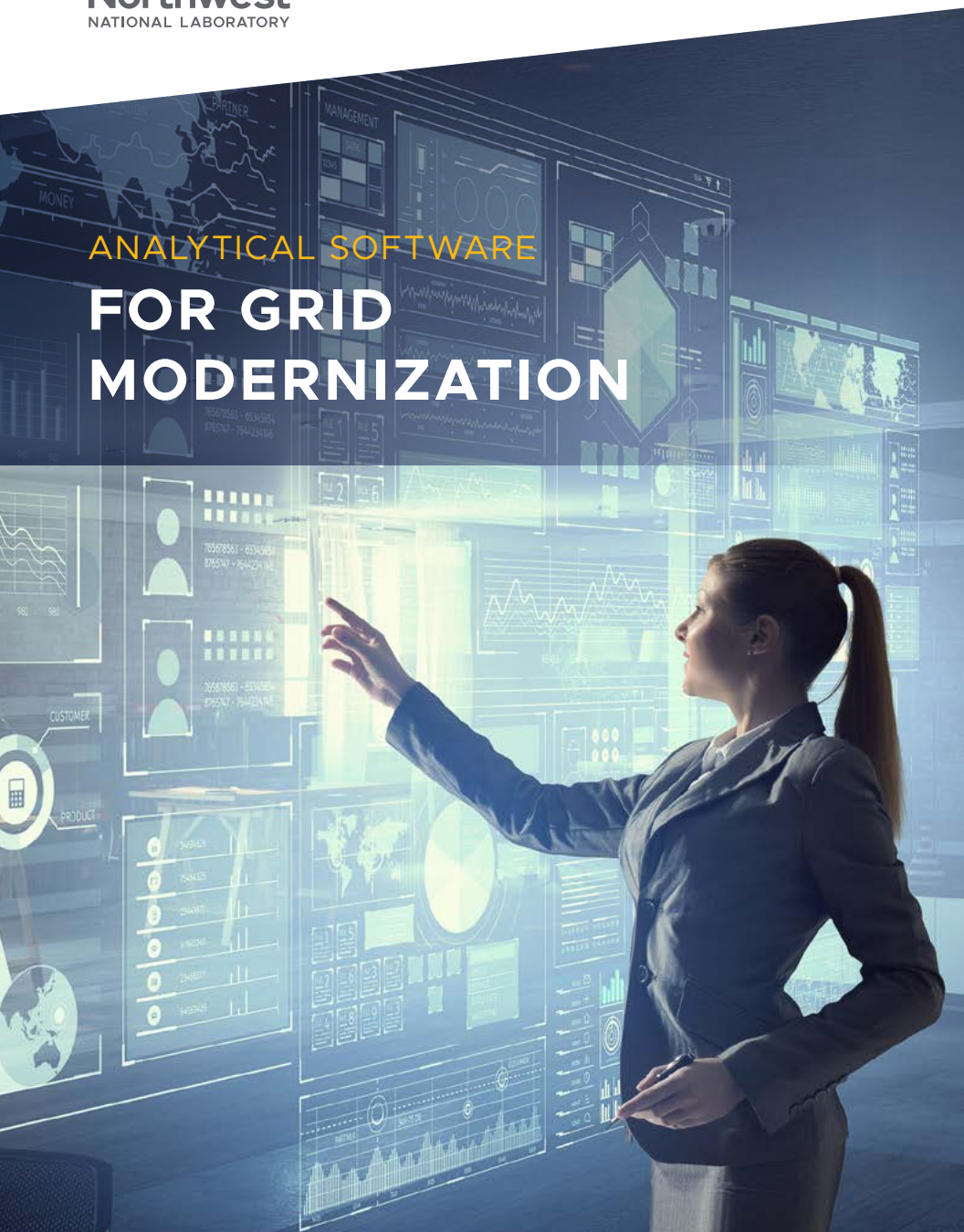
Pacific Northwest
NATIONAL LABORATORY



ANALYTICAL SOFTWARE

FOR GRID MODERNIZATION

By choosing the latest grid analytics software tools from Pacific Northwest National Laboratory, you can:

- Gain greater efficiency, resiliency, and integration of your grid assets
- Improve forecasting, operational compliance, and response time
- Optimize your grid operations or improve your product offerings.

The tools described in this brochure were developed and tested with utilities, independent system operators, regulators, commercial vendors, and other grid stakeholders.

