BPA Grid Operations, Bi-Lateral Markets, and Transactive Energy

Gordon Matthews
Bonneville Power Administration
905 NE 11th Avenue, ST-3, Portland, OR, 97232
ghmatthews@bpa.gov

Terry Oliver
Bonneville Power Administration
905 NE 11th Avenue, ST-3, Portland, OR, 97232
tvoliver@bpa.gov

Donald Watkins
Bonneville Power Administration
5411 NE Hywy 99 - TO
Vancouver, WA 98665
dswatkins@bpa.gov

Katie Pruder
Bonneville Power Administration
905 NE 11th Avenue, PES, Portland, OR, 97232
kpruder@bpa.gov

Joshua Binus
Bonneville Power Administration
905 NE 11th Avenue, PEH, Portland, OR, 97232
jdbinus@bpa.gov

Lee Hall
Bonneville Power Administration
905 NE 11th Avenue, PES, Portland, OR, 97232
ljhall@bpa.gov

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Abstract: Integrating renewable generation such as wind and solar is problematic for electric utilities. Where generation has historically been dispatched to meet loads, optimizing the value of this new generation may be best served by dispatching loads. A mechanism proven in pilot testing on the Olympic Peninsula may provide a solution: the Transactive Signal.

1. INTRODUCTION

Today's electric grid is changing. The interplay between generation and loads connected to the bulk electric grid and the power system is increasingly different. Where we used to provide electricity when and where people needed to use it, we are now finding that we often must find means to accommodate a variable supply of electricity. No longer can we assume that generation will be dispatched to follow loads. Instead we are increasingly called upon to follow wind speed or solar intensity that may have no correlation to the demand for power.

In addition, there is increasing need to address transmission congestion. Operating the optimal generation sources could cause some transmission lines to be overloaded if certain single contingencies occurred. Methods of adjusting the distribution of power are needed to assure reliability requirements are met. And, there is increasing interest in providing for actions that will reduce the loading on transmission and distribution lines in a systematic manner to mitigate or defer capital investments such us upgrading or replacement.

How are these pressures addressed? What is a reasonable set of alternatives to the expense of keeping generation on standby to provide flexibility? Can demand response shut off (or turn on) consumer load to balance supply and demand for short periods until other sources could be put in service? If so, how are such resources coordinated, considering that different entities own the assets and have control? How are critical requirements assured to be met and the highest priorities served? What mechanisms can be used to negotiate this in real time with many levels of interactions taking place?

Transactive controls offer a potential solution, establishing a methodology and means for addressing many of these issues.

2. BPA AND THE PACIFIC NORTHWEST

The Bonneville Power Administration (BPA) is a federal power marketing agency, created by act of Congress in 1937, to fulfill two primary missions: market generated output of the Federal Hydro system and provide for the delivery of that system power across the Pacific Northwest as a transmission operator.

As prescribed by Federal Energy Regulatory Commission (FERC) Orders 888 and 889, BPA integrates power from both federal and nonfederal resources, ensuring open access to the transmission grid. While not under FERC jurisdiction, BPA maintains a policy of voluntary compliance. Our operations are run with an open book, accountable to the region through public processes.

BPA was founded on the principle of "providing power at cost". The Agency is nonprofit: supported exclusively by rates and our ratepayers, not through taxpayer appropriations. BPA markets power at a price sufficient to produce revenues to cover the operating maintenance and financing of all the federal resources, including maintaining financial reserves appropriate to sound business practices.

The Federal Columbia River Power System (FCRPS) consists of 31 federal dams sized from 3 to 6,765MW capacity that are operated by either the Army Corps of Engineers or the Bureau of Reclamation. BPA also markets the output from the Northwest's single nuclear plant: the Columbia Generating Station (CGS). The federal system provides about one third of the power used in the Pacific Northwest.

