Sandia National Laboratories

SAND2018-3008C

Grid Modernization Laboratory Consortium Testing Network (GMLC 1.2.3)

PRESENTED BY

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IAPG Electrical Systems Working Group Meeting, Dayton, OH
March 22, 2018

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Grid Modernization Initiative

- The Grid Modernization Initiative (GMI) works across the U.S. Department of Energy (DOE) to create the modern grid of the future.
  - Primary funding support comes from the Office of Electricity Delivery and Energy Reliability and Office of Energy Efficiency and Renewable Energy, with the Office of Energy Policy and Systems Analysis providing policy recommendations.

- GMI focuses on the development of new architectural concepts, tools, and technologies that measure, analyze, predict, protect, and control the grid of the future, and on enabling the institutional conditions that allow for more rapid development and widespread adoption of these tools and technologies.

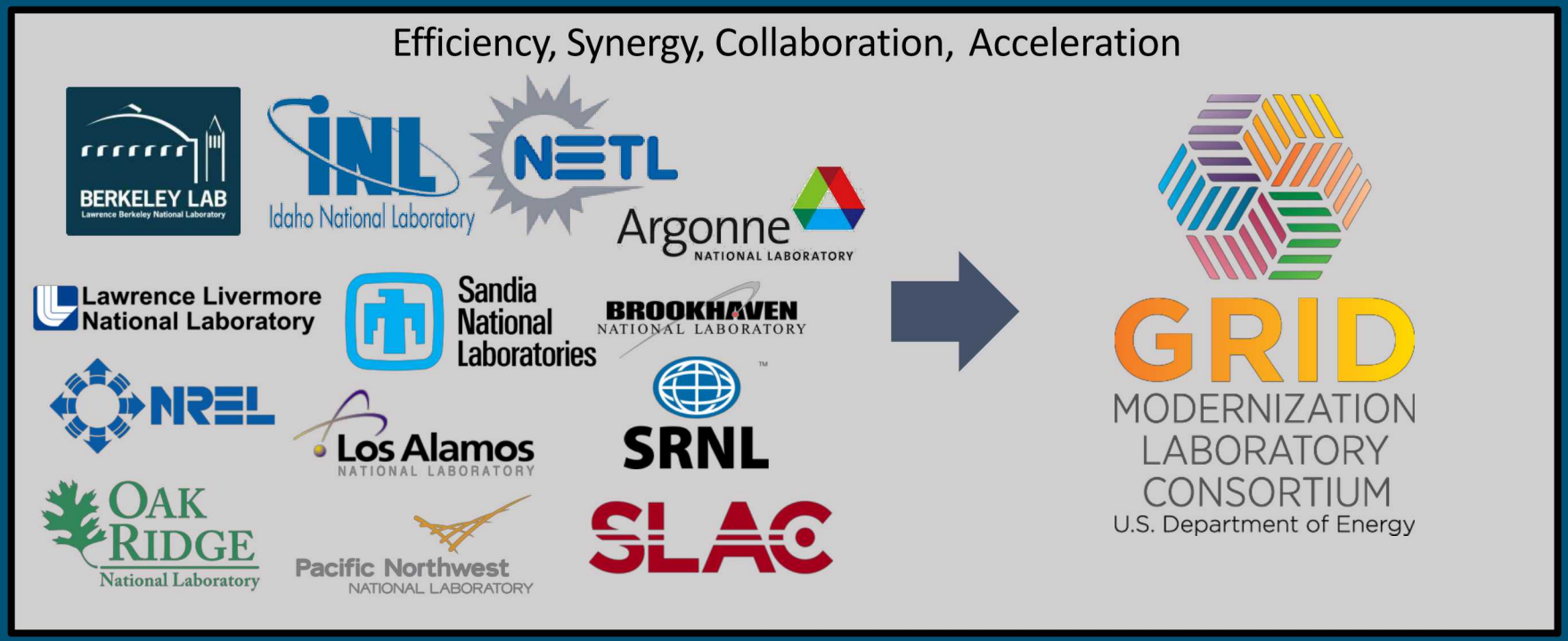
Grid Modernization Laboratory Consortium (GMLC)

- https://gridmod.labworks.org/
- Strategic partnership between DOE and the national laboratories to bring together leading experts, technologies, and resources to collaborate on the goal of modernizing the nation's grid.
- Grid Modernization Lab Call provided funding to GMLC through a comprehensive effort of eighty-eight projects managed by the national laboratories.
- Benefits of the GMLC include more efficient use of resources; shared networks; improving learning and preservation of knowledge; enhanced lab coordination and collaboration; and regional perspective and relationships with local stakeholders and industry.

GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

Grid Modernization Laboratory Consortium (GMLC)

Move from a collection of DOE and lab projects to a DOE-Lab Consortium Model that integrates and coordinates laboratory expertise and facilities to best advance DOE Grid Modernization goals.



