Pacific Northwest
NATIONAL LABORATORY

GRID MODERNIZATION

Planning & Operations Software for Electricity Transmission and Distribution Systems

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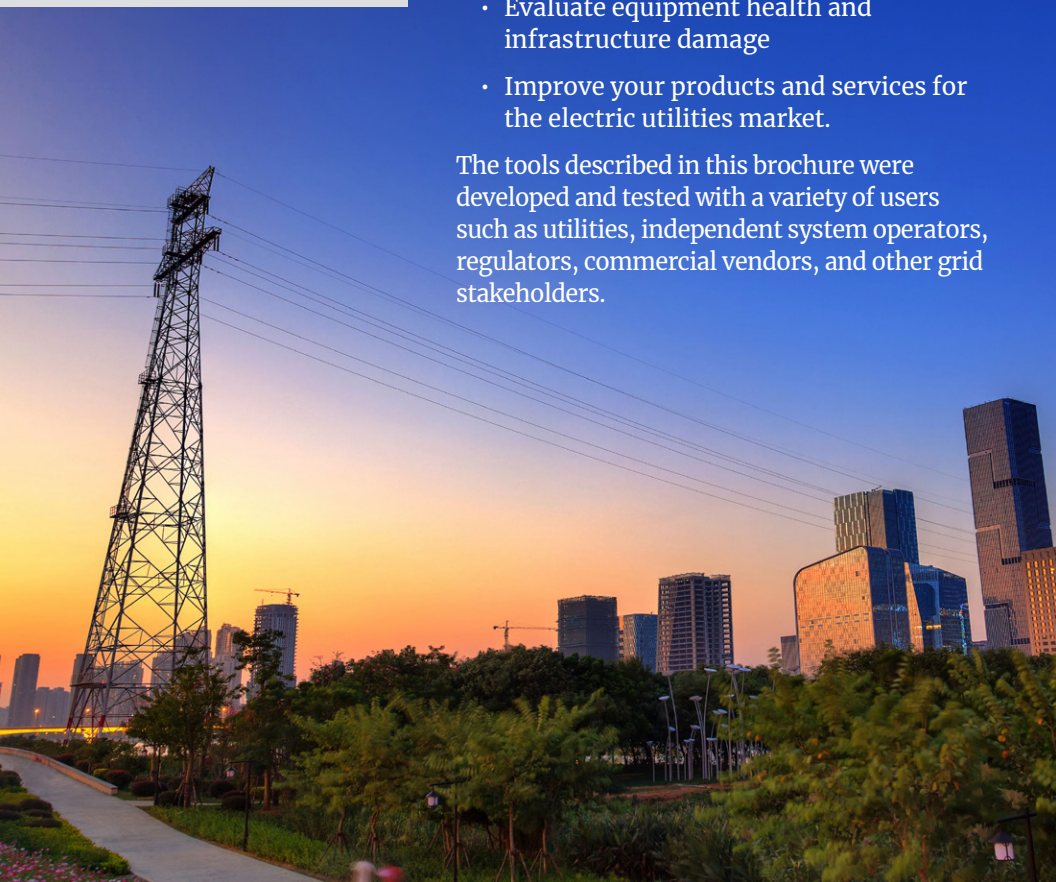
By choosing the latest grid operations and analytics software tools from Pacific Northwest National Laboratory (PNNL), you can

- 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.



TRANSMISSION AND PLANNING

Transformative Remedial Action Scheme Tool (TRAST) | 32017, 31349, 31490

Cost-effectively enhance grid reliability and resilience

Remedial action schemes hold promise for ensuring grid reliability, but they only determine the worst operation conditions and may miss critical contingencies, result in under-used 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.

Automatic Creation of Chronological Power Flow Cases | 32038

Automatically generate chronological hourly power-flow cases

Power system planning engineers currently perform planning studies based on a few snapshots of typical system operating points. However, these data are insufficient to fully understand and evaluate operational impacts to the grid, especially during high uncertainty and extreme events. PNNL has developed a software tool to automatically generate chronological hourly power-flow cases based on production cost module simulation data for various generation and load cases. This patent-protection methodology covers the linear DC power-flow from a production cost module model to AC power flow to enable reliability planning studies. The tool can create chronological power-flow models in GE PSLF, Siemens PTI PSSE, and PowerWorld formats.