The system's primary fuel supply is the river, and its output is dependent on weather patterns of the United States and Canadian Northwest as well as the amount of Canadian storage over the course of a year. In addition to power production, the entire Columbia River and its tributaries is carefully regulated for flood control, fish passage and preservation, irrigation, and recreation, as well as preserving the river banks themselves. . In an average year the system provides 3000 average megawatts (MW) of marketable surplus but this is never certain because of changes in weather that affect fuel and storage.

The BPA transmission system started when BPA energized three and a half miles of line between Bonneville Dam and the City Of Cascade Locks in 1938. Today, BPA's system includes more than 15,000 circuit miles of high voltage transmission lines spanning the Pacific Northwest. It includes Washington, Oregon, Idaho, northern California and western Montana. BPA also operates the Pacific Coast Interties that include three, 500 kilovolt alternating current lines to Central California, and a one million volt direct current line that runs from the Columbia River to southern California. The Northwest grid also has strong transmission connections to British Columbia.

The primary backbone of the bulk electric transmission system and about a third of BPA's circuit miles is a network of 500 thousand volt (500kV) transmission bolstered by 345kV, 287kV, 230kV and 115 kV. BPA operates and maintains about three-fourths of the high-voltage transmission in the Pacific Northwest.

BPA's system is part of the North American Western Interconnection and part of the Western Electricity Coordinating Council (WECC). BPA is required to comply with all the applicable North American Electric Reliability Corporation (NERC) and FERC approved reliability standards.

The system's electrical locations that interconnect are made up of sets of parallel transmission lines called paths. The characteristic of these paths is that the demand for power flowing on them can exceed the capability of the path to reliably carry it. Exacerbating the impacts of this sometimes limited capacity is the explosive growth in wind generation. Hydropower is a well-suited resource to follow the second-by-second changes in wind output, but in the Pacific Northwest, it is increasingly constrained by operations limits for flood control, endangered species protection, and the Clean Water Act.

BPA is a balancing authority (BA), which means it must match its generation to its obligations, accounting for any variations in loads, generation, or external interchanges of power. BPA's balancing area maximum loads are about 8,000-9,000 MW. The BPA BA area has more than 3,500 megawatts installed wind generation, which is expected to grow to 6,000 MW peak by 2014 and potentially 12,000 MW by 2016. The interconnected wind generation will then exceed the entire BPA load at times.

Adding to this challenge is the fact that the vast majority of the wind built in the Northwest is concentrated at the east end of the Columbia River Gorge. Consequently, almost all of the wind generation is concentrated; creating very large changes and sometimes at relatively fast rates in a small area in the BPA balancing authority. This nearly eliminates the benefits of diversity that would occur if wind units were more geographically dispersed with varying outputs. The existing number of wind plants located in the region already is equivalent to 50 percent of the entire within-hour load and, we have experienced swings of greater than 2,400 MW within a single hour. The majority of the installed wind capacity is contracted with, and intended for delivery to the California market to satisfy renewable energy mandates.

So how is BPA maintaining system integrity and reliability? The Agency is in the process of one of the largest transmission construction programs in recent times and BPA is also aggressively implementing operational improvements, and funding research and development projects to advance Bonneville's ability to continue to successfully deal with a transforming power system[1].

BPA is also working closely with all of our partners in the Pacific Northwest to develop the technologies to effectively integrate variable energy resources. These include tools and products to manage periods when the Region experiences high winds and high water that combine to create an oversupply generation in the Northwest. We are also evolving our thinking about how a power system fundamentally works. A significant issue for BPA arises when loads are low, other generators are at their minimums, and wind generation picks up to maximums above planned levels such that there is no "sink" for the energy to be absorbed. Can we develop the means of providing loads on call and fit that into the Transactive framework?

Another issue BPA grapples with is the ability to manipulate the flow of power to reliably reduce the peak power carried by transmission lines to avoid or postpone capital investments while serving the needs of electric customers. This can be done by adjusting either the loads or generation that contribute to the transmission "congestion." How do we assure this is reliable so that we don't end up having to shed load because of competing interests?

