Pacific Northwest Smart Grid Demonstration Project
SUCCESS STORIES

PORTLAND GENERAL ELECTRIC

Smart power in store for the future

Getting smart about electricity has never been more exciting. That's especially true at Portland General Electric – Oregon's largest investor-owned utility. PGE's Salem Smart Power Center is a new five-megawatt battery storage facility that is part of the larger Pacific Northwest Smart Grid Demonstration Project. This first-of-its-kind facility is one of the most advanced electrical systems in the nation and, as such, has inspired the imagination of a region. Energy storage is just one of the new technologies being tested by the project to integrate renewable energy, improve grid reliability and lower costs to customers.

The $178 million cost-share demonstration — the largest in the United States — spans five years of effort across five states and involves 11 utilities, two universities and five technology firms. Each participant's funds, including a $10 million investment by the Bonneville Power Administration, were matched by the Department of Energy through the American Recovery and Reinvestment Act of 2009. PGE invested $6.5 million, and PGE's major equipment suppliers contributed another $6.8 million.

With the foundation of a smart grid already in place — 800,000 smart meters — PGE was inspired to integrate several smart grid programs into one effort. It was an endeavor much larger than PGE could tackle on its own. The heart of it centered on the Salem Smart Power Center.

"A five-megawatt lithium-ion battery system that is grid-tied is very rare in the electricity business," said Wayne Lei, director of R&D for PGE. "It's one of just two owned and operated by an investor-owned utility."

Portland General Electric

PORTLAND GENERAL ELECTRIC
Portland, Oregon

- Founded in 1889
- Oregon's largest invester-owned utility
- Serving 52 communities across Oregon
- 842,000 customers
- 13 power plants with capacity of 2,781 megawatts

INVESTMENT
$6.5 million

HIGHLIGHTS
- Distribution microgrid
- Five-megawatt lithium-ion battery
- Intelligent distribution management
- Commercial demand response
- Demonstrates renewable integration

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Lithium batteries are widely used because of their high-energy density — the ability to store a lot of energy in a lightweight, compact form. It's the same battery technology used in laptops and cell phones but on a much larger scale. The key feature of the 8,000-square-foot center is a five-megawatt lithium-ion battery-inverter system. The bank of batteries stores 1.25 megawatt-hours of energy, which allows PGE engineers and planners to demonstrate high-reliability strategies involving intentional islanding of the feeder, distribution automation using smart switches, demand response, renewable energy integration and automatic economic dispatch.

Building the battery facility was an undertaking. But integrating the technologies was the real feat. It required a dedicated engineering team to address the complex challenges that arose in bringing this innovative facility to life. After all, many of the technologies implemented were new to the market.

"We underestimated what it takes to attach a five-megawatt battery to our own system," said Kevin Whitener, the lead engineer for the project. "The complexity and the engineering challenge of doing that is something we hadn't fully anticipated."

Thousands of battery cells are stored in racks and wired together into a single system. Batteries use direct current while the distribution system uses alternating current, so inverters sit between the grid and the batteries. This allows power to flow in either direction, converting from AC to DC and back on demand. Coordinating the communication between the systems and components was substantial and complex.

For example, between the inverters, the battery management system and the other controllers in the facility, there are five different communication protocols. There are sixty-seven separately addressed internet devices communicating on two different networks within the facility. That created a lot of data handling challenges.

"The protocols had to be sorted out and interfaced together," said Whitener. "There's no way to do that short of spending weeks and months struggling to get it to work. But we did it."

The safety of employees and the public is important to PGE, which is why the Salem Smart Power Center was constructed with a focus on safety. Due to the high energy density of the large battery, a unique fire control system was specially designed for the lithium-ion application that includes giant fans that keep the batteries cool at all times.

Creating a microgrid with macro resiliency

A microgrid improves a system's resiliency by allowing the utility to segment a certain part of the feeder and to provide back-up electricity during an outage. When a substation loses its power supply from the transmission lines, the battery system starts immediately, serving as an uninterruptable power supply.

If an outage were to occur in Salem, all residential, commercial and industrial customers on the circuit can be supplied electricity from the battery's 1.25 megawatt-hours of energy for 15–20 minutes. This is more than enough time to start the six customer-owned distributed diesel generators and synchronize them on the line. Once the feeder is isolated from the utility grid, the generators start up, and the circuit becomes a microgrid.

PGE has been working for more than 10 years to establish cooperative microgrids with customers that own standby generation. Together, they have built the nation's largest distributed generation program which shares customer

WHAT IS A MICROGRID?

A microgrid is a small-scale version of an electrical grid. It can be "islanded," or disconnected from external transmission services. Local distribution provides power for customer's electrical needs with only local generators and battery storage.

> Our electrical grid in the United States is one of the greatest accomplishments of the 20th century. Portland General Electric and its partners are demonstrating new technologies that hold promise for building a more efficient, sustainable and reliable grid. As these technologies became cost effective they can provide the opportunity to reshape not only the infrastructure that makes up the grid, but the approach utilities take to meeting the needs of our customers, the economy and the environment in the 21st century.
>
> — JIM PIRO, PGE CEO AND PRESIDENT

generation with the utility in times of need. Many of PGE's large customers have local diesel generation on site to prevent a power outage in case of an emergency. By partnering together, PGE is able to tap into this standby generation during an outage situation. The result is a highly resilient system.

A High Reliability Zone

PGE named its microgrid a "High Reliability Zone." The HRZ includes the large-scale energy storage system, customer standby generators and distribution automation components. These components, called smart switches, quickly sectionalize the microgrid in case of a fault, like a downed power line. The switches bring an even higher level of reliability to customers.

