

Executive Summary

Battery Storage for a Smarter Grid: The Case of Portland General Electric's Feeder Advanced Storage Transaction (FAST) Project

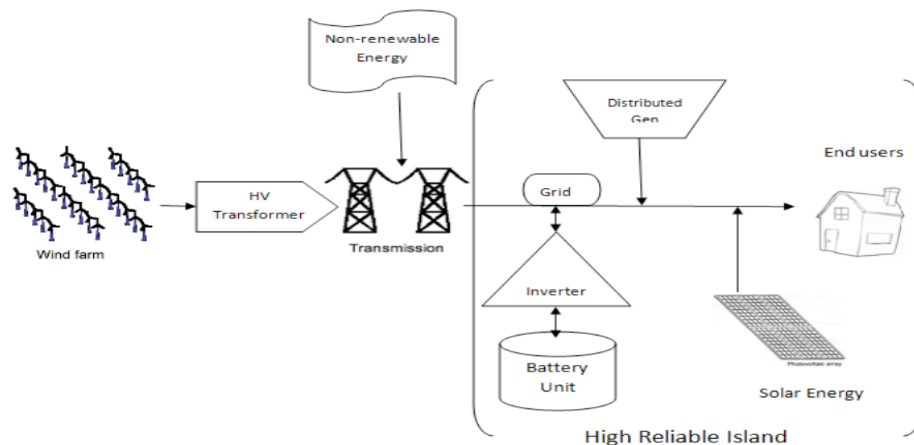
The EverReadys Team

Naresh Bokka • Michael Broda • RK Karduri • Cynthia Kan • Ken Nichols
Anil Palliboina • Victor Shestakov

Introduction

FAST is an early stage microgrid research project investigating the benefits, costs, and complexities of a microgrid within the territory of Portland General Electric (PGE). A microgrid is a local scale power system using distributed energy generation, storage, and demand management to meet customer power and power quality requirements.¹

The EverReadys team is providing PGE with a preliminary analysis of Smart Grid opportunities, challenges, and recommendations. The Smart Grid technical opportunity is to test the automatic control systems needed to intentionally isolate a portion of the system during an outage, without any degradation of power quality. Although this concept has been discussed in the industry, we could find no examples of it in use in the US. Another SMART GRID opportunity is to utilize the higher resolution electric use data from the 800,000 smart meters PGE has installed over the last several years. This data can 1) assist PGE in locating feeders and equipment in need of upgrade or those reaching capacity, 2) intelligently target distributed resource locations, and 3) identify demand response customers. PGE built and currently operates a dispatchable control system, called GenOnsys, which in 10 seconds can contribute 52 MW of grid quality power to the PGE system. GenOnsys should be expanded to provide control over all distributed resources. Smart Grid challenges at PGE include appropriate pricing mechanisms, and FERC and PUC policies that do not incorporate Smart Grid concepts and thereby inhibit innovation.



¹ We purposefully use the term energy because generation and storage technologies can have energy inputs/outputs that are electrical, chemical, or thermal.

The Project

The PGE Feeder Advanced Storage Transaction (FAST) project is one of fifteen projects supported with \$178 Million in federal ARRA stimulus funds through the Pacific Northwest Smart Grid Demonstration Project (PNW-SGDP).² The \$20 Million 5-year project includes the following technologies and processes:

1. Testing, control, and operation of a 1,300 kWh Lithium Ion battery (battery) from Enerdel, and a 5,000kW Power Conversion System (PCS) from Eaton.
2. Integration of 5 MW of existing utility dispatchable, customer-owned Distributed Standby Generation (DSG), consisting of 6 different backup diesel generators located at 3 separate sites.
3. Implementation of a Demand Response (DR) program for residential and commercial customers in the South Salem area.
4. Inclusion of other distributed electric resources, e.g., 113 kW PV solar at the Kettle Chips plant.