GMLC Projects

- **Core Activities –** These projects (**1.1-1.2.5**) provide the fundamental knowledge, metrics, and tools needed to support all the Cross-Cut R&D and regional partnerships.
  - e.g., 1.2.5: Grid Sensing and Measurement Strategy
- **Pioneer Regional Partnerships –** These partnerships (**1.3.01-1.3.99**) involve technical assistance to states, utilities, or other stakeholders that are facing key emerging grid modernization challenges.
  - e.g., 1.3.10 Vermont Regional Partnership Enabling the Use of DER
- **Crosscutting R&D –** These integrated projects (**1.4.01-1.4.29**) will further advance grid modernization by coupling multiple hardware, software, and institutional solutions into integrated and modernized grids at a scale and a pace necessary to meet national goals.
  - e.g., 1.4.9: Integrated Multi Scale Analytics and Machine Learning for the Grid

GMLC 1.2.3: Goal and Impact

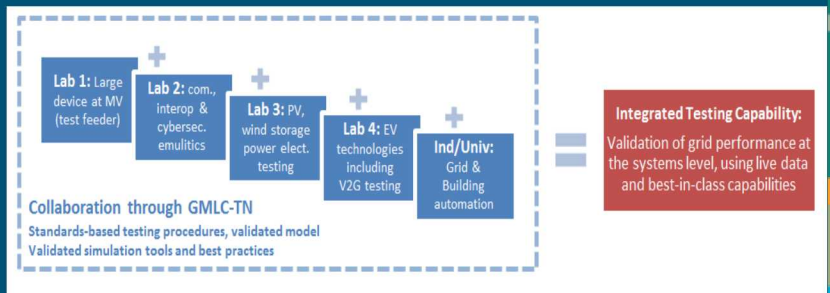
GMLC 1.2.3: Testing Network and Open Library

Overall Goal:

Accelerate grid modernization by improving access to and visibility of National Lab testing infrastructure for grid devices and systems, and related models and tools. Enable national labs to drive innovation more effectively and synergistically.

Impact :

- Effectively utilize world-class testing resources and validated models at National Labs and beyond.
- Encourage National Lab-industry, National Lab-government, National Lab-University collaboration
- Enable integrated test capabilities by leveraging multiple facilities



GMLC 1.2.3: Team and Organization

Project Team

Sandia National Laboratories

Idaho National Laboratory

Berkeley Lab — Lawrence Berkeley National Laboratory

NREL

Oak Ridge National Laboratory

GMLC 1.2.3

Testing Network (TN)

Federated, lab-based resource for testing and performance validation of grid devices and systems.

Open Library (OL)

Public repository for validated models, simulation tools, and testing resources.

project organization

gridPULSE

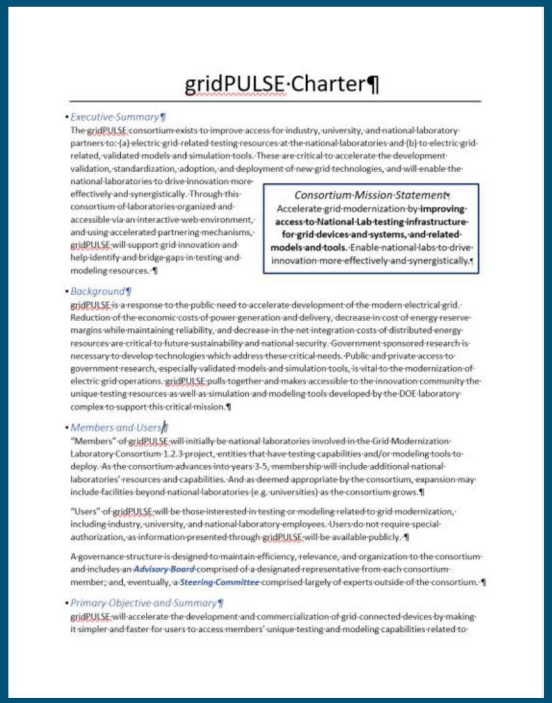
Public User Library for Systems Evaluation

Consortium formed to address the project's goals of accelerating grid modernization by enabling access to a comprehensive testing infrastructure and model library

project outcome

GMLC Testing Network

Significant outcomes so far:



gridPULSE·Charter¶

• Executive·Summary¶

The gridPULSE consortium exists to improve access for industry, university, and national laboratory partners to: (a) electric grid related testing resources at the national laboratories and (b) to electric grid related, validated models and simulation tools. These are critical to accelerate the development validation, standardization, adoption, and deployment of new grid technologies, and will enable the national laboratories to drive innovation more effectively and synergistically. Through this consortium of laboratories organized and accessible via an interactive web environment, and using accelerated partnering mechanisms, gridPULSE will support grid innovation and help identify and bridge gaps in testing and modeling resources. ¶

Consortium·Mission·Statement¶
Accelerate grid modernization by **improving access to National Lab testing infrastructure for grid devices and systems, and related models and tools.** Enable national labs to drive innovation more effectively and synergistically.¶

• Background¶

gridPULSE is a response to the public need to accelerate development of the modern electrical grid. Reduction of the economic costs of power generation and delivery, decrease in cost of energy reserve margins while maintaining reliability, and decrease in the net integration costs of distributed energy resources are critical to future sustainability and national security. Government sponsored research is necessary to develop technologies which address these critical needs. Public and private access to government research, especially validated models and simulation tools, is vital to the modernization of electric grid operations. gridPULSE pulls together and makes accessible to the innovation community the unique testing resources as well as simulation and modeling tools developed by the DOE laboratory complex to support this critical mission. ¶

