Pacific Northwest
NATIONAL LABORATORY

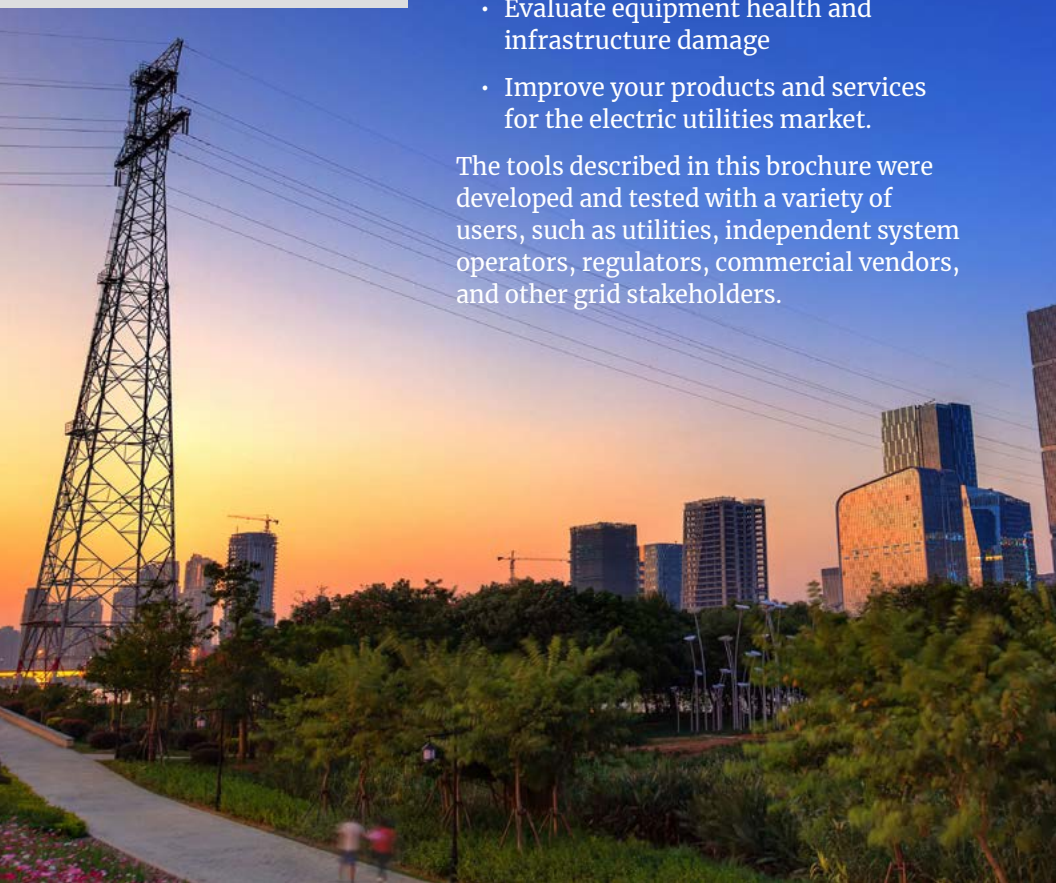
OPERATIONS AND
ANALYTICS SOFTWARE

FOR GRID MODERNIZATION

By choosing the latest grid operations and analytics software tools from Pacific Northwest National Laboratory (PNNL), you can:

- Optimize grid operations, resiliency, and controls while reducing costs
- Improve forecasting, operational compliance, and response time
- Inform decisions about distribution systems and grid energy storage
- Evaluate equipment health and infrastructure damage
- Improve your products and services for the electric utilities market.

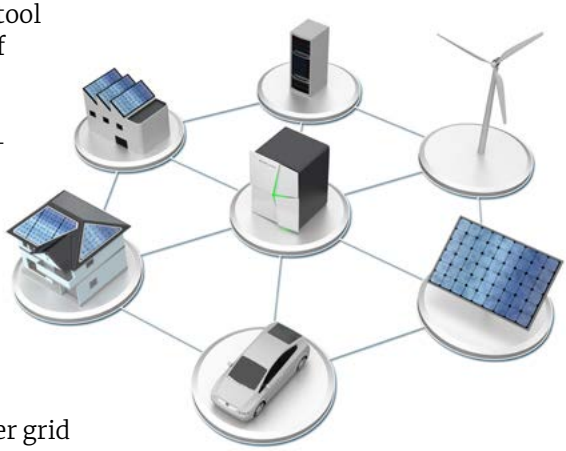
The tools described in this brochure were developed and tested with a variety of users, such as utilities, independent system operators, regulators, commercial vendors, and other grid stakeholders.