The purpose of the project is to test the operation of a high reliability island, also known as a microgrid, for a particular feeder off the Oxford substation in South Salem. Potential benefits that apply and a few that do not are listed in Table 1 below.

	Battery Benefit	Benefit
Reliability Island	Yes	PGE needs to understand if this is valuable to its customers
Power Quality	Yes	
Peak Power	Yes	Depends on real time prices and other signals
Defer T&D Upgrades	Yes	PGE should identify equipment due for replacement to accommodate increased capacity requirements
Wind Integration	Unlikely	SCE and Duke working on batteries for wind firming at the source. FAST would provide firming on the demand side.
Spinning Reserve	Potentially	Current value of spinning reserve in PGE territory ranges from \$5 to \$15/MWh during peak demand
Frequency Regulation	Depends on battery	Pacific Northwest frequency regulation less valuable than PJM ISO (\$30/MWh) and NYISO (\$50/MWh)

Table1. FAST Benefits

² <http://www.greencarcongress.com/2009/11/doe-620-200091125.html>

Technology Analysis

One of the most important elements of FAST is testing how several distributed resources will behave when intentionally isolated from the grid during a system fault. This concept is called "islanding" and is a relatively new idea in the industry such that we could find no good examples of its use in the U.S. Islanding will require approximately 10-20% more voltage and frequency stabilization as compared to most utility grids which require 1-2% adjustment for voltage and frequency stabilization.³

Battery

The battery/PCS was specified so that in the event of a grid failure and intentional isolation of the grid, the battery could provide all feeder power in milliseconds and operate for a minimum of 10 seconds before being relieved by the backup generation. The feeder chosen has a peak load below 5 MW. With this power requirement and an assumed battery efficiency of 90%, the 1300 kWh battery must retain an assumed minimum charge of at least 14 kWh, which is why the PCS is supersized for 5 MW.

The type of battery technology used in this project is not as important as the requirement that the battery must respond quickly to discharge and charging events. Other storage technologies that have this fast response include flywheels and advanced lead-acid, and most bulk storage e.g., CAES, Pumped Hydro, sodium sulfur⁴, Ni-Cad, Vanadium Redox, etc. The limiting economic factors for batteries are high cost and lifetime. Batteries have a capital cost that is higher than SCCT and lifetimes much shorter than a SCCT. LI-Ion battery lifetimes are generally determined by depth of discharge and number of cycles, i.e., the more cycles and deeper discharge, the lower the lifetime. Therefore, applications such as frequency regulation, which requires numerous cycles in a day, will significantly reduce battery lifetimes unless depth of discharge remains a low percentage of battery capacity

The Eaton PCS has been oversized to accommodate the high power requirement needed for islanding, and has been configured to be able to provide reactive power and VAR support. The two smart grid challenges for integrating the battery/PCS are:

1. **Reliability Island.** In the event of grid failure, it is critical to develop the automatic controls, requiring no human interaction, that will properly isolate the island from the grid and operate the battery and distributed resources so there is no loss of power or power quality. Issues will be safety, power quality, control/communication, testing, and duration.
2. **Balancing the Ability to Respond to Grid Failure with Other System Benefits.** A significant challenge is how PGE can utilize the battery to provide other system benefits while ensuring the battery's capability of responding to a grid failure. For islanding, the battery must be able to respond to a grid failure in milliseconds and must hold some charge until distributed generation can respond. The testing question is how much charge must be available at all times.

³ <http://www.faqs.org/patents/app/20080278000>

⁴ <http://www.inhabitat.com/2010/04/06/bob-americas-biggest-sodium-sulfur-battery-powers-a-texas-town/>

Distributed Generation (DG)

PGE's GenOnsys currently has a control system that allows a utility operator to dispatch Distributed Standby Generation (DSG). According to PGE:

No other electric utility in the U.S. has the capability to dispatch from the utility's system control center this level of energy from customer owned generation.⁵

PGE has control for more than 52 MW of diesel and natural gas fired backup generators. The backup generators are currently used during high load periods. In 2010 to date this capacity was used three times to provide energy to the system. From the customer perspective, PGE pays all fixed operating, maintenance, and fuel expenses. Connecting to the grid can offer better load testing and periodic operation. The only drawback in realizing bigger benefits is a *400 hour per year* limit on use.

