EXECUTIVE SUMMARY

Can distribution utilities use a mixture of demand response (DR) and distributed generation (DG) to defer construction and manage peak loads?

Must those approaches be applied system wide? Or can they be put to work for individual substations on an as-needed basis?

An ongoing GridWise™ demonstration project suggests utilities can mix and match DR and DG. What's more, they can apply those technologies just to the substations with urgent problems. These two capabilities – to combine DR and DG and to apply them only where needed – will give utilities great flexibility and precision in solving problems while minimizing cost.

Mix and Match for Peak Reduction

A SMART GRID NEWSLETTER

CASE STUDY

JUNE 2006

THE PROBLEM

Distribution utilities face the problem of meeting peak loads in an era where it is increasingly difficult to obtain the funding, siting, permitting and rate increases necessary for large-scale upgrades. But are the latest cost-saving solutions up to the task?

Challenging times

Energy companies at every level—generation, transmission, distribution—are facing challenges of growing markets and aging infrastructure. Utility companies are demanding greater capacity in cold weather periods while wanting to control rates for their customers. Building more facilities is a partial solution, but one that often comes at a considerable cost. Indeed, the Pacific Northwest National Laboratory (PNNL) estimates that the United States will invest nearly $500 billion in traditional electric infrastructure over the next 20 years. Currently, energy companies lose $150 billion each year from power outages and disturbances according to the Electric Power Research Institute. Washington state's Olympic Peninsula is no different than the rest of the country. Citizens of this region face a growing need for energy while wanting to protect their environmentally sensitive forests.

Alternatives considered

Currently, programs such as the Modern Grid Initiative and others sponsored by the U.S. Department of Energy (DOE) have looked into solutions such as integrated resource planning, distributed generation, and demand-response programs. Distributed generation studies look at drawing energy from small power plants around the system instead of relying on a few large centralized plants. Demand response programs typically provide customers with changing rate information to encourage them to use less energy at times of peak demand. Still other programs are testing appliances that shut down the heating element during peak load periods.

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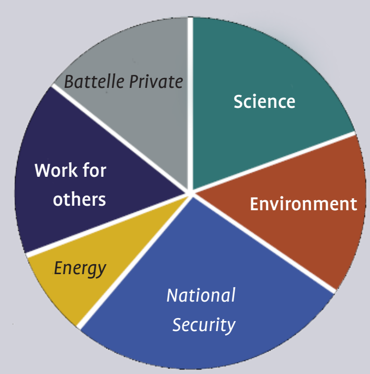
PNNL is one of nine multiprogram laboratories funded by the U.S. Department of Energy (DOE). PNNL is operated by Battelle under the auspices of DOE's Office of Science. With a staff of over 4,200 and a business volume of $720M, PNNL solves complex problems in a variety of fields (see chart) by advancing the understanding of physics, chemistry, biology, and computation.



THE SOLUTION

The Pacific Northwest GridWise™ Demonstration may establish the feasibility of reducing peak load through a mixture of demand response and distributed generation. It may also show how to apply these strategies at the substation level.

In 2005 Pacific Northwest National Laboratory received funding from DOE for a new demonstration as part of the existing GridWise™ program.

Unlike past pilots, which frequently considered only a single option, the Pacific Northwest GridWise Demonstration is investigating two strategies: (1) Whether distributed generation and demand-reduction programs can be combined to reduce peak load, and (2) whether principles tested on generation and transmission systems can also be used at the substation and distribution level.

Mix and Match

The first hypothesis PNNL is testing is whether a combination of approaches will provide a more reliable reduction of peak load than the single-mode strategies tried in the past. To do this, the Pacific Northwest GridWise Demonstration attacks load problems on two fronts:

1. Demand response (DR): Participants have automated control equipment installed to help them reduce electricity consumption during times of peak demand or when prices are high.

2. Distributed generation (DG): Industrial and commercial customers are allowing their existing backup generators to produce power for local distribution to relieve the grid at periods of peak use.

(PNNL is also conducting a separate demonstration involving "Grid Friendly™" Appliances" that can reduce demand automatically when their controllers sense a disturbance on the grid.)

This blending of approaches makes the Olympic Peninsula study unique and potentially very revealing. Rob Pratt is Program Manager for GridWise activities at PNNL. He observes that controlling demand alone may get the low-hanging fruit. But real savings may require more expensive solutions once you've exhausted the ability of DR to manage the problem.

The study also will look at the value of these approaches not just to generation and transmission systems but to individual substations as well.