Dynamic Contingency Analysis Tool (DCAT) | 30834, 31683

Find weak spots to mitigate power instability

A 2018 R&D 100 Award winner, DCAT enables utilities to understand power instability during extreme events, helping mitigate cascading power losses or blackouts. 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.

HPC-Powered Real-Time Transmission Rating Calculation Tool | 30896

Real-time simulation and decision-making tool

Every year, transmission congestion costs electricity customers billions of dollars and places significant pressure on transmission companies to build new transmission lines to relieve congestion. Transmission congestion also poses significant challenges for power grid reliability in stressed conditions because of heavy loading and in uncertain situations because of variable renewable resources and responsive smart loads. The key to improving the transfer capabilities of existing transmission assets is performing stability rating studies in real time with fast simulation techniques, in contrast to traditional offline approaches using assumed conservative, worst-case scenarios.

PNNL has develop advanced high-performance-computing (HPC) techniques to enable a non-wire solution that releases unused transmission capacity by performing realistic, real-time path rating studies. These copyrighted HPC-based algorithms can be incorporated into commercial transmission planning and operational software systems for real-time simulation and decision-making and can bridge the gap between operational decision-making and planning analysis, maximize the utilization of existing transmission assets, and facilitate the integration of renewable energy and smart loads.

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

Store 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.

Sensor Anomaly Detection and Failure Prediction (SENTIENT) | 32212

Applies physics-based sensor models and machine learning

Increased integration of renewable resources is driving the need for greater grid observability, more advanced sensors, and advanced data-intensive applications at both the transmission and distribution levels. To address this need, PNNL developed a sensor anomaly and failure prediction tool, called SENTIENT. The innovation detects sensor data anomalies and predicts sensor failure in grid-sensing and-measurement systems. Our system applies physics-based sensor models and machine learning to accurately capture the device's behavior, detect the failure of these sensors, or detect a cyber-attack on the signal path from the sensor to other devices.

SENTIENT is designed for three purposes. It accurately identifies the nature of the error associated with grid signals and correlates the error components with the sensor subcomponents. The tool detects the cause of the error (for example, sensor malfunctioning, system failure forecast, etc.). Lastly, the SENTIENT system can be integrated with power systems' numerical simulations to help increase the accuracy of their applications. The newly developed system can generate realistic noise profiles for different sensor types based on a proprietary mixture of historical records, machine learning techniques, and noise-extraction models. These noise profiles can later be used to augment the fidelity of numerical simulations, thereby empowering users' ability to create realistic sensor signals.

High-Performance Power Grid Optimization (HIPPO) | 31557, 31055, 31328

Inject high-performance computing into electricity market operations

Security constrained unit commitment is the scheduling and dispatching of generation resources to meet electricity demands that must be solved in electricity markets. Long computation time for solving security constrained unit commitment 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.

Grid Reserve and Flexibility Planning (GRAF-Plan) Tool | 31409, 31519, 32124

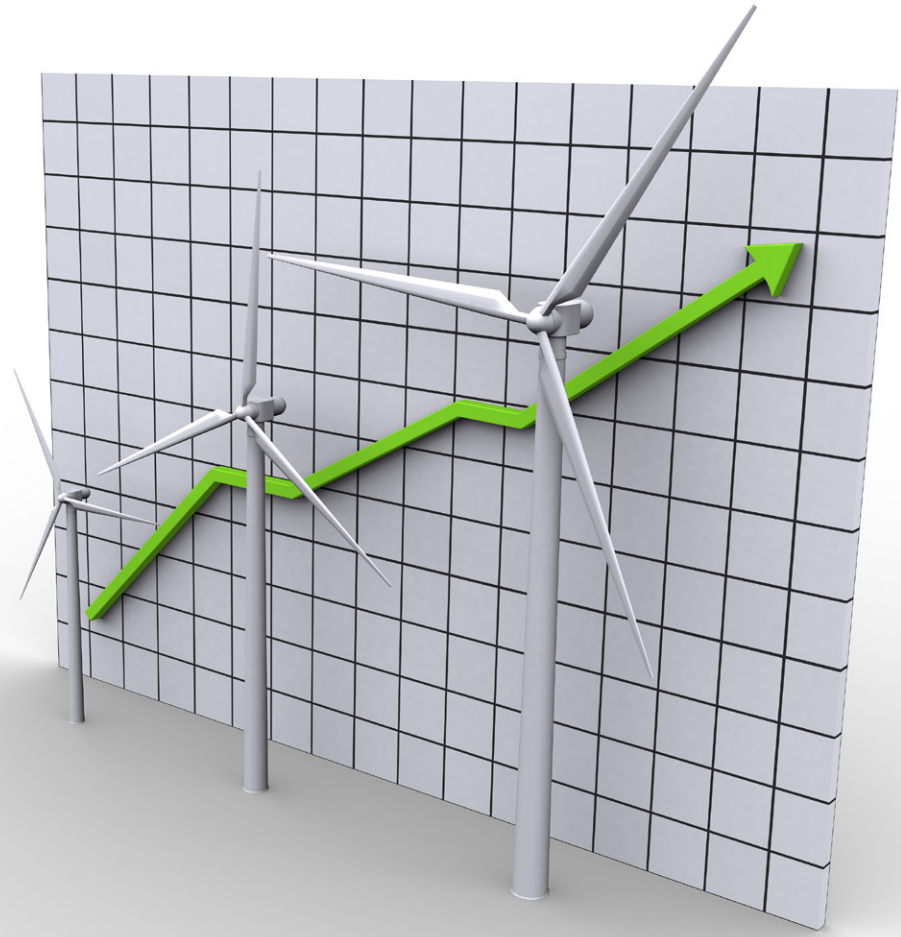
Seamlessly integrates renewable energy sources