Expanding this group to oversee all distributed resources would potentially benefit PGE and its ratepayers. This group should: 1) monitor/forecast distributed generation (e.g., solar), 2) design/value/forecast demand response, and 3) value/dispatch energy storage.

Demand Response (DR)

According to NWPPC:

PacifiCorp has more than 5 percent of peak load in firm demand response, and Idaho Power had about 60 megawatts of demand response in 2008, made up of direct load control of residential air conditioning and timers on irrigation pumps.⁶

At present, PGE has only run a few demand response pilot programs, and has not found a project that would be of potential benefit to ratepayers.

The drawbacks of DR are:

1. Hydro capacity entitlement has historically kept on peak power prices low, relative to other parts of the United States;
2. Increased energy efficiency and conservation will potentially diminish demand reduction opportunities.

DR is potentially beneficial if considering the following:

1. The reserve capacity of the hydro system is reaching a limit due to river and environmental constraints and DR could enable better control of capacity;
2. Wind generation is using up the reserve capacity of the hydro system;
3. Advances in smart grid technology are making customer end use load control less costly and providing new benefits, such as energy efficiency and customer savings.

Our recommendation is that PGE should continue to pursue its RFP with third parties providers of DR and DLC in its territory and utilize meter interval data to identify customers and substations that would provide the best system benefit.

⁵ 2009 PGE IRP, page 148

⁶ NWPPC 6th Plan, 2010, page H-11

Business Analysis

The system has been designed to accomplish two primary tasks: high reliability islanding and providing other system benefits, such as peak demand shaving. Combining these capabilities into one system appears to be technically possible, as FAST will examine, but complicates the cost/benefit analysis. The business analysis considers the various value areas.

Reliability

The feeder has a load that does not exceed 5 MW. In order to meet isolation requirements the inverter must be supersized to 5,000 kW from an approximate required size of 325 kW, which would be sufficient for a peak shaving scenario. Assuming \$250/kW inverter cost, supersizing the inverter adds over \$1 Million to the cost of project. If all 5 MW of load shared in this incremental cost, the cost would be \$1.56/kW-month. The capacity charge for a large nonresidential PGE customer is \$1.97/kW-month.⁷

The reliability adder would double the capacity charge. Would customers pay this? According to Mark Osborn, Manager of Distributed Resources at PGE, customers are currently unwilling to pay PGE for this reliability, though they might pay to achieve this reliability on their own premises. The marketing/policy challenge is to convince customers that being in a utility owned reliability-island could meet customer specific backup generation requirements. Targeting customers such as hospitals that have codes that only recognize onsite technology, municipalities that wish to attract businesses, or manufacturers that are uncomfortable relying on equipment that they do not own or operate may be beneficial to PGE.

Peak Power and Wind Integration

The current alternatives being specified at PGE for providing incremental peak power and wind integration are simple cycle combustion turbines (SCCT), reciprocating engines (Recip), and market purchases. PGE's 2009 IRP and the Northwest Power Planning Council's 6th Power Plan (2010) both discuss wind integration with no mention of energy storage or distributed generation. Both studies suggest reliance on energy markets and flexible thermal power generation. PGE's 2009 IRP states that, wind integration costs to be approximately \$13.50/MWh (\$2014, or \$11.75 in \$2008) when averaged across all 8,760 hours of 2014.⁸

Our analysis shows the cost of an SCCT, if used every day for 4 hours, would cost \$155/MWh. The proposed Li-Ion battery with a 325 kW inverter charging at \$0/MWh would still cost over \$1,000/MWh. Therefore, in the short term it makes sense that PGE is not considering batteries as viable to support wind integration. CAES and Pumped Hydro will get