3. AN OPPORTUNITY FOR INNOVATION

Historically, the prime directive for an electric utility was satisfying loads by providing power and building the transmission to insure that the power is delivered to loads as required. If loads grow, the utility acquires more generation and provides additional transmission capacity sufficient to deliver the power to meet demand.

In the 1980's, the Northwest Power and Conservation Act significantly changed Bonneville's policies and actions on energy supply.

BPA developed an aggressive energy efficiency program. Improved residential 'weatherization', adoption of low-flow showerheads, water heater insulation, and the promotion of Energy Star products resulted in substantial energy savings. BPA support for developing and promoting the use of variable-speed drives for industrial applications, dramatic improvements in fluorescent lighting and introduction of CFLs, and heat pumps, to name a few, over the last 30 years, established BPA and our customers as national leader in delivering what now amounts to 1,136.1 aMW of energy efficiency equivalent of new generation.

BPA has also supported efforts among its customers to help load shedding become a tool to meet constrained generation periods, establishing the foundation for what is now termed 'demand response' (DR). The flexibility afforded by subscribing demand response resources greatly helps minimize the magnitude of ultimate system peaks, forestalling the need to acquire costly new generation. This concept has been widely adopted; perhaps most notably on the U.S. East Coast to address summer peaks. Demand response has spawned a new industry with aggregators such as EnerNOC and Comverge assuming prominent roles in energy markets.

4. UNCONVENTIONAL REQUIREMENTS: PROVIDING FOR ABSORBING ENERGY WHEN YOU CAN'T OTHERWISE REDUCE GENERATION

BPA is now contemplating whether demand response can be expanded to not just reduce loads but also to *dispatch loads* in periods of excess renewable generation availability or to "pre-deliver power" to end-users in anticipation of impending system peaks or severe transmission congestion. This transforms the classic utility paradigm of balancing generation and loads to a new way of conceptualizing the resource balance in terms of INC's and DEC's. By this, we mean that the same effect is realized by **increasing generation** or by reducing loads (INC's) – the classic DR definition – and that we can achieve the same effect of decreasing generation **by increasing load** (DEC's). Embracing this concept means that DR is no longer 'essentially the same' as altering generator output. It wraps demand response, by positive and negative applications, together with generation to provide new dimensions to the utility to manage demand. This "generation" DEC can re realized in situations where there are thermal equivalent energy storage such as well-insulated homes or water heaters, capable of increasing or decreasing energy use across a broader comfort period due to enhanced thermal lag. It can also be gained from industrial processes with loads that have flexibility as to when they are run.

5. A PERFECT STORM OF OPPORTUNITY

Transactive control is a negotiated system based on market-like interactions. Provision of energy is responsive to some form of dynamic bid or feedback that is received

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[1] See BPA's Technology Innovation program at www.bpa.gov/ti.

from responsive electrical loads and generators. It's most basic element is the individual nodes and their characteristics. All these nodes will then negotiate optimal states in view of what they "learn" from their interactions with the other nodes.

While transactive control makes conceptual sense, it is through the smart grid (SG) framework and tools that the theoretical can become reality.. Formally imposing information, control, and communications technologies on top of traditional energy-delivery infrastructure from generation to end-uses is what distinguishes smart grid technologies.

The traditional solutions promoted to provide demand response are typically presented as an either - or proposition: direct utility control or imposition of time of use pricing with active decision making by end-users.

Direct utility control can directly and efficiently enable actions such as load shifting or load reduction to lower utility operational and capital costs. It also introduces the infrastructure challenges and complexity of wiring everything back to Control Centers. It also introduces the potential for big ON and OFF Events which if not carefully managed could overwhelm the System, introducing instability. And given the controversy of some recent smart meter roll-outs, direct utility control risks the characterization of utility" intrusion" in end-user spaces.

