	✓	✓	✓	
Pacific Northwest National Laboratory PowerNET IED Test Bed	Y	✓	✓	✓	✓	✓	
Sandia National Laboratories Microgrid Test Bed	Y	✓	✓	✓	✓		
Sandia National Laboratories DER Test Bed	Y	✓	✓	✓	✓	✓	
Sandia National Laboratories Scaled Wind Farm Test (SWiFT) Facility	Y	✓	✓	✓	✓		
Savannah River National Laboratory Electrical Grid Research Innovation and Development (eGRID) Center	Y	✓	✓	✓	✓		

UTILITIES LABS **COLLABORATION**		Potential Partners			How Do You Handle Costs?		
Respondent And Test Bed Name	Will Collaborate?	Utilities	Vendors	Academia	Fee	Shared Cost	No Cost
Ameren Illinois Technology Applications Center	Y	✓	✓	✓		✓	
American Electric Power Walnut Test Site	Y	✓	✓	✓		✓	
Powertech Labs, a division of BC Hydro BC Hydro Powertech Labs	Y	✓	✓	✓	✓		
CPS Energy CPS Microgrid							
Duke Energy Mount Holly	Y	✓	✓	✓		✓	
Southern California Edison SCE Advanced Technology Controls Lab	Y	✓	✓	✓		✓	

RESEARCHERS ON COLLABORATION

“Partners should be clear on the specific outcomes of the testing, how success will be measured, and specific timelines.”

Brian Lydic
Sr. Standards & Technology Engineer
Fronius USA Headquarters Test Bed

“Industry and utility involvement is a key ingredient in sharing the value of national laboratories.”

Rob Hovsapian, Ph.D. Dept. Manager Idaho National Lab
INL Microgrid Test Bed

DIRECTING THE FLOW

Drivers are used to following signals, be they the red, yellow or green lamps of a traffic light or the arm-waving of a traffic cop in the intersection. But, will drivers follow signals from power providers who are trying to charge electric vehicles without stressing the grid?

That's one of the questions under investigation at the University of California, Los Angeles, under the direction of Rajit Gadh, PhD, a professor in the Henry Samueli School of Engineering and Applied Science. Gadh is also founder and director of the UCLA Smart Grid Energy Research Center (SMERC), where a number of studies are underway.

One is the WINSmartEV initiative, a living lab that's examining how to manage the flow of electrons to EVs. Gadh invites parking structure operators to consider the day when they have 1,000 plug-ins that park on-site each morning and need to be charged sometime during the workday. "If we're talking an average of 6.7 kilowatts per plug-in, that would be 6.7 megawatts of additional load. On hot days when air conditioners are pumping cool air into the building, that could be significant."

It's also a short-term peak. "The average driver needs 40 miles of range per day – about 14 kilowatt hours – so that means you can charge an EV in roughly two hours," Gadh explains.

And, it's potentially pricey. Charger installation is expensive and can cost $10,000, says Gadh. But, given the two-hour charging window, he also estimates each unit can accommodate up to four vehicles in an eight-hour day because not everyone needs to be charged immediately. If everyone comes in around 8 and leaves around 5, there's time to juggle the charging activity, which is exactly what the quad-multiplex power management technology developed by UCLA does.

Drivers wanted

The university researchers are examining the charging preferences and driving patterns of participating EV owners along with grid stability, energy cost, vehicle location and battery status. Using such inputs, the researchers control the charge rate and extent of charge backfill.

A key finding from this effort is that EV drivers are willing to hand over control to the power supplier provided their requirements are satisfied. "They know that this will benefit the grid, that we're are trying to reduce peak demands and use more solar power," Gadh says.

Just as EVs pose a charging challenge, they also offer up vehicle-to-grid (V2G) opportunities. Gadh and his team are leveraging the energy storage in EVs for grid support applications such as reactive power compensation to address voltage excursions, frequency regulation and distributed storage for quick-ramping capacity.