1 Cross-Cutting Support

2 Modeling

4 Synchrophasor Data Analysis

6 Uncertainty Management

8 Oscillation Detection

9 High-Performance Computing

CROSS-CUTTING SUPPORT

GridOPTICS™ Software System (GOSS) | 30384, 30805

Supports new grid management applications

This open-source, middleware framework enables easy deployment of new applications for the future power grid. GOSS easily integrates grid applications with data sources and facilitates communication between them. This capability provides a foundation for developing a range of applications to improve grid management.

Hierarchical Engine for Large-scale Infrastructure Co-Simulation (HELICS) | 31104, 30973, 30783

Enables the design of more effective grid hardware

This open-source, federated, co-simulation platform enables developers to model and design more effective grid modernization hardware and other tools, ultimately improving grid efficiency and performance. It merges communication (data) simulators with distribution and transmission simulators, thereby synchronizing and delivering inter-simulator messages. In an example case study, it co-simulated transmission, distribution, and communications networks in a test to calculate the cleared price of electricity.

Grid Parallel Advanced Computational Kernels (GridPACK™) | 30437

Results in models that run on high-performance computers

GridPACK™ is an open-source software framework that makes it easier to develop power grid models that run on high-performance computing architectures to achieve exceptional performance and scalability. With this tool, power engineers can spend more time developing their models without getting bogged down in the details of parallel computing, such as managing data exchanges and partitions.

GridAPPS-D | 31365

Makes independent, data-rich applications possible

This open-source, open-architecture, standards-based platform allows developers to easily create advanced electric power system planning and operations applications never before possible. The documented data abstraction process yields versatile applications that can run on any compliant system or platform, making such applications independent of vendor platforms. This approach opens the door to much-needed, data-rich, and data-driven applications for smart grid devices and systems.

MODELING

Energy Operation Model (EOM) | 30502, 31158, 31172

Optimizes energy operations through robust production cost calculations

This open-source tool simulates the operation of the electric grid at the zonal scale to optimize energy operations. It generates production cost, power generation by plant and category, fuel usage, and locational marginal price to assess impacts, such as heat waves, constraints on water resources, and the addition of renewable energy sources. Unlike other commercial software, EOM matches load on a minute-by-minute basis and for simulated periods of up to three years. It is the only software that can use weather data as input for robust cost calculations.

Shared Perspectives | 30137

Reduces operator response time by up to 40%

During power outages and other grid events, this patent-pending tool enables neighboring organizations, such as adjoining 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 situation awareness while reducing their response times by up to 40 percent.

Sustainable Data Evolution Technology (SDET) for Power Grid Optimization | 31179

Builds realistic datasets for operations and planning

SDET creates open-access transmission and distribution power grid datasets that the grid community can use to create new datasets based on user requirements and changing grid complexity. SDET's realistic datasets provide researchers, developers, and end users the ability to develop, benchmark, and compare new methods and tools for optimizing grid planning and operation. When coupled with DR POWER (see https://egrid-data.org), an open-access, international repository that manages datasets through a web portal, datasets can evolve over time and significantly improve the reliability, resiliency, and efficiency of the power grid.

Multi-Layer Market-Based Framework for Seamless Integration of Distributed Energy Resources | 31133

Coordinates and controls distributed energy resources

This framework aggregates distribution system modeling with distributed energy resources into a larger transmission or market-pricing model. It provides a systematic view of the overall structure of distribution systems along with the underlying information flow, functional organization, and operational procedures. It is open, flexible, and interoperable with the potential to support dynamic system configuration. This multi-layer, market-based framework effectively coordinates and controls many distributed energy resources to more reliably manage electric power grids under the high penetration of renewable generation.

SYNCHROPHASOR DATA ANALYSIS

Archive Walker Software | 31290

Easily identifies events to speed analysis

This MATLAB-based, modular analysis software processes phasor measurement unit (PMU) data, detects events and oscillations, and shares information with end users via alarms and visualization. The easy-to-browse summary gives engineers an efficient way to pinpoint events and determine which datasets to review, rather than having to manually check everything. Event types detected and examined include forced oscillations, out-of-range issues, wind ramping, and oscillatory ringdowns.

Power Plant Model Validation (PPMV) | 30764

Automates the model validation process

This tool automates the validation process for power plant models using PMUs and makes it easier to comply with reliability standards for ensuring that such models are accurate and current. The PPMV tool contains a collection of power plant models and model validation studies, as well as disturbance recordings from a number of historical grid events. After the user imports measurement data from a new disturbance into the database, the PPMV tool validates or invalidates the model for a specific power plant against its actual performance. This open-source tool offers a user-friendly interface and automatic report generation.