Unlike a standard feeder switch, which must be manually operated to change or stop the flow of power on a feeder, a smart switch "senses" changes in the feeder, like a fault, and activates the switch automatically. This changes the physical configuration of the feeder within seconds.

It's a microgrid that heals itself.

For solar, it's all in the algorithm

One of the most exciting parts of the project for PGE was exploring solutions to integrate renewable energy into the grid using battery storage. A key challenge to using solar as a power source is that sunshine is intermittent, especially in Oregon. Using an algorithm, PGE demonstrated how solar energy can be combined with a battery to fill in the gaps when the sun isn't shining and offer a seamless power flow.

With more than 6,000 megawatts of intermittent wind and solar power sweeping the Pacific Northwest electrical grid, the project provided an opportunity to learn how to best partner with customers to deliver high reliability. To test the integration, PGE used the solar output from the local potato chip maker, Kettle Brand, and then aimed to levelize, or fill in the blanks of this irregular output, using the battery.

Here is how the process works. First, an instantaneous measurement is taken of the customer demand on the circuit. Then a measurement is taken of the instantaneous power output from Kettle Brands' solar plant. This information is compared to the theoretical ideal load for the utility's circuit. The battery makes up the difference in the output in real-time, either filling in the gaps where the clouds caused output to fall short of the best possible power or charging the batteries when the output from the panels is higher than normal.

"This is one of the few opportunities that the industry has had to prove these concepts and demonstrate that energy storage is indeed a solution to integrating solar energy," said Whitener. "Impacts from what we're doing here are far-reaching."

An interesting exhibit

The Salem Smart Power Center has had many curious visitors. Tours feature a video reviewing the safety of the system, smart grid exhibits and an educational gallery with views into the operations center. Schools, other utilities, industry suppliers, consultants and government representatives all wanted to see this state-of-the-art facility.

"We've had more than 1,200 people visit the facility and learn about the project," said Whitener. "That's pretty astonishing."

Partnering with customers

PGE's smart meters enable a two-way conversation between PGE and its customers, helping the utility to optimize its services, add convenience and lower energy costs. As part of this demonstration project, residential and business customers were enlisted to respond to grid conditions by reducing energy during peak times or during a test.

"The utility can decrease the load at peak times of use, or shift loads from one period to another," says Carol Mills, PGE's senior project manager. "The objective was to offer demand response assets that could respond to the project's integrated systems."

Although PGE installed a demand response management system in Salem, a 'human in the loop' was used to ensure the programs would be initiated and observed carefully when called into action.

An impressive transactive system

As part of this project, PGE is testing ways in which we can automate renewable integration and demand response opportunities to ensure customers receive the most benefit from energy resources for the least cost. The project includes testing a transactive system, an information system that automatically shares real-time data between computers at utilities and the transmission coordinator. Similar to how utilities get information from wholesale power markets today, this system sends out a price signal every five minutes, which reaches a multiple utility footprint at the same time. The signal shows how the price of power is expected to change over the next three days.

Utilities then respond with a load forecast based on that string of future prices. This allows a system coordinator, in this case the Pacific Northwest National Laboratory, to calculate where the entire grid may have congestion issues in advance. The process is then repeated every five minutes, allowing for planning around congestion and prices to occur for everyone in the system.

Using artificial intelligence

Although, automating the electricity market is still in testing stages, strides were made learning about which tools are needed for its development.

"We've proven that we can dispatch resources at the command of the transactive node," said Whitener.

The transactive node, which PGE calls the Smart Power Platform, is the main computer program that optimizes the economic decisions about the smart grid assets: when to dispatch, when to charge or discharge the battery, and when to use the demand response capability. The node responds to a signal from PNNL. To interact with the signal, PGE wrote its own software program using artificial intelligence. Neural networks analyze the thousands of data points in the system and respond to the transactive signal. The computer absorbs all that information, synthesizes it, and makes a decision.

"We were able to demonstrate the ability of the computers on both sides to learn and get better at optimizing power for the least cost to customers," said Lei. "It's literally a monetary estimation in terms of the value to deliver and the value to acquire that power."

Learning from unique systems

Virtually all systems tested by PGE were new and unique. The Salem Smart Power Center demonstrated the ability to island a microgrid with utility-scale storage and customer standby generation, operate demand response, respond to a transactive signal, and how to integrate these complex resources into a single control system. As a result, PGE offered several key takeaways:

- Take full advantage of consulting talent both within and outside the company to assess risk and make plans to mitigate that risk.
- Reduce financial risks by using government funds when possible.
- When it comes to a first-of-its-kind project, testing is your best friend. PGE sought to protect customers by ensuring the systems were reliable and robust. Perform and document lots of testing, especially when there is a potential to impact commercial and residential customers.
- Thoroughly vet vendors' capabilities and financial strength. Smart grid technology is a growing industry, full of emerging companies. Ensure those companies are well-capitalized.
- To ensure the safety of employees and the public, it's critical to have a robust set of safety requirements in place that serve as a system of checks and balances. For example, every test was preceded by a test plan. Test plans were circulated through the project team and various departments within the company for approval.

Finally, assembling a strong, adaptable engineering and project management team makes all the difference.

"The team was able to lead the project over many different hurdles," says Lei. "As the recognized experts in the topic, the team not only had to work with the management and technical aspects, but also to be able to communicate well with everyone in and outside the company."

WHAT'S NEXT for PGE?

Smart grid technologies represent an opportunity to enhance the value customers receive from the electric system. This transition will be a significant challenge — one that involves not only leveraging new technology, but also making major changes in the way electricity is provided and used. PGE is eager to engage in the research and development needed to bring our local and regional grid into the 21st century.