• Members and Users¶

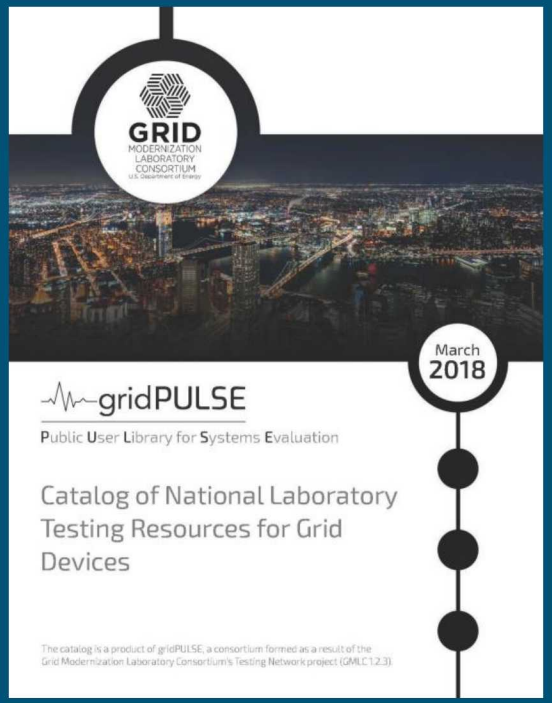
"Members" of gridPULSE will initially be national laboratories involved in the Grid Modernization Laboratory Consortium 1.2.3 project, entities that have testing capabilities and/or modeling tools to deploy. As the consortium advances into years 3-5, membership will include additional national laboratories' resources and capabilities. And as deemed appropriate by the consortium, expansion may include facilities beyond national laboratories (e.g. universities) as the consortium grows. ¶

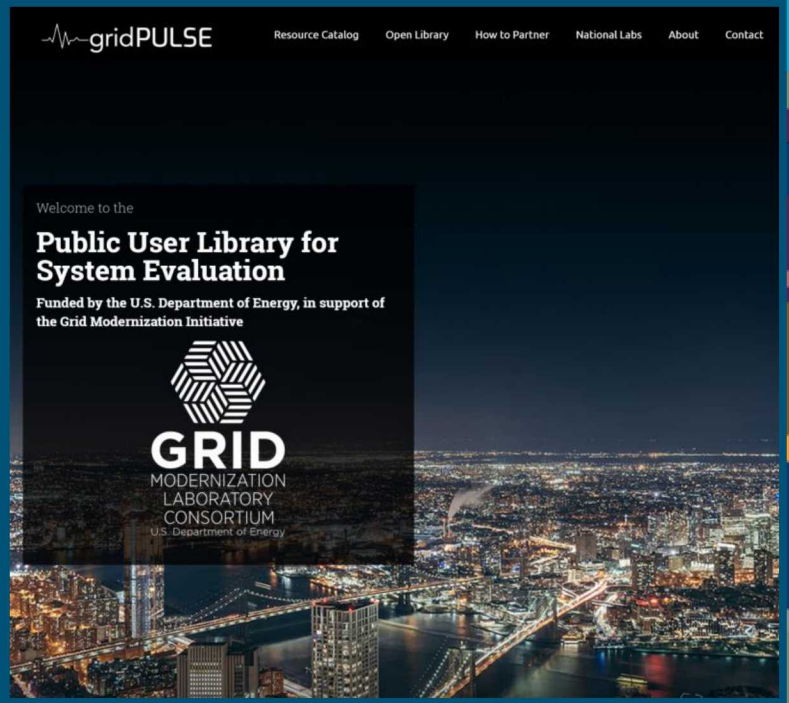
"Users" of gridPULSE will be those interested in testing or modeling related to grid modernization, including industry, university, and national laboratory employees. Users do not require special authorization, as information presented through gridPULSE will be available publicly. ¶

A governance structure is designed to maintain efficiency, relevance, and organization to the consortium and includes an ***Advisory Board*** comprised of a designated representative from each consortium member; and, eventually, a ***Steering Committee*** comprised largely of experts outside of the consortium. ¶

• Primary Objective and Summary¶

gridPULSE will accelerate the development and commercialization of grid connected devices by making it simpler and faster for users to access members' unique testing and modeling capabilities related to