Oscillation Baselining and Analysis (OBAT) | 31043

Identifies "at risk" system operating conditions

Oscillations can be a warning signal, indicating impending power grid instability or equipment malfunction. Unlike other products that perform oscillation analysis alone, OBAT also conducts baseline studies based on the analyses. For baselining, OBAT finds correlations between oscillation characteristics and system operating conditions. Thus, it not only detects and localizes oscillation behavior but also helps identify conditions when the system is at risk. This open-source tool also maintains the database of oscillation events and supports external analytical modules.

Dynamic State Estimation | 30590

Enables preventive actions in real time

With this Dynamic State Estimation software, operators can predict future system operations and take preventive—rather than reactive—actions against contingencies in real time. This 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.

Data Management for Phasor Measurement Units | 30140, 30116

Stores large datasets up to 4X 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 showed a three- to four-order-of-magnitude increase in data ingestion performance compared to existing database algorithms.

Frequency Response Analysis Tool (FRAT) | 30523

Automates the frequency response process

A key problem with existing processes for collecting and analyzing frequency response in the power system is the significant manual operations involved. FRAT automates the analysis process, saving time and adding flexibility. It calculates and displays frequency response performance characteristics using PMU data. Users can inspect and adjust initial estimation of frequency response parameters. This open-source tool stores analysis results in an internal database, and it can represent the output in tabular or graphical form.

UNCERTAINTY MANAGEMENT

Net Interchange Scheduling Tool | 30835, 30464, 30133

Reduces forecasting errors

This superior forecasting technology more accurately predicts power needs than existing models, helping operators better estimate energy demands up to four hours in advance. The patented 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.

Ramping Uncertainty Tool (RUT) | 17064, 30802

Predicts balancing deficiencies

Regional balancing authorities can use RUT to predict generation capacity and ramping requirements needed to balance the system. This copyrighted software incorporates multiple sources of uncertainty, such as load and wind/solar forecast errors. It can predict balancing deficiencies, which cause price spikes in the real-time market. In a test of 398 spikes in energy market prices, RUT predicted generation deficiencies in 94 percent of the cases.

Transmission Uncertainty Tool (TUT) | 30661, 30927

Manages intermittent energy sources

This forward-looking planning and analysis tool models the impact of intermittent energy sources, such as wind and solar, on transmission performance a few hours in advance. Then it proposes actions to mitigate any problems, such as congestion and voltage drops. The copyrighted software uses a smart sampling approach and high-performance computing techniques, offering faster computation time and more accurate results than existing products. It can stand alone or be integrated with commercial vendors' contingency solver software.

Day Ahead Uncertainty Tool (DAUT) | 17049

Helps meet regulation generation requirements

Balancing authorities must determine regulation requirements in the day-ahead time frame. But sources of uncertainty—such as real-time load, wind, and solar forecast errors—and conventional generation deviation can affect these regulation requirements. The copyrighted DAUT helps operators—in real time—meet requirements for regulation generation, including wind and solar. It estimates needed reserve in terms of capacity, ramp rate, and ramp duration for each operating hour of the next day. It minimizes procurement requirements without compromising reliability and mandatory control performance standards.

