PATENTED TECHNOLOGIES FOR

TRANSACTIVE ENERGY CONTROL

OUR POWER SYSTEM IS CHANGING

With significant growth in renewable energy resources, power generation is becoming more intermittent and distributed. Further, millions of smart sensors and meters are transforming the traditional, one-way electricity delivery system into a two-way, information-packed power grid.

Through this groundbreaking research and these demonstration projects, PNNL has developed a portfolio of intellectual property, primarily patents, that cover a broad range of transactive energy and control concepts, systems, and functionality. These patents are generally available for licensing to help your organization take a lead role in transforming the U.S. power grid.

Transactive energy and control combines economics with power engineering. In essence, how much is an individual or entity that consumes power willing to pay for energy when there is too much demand and not enough supply based on that consumer's preferences and lifestyle choices? These factors work together via smart devices that communicate with the energy market to make decisions on behalf of the consumer—whether to pay higher energy costs during times when power use peaks or delay energy use to pay less and alleviate strain on the power grid.

Pacific Northwest National Laboratory (PNNL) pioneered the concept and philosophy of transactive energy and control back in 1996. We laid the groundwork for and demonstrated a choice-oriented model that incentivizes consumers, suppliers, and distributors. We also conducted two large, successful transactive demonstration projects–the Olympic Peninsula demonstration in 2006 and the Pacific Northwest Smart Grid Demo in 2013.

The benefits of transactive energy and control include the following:

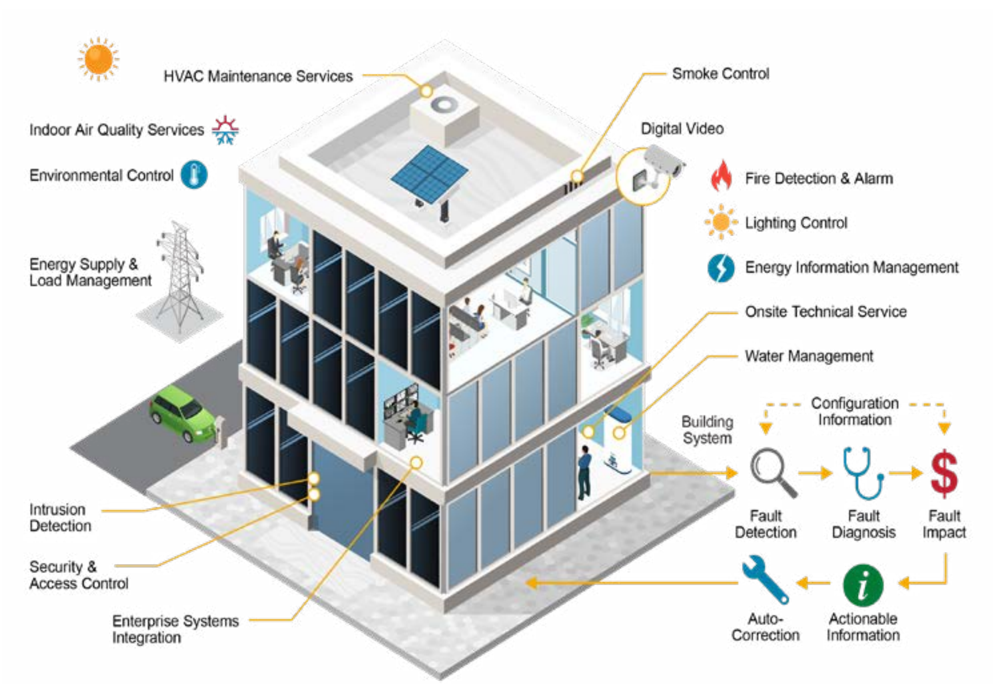
Greater optimization of energy and the coordination of consumption, alleviating strain on the power grid and improving reliability and predictability.

Increased consumer flexibility around energy pricing, including the ability to buy or sell energy according to consumer preferences and lifestyle choices, predetermining actions, timing, and cost of energy use.

A beneficial supply and demand model for energy distributors and consumers. For example, when the amount of power from renewable sources is higher on the grid, energy costs may be lower than usual to avoid excess power generation and encourage greater use of electricity to balance the supply. This approach allows distributors to offload extra electricity while allowing more choice for consumers, such as precooling their homes at reduced cost during periods of excess generation.

Example of Transactive Energy and Control

A water heater is connected to a smart device that includes a software "agent" acting on the consumer's behalf for life-style preferences previously programmed by the consumer. The device communicates with the energy distributor on the amount it will pay to operate the water heater in a coming period (say 5 minutes). Once all smart device requests are balanced against available energy, a market price for energy is obtained—typically higher during peak use and lower during non-peak use. Finally, depending on that market price and the consumer's programmed preferences, the water heater will decide when to operate so that the consumer gets the lowest price while the grid balances load with supply on a continuing basis.



PATENTED TECHNOLOGIES

PNNL tracks all its intellectual property with a five-digit code, used below with short titles. Specific U.S. patent numbers are available on request. The patents below are listed in the order in which they were filed.