gridPULSE consortium established

testing capabilities and facilities catalog

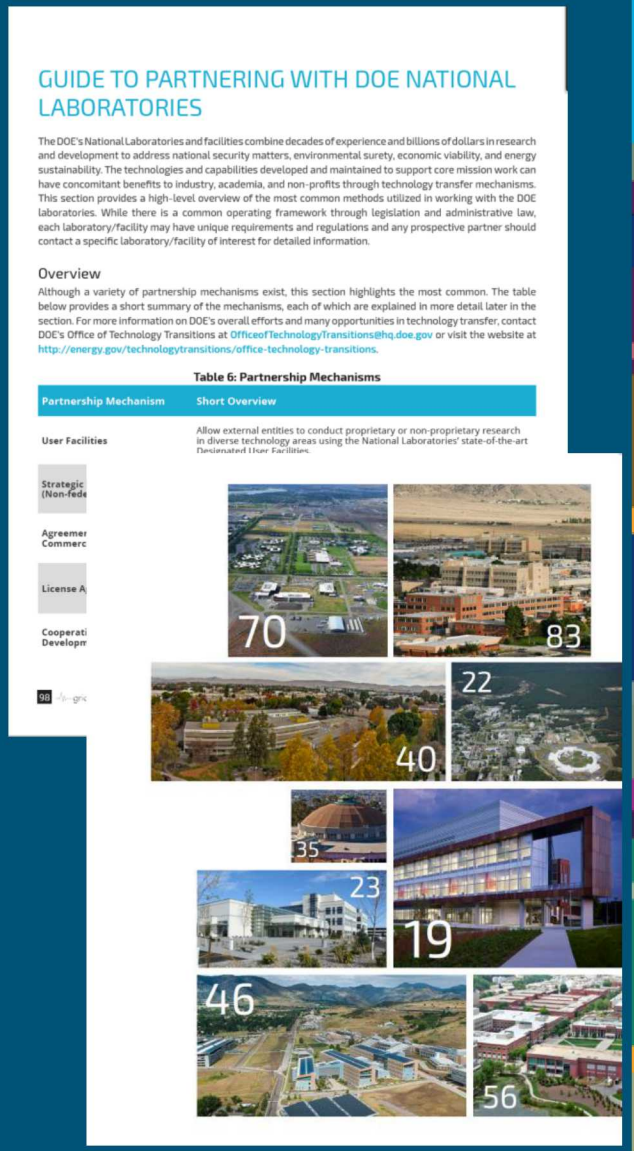
website to facilitate user interaction

gridPULSE

- gridPULSE Charter defines members, users, operation, goals, etc.
  - Adopted by the 5 National Lab team members on October 3rd, 2017
  - Modeled after other successful DOE consortia
- "Members" of gridPULSE have testing capabilities and/or modeling tools.
  - Initially 5 project team member national Labs
  - Later, expansion to other national Labs and beyond (e.g. universities)
- "Users" of gridPULSE are those interested in testing or modeling.
  - Publicly accessible: industry, university, national laboratory employees are all users
  - Users can access information on models and testing resources; can submit testing requests
- Working on streamlined approach to executing necessary agreements among members and users.
  - Standardized agreements that members have agreed to which users can accept and quickly enact
  - Agreements which facilitate partnerships among multiple members to enable enhanced capabilities

Testing Capabilities and Facilities Catalog

- Extensive self-assessment of grid-related test capabilities and facilities
  - 12 DOE National Labs
  - 49 distinct facilities
  - 100s of test facility/test capability pairs
- Formatted as report:
  - Introduction on motivation and how to use information
  - Appendix on partnerships
  - Test facility/capability information presented as both overview tables and detailed paragraphs


GUIDE TO PARTNERING WITH DOE NATIONAL LABORATORIES

The DOE's National Laboratories and facilities combine decades of experience and billions of dollars in research and development to address national security matters, environmental surety, economic viability, and energy sustainability. The technologies and capabilities developed and maintained to support core mission work can have concomitant benefits to industry, academia, and non-profits through technology transfer mechanisms. This section provides a high-level overview of the most common methods utilized in working with the DOE laboratories. While there is a common operating framework through legislation and administrative law, each laboratory/facility may have unique requirements and regulations and any prospective partner should contact a specific laboratory/facility of interest for detailed information.

Overview

Although a variety of partnership mechanisms exist, this section highlights the most common. The table below provides a short summary of the mechanisms, each of which are explained in more detail later in the section. For more information on DOE's overall efforts and many opportunities in technology transfer, contact DOE's Office of Technology Transitions at OfficeofTechnologyTransitions@hq.doe.gov or visit the website at http://energy.gov/technologytransitions/office-technology-transitions.

Table 6: Partnership Mechanisms

Partnership Mechanism	Short Overview
User Facilities	Allow external entities to conduct proprietary or non-proprietary research in diverse technology areas using the National Laboratories' state-of-the-art Designated User Facilities
Strategic (Non-fede	
Agreemer Commerc	
License A	
Cooperati Developm	

Test Facility

- Energy Systems Integration Facility (NREL)
- Distributed Energy Technologies Laboratory (Sandia)
- …

Test Capability

- Communications Interoperability
- Cybersecurity
- Hardware in the Loop
- Grid Compatibility and Interconnection
- Reliability / Safety / Failure Analysis
- Systems Integration and Control

Application Technology

- Building Technologies
- Dist. Sys. Components
- Electric Vehicles
- Energy Storage
- Fuel Cells
- ICT and AMI
- Integrated Energy Systems
- Microturbines and Gensets
- PV
- Trans. Sys. Components
- Wind

Testing Capabilities and Facilities Catalog

Capabilities/Technology Areas table

OVERVIEW OF CAPABILITIES

Laboratory capabilities can be present within a single facility, or spread across multiple facilities to incorporate a more robust set of equipment and expertise. As stated in the "Definitions" section of this catalog, capabilities represent a type of test (or set of tests) that can be completed through the combination of available expertise, experience, equipment, and other resources. Table 4 provides an overview of which capabilities are actively available for which technology areas at a given national laboratory. Additional details for each capability are found later in this catalog.