PLANNING AND ANALYTICS

Parallel Contingency Analysis and Visualization | 16023, 16953, 16975

Visualizes ranked contingencies



This patented, copyrighted tool converts the large volume of grid contingency analysis results to a visual space and presents the results as user-friendly, color-contoured maps. It assesses and ranks contingencies to guide operators on the most effective preventive actions. This novel visualization method reduces the burden of examining raw data by power grid operators, thereby enabling them to focus on critical portions of the grid and quickly respond to adverse situations. Geographical information is readily included in the visualization techniques, along with a quantitative assessment of the contingency risks.

Net Interchange Scheduling Tool | 30133, 30464, 30835

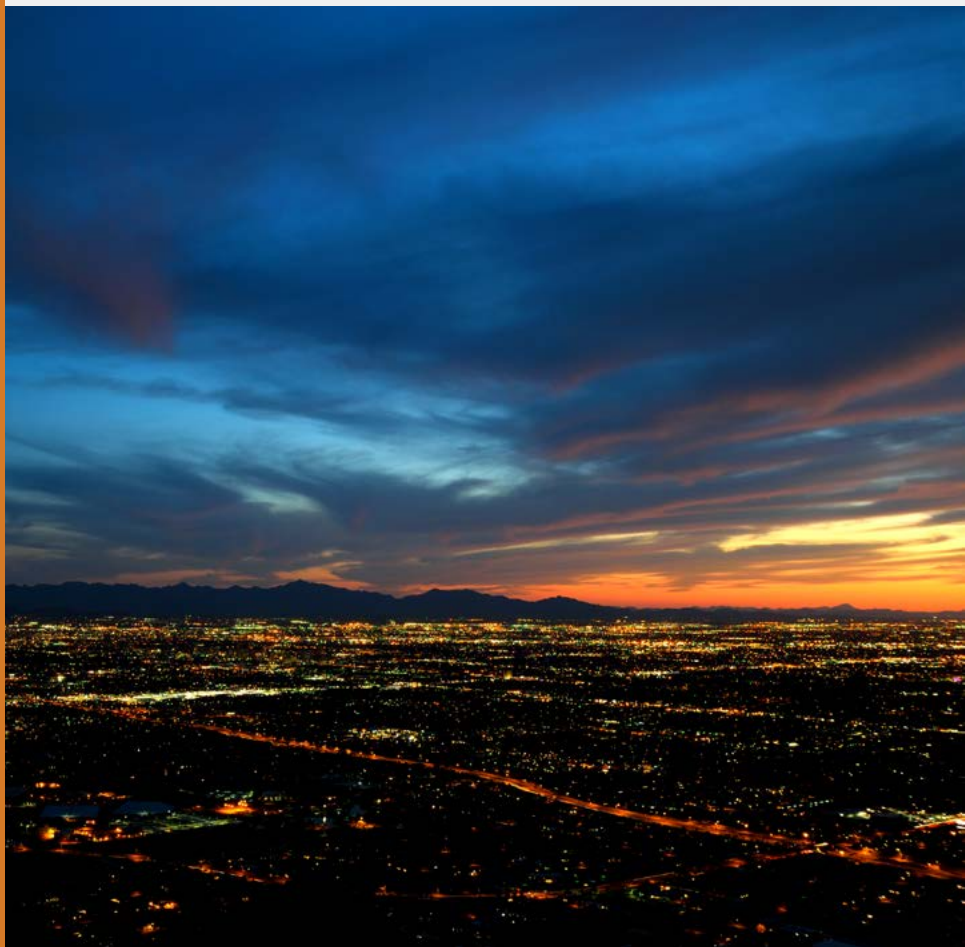
Reduces forecasting errors

This superior forecasting technology predicts power needs more accurately than existing models, thereby helping operators better estimate energy demands up to four hours in advance. The patented, copyrighted technology uses a statistical framework to combine forecasts from multiple scenarios into one that is the most reliable and accurate for the current energy landscape. With more accurate energy forecasts, utilities can reduce the amount of excess power generated and decrease the more costly emergency power they purchase from neighboring energy organizations.