Reducing Demand

For the first prong of the study, PNNL and its partners (see "Play-

Case Studies at Smart Grid News

This article is one of a series of case studies created as part of a cost-shared, public-private initiative with support from the Office of Electricity Delivery and Energy Reliability and U.S. Department of Energy and produced by Smart Grid Newsletter and Global Smart Energy. You'll find a growing library of position papers, case studies, and third-party reports of pilot installations at www.smartgridnews.com. Contact us for a quote on your needs.

The GoodWatts equipment can automatically lower thermostats in response to real-time pricing signals.

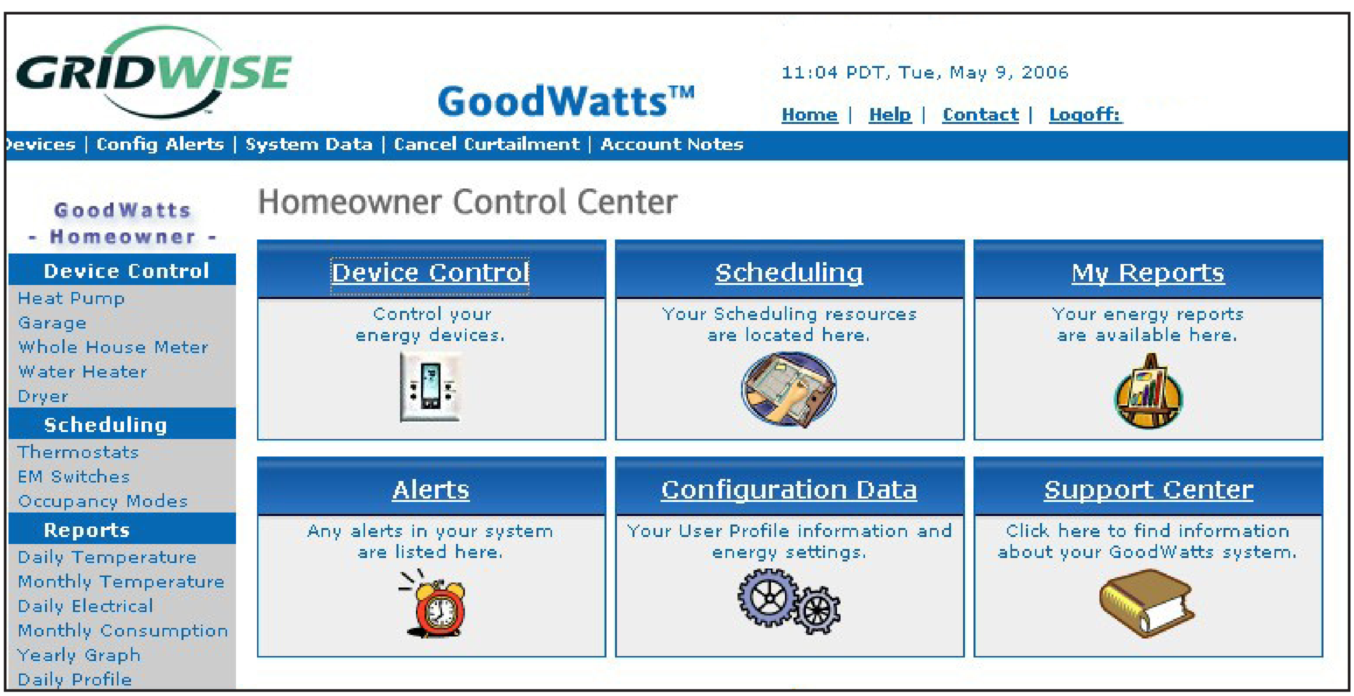
ers and Payers") set out to provide residential power customers with two things: (1) constantly updated pricing information, and (2) tools to reduce usage in peak periods (when power is most expensive). GridWise planners hope to achieve a savings of 1.5 to 1.75 kW per home with this system.

Real-time pricing information. Most utility customers pay a single rate regardless of when they use power. Yet the wholesale cost of generating and distributing electricity varies by time of day. Some programs have experimented with time-of-use pricing, charging more at times when power is in high demand (usually mornings and evenings), very little when power is not in demand (usually the middle of the night) and somewhere in between (for other times). The prices approximate the actual cost of producing and sending power to customers.

Making this price information "visible" is essential to implementing tools for reducing peak demand. The Pacific Northwest GridWise Demonstration participants receive pricing information via a two-way broadband Internet connection, set up and managed by IBM.

Tools for reducing peak demand. PNNL and its partners installed automated controls in participants' homes. Those controls can respond to energy price changes every five minutes.