Time of use rates (TOU) provides the opportunity for electricity users to manage their costs by shifting what loads they can to less expensive periods. Homes do this by delaying appliance use to the low cost periods. Large commercial facilities with dedicated energy managers can realize substantial savings while both aid the power, transmission, and distribution costs. This can also lead to complexities that many might not manage well, particularly if the TOU schedules are complicated or have substantial variability for time and prices.. Additionally, it can be time-consuming and challenging to achieve regulatory approval. For BPA, where our service territory spans multiple balancing authorities across numerous regulatory jurisdictions, this would be a complex undertaking.

Now with the implementation of technologies such as sensors, and the ability to embed digital controls in end use devices, and particularly extensive digital communication-enabled metering and other devices, the potential to implement loosely coupled systems with feedback loops to manage energy use and customer energy response is greatly enhanced.

6. ENTER THE TRANSACTIVE SIGNAL

Pacific Northwest National Laboratories took up the challenge of delivering demand response nearly a decade ago, focusing initially on commercial buildings as part of the Pacific Northwest GridWise Test Bed[2]. Commercial facilities larger than 100,000 ft^2 typically are operated with the help of a building automation system (BAS) to manage, at a minimum, HVAC. Contemporary systems are microprocessor controlled and operate on one of the commercially available and often proprietary operating systems.

BAS controllers monitor physical conditions with a facility and adjust heating – cooling and ventilation levels delivered to each zonal area to maintain comfort settings. This PNNL study introduced an additional dimension to the controller logic: market pricing. Rather than establishing a specific comfort temperature, a correlation establishing the 'comfort' temperature as a function of market clearing price was established.

The study successfully demonstrated the response of the test building, but PNNL found the biggest challenge to wide-spread adoption of this architecture is the lack of standardization of BAS interface hardware and software, necessitating a significant customization for each BAS. PNNL concluded that:

"… control manufactures and energy service providers will benefit from having access to [standardized] technologies… . utility partners will benefit from help alleviating transmission and distribution reliability problems."

Transcending the challenges of classic demand response is the introduction of a *Transactive Signal* to the technological toolkit. Using the best of historical DR methodologies and avoiding some of the larger pitfalls, the Transactive Signal recognizes the potential for generation and load dispatch, and even the potential for both generation and loads to participate in the evolving energy markets.

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[2] "Transactive Controls: Market-Based GridWise Controls for Building Systems". S. Katipamula, et al., July 2006, PNNL-15921. Available from National Technical Information Service, US Department of Commerce, 5285 Port Royal Rd, Springfield, VA 22161

The Pacific Northwest Smart Grid Demonstration, with 50 percent funding from the U.S. Department of Energy, is comprised of five project-level infrastructure providers, 11 subproject utilities, the University of Washington, and the Bonneville Power Administration (BPA). Lead by Battelle Memorial Institute, Pacific Northwest Division, the demonstration will last five years, from 2010 into 2015, including a one-half year design phase, a two-year construction phase, a two-year observation phase, and a one-half year closeout phase.

According to the Pacific Northwest Smart Grid Demonstration Project's Conceptual Design document, it will be "a truly regional demonstration of smart grid functions. One important featured innovation of the demonstration will be its scalable, hierarchical transactive control approach, by which a representative cross section of responsive smart grid assets throughout the five-state region will be coordinated to respond to several of the region's most important operational objectives"

…"Transactive control is the approach being used by the demonstration to couple the subproject and regional operational objectives to the dynamic behaviors of a set of representative responsive assets in the demonstration region. Most generally, transactive control is a bidirectional negotiated system behavior. Market-like principles facilitate the negotiation; however, the signals need not be used to account for any monetary or revenue exchanges. In theory, the "winning" behaviors are optimal in some sense, having competed successfully in a "market" against alternative actions that could have been taken."

There are two Transactive Signals at each transactive node:

A transactive incentive signal (TIS) time series consisting of the aggregated present and future values of the electricity supplied at and through each transactive node.