Real-Time Data Management for Phasor Measurement Units (PMU) | 30140, 30116

Stores large datasets orders of magnitude faster

This patented data management tool quickly and efficiently stores large amounts of streaming data, such as the massive quantities of data generated with PMUs. It assigns disk space efficiently without indexing, thus eliminating all search times and disk allocation processes. Tests have shown increases of three to four orders of magnitude in data ingestion performance compared to existing database algorithms. The tool's algorithm applies to data streams for which the record size is known and is generated continuously in precisely known time intervals.



Modal Analysis for Grid Operation (MANGO) | 15967, 30682, 30885, 31297, 31378

Provides wide-area oscillation control

Electromechanical oscillation modes carry important information about power system stability, but if these modes are not well damped, they can result in power outages and cascading grid failures. With MANGO, operators can better control grid modal variables based on analyses of data from PMUs. MANGO provides control suggestions, such as increasing generation or decreasing loads to mitigate inter-area oscillations. This copyrighted tool incorporates two significant innovations—control suggestions that are generated in real time and an operator-in-the-loop control strategy that combines the operator's expertise and mathematical models for making informed operational decisions. MANGO also includes two copyrighted tools: 1) Decoupled Modulation Control, which uses multiple wide-area signals to act on a selected mode without affecting other modes in the system and 2) Modal Mode Meter, which identifies power system modes based on PMU data in real time, so operators can take remedial action when a power system approaches unstable conditions.

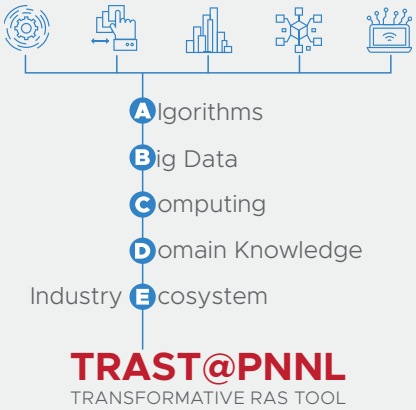
High-Performance Power Grid Optimization (HIPPO) 31055, 31328

Inject High-Performance Computing Into Electricity Market Operations

Security constrained unit commitment (SCUC) is the scheduling and dispatching of generation resources to meet electricity demands that must be solved in electricity markets. Long computation time for solving SCUC directly increases cost, reduces the reliability of delivering electricity, and slows down the progress of adapting new grid technologies into markets. Taking advantage of high-performance computers and advanced optimization algorithms, PNNL's patented HIPPO technology introduces a concurrent optimizer that can simultaneously launch multiple algorithms and manage communication among these algorithms to synergize the advantages from individual algorithms and achieve overall computational efficiency. The computation power HIPPO technology provides to system operators could lead to improved electricity market operations and flexibility in the power grid to integrate more smart grid technologies and renewable energy.

Transformative Remedial Action Scheme Tool (TRAST) | 31349, 31490

Cost-effectively enhances grid reliability and resilience



Remedial action schemes hold promise for ensuring grid reliability, but they only determine the worst operating conditions and may miss critical contingencies, result in under-utilization of assets, and cause the very reliability issues they seek to solve. TRAST has been tested in the Western Interconnect to validate and improve a manually created remedial action scheme based on realistic and near-real-time operational conditions, thus improving power grid reliability and grid asset utilization. The tool provides advanced statistical data analysis, customized dynamic simulation, a prediction based on machine learning, and a reliable validation strategy on multiple commercial platforms. The automatic/semi-automatic functionalities in TRAST could significantly simplify and shorten the remedial action scheme design and study process, from end to end.

DISTRIBUTION AND OPERATIONS

Bump Test and Evaluation for Volt/VAR Optimization Systems (VVO)| 30640

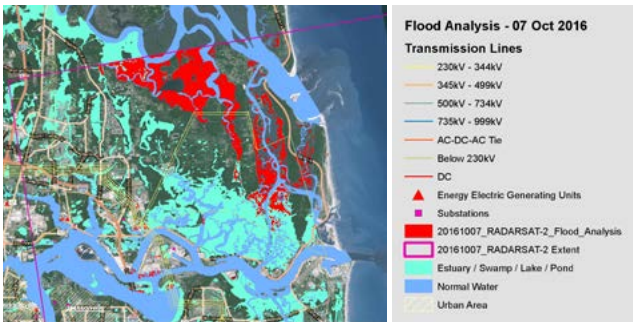
Validates VVO systems in less time

Regulatory authorities require utilities to validate the effectiveness of their VVO systems for peak and energy reductions. However, validation typically requires an expensive two- to three-month, on-and-off operating process. This new software saves time and money by providing an accurate evaluation in just two weeks. Also, if integrated into VVO tools, it could show system performance not just when commissioned, but continuously.