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. The GRAF-Plan has been developed specifically for smaller utilities and those without larger Energy Management Systems and planning tools, but it also can be used for integrating renewable energy sources into any energy management and planning system.

Net Interchange Scheduling Tool | 30133, 30835

Reduce 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 and 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.



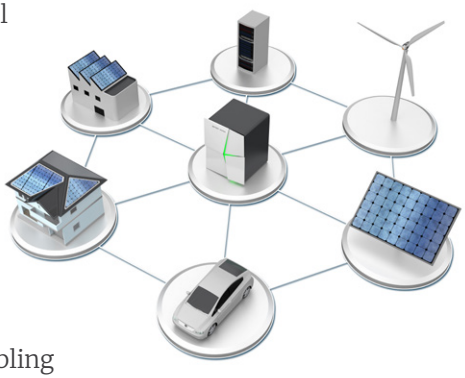
Modal Analysis for Grid Operation (MANGO) | 31297, 31378

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.

Parallel Contingency Analysis and Visualization | 16023, 16975

Visualizes ranked contingencies



This patented and 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.

DISTRIBUTIONS AND OPERATIONS

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

Manage distribution voltage control for high DER penetration

The use of Distributed Energy Resources (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 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.

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

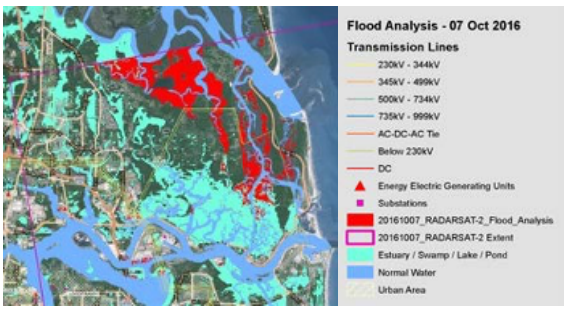
Validate VVO systems in less time

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, and other weather events. 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.

Distribution Grid Observability Evaluation and Sensor Allocation Tool | 31833, 31948, 32155

Identify areas of inadequate observability

Developed with electric utility distribution planners in mind, this software tool identifies areas of inadequate observability (i.e., the ability to determine a set of operating parameters such as voltages, currents, and real and reactive power flows). The innovation also helps planers determine where additional sensors are needed. The tool utilizes a patent-pending methodology that determines the relationships between sensors and the required grid parameters for three-phase unbalanced distribution circuits. The tool considers grid model uncertainty and communication system characteristics and determines zones where full observability is possible and where it is not. Further, it allows interactive placement of sensors with continual recalculation of observability indices and observability islands to automatically optimize sensor allocation and placement.

New Control Approach for Power Modulation of End-Use Loads | 31337

Facilitate load controller design with a novel signal decomposition method

PNNL has developed a unique control methodology to modulate the aggregated power of a population of heterogeneous end-use loads to follow desired power modulation signals. This control methodology can provide both frequency regulation and damping of inter-area oscillations. The patented algorithm incorporates a novel signal decomposition method to facilitate load controller design so that heterogeneous end-use loads can provide frequency regulation—as opposed to only homogeneous loads—and can damp inter-area oscillations for improving grid reliability (normally done only with transmission-level control).