The transactive load feedback signal (TFS) consisting of the sum of an estimate of the future quantity, both unresponsive and responsive electrical load to be consumed by the entire load downstream from the transactive node.

A widely recognized example for the power of the *Transactive Signal* is the recently concluded Olympic Peninsula Demonstration Project (OPDP)[3]. Tom Friedman described the results of the Project in his book, Hot, Flat, and Crowded:

"The model that (PNNL) tested out would involve a revolutionary change to the utilities industry. Utilities, instead of limiting their vision from the power plant to your home electricity meter, would be wholly transformed. Their universe would stretch from the generation of clean power on one end right into your home appliances, your car battery, and even the solar panels on your roof. Rather that just being a seller of dumb and dirty electrons, it would be an enabler of this whole smart grid-energy Ethernet system. And it would make its money from optimizing the system."[4]

Conducted as part of the GridWise Test bed Demonstration, the "objective of the project was to convert normally idle distributed generation into actively participating resources that were optimally coordinated in near real-time to reduce stress on the local distribution system"[5].

The OPDP "looked specifically at the interaction of retail choice and enabling technologies …(by) ...employ(ing) a combination of smart technology and dynamic pricing to enable consumer-centric, decentralized coordination that achieved enhanced reliability increased capacity utilization, and higher customer satisfaction"[6]. Customers

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[3] Hammerstrom DJ, R Ambrosio, TA Carlon, JG DeSteese, GR Horst, R Kajfasz, LL Kiesling, P Michie, RG Pratt, M Yao, J Brous, DP Chassin, RT Guttromson, OM Jarvegren, S Katipamula, NT Le, TV Oliver, and SE Thompson. 2008. Pacific Northwest GridWise™ Testbed Demonstration Projects; Part I. Olympic Peninsula Project . PNNL-17167, Pacific Northwest National Laboratory, Richland, WA.

[4] Hot, Flat, and Crowded: Why We Need a Green Revolution and How it Can Renew America, Thomas Friedman, Farrar, Staus and Giroux, New York, Page 239, para. 3, 2008

[5] "The Smart Grid and Key Research Technical Challenges, M.G. Rosenfield, IBM T.J. Watson Research Center, Yorktown Heights, NY

[6] "Decentralized Coordination through Digital Technology, Dynamic Pricing and Customer-Driven Control: the GridWise Test bed Demonstration project, Chassin and Kiesling

were incentivized to participate by a reduction in their electric bills. The project resulted in almost a 15% average reduction in peak demand over the period of the annual study period. While the goal of this study was to demonstrate the potential of smart-technology to reduce peak demand stresses on a utility (distribution) system, the results also point to the potential to apply the same and related methodologies to facilitate Renewables integration.

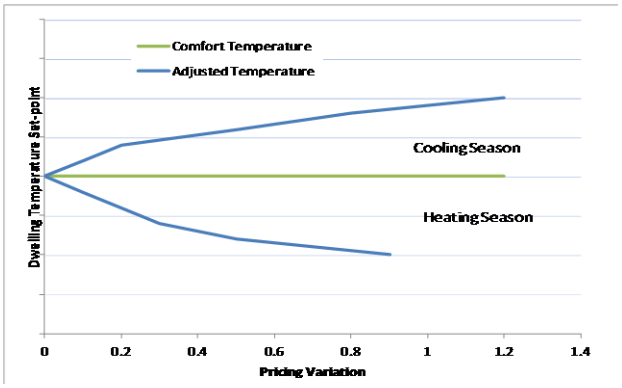

Figure 1. Example of the Transactive Signal at Work. As, the temperature deviates further from the "Comfort Temperature" the incentive increases.

Conducted at the residential-sector level, 112 households were enrolled in the project. Participating households were equipped with a programmable thermostat that included two-way communication technology that featured a graphical user interface. End-users were able to define 'rules' relating how much of a departure from the preferred dwelling temperature that they would accept based on the price of electricity.