UCLA is in a unique position to conduct such research because the campus runs its own utility. "We have our own co-generation plant, our own facilities management, and we have our own grid management," Gadh says. "That allows us to try out certain things that perhaps most other places cannot." Along with EV research, Gadh's research center is also looking at demand management, communications, DER integration and cybersecurity.

CHOREOGRAPHING THE GRID EDGE

Some years back, engineers at Duke Energy were trying to coordinate solar generation with battery energy storage, and they saw first-hand why distributed energy resources require grid-edge intelligence and control.

“We were reading the solar meter, then sending that data back through its proprietary telecommunications to a centralized system which then sent a message back down to the battery inverter telling it what to do. It took about 45 seconds,” recalls Jason Handley, director of the utility’s Emerging Technology Office.

This led Duke to embark on its Open Field Message Bus (OpenFMB™) initiative, which began with a reference architecture that leverages Internet-of-Things protocols to facilitate interoperability. In phase two Duke built a microgrid with:

- Solar PV and EV charging capabilities
- A grid-scale battery energy storage system
- A 500-kW resistive load bank
- Automated reclosers, smart meters, sensors and PMUs
- Wireless devices supporting Wi-Fi, 4G LTE, 900 MHz RF and AMI Mesh
- An envision room that emulates a smart home
- An operations room to monitor and control microgrid components

What’s phase three? “We’re completing the circuit that the microgrid is on. We’re going from the sub-station all the way to the end-of-line,” Handley says.

Good hair day

Handley jokes that the resistive load bank is basically “a big hair dryer.” Like the salon essential, it has a resistor core inside and a large fan. It’s job? To prevent the microgrid from pushing excess generation back onto the grid, and Handley says it’s turned out to be a valuable testing tool.

“We can actually island with different load levels,” he explains. “We can see how the software reacts when we only have 35 kW versus 350 kW. Does it take any longer?”

According to Handley, true microgrids are more than backup resources, which generally result in momentary outages as generators or battery systems kick in. To avoid such outages, Handley and his team are using PMU data to match up voltage, frequency and phase angles of both the grid and the microgrid output.

“You can’t open your switch to island the microgrid until your battery or generation has picked up the load and is starting to serve it,” he says.

Handley says the battery can detect grid instability and switch from current source mode to voltage source mode. As soon as the microgrid switch detects that the battery has begun that shift, it opens. And, all of this happens within 100 milliseconds because the equipment has built-in, mechanical latencies to accommodate.

Using the open field message bus, all of the devices can interconnect at grid edge and operate with precise choreography. “We’re islanding in 2.5 cycles,” Handley says. “You can’t see that with the naked eye.”

A MICROGRID IN EVERY GARAGE

When you think of the word "microgrids," do you think of the building- or campus-sized systems that kept lights burning at places like Princeton University when Super Storm Sandy hit? The school's 40-megawatt cogen facility powered some 4,000 apartments when every other building in the neighborhood was dark.

Wouldn't it be nice to have a microgrid of your very own? Well, wait a few years, and you may be able to buy one. "The Energy Switch is a single-home microgrid in a box," says Bert Haskell, chief technology officer for Pecan Street, an Austin-based energy think tank.

Funded in part through the U.S. Department of Energy **SunShot initiative**, the Energy Switch is a refrigerator-sized device that manages electron flow between household loads, a home's solar panels, an on-site battery, back-up generation and the electric grid. "It has 9.6 kilowatt hours of energy storage built in, load monitoring control of all residential circuits and a connection point for a rooftop PV system," Haskell says.

Plug-in energy security

Designed by Pecan Street researchers, the device also has power-factor correction technology for both the home and grid. This can be automated or controlled by an on-device panel as well as online through an application program interface (API).

"The system enables pretty much any conceivable business model a utility might want to engage in," Haskell notes. "It also gives the homeowner total control over their energy systems, including the ability to go off grid whenever they want to."

Right now, Pecan Street has four units under evaluation. Two are in homes in Central Texas, one is at the Pecan Street lab and one is undergoing functional testing at the National Renewable Energy Laboratory in Golden, Colorado.