Automated Damage Assessment for Disaster Response | 30963, 31614

Shows damage in a utility's territory

When a disaster strikes, utilities must respond quickly and efficiently. This copyrighted software detects and displays areas damaged by extreme weather events using remote sensing imagery and meteorological data. The software looks for rubble, land-cover changes, and damage from tornados, hurricanes, ice storms, etc. The results show areas of a utility's territory that may have been damaged by high winds, are flooded and inaccessible, or have damaged vegetation indicating power lines downed by fallen trees. The maps can be combined with the utility's own infrastructure information, such as locations of transmission lines and substations. The resulting images can be viewed in Google Earth or any other geospatial software.



With the PNNL Automated Damage Assessment tool, operators can see where electrical utility infrastructure may have been affected. This image shows flooding impacts in Jacksonville, Florida, after Hurricane Matthew hit in 2016.

Coordinated Real-Time Sub-Transmission Voltage Control Tool (CReST-VCT) | 31485

Manages distribution voltage control for high distributed energy resource (DER) penetration

The use of DERs, such as rooftop photovoltaics, is expected to surge in the next 10 to 20 years. However, finding ways to model and control these resources is a challenge for current distribution and transmission systems. CReST-VCT provides a new approach for coordinating volt/VAR reactive control between the transmission system and the distribution system to control DERs as a virtual power plant that provides various grid-support services. The tool minimizes voltage deviations at load buses, losses, solar curtailment, demand-response (DR) use, and the mechanical act of switching shunt elements. The algorithm runs every five minutes and meets sub-transmission service requirements while satisfying all the constraints at the distribution side. The tool has been used to successfully simulate a major utility system, demonstrating the ability to provide voltage support by dispatching reactive power.

Grid Reserve and Flexibility Planning (GRAF-Plan) Tool | 31409, 31519

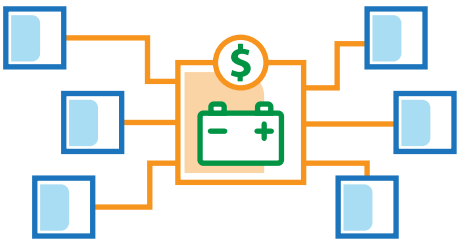
Seamlessly integrates renewable energy sources

Wind and solar photovoltaic power generation could replace carbon-emitting sources, but their intermittent nature introduces significant challenges in terms of system variability and uncertainty. The copyrighted GRAF-Plan tool helps utilities and system operators plan and maintain intra-day and intra-hour balances between generation and load. The user-friendly GRAF-Plan tool uses minute-by-minute, site-specific generation and load information, as well as information from generation and load-forecasting algorithms to integrate intermittent renewable resources.

ENERGY STORAGE INTEGRATION

Battery Storage Evaluation Tool | 30603, 30651

Evaluates the combined monetary benefits of batteries for specific uses



When considering various battery storage systems, utilities and vendors need to understand the financial benefits of certain battery types in specific locations. The copyrighted Battery Storage Evaluation Tool can determine those benefits. It defines optimal control strategies and estimates revenue for a variety of use cases or possible grid applications, including ancillary services, energy arbitrage, balancing service, distribution system equipment deferral, and outage mitigation. It looks at the entire system, down to the local distribution level. The results show the monetary benefits of a battery, used for various services, in certain grid locations.

Virtual Battery Assessment Tool | 31165

Determines optimal placement of DR assets to replace grid-scale battery storage

This planning and assessment tool determines where DR assets should be deployed to achieve a value that would otherwise be provided by grid-scale battery storage. That value depends on utility goals, such as spinning reserve, regulation service, and demand deferment. The tool models building loads down to the residential level by county for each state and returns a graph showing how much capacity or energy can be delivered or absorbed over any time period. The process enables DR to be operated like an energy storage device or virtual battery for optimal operations.