The participants in the study were divided into smaller groups to determine the specifics of the pricing signal each would receive. Some were provided with time-of-use (TOU) pricing that also included a special critical-peak pricing (CPP) rate. Others were offered real-time pricing (RTP), based on retail market clearing prices established at five-minute intervals. A third group was provided traditional fixed-pricing, and a fourth group was provided the technology, but not charged for their power usage to serve as a control group.

The results were striking. Of all the participants, TOU customers reduced consumption the most. The RTP customers ended up reducing their bills the most – indicating that they were able to shift usage from higher price periods. The study also showed that the greatest savings among the RTP group was realized by those that consistently selected the most economical appliance settings and in lieu of greater comfort.

The importance of this experiment is that for all pricing structures, it was the technology and not the end-user that was engaged around the clock in managing energy usage, informed by the rule set established by the customer. The infrastructure required by the utility was to enable the transmission of the pricing information rather than to directly control in-premises devices.

7. A SYNERGISTIC SOLUTION: TRANSACTIVE SIGNAL AND DISTRIBUTED INTELLIGENT DEVICES

Based on the results of this study, the U.S. Department of Energy invested American Recovery and Reinvestment Act (ARRA) funding to expand this work to 60,000 customers across the Northwest Region through the Pacific Northwest Smart Grid Demonstration Project.

While the OPDP was focused on demand response it only demonstrated the load reduction (INC) side of the equation where consumers reduce or shift usage in light of higher prices that result from higher costs of power to meet demand. But what about the load-increase (DEC) part of the equation that is needed to absorb generation that needs to run but exceeds the loads? Can end-users be appropriately incentivized to use *more* power when excessive amounts of renewable (wind or solar) generation is available?

The results gained to date from another pilot project in the Pacific Northwest Smart grid demonstration project are instructive. In this study, specially designed and configured water heaters are designed to produce and store hot water at temperatures significantly higher than conventional units. The temperature set points are established based on the amount of wind energy being produced on a real-time basis. If excessive amounts of power are available, the water heaters operate to produce water heated to the maximum allowable temperature, thus storing the energy. If wind is not available, or other factors establish that the grid is operating in a constrained regimen, the water heaters suspend operation until the stored water reaches the lowest acceptable temperature as established by the end-user. In effect, the devices serve as energy storage devices that transform wind energy to thermal energy.

Based on this, BPA sees game changing potential benefits from tightly coupling DR products into our product portfolio. DR products provide a mechanism to effectively and constructively integrate intermittent renewable generation by adding the ability to dispatch loads to compensate for intermittent and variable, non-dispatchable generation.

Using simulation tools currently available in control centers System Operators can identify specific areas or pockets of loads which can be managed through the transactive notes and controls to help manage transmission path congestion, utilizing both INC's and DEC's to reduce peak transmission loading to at least postpone transmission construction. The two graphs (Figures 2 and Figure 3) demonstrate the potential for the Transactive Signal to manage energy use, responding to the difference between scheduled and actually delivered generation. The Figures also illustrate the power of the Transactive Signal to manage the system within hour. This is a valuable tool for utilities in general and BPA in particular. While the Federal Hydro system is remarkably well suited to manage the constant variability in non-dispatchable renewables such as wind generation, that flexibility does not come without a cost and at times the need exceeds the available Federal assets. The constant varying of the physical infrastructure of the dams to follow the minute-by-minute changes in wind-plant output exacts a toll in their service life and shortens maintenance intervals.