Market-Based Pricing System

13202, one patent

This 2001 invention and the resulting patent claims, generally, a resource allocation system controlled by a market-based pricing system. Specifically, the patent claims multiple requests for demand, offers to supply, price setting, and then altering the electrical loads in response to the price. This approach was referred to as hierarchical because the demand and price information is gathered and disseminated at multiple levels. This patent is the result of the application of transactive control for demand response as designed for the Olympic Peninsula demonstration project.

Distributed Hierarchical Control

16046, six patents

These patents are also based on the Olympic Peninsula demonstration project and bring the concept of distributed control to the hierarchical nodal price structure of 13202. Specifically, among many other features, these patents cover the concepts of providing and receiving price and demand information at the nodes; the user comfort setting, which is the slider function given to users to select degree of participation and willingness to respond to price signals; and details on the bidding and dispatch value calculation process.

Load Manipulation

16919, two patents

The first patent covers the double-curve method for thermostatically controlled loads, one for heating and one for cooling. The second adds a random number feature to the probability calculation to determine when a device operates. This randomizer feature addresses the situation when too much load can respond to a price signal, so the participating loads are randomly selected.

Futures Market

16920, three patents

These patents add the concept of using a futures market, specifically a day-ahead market, for the source of price information and using the electricity futures market and the availability of supply at the time. The overall system is similar to the 16046 series, and the various claims sets embody those features from the 16046 patents (e.g., user comfort and tolerance settings).

VOLTTRON™

17008, two patents

These patents cover the data verification, validation, and security aspects of VOLTTRON™, which are not included in the open-source version of that software system (see 31462 below). The claims are specifically related to power system applications. Users of the open-source version of VOLTTRON™ have access to these patents via the Eclipse Foundation.

Thermocline Measurement

17054, one patent

This technology measures the position of the thermocline in a water heater, thus providing information on the state of charge of the water heater, which the transactive control system needs for bid generation.

Transactive System Coordination

30156, one patent

Generally, this patent claims the coordination of a transactive system and smart grid assets, including PNNL's autonomous, frequency-based demand-response system.

Transactive 2.0

30210, patent pending

This pending patent covers the fundamental and novel features of the transactive system used in the Pacific Northwest Smart Grid Demo, which PNNL refers to as Transactive 2.0. The primary claimed attributes are 1) a feedback signal to each node that adds a temporal dimension to the market clearing function (the bids and asks can fluctuate over time but will converge as the closing time nears); and 2) the toolkit architecture in which each device has specifically defined inputs and outputs (incentive and feedback signals) with a common data structure. The specific intelligence for each device is in the node, not the general system, so additional types of devices can be easily added. This application will likely result in multiple divisional patents.

Submission of Response Curves

30589, pending

One of a set of intellectual property that is optimizing and perfecting the transactive system. This patent application claims the submission of response curves for devices to the system, as opposed to just sending bids, which moves the model of the device from the system to the device.

External Temperature Controlled Loads

30658, pending

Expanding on 30589, this patent application claims controlling a population or group of thermostatically controlled loads, even without direct information on each one by considering them generally based on temperatures measured in the area.

Automated Negotiation

30772, pending

This patent claims replacing the auction approach with an automated negotiation between the power suppliers and the users to greatly increase the speed of the transactive mechanism by accelerating the convergence of the negotiated prices. Each party supplies a minimum and maximum price, based on such factors as user comfort and market prices, and then the system uses an automated negotiation algorithm to settle on the clearing price.

Transactive Energy Simulation Platform (TESP)

31092, open-source software

TESP combines domain simulators with transactive agents, growth models, and evaluation scripts for a customizable way to test changes to the electric grid. It runs on Linux, Windows, and OS X.

Navigating Between DERs and Larger Markets

31133, pending

This pending patent will claim the system and method for aggregating the modeling of a distribution system with distributed energy resources (DERs) into a larger transmission or market pricing model. Traditionally, distribution circuits are modeled in larger systems as static equivalents, which do not reflect the variability of DER output or smart loads. This system will step between the hierarchical models to continually adjust the equivalents, and it works in both directions—it can inform the larger models with information from the DERs and it can inform distribution circuits with changes in market prices.

VOLTTRON™ 6.0

31462, open-source software

VOLTTRON™ 6.0. is an execution platform for an agent-based, transactive control system specifically designed for buildings control. This independent language-agnostic agent platform has built-in security for resource management. It supports distributed control of various devices for better energy efficiency and reliability.

Work With Us

This innovative suite of technologies is generally available for fee-based commercial licenses. We also offer a low-cost, six-month exploratory research license and option agreement to “test-drive” these technologies.

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

A specialized facility—the Electricity Infrastructure Operations Center—is available on the PNNL campus in Richland, Washington. It 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. 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 energy 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. For more information on PNNL's transactive energy and control technologies, see pnwsmartgrid.org. You can view all our innovations available for commercialization at availabletechnologies.pnnl.gov.

Contact

Peter Christensen

Commercialization Manager

509.371.6159

peter.christensen@pnnl.gov

Pacific Northwest NATIONAL LABORATORY

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