Table 4: Capabilities Matrix

	Technology Areas										
	Building Technologies	*Distr. System Components*	*Electric Vehicles*	*Energy Storage*	*Fuel Cells*	*ICT & AMI*	*Integrated Energy Sys.*	*Microturbines & Gensets*	*PV*	*Trans. System Components*	*Wind*
Argonne National Laboratory											
Communications Interoperability	■	■	■		■	■					
Reliability/Safety/Failure Analysis		■	■			■					
Systems Integration and Control	■	■	■		■	■		■			
Brookhaven National Laboratory											
Systems Integration and Control			■			■		■			■
Idaho National Laboratory											
Cybersecurity	■	■	■	■	■	■	■	■	■	■	
Hardware-in-the-loop	■	■	■	■	■	■	■	■	■		
Reliability/Safety/Failure Analysis	■	■	■		■	■		■	■	■	■
Systems Integration and Control	■	■	■		■	■		■	■	■	
Lawrence Berkeley National Laboratory											
Communications Interoperability					■	■					
Hardware-in-the-loop	■	■	■			■					
Reliability/Safety/Failure Analysis			■	■							
Systems Integration and Control	■	■				■			■		
Lawrence Livermore National Laboratory											
Cybersecurity										■	
National Energy Technology Laboratory											■
Systems Integration and Control	■	■	■	■		■	■	■	■	■	
National Renewable Energy Laboratory											
Cybersecurity	■		■		■	■		■	■		
Grid Compatibility and Interconnection	■	■	■	■		■	■	■		■	
Hardware-in-the-loop	■	■	■	■		■	■	■		■	
Reliability/Safety/Failure Analysis	■	■	■	■		■		■		■	
Systems Integration and Control	■	■	■	■	■	■	■	■	■	■	
Oak Ridge National Laboratory											
Communications Interoperability	■	■	■		■	■	■	■			
Cybersecurity	■	■			■	■		■	■	■	
Grid Compatibility and Interconnection	■	■				■					■
Hardware-in-the-loop	■	■			■	■	■	■			
Reliability/Safety/Failure Analysis	■	■			■	■				■	
Pacific Northwest National Laboratory											
Cybersecurity	■									■	
Hardware-in-the-loop		■	■		■	■		■	■	■	■
Reliability/Safety/Failure Analysis										■	
Sandia National Laboratories											
Communications Interoperability	■		■		■			■			
Cybersecurity	■		■		■	■		■	■	■	■
Hardware-in-the-loop			■					■	■	■	
Reliability/Safety/Failure Analysis	■	■	■			■	■	■	■	■	■
Systems Integration and Control	■		■					■	■	■	
Savannah River National Laboratory											■
Hardware-in-the-loop	■							■	■		
Reliability/Safety/Failure Analysis	■								■	■	■
SLAC National Accelerator Laboratory											■
Systems Integration and Control	■	■	■			■	■	■			■

Testing Capabilities and Facilities Catalog

Facilities/Technology Areas table

		Technology Areas											
		Building Technologies	Distr. System Components	Electric Vehicles	Energy Storage	Fuel Cells	ICT & AMI	Integrated Energy Sys.	Microturbines & Gensets	PV	Trans. System Components	Wind
ANL	Advanced Powertrain Research Facility			■	■	■						
ANL	Battery Research Facilities			■	■							
ANL	EV Smart Grid and Interoperability Center		■	■	■		■	■		■		
BNL	Northeast Solar Energy Research Center				■			■		■		
INL	Battery Test Center		■	■	■			■				
INL	Cybersecurity Test Facilities		■	■	■	■	■	■	■	■	■	■
INL	Electric Grid Test bed		■	■	■		■	■			■	
INL	Electric Vehicle Infrastructure Laboratory		■	■	■			■				
INL	Power and Energy Systems Real-time Laboratory		■	■	■	■	■	■	■	■	■	
INL	Smart Microgrid Test bed		■		■		■	■		■		■
LBNL	Building Technologies Test Chambers	■										
LBNL	Demand-to-Grid Lab	■		■			■					
LBNL	Electrochemical Technologies Laboratory				■							
LBNL	Facility for Low Energy Experiments in Buildings	■	■	■	■							
LLNL	Skyfall Cyber-Physical Test bed										■	
NETL	Electromagnetic Component Testing & Fabrication Lab		■			■				■		
NETL	Energy Infrastructure Monitoring Sensor Dev/Test Lab		■		■	■			■		■	
NREL	Energy Storage Facilities			■	■							
NREL	Energy Systems Integration Facility	■	■	■	■	■	■	■	■	■	■	■
NREL	National Wind Technology Center		■		■	■		■		■		■
NREL	Vehicle Testing and Integration Facility	■		■								
ORNL	Advanced Cable Test Development Facility		■									
ORNL	Building Technologies Research and Integration Center	■										
ORNL	Center for Trustworthy Embedded Systems	■	■	■			■	■				
ORNL	Distributed Energy Comms. and Controls Lab		■		■		■	■	■	■		
ORNL	HV Dielectrics Research Facility		■								■	
ORNL	Multi-Zone Environmental Chambers	■										
ORNL	Powerline Conductor Accelerated Test Facility										■	
ORNL	Power Electronics & Electric Machinery Res. Center	■		■	■			■		■	■	
ORNL	SI-GRID						■	■				
ORNL	Technical Testing and Analysis Center	■	■	■	■			■		■	■	■
PNNL	ADMS Test bed		■				■	■			■	
PNNL	Advanced Battery Facility				■							
PNNL	Advanced Building Controls Test Facility	■										
PNNL	Control of Complex Systems Test Bed	■	■				■	■			■	
PNNL	Electricity Infrastructure Operations Center	■	■	■			■			■	■	■
PNNL	Energy Communications Cyber Test Bed						■	■				
PNNL	Pacific Northwest Side-by-Side Laboratory Homes	■		■								
PNNL	PMU Metrology Facility										■	
PNNL	PowerNET	■	■	■	■		■			■	■	■
SNL	Battery Abuse Testing Laboratory				■			■				
SNL	Control and Optimiz. Networked Energy Tech. Lab		■		■		■	■			■	■
SNL	Distributed Energy Technologies Laboratory		■		■		■	■	■	■		
SNL	Emulytics and Threat Analysis Laboratory	■	■				■	■		■		■
SNL	Energy Storage Testpad and Analysis Laboratory				■	■		■				
SNL	Scaled Wind Farm Technology Facility						■					■
SNL	Secure Scalable Microgrid Test bed				■		■	■	■	■		■
SRNL	High Current Calibration Facility		■								■	■
SLAC	Grid Integration, Systems, and Mobility Lab		■	■	■			■	■	■		

Testing Capabilities and Facilities Catalog

Facility description example

The Energy Storage Test Pad and Analysis Laboratory evaluates the controls and operation of the energy storage system through developing control algorithms and conducting real-world development tests. In 2017, Sandia revamped the Test Pad to help answer basic questions such as "How do you optimize the operation of an energy storage system?" Users can analyze system parameters, develop testing procedures, or create new energy storage standards using real-world situations – rather than simulations – that are applicable to renewables, the microgrid, islanding, and the connected grid.