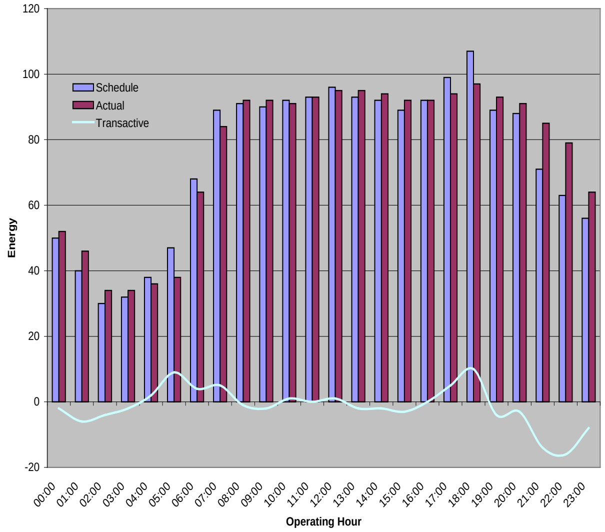

Figure 2. Impact of the Transactive Signal on Hourly Balancing Responsibilities – The Chart shows the impact of the Transactive Signal to raise or lower energy use to align "scheduled" and "actual" energy.

Building upon the existing work to refine and extend the Transactive Signal also will serve to provide end-user choices. Choices to contribute to the reduction of green-house gases and enhancing energy security by enabling the integration of intermittent renewables provide powerful incentives to some. Or the option to realize economies and savings in their energy finances.

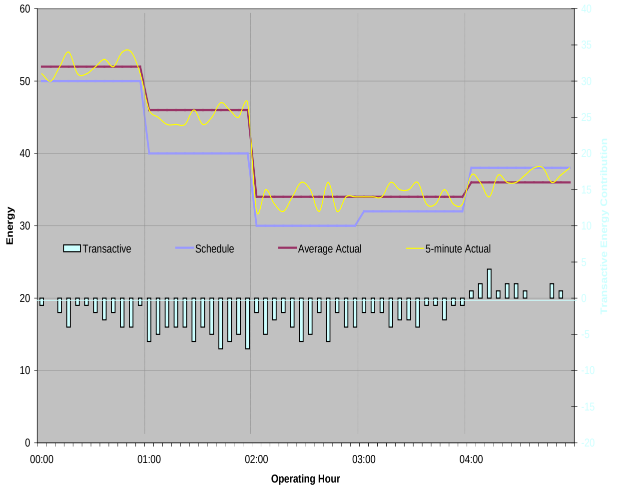

Figure 3. Transactive In-Hour Applicability to Balancing and Control.

Potential participants can not only decide if, but to what degree they are interested in participating on a generalized basis and accorded the option to make episodic changes or modify their degree of commitment. Given the resistance encountered by some utilities in merely swapping out metering technologies, this is a most important imperative to establish with customers before entertaining any discussion on actually changing their usage patterns. A strength of the Olympic Peninsula project was that participation was not only voluntary; but the actual devices installed can belong to the Customers.

Once the extended and enlarged projects of the Pacific Northwest Demonstration Project validate the results of the earlier Olympic Peninsula Demonstration Pilot program, manufacturers will likely be incentivized to incorporate the communications and control devices with the next generation of energy smart appliances. This will insure a growing pool of customers enabled to participate as the programs develop and mature.

8. CHALLENGES

Despite the demonstrated technical success of the Transactive Signal to deliver benefits in demonstration projects, there is still a family of issues that must be addressed before the concept can be extended to the utility operating environment.

Incentives: First, to make transactive control systems viable on a large scale with full participation of regional generation and transmission a means of a financial value has to be developed as the basis for Transactive activity. This can be a market based cost or based on a calculated cost, but in any case requires data sources that include inputs from any type of power producer, including wind developers and other commercial interests which have an inherent motivation to protect commercially sensitive information. In other words, the process to determine the real-time cost of power, especially in the Pacific Northwest where no real-time market exists, would rely on participation by numerous entities that may be reluctant to provide real-time data or even wind forecasts. And beyond the issue of data availability, the sheer complexity of ensuring that the price signal accurately reflects the price of power is problematic in terms of regulatory oversight.

Additionally, there are financial considerations to address. The Olympic Peninsula project provided a direct financial incentive to participate. Participants were provided an ‘incentive account’ that shielded them from any negative exposure. That may not be a feasible model for implementation across all rate-payers. There was no direct and discernable negative consequence. While there are potent philosophical incentives to recruit participants, for many there must be a financial rational to alter their current relationship with their electric energy provider and their usage preferences.