Non-Linear Battery State-of-Charge Model | 30953

Reliably estimates a battery's charging state during operation

This software estimates the state-of-charge in a battery energy storage system during operation, thereby reflecting the actual performance of the system. Because it is a self-learning model that uses data directly from the battery, the estimate is more reliable than results from other, indirect methods used to estimate state-of-charge. The estimate accounts for conditions, such as operating mode, power, battery state-of-health, state-of-charge range, and temperature. This information provides operational knowledge that utilities can use to improve the economic operation of a battery storage system. For example, to maximize revenue during market operations, the model can define optimal charging rates and find operational "sweet spots" that minimize energy losses.

MODELING

Shared Perspectives | 30137

Reduces operator response time by up to 40 percent

During power outages and other grid events, this tool enables neighboring organizations, such as nearby electric utilities, to more effectively partner to solve problems. With Shared Perspectives, organizations can safely stream information from different organizational service areas.

The technology then combines and aligns this information into a common, global view. An interactive interface lets users highlight details during collaboration. User tests with urgent and complex grid scenarios showed that operators increased their situational awareness while reducing their response times by up to 40 percent.

Dynamic Contingency Analysis Tool (DCAT) | 30834, 31128

Finds weak spots to mitigate power instability

DCAT enables utilities to understand power instability during extreme events, helping mitigate cascading power losses or black-outs. The copyrighted technology uses cascading failure analyses to screen for weak spots on the grid. By simulating thousands of extreme events, DCAT automatically meshes the evaluation of steady-state operations with changing conditions in the electric grid. Once a weakness is identified, DCAT determines the impacts that would result and provides the power operator with actions to stop the impacts before they happen. With this knowledge, operators can take targeted actions to stop a cascading event, and planners can strengthen weak spots. The tool also integrates protection scheme models for generation, transmission, and load, including special protection systems, remedial action schemes, and automatic and manual corrective actions.

DCAT was developed using the open Python™ and EPCL computer codes and piggybacks on well-known industry planning tools, such as Siemens' PSS®E and GE's PSLF, although any software meeting technical requirements can connect. With DCAT, a utility would improve its efficiency in analyzing grid occurrences by at least 50 percent over the more manual processes currently used. DCAT won a 2018 R&D 100 Award for its ability to positively impact the power industry.

Dynamic State Estimation | 30590

Enables preventive actions in real time

With this software, operators can predict future system operations and take preventive—rather than reactive—actions against contingencies in real time. This copyrighted look-ahead simulation software is based on data from synchrophasor measurement units. It takes a snapshot of the current power grid status and then simulates and outputs the transient response of the power system in real time. This tool also can help calibrate parameters for power grid dynamic models. The benefits include more transparency, faster solutions for each simulation case, and improved reliability and asset use.

MICROGRIDS

Microgrid Stabilization Using VVO | 31079, 31348

Stabilizes microgrids with no added equipment

Microgrids typically use oversized generation units to maintain stability, which can be expensive. Instead, this PNNL-developed method uses existing voltage regulation equipment with a VVO approach to improve microgrid stability. With this approach, operators can adjust generators, voltage regulators, and reactive power sources in real time, thereby increasing system stability without adding expensive new equipment. In addition, microgrids can use smaller, less expensive generators while operating at more efficient levels. The approach includes a slider setting for microgrid operations, which allows a user to select between "more efficient" and "more resilient" operations.

Remote Measurement of Transformer Loading/ Overload Conditions | 31304

Provides a simple way to calculate conditions during normal and emergency operations

This unique software calculates distribution transformer loading conditions. With readily available data, such as the transformer's full-load, core-loss value; base load; and secondary voltage, the user can calculate a no-load transformer voltage that will indicate if the transformer voltage will remain above its minimum level and also determine the transformer's current loading to ensure safe and stable operation during typical and atypical conditions.

WORKING WITH US

These innovative software tools are generally available through open-source platforms, no-fee licenses, or fee-based commercial licenses. We also offer a low-cost, six-month exploratory research and option agreement to "test- drive" the technologies.