The Test Pad is integrated with Sandia's Distributed Energy Technologies Laboratory (DETL) and allows for access to the microgrid through DETL's interoperability network which is linked to data acquisition systems, grid and photovoltaic simulators, and DER. The Test Pad utilizes a 1 MW hour vanadium redox flow battery for storage and simulators for various grid voltage and voltage current frequency scenarios. The electric distribution switch gear provides connection or disconnection from the grid; configurations are connected to resistive and capacitive load banks and can be taken through a wide range of operational states, which allows the test bed to generate its own microgrid.

BENEFITS OF WORKING WITH THE ENERGY STORAGE TEST PAD AND ANALYSIS LABORATORY

Most energy storage system testing relies on computerized simulations and desktop analysis to generate results. The Energy Storage Test Pad and Analysis Laboratory takes desktop analysis and utilizes it to create actual demonstrations and experiments (using a wide variety of equipment) that provide real-world data that can inform improvements and optimization strategies for controls and operations within energy storage systems. The connection to DETL allows researchers and users to extend experiments to additional physical equipment and simulated systems for a complete understanding of systems-of-systems impacts.

Scaled Wind Farm Technology Facility

ICT and AMI, Wind

Courtesy of Sandia National Laboratories.

OVERVIEW

The Scaled Wind Farm Technology (SWiFT) Facility focuses on enabling rapid, cost-efficient testing and development of transformative wind energy technology. SWiFT operates with the goals of a) reducing

turbine-turbine interaction and wind plant underperformance, b) developing advanced wind turbine rotors, and c) generating and utilizing open-source information to advance simulation capabilities. The facility consists of three variable-speed, variable-pitch modified wind turbines with full power conversion and an extensive sensor suite; two heavily instrumented inflow meteorological towers; and site-wide time-synchronized data collection. As it relates to grid modernization, SWiFT hosts a control building that handles all central control and operations of the facility (including proprietary work). The Control Building is integrated to each turbine via an individual fiber-optic bundle connection, offering data transfer capabilities and flexible site network reconfiguration. The following provides additional detail on the control software for the facility's wind turbines:

- Open source code
- Modularized by subsystem
- EtherCAT up to 1000 Hz
- All DAQ signals available for control
- Running on NI Veristand
- Parameterized variable speed and torque controller
- Maintains all original safety systems and alarms

UNIQUE FEATURES OF SWIFT

SWiFT is the first public facility specifically designed to use multiple wind turbines to measure turbine performance and wake interactions in a wind farm environment. The site's strategic location at the Reese Technology Center and hosted by Texas Tech University (TTU) in Lubbock, Texas is key; the Lubbock area has a high wind resource and consistent wind direction, which is ideal for research. The site is in the southern end of the U.S. wind corridor which provides favorable weather conditions all year due to Lubbock's directional, high average wind speed.

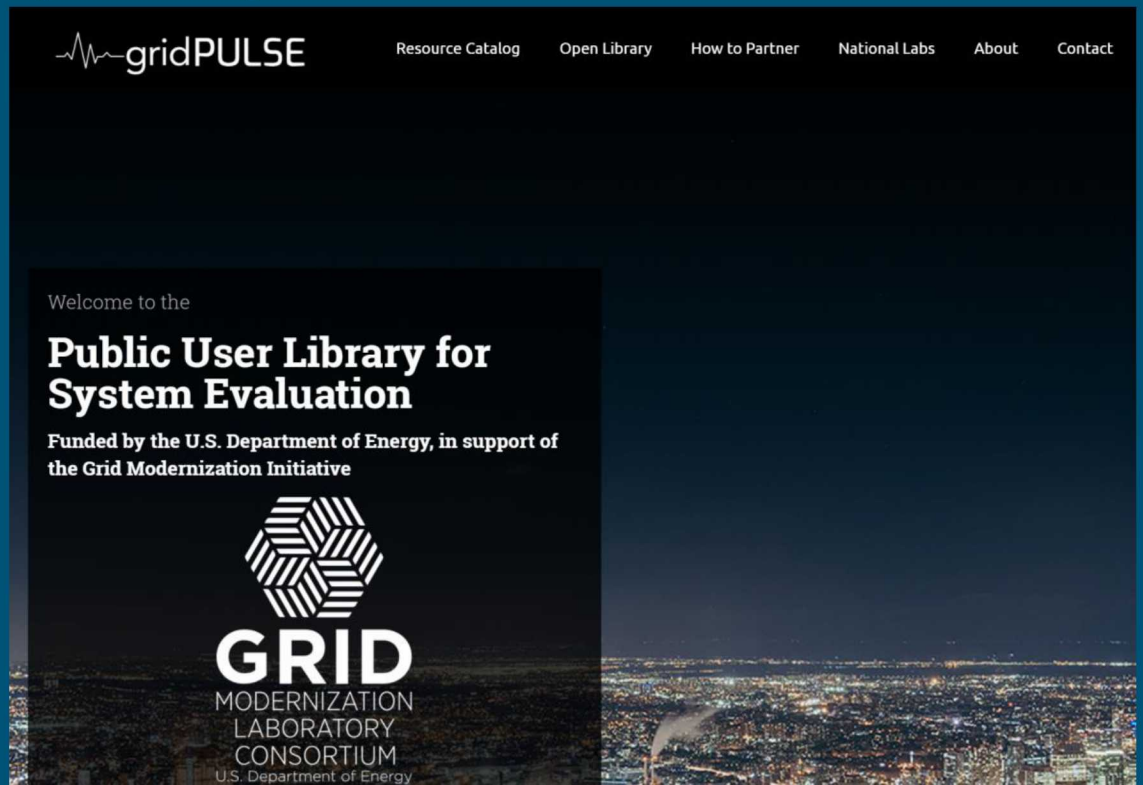
The SWiFT turbines are research-scale and can operate together to simulate a wind farm or independently from one another for different test scenarios. The arrangement of the turbines has been designed so that interactions typically observed in utility wind farms will occur throughout the year. Additional on-site capabilities provided by research partners include a 1 MWh battery owned by the local electric utility, 150 kW of solar panels owned by TTU, and significant investments by GroupNIRE in electrical substations, leased land, and a microgrid facility.