⁷ Portland General Electric Company Fourth Revision of Sheet No. 83-1 P.U.C. Oregon No. E-18, SCHEDULE 83 LARGE NONRESIDENTIAL STANDARD SERVICE

⁸ PGE's 2009 IRP, page 129. "This is the estimated cost to integrate 1,100 MW of wind energy into the PGE system based on PGE's existing resources (less those that expire prior to then), 2014 loads, market prices, and gas costs, and 2005 hydro and wind data. We note the following caveats regarding this estimate:

- This cost assumes PGE self-integrates its entire wind requirement. Lower amounts of self-integration will lead to lower costs.
- This cost is before the beneficial impact to variable costs of adding new flexible generating resource to PGE's system.
- It assumes that some PGE thermal units not currently on Automatic Generation Control (AGC) will add AGC capability."

most of the non-fossil based storage attention for wind integration. PGE should continue to look for opportunities to leverage these distributed resources to help address peak system demands.

Deferred Transmission and Distribution Cost

FAST and DR are economically viable for eliminating expansions of transmission and distribution facilities when the load on the feeder is growing. We did not have any data, however, to estimate this value for PGE. PGE's IRP, however, considers DG as inconsequential in deferring T&D costs. According to PGE's IRP:

T&D investments are currently not significant enough to be quantifiable. That is, DG at this time is too distributed to make a practical difference in how substations are maintained and upgraded. Furthermore, conservation and energy efficiency also confer similar benefits and in aggregate currently tend to be larger amounts than DG.⁹

Despite this analysis in the IRP, we think that whenever PGE is considering new T&D investments they should consider deferral through demand-side alternatives.

Wind Integration and Firming

Since most transmission for wind must be built for the maximum capacity of a wind farm, there is no extra upfront transmission savings to put storage at demand. In fact, from the transmission perspective, it is preferable to locate the storage at the source and thereby increase the capacity factor of the transmission line.

Spinning Reserve

Intuitively we considered that provision of spinning reserve might have value because it simply requires that the battery remain charged and available. Keeping the battery charged at 8,760 hours per year availability lowered the cost to \$250/MWh. Current cost of spinning reserve for PGE during the peak seasons of winter and summer ranges from \$5 to \$15/MWh. For comparison, PJM ISO had an average spinning reserve price in 2002 of \$19.65/MWh.¹⁰ Spinning reserve requirements will increase with increasing wind generation, so look for increasing cost for spinning reserve cost and on peak energy.

FAST

The business case for FAST elements and distributed resource development lies in identifying the best value to PGE, or other stakeholder. To this end, we suggest that PGE creates an algorithm for determining dynamic forward pricing for the various electric services (e.g., energy, capacity, ancillary services, etc.)¹¹

With historical and dynamic forward pricing in place it will be easier to evaluate the many and varied resource alternatives. This price mechanism should be tested at the OPUC in order to avoid a new conversation every time there is an IRP or utility decision. Expected business opportunities include:

⁹ 2009 PGE IRP, page 148.

¹⁰ 2004, Electricity Prices in PJM: A Comparison of Wholesale Power Costs in the PJM Market to Indexed Generation Service Costs

¹¹ Different than PNNL's transactive value approach. Dynamic Forward Pricing in the PNW would be an algorithm based system using various market and PGE data, such as Mid-C hourly pricing.

1. Adding DR to the GenOnsys system;
2. Proposing new or expanded substations as opportunities to defer T&D;
3. Targeting customers and locations interested in high reliability
4. DR in any location that meets the cost/benefit test.

Our conclusions are that the following conditions may enable elements of FAST become economically viable:

1. Energy storage technology could improve in cost and performance.
2. Wind integration puts increased price pressure on capacity costs.
3. Certain customers or municipalities may be willing to pay up for 100% reliability in power and better power quality (e.g., Intel).
4. The exponential increases in costs for transmission and distribution may begin to become consequential.