Shared Perspectives | 30137

Reduce 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 partner more effectively 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.

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.

MICROGRIDS, STORAGE, AND DERs

Energy Storage Evaluation Tool (ESET) | 32033

Evaluate the combined monetary benefits of batteries for specific uses

ESET is a suite of several modules and tools developed for evaluating and sizing battery and non-battery energy storage systems for grid, microgrid, and end-user applications. This copyrighted software incorporates advanced modeling, optimal dispatch, evaluation, and sizing methods to optimize energy storage deployment and control strategies for any energy system. The tool determines the value proposition and projected revenue streams for a variety of use cases and possible grid applications, including ancillary services, energy arbitrage, balancing service, distribution system equipment deferral, and outage mitigation, among others. ESET currently is available to users through a PNNL-hosted website, but the copyrighted source code is also available for licensing and development into a commercial product or for consulting services.

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

Reliably estimate 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.

Controlling DERs for Grid Resiliency | 31489, 31546, 32018

Restore service during abnormal grid conditions such as blackouts

This patent-pending method and system incorporates a series of novel algorithms for a transactive framework to engage behind-the-meter DERs during abnormal grid conditions to support service restoration, including black-start services. Consumer-owned DERs are usually neither accessible from central distribution management systems, nor is their control economically justified without proper design of transactive framework. This algorithm formulates the reconfiguration problem as an optimization algorithm and handles complex constraints that include the legacy power flow, generating capacity, power demand, and network stability constraints. The optimization incorporates the availability of flexible DERs and microgrid assets for improving service restoration and system recovery.

Control of Energy Storage for Frequency Regulation | 31558

Increase power system frequency stability

This algorithm is a patent-pending method to use signals from an energy storage system (ESS) to control either the governor of a synchronous machine or an electronic inverter to improve synthetic inertia. This tool dynamically adjusts the interaction of an ESS with traditional sources of inertia or the power system's measured frequency to meet the objective of increasing power system frequency stability. A key feature of this algorithm is the synergistic impact of having the ESS interact with a source of actual physical inertia (i.e., synchronous generators), versus the ESS simply providing synthetic inertia directly by modulating ESS bi-directional power output proportionally to measured power system frequency.

Microgrid Stabilization Using VVO | 31079

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.

Considering Degradation when Dispatching Energy Storage Systems | 32148

Determine the dispatch of grid-scale battery assets on the grid

The economic assessment of energy storage systems (ESSs) is highly important for advancing their deployment in power systems. Optimal dispatch is required to maximize benefits and enhance the cost-effectiveness of these systems. A primary challenge in scheduling and dispatching is to make decisions without having exact information about system health. Frequent charging and discharging operations may help increase benefits in the short term, but they accelerate battery aging and negatively affect the use of a battery in the future.

PNNL has developed a novel approach to determining the dispatch of grid-scale battery assets on an electric grid that is peak-demand limited (or in cases where costs are based on peak demand) and that takes overall battery lifecycle costs into account. This copyrighted algorithm incorporates a two-stage probability assessment that identifies peak days and peak hours and then factors in battery availability and cycling costs compared to savings from peak shaving. This methodology ensures that the battery is not needlessly used when the cost of cycling the battery is more than the savings achieved. Compared with conventional optimal dispatch algorithms, this algorithm can significantly improve the economic benefits of an ESS scheduled under conditions of forecast uncertainty.

Using Inverters for Voltage and Frequency Stability | 31758

Improve the voltage and frequency of transient stability of distribution systems

PNNL developed an algorithm to use distributed power-electronics-based devices, such as inverters or SVCs, along with advanced communication systems and machine learning technologies to improve the voltage and frequency transient stability of distribution systems and networked microgrids. Traditional power-electronics-based devices used in distribution systems mainly focus on voltage regulation such as power-electronics-based series/shunt compensators. Frequency transient stability is becoming an important issue for the emerging generation of resilient distribution systems and networked microgrids. Therefore, the patent-pending methodology adds advanced control algorithms to existing power-electronics-based devices to improve the voltage and frequency transient stability of distribution systems. The operation of these controllers can be fully autonomous but also can be controlled by advanced communication systems to further improve the dynamic performance.

WORKING WITH US

These innovative software tools are generally available through patent and copyright 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 5,000 staff and has an annual budget of nearly $1.1 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.

CONTACT

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