BENEFITS OF WORKING WITH SWIFT

SWiFT provides open-source turbine access to potential partners and researchers, which allows for a thorough working knowledge of each turbine's structural characteristics and control system programming prior to initiation of a partnership at the site. The control system programming is completely accessible and can be modified to support research objectives. Each turbine has a variable frequency drive whose internal functions are accessible through the turbine control system for torque and power quality control applications. Private wind turbine manufacturers and operators generally do not make these control capabilities accessible to the degree that SWiFT does. SWiFT turbines are smaller than most utility-scale

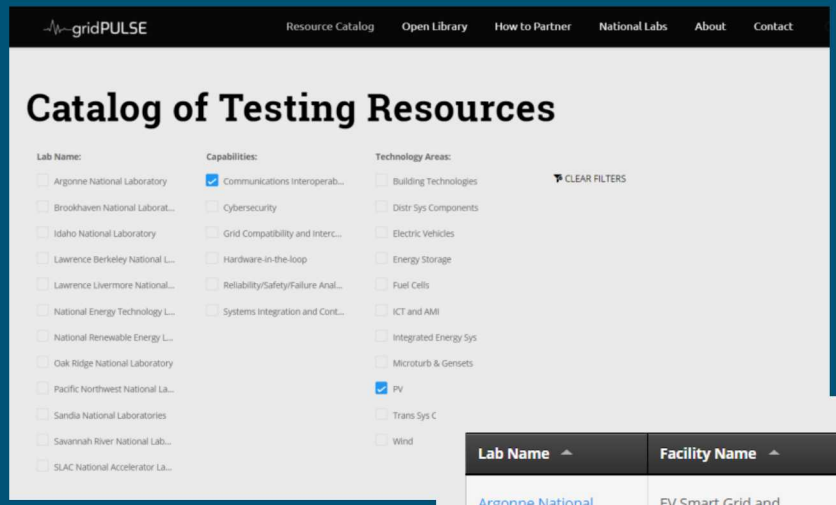
gridPULSE Website

- https://gridmodtools.org/; being finalized
- Main vehicle for:
  - Viewing resource catalog of test capabilities and facilities
  - Viewing and entering models into the Open Library
  - Submitting testing requests/requests for more details
  - Details on partnerships



gridPULSE WEBSITE

Resource catalog is sortable and searchable for efficient access to info



Lab Name	Facility Name	Capabilities	Technology Areas	Differentiating Capabilities
Argonne National Laboratory	EV Smart Grid and Interoperability Center	Communications Interoperability, Reliability/Safety/Failure Analysis, Systems Integration and Control	Distr Sys Components, Electric Vehicles, Energy Storage, ICT and AMI, Integrated Energy Sys, PV	Charging interoperability; grid connectivity; metering, communication, and control
National Renewable Energy Laboratory	Energy Systems Integration Facility	Communications Interoperability, Cybersecurity, Grid Compatibility and Interconnection, Hardware-in-the-loop, Reliability/Safety/Failure Analysis/ Systems Integration and Control	Distr Sys Components, Electric Vehicles, Energy Storage, Fuel Cells, ICT and AMI, Integrated Energy Sys, Microturb & Gensets, PV, Trans Sys Components, Wind	HIL at MW scale; petascale computing center; real-time simulation; high-speed data links to different lab facilities for HIL testing
Oak Ridge National Laboratory	Distributed Energy Communications and Controls Lab	Communications Interoperability, Cybersecurity, Grid Compatibility and Interconnection, Hardware-in-the-loop, Reliability/Safety/Failure Analysis, Systems Integration and Control	Distr Sys Components, Energy Storage, ICT and AMI, Integrated Energy Sys, Microturb & Gensets, PV	connected to ORNL distribution system; communications through dedicated network
Pacific Northwest National Laboratory	Electricity Infrastructure Operations Center	Communications Interoperability, Grid Compatibility and Interconnection	Building Technologies, Distr Sys Components, Electric Vehicles, Fuel Cells, PV, Trans Sys Components, Wind	Fully configurable grid control rooms; real-time streaming synchrophasor data; energy/distribution management systems
Sandia National Laboratories	Distributed Energy Technologies Laboratory	Communications Interoperability, Cybersecurity, Grid Compatibility and Interconnection, Hardware-in-the-loop, Systems Integration and Control	Distr Sys Components, Energy Storage, ICT and AMI, Integrated Energy Sys, Microturb & Gensets, PV	Up to 10 inverters in simultaneous test; 120/240 and 480V; up to 600V DC, 150 kW; 40 kW and 200 kW PV simulators
Sandia National Laboratories	Secure Scalable Microgrid Testbed	Communications Interoperability, Cybersecurity, Hardware-in-the-loop, Systems Integration and Control	Energy Storage, ICT and AMI, Integrated Energy Sys, Microturb & Gensets, PV, Wind	Highly configurable through emulation; 9 energy storage emulators capable of 5 kW