Home participants were recruited through television, newspaper articles, town meetings, mailings, and ads on utility Web sites. The initial goal was to involve 250 homes in the Olympic Peninsula, but to date only about half that many have been signed up. To help make up the difference, PNNL has turned to Portland General Electric (PGE) to get additional customers from Oregon.



Participating customers get pricing and rate feedback online via a secure Internet connection.

Getting equipped. To get the desired controls, PNNL sought bids from various companies, ultimately awarding the contract to Invensys Controls to develop a custom product based on their existing GoodWatts™ software. The software does not require users to constantly adjust their power usage or enter complex preferences. Rather, it lets them choose from five set-it-and-forget-it options ranging from "maximum comfort" to "maximum economy." The controls automatically lower thermostats or shut off the heating element of water heaters in response to the pricing signal, but only within the limits set by the user. Users can override their pre-programmed preferences whenever they want.

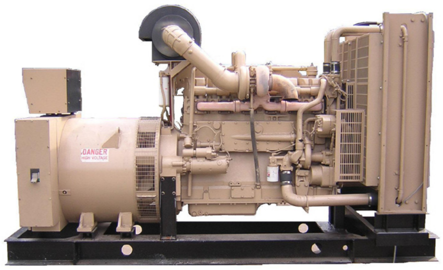
In the past, the hardware needed for controlling water heater and home conditioning was potentially cost prohibitive. However developers of such products believe they can have the price down to less than $600 per home (not including installation) in the near future. In the case of the GridWise demonstration, there is an additional labor charge for exchanging the normal utility meter (which will be replaced at the end of the study).

The shadow knows. Because this is a demonstration, these smart controls aren't responsible for the customer's actual utility bills. Instead, PNNL has set up simulated electric bills and deposits money in a "shadow" account. This lets PNNL analyze user behavior and helps them set appropriate prices. At the end of each quarter, users are sent a check for money saved. Frugal customers are expected to earn up to $150 over the course of a year.

Players and Payers

Funding for GridWise came from many sources:

- **DOE Office of Electricity Delivery and Energy Reliability.** The DOE's GridWise program (managed by Eric Lightner) furnished the bulk of the funding.
- **Washington State Congressional Delegation** provided key support for DOE funding.
- **Bonneville Power Administration** contributed financial resources, staff expertise, and leveraged existing assets from other pilot projects.
- **IBM** provided in-kind contributions including an Internet server and communications and market integration software.
- **City of Port Angeles Public Works and Utilities Department** and **Clallam County PUD #1** are hosting the demonstration on their grids and providing in-kind support.
- **Portland General Electric (PGE)** contributed financial and in-kind resources and has allowed the project to offer participation to its residents in Gresham, Oregon.
- **Invensys Controls** won a competitive bid to supply its GoodWatts home energy management system and has assisted with the modification of its equipment to facilitate the project's unique needs.



Using existing commercial and industrial backup generators is an economical means of adding distributed generation to a regional power system.

None of the participants will lose money. IBM manages this shadow market.

Distributing Generation

Giving power customers the information and tools to reduce demand is only one part of the GridWise demonstration. PNNL's Rob Pratt points out that at the end of a long cold season, customers may grow tired of being cold and return to the level of demand that causes power shortages or congestion. "One hypothesis we're testing is that distributed generation will be extraordinarily valuable in that case."

Not just for backups anymore.

With distributed generation, power is produced in multiple locations close to where it's needed, rather than at large, distant plants. But even small, distributed generators are expensive, especially if constructed only to solve peak demand problems that occur a few times per year. One solution, which the GridWise demonstration is exploring, is to marshal existing industrial and commercial generators that are normally used only for emergency backups. The GridWise program will use these same generators, including two at the PNNL Marine Sciences Laboratory (MSL) in Sequim and, if all goes well, another at the Port Angeles Water Supply District. These generators will be set up for remote operation, so the utility can start them up immediately if power is needed to prop up the grid.

As of this writing, the contract with Port Angeles is still in negotiation. But the cost of modifying the two MSL units in Sequim to work with the experiment was approximately $12,500, according to PNNL scientist Don Hammerstrom. "It appears quite economical to convert commercial and industrial DG units that already have emergency transfer switches to become demand-responsive DG units," he observed.

The Lower Depths

A second question that the Pacific Northwest GridWise Demonstration hopes to answer is whether strategies tested on generation and transmission systems work at a more local level. For example, one strategy for dealing with grid congestion has been Locational Marginal Pricing (LMP), the practice of providing the electricity to a specific location in the least costly manner given transmission constraints. With LMP, companies facing congestion in the transmission system can avoid congested areas if they are willing to pay a higher price. Similarly, PNNL wants to know if customers of a given substation will reduce their demand if they have to pay more for using power via a congested feeder or, conversely, get a discount for reducing load on that feeder and substation. If so, pricing strategies can benefit distribution utilities just as they do transmission and generation entities.