Because the Pacific Northwest lacks a transparent liquid market in power services, and has historically been able to rely on hydro capacity, many power system benefits (e.g., Voltage support) could have higher or more confident value in other parts of the US.

Policy Analysis

Since FAST is a government sponsored project, the stakeholders include many other parties in addition to PGE and its ratepayers. Other stakeholders include: BPA, US DOE, City of Salem, and the utility industry. PGE should maintain an open dialog with all stakeholders during the various stages of project implementation. As appropriate and feasible, PGE should consider the adoption of practices that stakeholders suggest.

FAST and distributed resources have several policy and political challenges, and business inertia.

1. The lack of a transparent and liquid PNW market for power services makes the evaluation of alternatives in a regulated setting very difficult. This will require PGE to spend time and resources to develop models and convince stakeholders.
2. The energy and energy utility industry in the US is too complex to manage by political mandate. Mandating particular resources (e.g., Renewable Portfolio Standards, and energy storage mandates (AB 2514), while politically friendly, may stifle new and creative means of achieving the social goals which were sought (e.g., reduction in CO2 emissions and imported oil). In order to attain innovation in technology and processes, we recommend a consistent federal tax (e.g., carbon tax or gasoline tax) on various energy uses that would accomplish social objectives.
3. Distributed Resources are relatively new to the state and federal energy regulatory arena. Customers who might invest in DR may be inhibited due to FERC limitations on the sale of power. At the current time, utilities are the primary drivers and beneficiaries of Smart Grid research and implementations. Getting energy users and innovators involved will result in more projects being considered and eventually implemented.

Sustainability

The three-legged stool approach is often considered to show the integration of the social, economic and environmental aspects of sustainability.

Economically, the elements of FAST may become sustainable when the cost benefit analysis shows net benefits over the life of the system without subsidies. Pressure to meet RPS standards, increasing cost of CO₂, limits to hydro capacity, T&D costs, customers willingness to pay for power quality may be some factors to favor unsubsidized implementation of FAST elements. Projects that are not least-cost shall increase rates relative to other utilities, which create an unsustainable cost environment for businesses and ratepayers in that utility territory.

Socially, the concept of the microgrid is a step in the right direction to encourage community participation and control in electric power delivery (such as installing PV systems on a resident's rooftop). Problems that remain in the societal domain include participation by low income households that cannot afford their own generator or PV systems, and do not consume enough energy to be good DR candidates. PGE can address this by offering DLC programs to low income ratepayers.

Environmentally, the FAST project has the potential to offer assistance to integrate wind, solar and other resources that do not depend on fossil fuels. Reducing fossil fuel consumption will have a beneficial impact on air quality and reduce carbon emissions. However, one environmental problem which remains unsolved is the proper disposal of spent or used Li-ion battery. These batteries are made of complex materials and exotic compounds.

Conclusion

PGE's early stage FAST project has opportunities to explore several SMART GRID areas. A successful fully operational project will directly benefit PGE customers on the Oxford substation, and allow PGE to expand their expertise in managing a diverse distributed resource portfolio. In the short term, our recommendation is for PGE to consider Demand Response, Customer owned Distributed Generation and EcoDistricts (e.g., Combined Heat and Power), and managing EV car pricing program. Some of the top challenges/opportunities for PGE to be aware of are:

1. Focus on the technical challenges of intentional islanding;
2. Determine customer value for improved reliability (Marketing);
3. Evaluate the cost, type, and location of energy storage technology in PGE's territory, and prioritize the most valuable application;
4. Utilize AMI meter data to target DR customers, and identify equipment that is reaching capacity;
5. Develop evaluation tools such as market and forward pricing;
6. Evaluate State policy regarding energy storage cost recovery for utilities (California AB 2514);
7. Follow FERC policy regarding the sale and management of distributed resources;
8. Incorporate new distributed resources into the dispatchable GenOnsys system.