Showing 1 to 6 of 6 entries (filtered from 49 total entries)

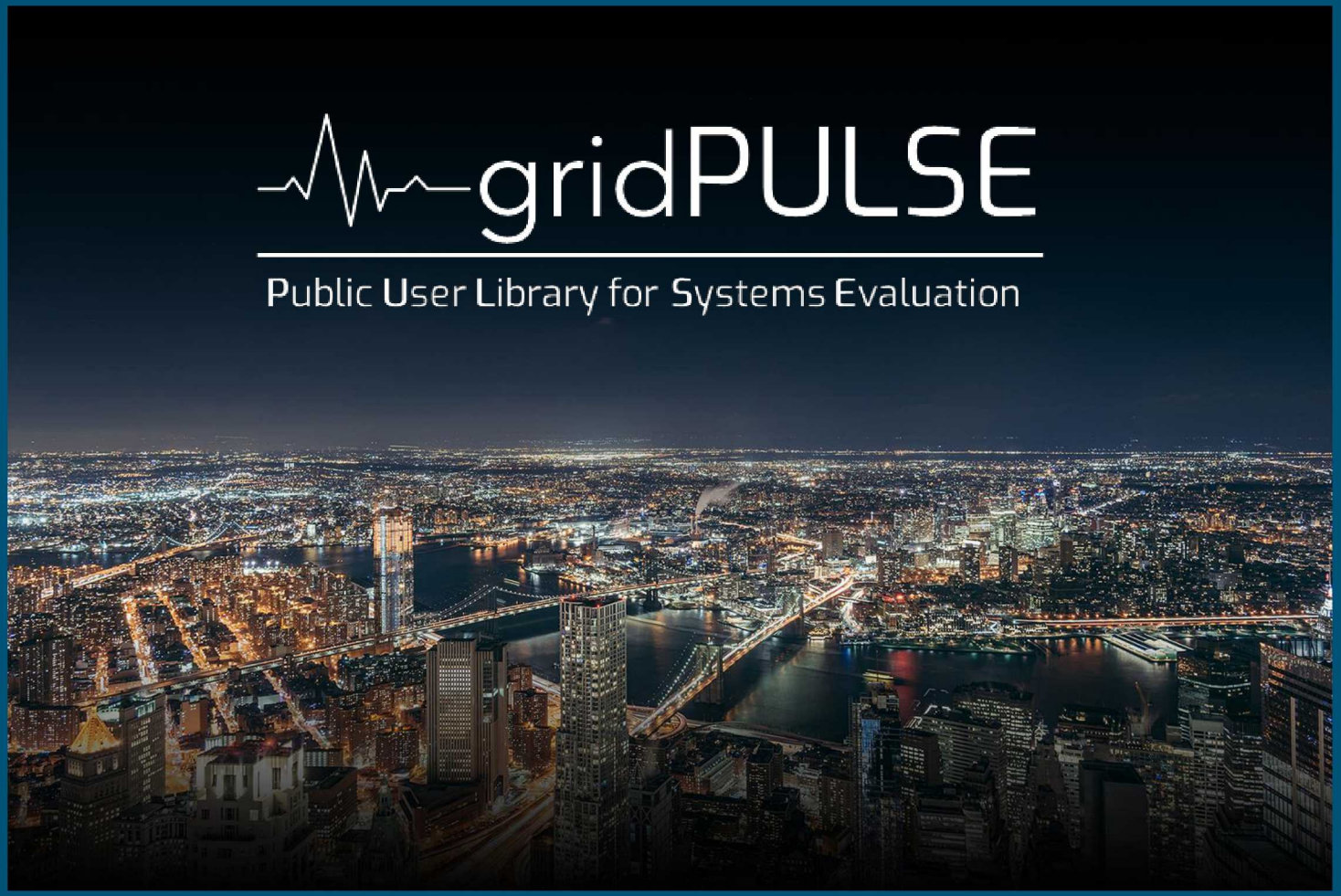
gridPULSE Website

Sortable catalog links to full details on each facility

Next Steps / Outlook

- Main focus of PY3 (Apr. 2018 to Mar. 2019) is on stakeholder outreach and establishing a sustainable organization for gridPULSE
  - Public release of catalog and website
  - Communications outreach including presentations to stakeholders
  - Understanding use cases and what more information might be necessary
  - Governance structure that creates value for members
  - Recruit additional members
- Additionally, working on:
  - Streamlining partnerships mechanisms
  - Keeping information in the Resource Catalog and Open Library up to date

THANK YOU!



http://www.gridmodtools.org

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