Participants in the GridWise study are not all using the same substation, much less the same distribution feeder. However, PNNL will be calculating the results as if participants lived in the same neighborhood, creating a "virtual feeder" for purposes of the study.

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With headquarters in Port Angeles and other offices in Seiku, Forks, and Sequim, Clallam PUD has approximately 130 employees and provides a range of energy services to over 26,000 customers in Clallam County (except Port Angeles):

Hydroelectric	83.09%
Nuclear	9.96%
Coal	4.17%
Landfill gas	1.49%
Natural gas	0.88%
Other	0.41%
Total:	100.00%

BENEFITS

The Northwest GridWise Demonstration will not be completed until 2007. Until then, transmission and distribution entities continue to monitor the project in hopes of seeing the gains of deferred construction and reduced demand in peak periods.

The benefits promised by GridWise drew participants from generation and transmission entities as well as local distribution utilities. The Bonneville Power Administration saw the program as an extension of their own studies to reduce peak load without costly construction (see “Bonneville, GridWise, and the Olympic transmission line”).

On the distribution side were utilities like Clallam County Public Utility District. Clallam had several reasons for getting involved. The area is growing, yet there were no new transmission lines in the works to satisfy the higher demand. According to Bronna Hankoff, formerly of Clallam’s Utility Services, the PUD wanted to learn if price signals would really cause customers to change behavior. That is, if customers would shift their electricity use to off-peak periods in return for rebates. If the program succeeds, “that is something we could take to the board of commissioners and say, ‘We need to start thinking about this.’”

Bonneville, GridWise, and the Olympic transmission line

Bonneville Power Administration (which, like PNNL, is part of DOE but is self-supporting through electricity and transmission sales) has been a big participant in the GridWise demonstration. Aging equipment and a growing population pointed to the need for a new transmission line in the Olympic Peninsula. But citizens didn’t want the line built in that environmentally sensitive area if it was possible to avoid. Through various programs begun early in the century, Bonneville was hoping to trim peak transmission demand by approximately 30 megawatts. The GridWise project offered the possibility of even more reductions. According to David Le, manager of the company’s energy efficiency non-wires program, reducing peak load by 50 mW (or 10 mW per year) would let them defer building the line for five years, saving approximately $6 million dollars.

But circumstances change. In 2006, a regional reliability workgroup led by Northwest Power Pool (a voluntary organization of major generating utilities, including Bonneville) developed and unanimously ratified new criteria for transmission adequacy. The criteria rendered obsolete the previous planning that Bonneville had done for the Olympic Peninsula. “The amount of energy savings [required to defer construction] is now so high that non-wires solutions couldn’t possibly achieve them,” notes Le. Consequently, Bonneville plans to replace one 115-kV line with a double circuit 230-kV line following an environmental impact study scheduled in June of this year.

Despite the change in plans, Le reports that Bonneville will continue to participate in the GridWise programs to see what solutions it may offer in other areas.

LESSONS LEARNED

Despite just beginning, the Pacific Northwest GridWise Demonstration has yielded important insights about customer preferences, scheduling, cost estimating, security, and setting pricing levels.

The Pacific Northwest GridWise Demonstration is still in its infancy. It's especially important for the study to last through at least one winter to see how much energy can be saved during cold months when power is used most. The experiment is expected to continue through April of 2007. Nevertheless, the GridWise team at PNNL already has garnered some interesting information and learned a number of important lessons:

Customers like it real. When participants were given a choice of pricing schemes, a majority took the real-time system (as opposed to existing flat rate or crude time-of-use schemes). Customers liked the idea of frequent pricing updates, even though it could potentially require more interaction from them. The reasons are not yet clear. Since the volunteers self-selected, they may be technically oriented "early adopters" who are not representative of the overall population.

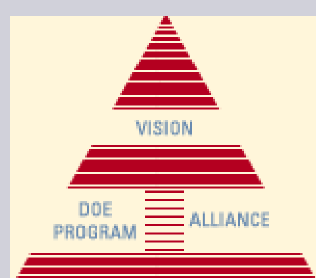
Delays. The demonstrations are currently six months behind schedule. Pratt attributes that to difficulties in recruiting participants and to the uncertainties surrounding the development of new or modified equipment and software. He hopes the demonstration will develop techniques and products that will minimize such delays for future projects.

Cost consciousness. The overall cost for they Olympic Peninsula project alone is over $1.3M. One of the most difficult aspects was figuring out how to implement a system that can change prices as often as every five minutes. "The development of the real-time pric-

What is GridWise?