What sets the Energy Switch apart from most solar-and-storage solutions is its simplicity and its anticipated affordability. While the first few units might command a price or more than $40,000 retail, each successive unit becomes less expensive. "They're gradually going to get cheaper and cheaper," Haskell says. "Five years out, they'll probably about $5,000 a piece for the hardware."

The units are also virtually plug-and-play. "If you bought just a battery system, you would still have to have a professional engineer and a master electrician involved in designing what's going into your house," Haskell continues. With this system, you just roll it into your garage next to your circuit panel and re-route the circuit panel through the device."

For consumers, the devices promise freedom from electric bills and pesky problems like of storm-damaged power lines. Each unit has two inverters: one to support the grid and one delivering household energy needs.

Power providers are likely to gain, too, Haskell says. "I think this device opens up huge opportunity for utilities because it enables a lot of new business models, including fully transactive energy," he concludes.

> "It has 9.6 kilowatt hours of energy storage built in, load monitoring control of residential circuits and a connection point for a rooftop PV system
>
> *Bert Haskell, chief technology officer for Pecan Street, an Austin-based energy think tank*

REAL-WORLD MODELS FOR THWARTING CYBER THREATS

If there is one issue that plagues most industry players, it's cybersecurity. Among those who responded to SGIP's 2016 Grid Modernization Text Bed Survey, 41 percent identified cybersecurity as an area needing more research and more is underway.

This year, the Defense Advanced Research Projects Agency (DARPA) granted nearly $19 million to the University of Illinois at Urbana-Champaign to build out highly realistic models for testing and validating cybersecurity tools.

Model behavior

The models will be created based on data from utilities and grid operators, as well as more than $10 million in hardware and software. This combination of virtualization, simulation and physical devices will enable researchers to build grid representations with unprecedented fidelity cybersecurity studies.

The team plans to first run the system in "blue sky" mode, which depicts the grid under normal conditions. Then, researchers will inject various disturbances into the system to replicate both natural occurrences – such as storms or wildlife tripping grid equipment – as well as cyber attacks.

Tim Yardley, principal investigator and associate director for technology at the University's Information Trust Institute, says the system generated by this project will be "true to reality rather than based off IEEE reference models."

Why is that so important in designing accurate security tools? "Reference models are based off the physics of what the ideal design may be, but when we deploy things in the real world, it's not always in an ideal situation," he explains.

Yardley adds that various vendors and pieces of equipment have their own characteristics associated with them, as do actual power lines. Even how things are configured and implemented impacts the way devices behave. "Each of those different nuances, those levels of detail, are types of things that we'll capture in our more representative models."

Called the Cyber-Physical Experimentation Environment for RADICS, the project Yardley and his team are creating will provide a way for utilities to explore their security measures and design more resilient approaches. RADICS stands for Rapid Attack Detection Solution and Characterization System.

Yardley notes that the solution he and his team are creating will cover a comprehensive range of technologies grid operators must protect. "Our goal is to model the grid at all levels necessary: generation, distribution, transmission and even consumption, all the way down to metering and consumer loads. We have gear covering that gamut and we'll adding more," he says.

41%

41% — Percentage of survey respondents focusing on cybersecurity

NOTABLE ACHIEVEMENTS, CONTINUED

More power from the wind

"We developed an open-source microgrid controller utilizing publish/subscribe communications on the platforms," said Michael Starke, principal investigator at Oak Ridge National Lab's Distributed Energy Communications and Controls (DECC) Test Bed. "This controller is able to perform self-discovery and supports interoperability. This platform is completely inverter-based, as well. We were also able to construct the needed device controls to support on- and off-grid functionality."

Frequency regulation with load management

"A hierarchical optimal control strategy is well suited for frequency regulation provision from building HVAC systems with variable frequency driven (VFD) fans," says Cindy Regnier, executive manager of the Lawrence Berkeley National Lab's FLEXLAB®. Her site has been called the most advanced building efficiency simulator in the world.