OSCILLATION DETECTION

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

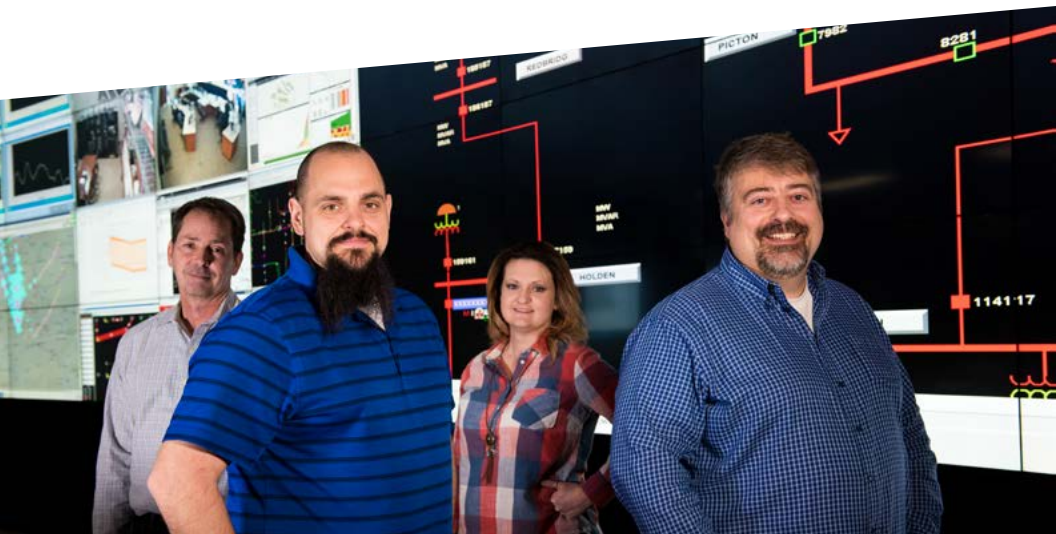
Provides real-time control suggestions

With MANGO, operators can better control grid modal variables based on analyses of PMU data. MANGO provides control suggestions, such as increasing generation or decreasing loads to mitigate inter-area oscillations. This copyrighted tool incorporates two significant innovations: 1) control suggestions are generated in real time, and 2) the operator-in-the-loop control strategy combines the operator's expertise and math models for making informed operational decisions.

Mode Meter | 15449, 31297, 31378

Improves grid stability

Electromechanical oscillation modes carry important information about power system stability. Mode Meter identifies power system modes based on PMU data in real time, so operators can take remedial action when a power system approaches unstable conditions. This copyrighted tool is an expert system based on an optimized output of three algorithms.



Decoupled Modulation Control | 30885

Provides wide-area oscillation control

Oscillations that are not well damped can result in power outages and cascading failures. But wide-area oscillation control has been challenging because of three deficiencies: 1) limitations of local measurements, 2) coordination among many generator units, and 3) the possibility of adversely affecting other oscillation modes. The copyrighted Decoupled Modulation Control tool addresses all three problems. Using multiple wide-area signals, the control acts on a selected mode without affecting other modes in the system.

HIGH-PERFORMANCE COMPUTING

Parallel Contingency Analysis and Visualization | 16023, 16953, 16975

Visualizes ranked contingencies

This patented 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 power grid operators' burden of examining raw data, enabling them to focus on critical portions of the grid and respond to adverse situations in a timely manner. Geographical information is readily included in the visualization techniques, along with a quantitative assessment of the contingency risks.

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 blackouts. The technology uses cascading failure analyses to screen for weak spots on the grid. With this knowledge, operators can take targeted actions to stop a

cascading event, and planners can reinforce the weak spots. The tool uses a hybrid dynamic and steady-state approach for simulating the cascading outage sequences. It 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 PythonTM 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.

Real-Time Transmission Path Rating | 30896

Finds unused transmission capacity

Transmission stability limits are often established using projected worst-case contingency scenarios several months ahead of time. In contrast, the Real-Time Transmission Path Rating software manages electricity flow by more accurately determining real-time limits and tapping into the unused capacity of transmission lines. Operators can perform assessments at intervals of 5 to 10 minutes using actual operating data, achieving much faster computational speed than today's simulation tools. In

demonstrations, users safely tapped into approximately 24 percent more existing transmission assets—a capability that could avoid or delay costly transmission line construction. This copyrighted tool contains every element required by the North American Reliability Corporation standards for determining transmission limits.

Electric System Intra-hour Operation Simulator (EISOS) | 30393, 30593

Balances renewables in the system

This copyrighted software helps operators simulate balancing system generation and load at sub-minute resolution. It does this by modeling the power system's generator capabilities, real-time dispatch, automatic generation control functions, and operator actions. The results give operators more insight into what to expect with different amounts of renewable generation in the system.

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 six-month, low-cost—just $1,000—exploratory research and option agreement to "test-drive" these technologies.

We are ready to collaborate with you to customize these tools for your systems and needs. We can test, demonstrate, and integrate technologies at your site or ours.

A specialized facility—the Electricity Infrastructure Operations Center—is available on PNNL's campus in Richland, Washington. The EIOC 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 4,400 staff and has an annual budget of nearly $1 billion. It is managed by Battelle for the U.S. Department of Energy's Office of Science.

PNNL is a recognized leader in electricity infrastructure, transactive control, cybersecurity, and buildings research. We collaborate with industry, utilities, universities, and government to improve the resilience, reliability, and security of the nation's electricity delivery system. You can view all of PNNL's intellectual property available for commercialization at https://availabletechnologies.pnnl.gov

CONTACT

Peter Christensen

Commercialization Manager

509.371.6159 | peter.christensen@pnnl.gov

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