Visualization and Decision Support

This research area delivered tools that convert large amounts of model and sensor data into information and knowledge to support decisions in grid operation, planning, and policy-making.

Efforts were concentrated in the development of coordinated visualization interfaces and decision support capabilities in a modular, extensible software environment that can be used for both real-time grid operations as well as long-term planning.

GRIDOPTICS™ PROGRESS: INTEGRATING TOOLS TO DELIVER RESULTS

In 2014, GridOPTICS™ capabilities were integrated to show they can be used by power system operators and planners to improve decision-making and grid operations.

A situation awareness demonstration integrated three tools: the GridOPTICS™ Software System (GOSS), Shared Perspectives, and the Multi-Layer Data-Driven Advanced Reasoning Tool for Smart Grid Integrated Information Systems (M-DART). Using scenarios from grid events, the tools cooperatively and rapidly deduced contributors to the events, provided accurate data and information to operators, and helped inform mitigation strategies. The demonstration also showcased the role that Shared Perspectives can play in simultaneously sharing information between two different utilities, allowing for more effective communication, collaboration and coordination.

An integrated demonstration focused on wholesale-retail market design concepts.

Four GridOPTICS™ workshops advanced the community concept.

The second demonstration featured four GridOPTICS™ tools: the Market Design Analysis Tool (MDAT); the Framework for Network Co-Simulation (FNCS); Advanced Visual Analytics for the Power Grid; and GOSS. This integration provided visualizations for real-time analysis and steering of distribution systems/markets, showing how visual steering can provide insights into available price-responsive load and financial decision-making.

GRIDOPTICS™ DEVELOPMENT: A "COMMUNITY" EFFORT FOR THE FUTURE

A key emphasis of GridOPTICS™ is to transition tools to open source status and create a community of users and advocates that will promote the use and further development of these beneficial grid resources. Toward this objective, four annual workshops (2012-2015) have been held. The workshops engaged experts from government, academia and industry to advance the community concept for the GridOPTICS™ suite and related and complementary tools developed by other organizations. As a result of the workshops, plans are being developed and implemented to fully realize the community approach.

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GridOPTICS™

Tools for an Efficient and Reliable Power Grid

The U.S. electric power grid is a complex marvel. Built over decades, the grid helped to power America's economic growth and improvements in quality of life. It remains a symbol of American strength and ingenuity.

As national energy requirements grow and evolve, the grid must keep pace. Technological advances are needed in many areas to optimize grid efficiency and reliability, and meet emerging challenges.

The GridOPTICS™ tool suite serves as a key national resource to achieve these objectives. GridOPTICS™—or Grid Operation and Planning Technology Integrated Capabilities Suite—is the core product of Pacific Northwest National Laboratory's **Future Power Grid Initiative** (FPGI), which concluded in 2015. As part of GridOPTICS™ development activities, FPGI performed groundbreaking research in data management, simulation, and visualization, ultimately to provide operators, planners and policy-makers with new tools to fully comprehend and utilize the 21st century grid.

GRIDOPTICS™ IS ABOUT *DATA* AND *ACTION*

Many grid-related challenges are already here or are on the horizon. These include:

- Steady growth in electricity demand
- The balancing act to bring increasing amounts of electricity from intermittent energy sources onto the grid
- Distributed generation that is shifting the paradigm of central power production facilities to multiple smaller electricity sources
- Greater numbers of plug-in hybrid vehicles.

U.S. DEPARTMENT OF
ENERGY

At the same time, an information revolution is occurring on the grid.

- Millions of smart meters and sensors are rapidly generating large volumes of data; the volume will only grow in the future.
- The increased availability of data and information will turn the traditional one-way, electron-flow grid with limited digital information into a two-way grid, transmitting both electricity and information and giving consumers more control.

The key is to harness the information revolution. By gathering large amounts of data, processing it at required speed and scale, and properly using it, grid planning and operations can be improved substantially.

That's what GridOPTICS™ seeks to accomplish, helping to:

- Securely collect and manage data in real time
- Use data to drive modeling and simulation
- Convert large volumes of data to actionable information.

GridOPTICS™ concepts and tools show and analyze grid performance at an unprecedented speed, scale, and resolution, and support operational and policy decision-making for the future grid.

GRIDOPTICS™: MULTI-DISCIPLINARY APPROACH LEADS TO INNOVATIONS

GridOPTICS™ tools were built through a multi-disciplinary, integrated approach involving the collaboration of power engineers, computational scientists, social scientists and other experts working in three research areas:

- Networking and Data Management
- Modeling, Simulation and Analysis
- Visualization and Decision Support.

Each research area, described in more detail on pages 3 and 4, contained a set of projects. The projects built the new knowledge and tools that comprise GridOPTICS™.

GRIDOPTICS™ SHOWCASE

GridOPTICS™ tools already are in use and providing benefit. These include **powerNET**—a realistic testing environment for power system and other technologies—and **decision support tools** for effective inter-organizational collaboration. Also, the **Power Model Integrator** for network interchange schedule prediction has undergone testing in an electric transmission environment.