The control approach Regnier is talking about "was able to accurately predict its available regulation capacity within day-ahead market timelines, maintain temperature levels within a pre-defined comfort range, and track a four-second real power signal from PJM's frequency regulation with greater than 95 percent accuracy." Regnier adds that because FLEXLAB® has side-by-side test cells, researchers could confirm that there was no "discernible temperature difference between the cell that followed the frequency regulation signal and the cell that did not."

Proof before purchase

Vidya Vankayaia is director of grid modernization at Powertech Labs, a fully owned subsidiary of BC Hydro. There, he runs the Distribution Automation/Optimization Test Facility, a site that's been a proving ground for several important technologies, including the first ever implementation of a mesh-network-based AMI system.

According to Vankayaia, his team's work "led to faster product development for the vendor and a proven solution for the utility" on that AMI project. Vankayaia concludes that a key to success with new technologies is "finding a realistic, representative test bed where concepts can be proven and tested for business relevance. There is a lot of hype. Utilities need better ways to evaluate options than through a paper RFP process."

SGIP: KEY INITIATIVES

Orange Button℠

Right now, high-quality data – or the lack of it – impacts more than half the total price of a residential PV system. SGIP is one of four organizations selected by the U.S. Department of Energy SunShot Initiative to lead Orange Button℠, a program that aims to facilitate solar deployments and boost bankability through easier exchange of high-quality data. SGIP is working with the SunSpec Alliance, kWh Analytics, and the National Renewable Energy Laboratory (NREL).

Cybersecurity

A key working group of SGIP, volunteer group members identify grid cybersecurity-specific gaps and challenges, then provide recommended security requirements. The group also has been working on a logical reference model of the Smart Grid, which supports the creation and maintenance of a logical security architecture. In addition, volunteers assess proposed standards for adoption into the SGIP Catalog of Standards and develop cybersecurity resources that can benefit industry stakeholders.

Distributed Energy Resources (DERs)

How can DERs be securely and safely integrated into our existing power networks in a reliable manner? That's a question SGIP members are working to answer. They're exploring new ways of system planning, operations, distribution teams and IT architecture. SGIP's work entails defining requirements, identifying gaps that need to be overcome to support DER, defining new standards where needed and/or modifying and harmonizing existing standards as required.

Grid Management

SGIP's utility-only Grid Management Working Group brings together grid operations technology and business leaders from utilities to discuss key operational concepts, capabilities and architecture principles needed to manage a more complex grid due to the rapid rise of DERs.

Energy IoT

A leader in helping power-sector players leverage the Internet of Things, SGIP's EnergyIoT™ efforts help utilities and grid operators apply existing processes, standards and technologies to create a grid that is secure, reliable, resilient and flexible. SGIP's newest EnergyIoT™ Priority Action Plan, OpenFMB™, is a utility-led project to create the reference architecture for an Open Field Message Bus that facilitates interoperability.

SGIP (www.sgip.org) is an industry consortium that represents a cross-section of the energy ecosystem and is focused on driving grid modernization and the energy internet of things through policy, education, and promotion of interoperability and standards to empower customers and enable a sustainable energy future. Our members are utilities, vendors, investment institutions, industry associations, regulators, government entities, national labs, services providers and universities. A nonprofit organization, we drive change through a consensus process.

CONTACT

Address

Contact SGIP to learn more about SGIP and get connected

SGIP
401 Edgewater Place
Suite 600
Wakefield, MA 01880

Online

LinkedIn: SGIP Organization Page:
www.linkedin.com/company/smart-grid-interoperability-panel

Twitter:
https://twitter.com/SGIPnews

www.sgip.org

Sharon Allan
CEO & PRESIDENT
sallan@sgip.org

Aaron Smallwood
VP TECHNOLOGY
asmallwood@sgip.org

Gabrielle Puccio
VP, MEMBER & PUBLIC AFFAIRS
gpuccio@sgip.org

This work was performed under the financial assistance award 70NANB16H002 from the U.S. Department of Commerce, National Institute of Standards and Technology.