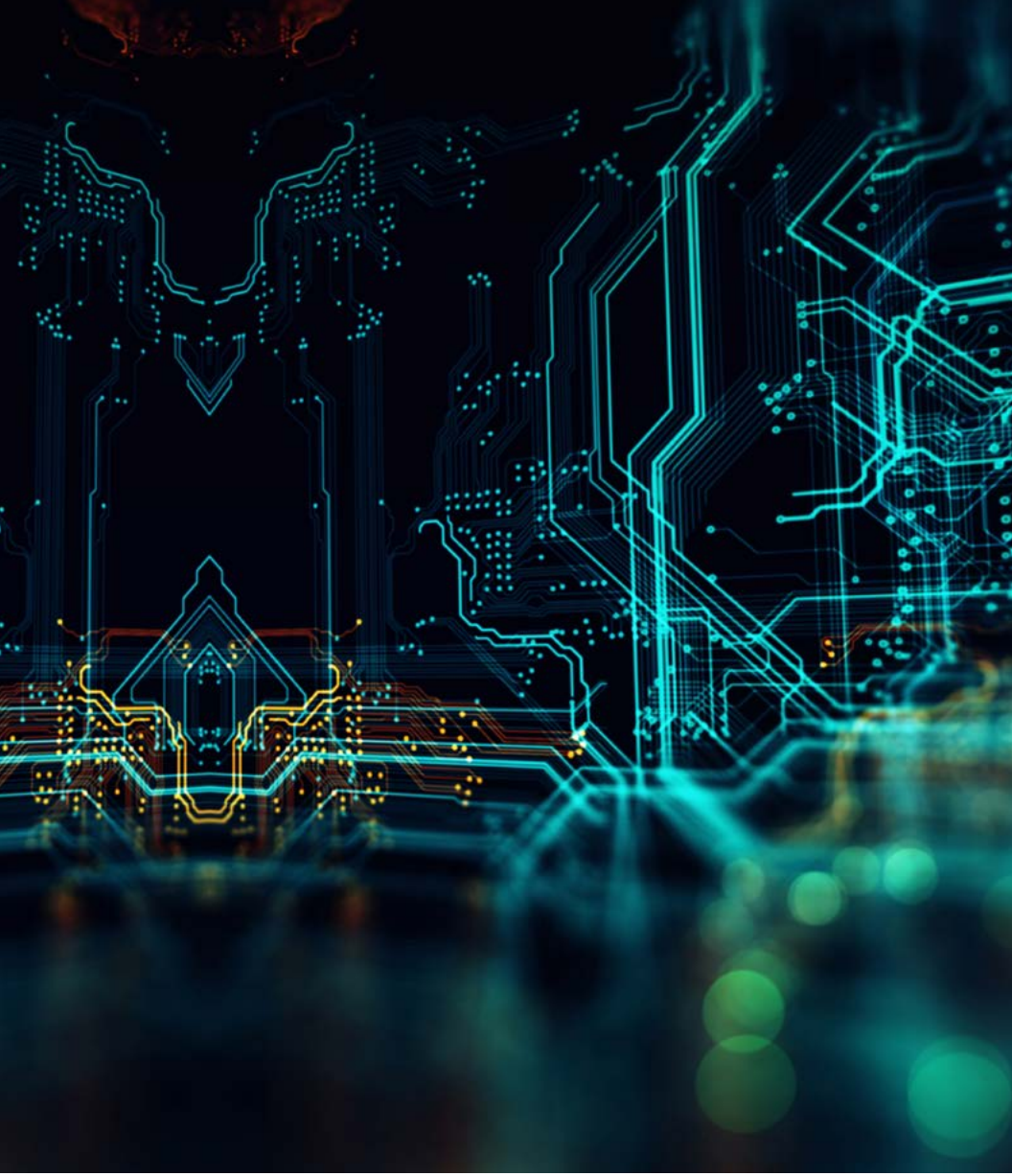
At PNNL, we can collaborate with you to customize these tools for your systems and needs. We can test, demonstrate, and integrate technologies at either your site or at ours. A specialized facility—the Electricity Infrastructure Operations Center—is available on the PNNL campus in Richland, Washington. The facility integrates industry hardware and software, real-time grid data, and advanced computation in three functional control rooms with a dedicated server farm. This facility is available via physical and remote access to utilities, vendors, government agencies, and universities for development, integration, verification/validation, testing, and training.

ABOUT PNNL

Interdisciplinary teams at PNNL address many of America's most pressing issues in energy, the environment, and national security through advances in basic and applied science. Founded in 1965, PNNL employs more than 4,000 staff and has an annual budget of nearly $1 billion. PNNL is managed by Battelle for the U.S. Department of Energy's Office of Science.

PNNL is a recognized leader in electricity infrastructure, transactive controls, cybersecurity, and buildings research. We collaborate with industry, utilities, universities, and federal and state agencies to improve the resilience, reliability, and security of the nation's electricity delivery system.

You can view all of our innovations available for commercialization at availabletechnologies.pnnl.gov.



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