The following GridOPTICS™ products are open source and publicly available:

Framework for Network Co-Simulation (FNCS)

FNCS—pronounced "phoenix"—is a federated co-simulation platform that merges communication (data) simulators with distribution and transmission simulators. In the federated environment, each simulator runs in its own process; FNCS performs the heavy lifting of synchronization and inter-simulator message delivery. This resource makes it possible to model and design more effective smart grid hardware and other tools, ultimately improving grid efficiency and performance. FNCS capabilities have been tested in case studies, including a smart grid application that calculates the cleared price of electricity, in which the tool successfully co-simulated transmission, distribution and communications network simulators. FNCS is available at ***https://github.com/GridOPTICS/FNCS***.

GridOPTICS™ Software System (GOSS)

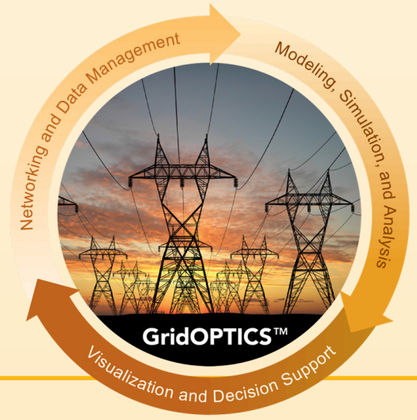
The GridOPTICS™ Software System—or GOSS—is a middleware framework that facilitates the deployment of new applications for the future power grid. This resource easily integrates grid applications with sources of data and facilitates communication between them. Such a capability provides a foundation for developing a range of applications that will improve grid management. GOSS is an open source, vendor-independent middleware framework designed specifically for the power grid. GOSS is available at ***https://github.com/GridOPTICS/GOSS***

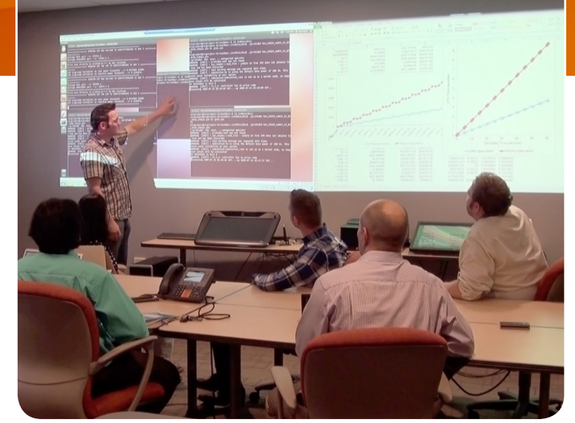
GridPACK™

Grid Parallel Advanced Computational Kernels—or GridPACK™—is a software framework that harnesses advanced computing to facilitate the development of programs that model and simulate the power grid. The toolkit's various modules help move model development from the workstation level to the advanced computing realm, while seeking to eliminate some of the lower-level details and complications typically involved in programming on parallel computers. The basic concept behind GridPACK™ is that power engineers can spend more time focusing on rapid development of their models and applications and less on trying to deal with data exchanges and partitions and similar issues pertinent to parallel computing. GridPACK™ gained funding from the U.S. Department of Energy's Office of Electricity Delivery and Energy Reliability for ongoing development. GridPACK™ is available at ***https://www.gridpack.org/***.

VOLTTRON™

VOLTTRON™ is a distributed control and sensing software platform. It creates an environment in which appliances and other devices are represented by "agents" that communicate among each other to prioritize power needs and deliver electricity accordingly. VOLTTRON™ allows researchers and others to build applications for more efficiently managing energy use among appliances and devices. VOLTTRON™'s open, flexible and modular software platform is interoperable across vendors and applications, and offers ease of application development, while hiding power and control system complexities from developers. VOLTTRON™ already has been used in projects for DOE and others. VOLTTRON™ is available at ***https://github.com/VOLTTRON/volttron***.





Multiple disciplines are represented in GridOPTICS™ development.

RESEARCH AREAS THAT SHAPED GRIDOPTICS™

Networking and Data Management

To manage and optimize the value of the massive volume of grid-related data, this research area addressed the gaps in networking and real-time data management by developing advanced algorithms, techniques, and software tools.

These resources will support the future grid's ability to identify, filter, and reduce data based on conditions and locations to ensure real-time performance; define criteria to enable large-scale information network modeling and simulation environments; develop operational sensor prototypes that support new distributed control paradigms; and address and develop capabilities for secure real-time data transfer.

Modeling, Simulation and Analysis

This research advanced the state-of-the-art in modeling and simulation in order to achieve much higher fidelity situational awareness and global comprehension for power grid stability, efficiency and flexibility.

Research was targeted toward advanced mathematical models, next-generation simulation, and analytics capabilities for the power grid. Projects in this domain used high-throughput data streams produced by networking and data management projects, and integrated them with sophisticated mathematical models to conduct large-scale power grid simulation and analysis. An advanced computing library for power grid applications also was conceptualized and developed as part of the efforts in this research area.