GridWise is many things, all of them important to our energy future:

- A vision for the electric system of the future.
- A trade alliance to move that initiative forward.
- A national initiative led by the DOE to make that vision a reality by transforming the technologies and the market.
- An architecture council to ensure interoperability and open standards.
- **An opportunity** to participate in an important new market that will revolutionize how electricity is produced, delivered, and used.



SHOW ME THE MONEY

The strategies promoted by GridWise are expected to result in increased capacity, avoided costs, reduced maintenance, shorter outages, price stability, and more. In addition, customers will benefit from a more stable electrical grid and fewer outages. (Outage-related productivity losses show up as higher prices to consumers.) Even at this preliminary stage, it is possible to identify a range of possible benefits, some of which are identified below.*

Generation

Deferred costs. Building new generation typically costs $ 250/kW to $ 600/kW for modular combustion turbines or combined cycle plants. Thus, a 50 MW plant might cost $ 12.5 million to $30 million. The after-tax weighted cost of carrying a capital project could be about 12% per year. Consequently, if a company can defer the cost of a 50 MW facility for 5 years, they can save this amount.

$150K–360K

per MW ($7.5M to $18M for a 50 MW facility)

Locational marginal pricing. LMP is a market-based approach to manage the transmission system during periods of congestion. LMP surcharges (i.e., differences between the average and least energy costs) can run from $10 to $70 per MW-hour (as an inverse function of duration). Reducing congestion 25% a year could save this amount.

$2–3

per MWh

Transmission

Deferred construction. Building a new 230-kV transmission line can cost $1.5M to $4M per mile and take 10-15 years to site, permit, and complete. So if a company can defer the cost of a 100 mile line over 5 years (with weighted cost of a capital project of 12%) they can save this amount.

$900K–2.4M

per mile ($90M to $240M for a 100-mile line)

Distribution

Substations. Distribution utilities must sometimes construct generation to handle load growth (see the deferred cost benefit described above). In addition they must often expand or upgrade substations. Substations often cost $18 to $30 per kVA (for example, $900,000 to $1.5M for a 50 MVA substation). A utility saves roughly this amount by deferring a 50 MVA substation for 5 years.

$10.8K–18K

per MVA ($540,000 to $900,000 for a 50 MVA facility)

Feeder system. Increasing capacity to serve growth typically requires upgrading distribution feeder systems that can cost $200 to $1500 per kVA of increased capacity. If a utility can defer such construction over 5 years, it can save this amount.

$120–900

per kVA ($6M to $45M for a 50 MVA capacity addition)

*Information provided by John DeSteese, staff engineer at PNNL.

The PNNL Marine Sciences Laboratory in Sequim is using two of its backup generators for the distributed generation portion of the program.

ing contract has been challenging and costly," says PNNL's Don Hammerstrom. Nevertheless, he hopes that their efforts, algorithms, and experiences will make future efforts more productive and cost effective. As Rob Pratt points out, running an experiment is more expensive than implementing an established program.

Setting incentives. Another challenge for setting up any DR system is establishing the right price levels, discounting energy at off-peak times and charging more for peak usage. The program must avoid over-rewarding customers (bankrupting the system) or under-rewarding them (discouraging participation). "A bit of guesswork is involved," says PNNL's Pratt. The team spent a lot of time analyzing the rate structure of their shadow market to get the numbers right.

Custom concerns. The mere use of custom products might raise a red flag for existing utilities. Most utilities don't want the risk of an undeveloped product, preferring to opt for off-the-shelf equipment instead.

Network security. A big concern for the demand-response end of the experiment was network security. Participants homes have a continuous two-way connection over the public Internet with the utilities supplying the pricing data. Any such system is vulnerable to hackers unless robust firewalls and other security measures are taken.

Future recommendations

Despite the fact that no hard data is yet available, Pratt says that if he had it to do all over again, he would not set up the program as an experiment, but move immediately toward real-world deployment. One problem of the current study is that individual participants are scattered over a large region, making it difficult to get data on how a particular community served by a single utility might be affected. Currently, PNNL is forced to extrapolate data from a "virtual feeder" rather than seeing the actual impact on a single substation and distribution system.

In the future, Pratt recommends working with developers of new subdivisions to have smart meters installed in the homes, recruiting customers as the homes are built. A similar approach could be taken with a high-rise apartment building. Although working with developers would inevitably impose a time lag, the net effect would be to concentrate the savings on a single wire. ◆

Sources and resources

In addition to the individuals cited, information for this report came from the following sources:

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