An alternative viewpoint is that the existence of incentives resulted in participants allowing their local energy management system to function, and further to reward energy use patterns that benefitted the electric power system. Such a system need not be implemented exclusively via a tariff, in fact the true marginal cost tariff approach builds in over-recovery issues, which may be avoidable with an incentive approach, while having an equivalent impact.

To the extent that Demand Response can eliminate the need for new transmission construction, there are calculable fiscal equivalents that can be re-directed as incentives.

Regulation: The role of Regulatory institutions is significant.. Institutionalizing even the ‘simple’ transference of funds as practiced during the OPDP may require regulatory changes or reform. The sale of ‘non-energy’ or the avoidance of energy usage for an hourly period will likely require affirmation by responsible regulatory authorities, as this requires re-definiting of the long-established value proposition governing a utilities accounting and its balance sheet.

“The traditional cost-based structure of regulation, and the reticence of regulators to enable consumers to choose dynamic pricing, is also a substantial barrier to the wide-scale adoption of these feasible technologies, which enable reliability and resilience through decentralized coordination.”[7] This becomes even more complex in establishing the actual value of the power (received, or foregone) since most regulatory jurisdictions favor ‘postage-stamp’ or ‘peanut-butter’ rates where little if any differentiation applies to time or thespecific location of the usage. In many ways, the technology is simple – potentially far simpler than the required changes to regulatory and accounting practices, and grappling with the questions of effective market design. However, such a frame work necessarily involves variability in cost and thus some financial risk. Regulators, at least in the Pacific Northwest to date are hesitant to endorse either Real-time Pricing (RTP) or Time of Use (TOU) Tariffs.

Activating a Transactive Signal: A fundamental fiscal consideration is establishing the actual clearing prices that will be applied to activate the Transactive Signal.. For example, in the Pacific Northwest, will the Mid-C clearing price serve as the Transactive Signal that is transmitted or will it use some other means be employed to calculate a cost or benefit? Is the complexity of establishing and broadcasting information representing a 10 minute match between generation and load warranted, or is coarser granularity adequate to achieve desired results? Is the program implemented with a ‘peanut-butter’ rate for all subscribers, or is the additional complexity of impressing a locational-marginal pricing (LMP) paradigm appropriate?

In large service territories such as that where the BPA performs as the Balancing Authority (BA), the BA and accompanying Transmission system span multiple types of distribution utilities and regulatory jurisdictions. Success of the Transactive Signal depends on large scale participation and may prove ineffective if the area assumes a Balkanized approach to establishing the program.

Generation Reserves for Generator/Load Balance: BPA operates under North American Electric Reliability Corporation (NERC) and Federal Energy Regulatory Commission (FERC) mandating reliability for circumstances such a large generator going off line or unexpected fast and large changes in wind generation. that

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[7] ibid

the Balancing Authority must hold balancing reserves sufficient to supply reserves within 15 minutes that restore their support of the grid frequency. For these situations, can the Transactive Signal be assured to provide adequate reserves if called upon through the transactive control signal to meet NERC and FERC reliability requirements? Will the signal be as reliable in delivering reserves equivalent to the current market that depends on bilateral contracts for balancing requirements?

Critical infrastructure: NERC also has stringent cyber security requirements under its Critical Infrastructure Protection plan, and complying with those requirements is mandatory for balancing authorities. How will a transactive control system take these into consideration?

Back office systems: Finally, significant complexity exists in the area of back office systems for utilities and wholesale power marketers. Scheduling, Metering, Billing, and Settlement systems may have to be substantially modified to allow for operation of the transactive control signal. Utilities may have to make new system investments and upgrades to accommodate the signal, and this will need to be factored into the business case to determine the cost effectiveness of the transactive control system. BPA is now looking at the information technology implications of various demand response scenarios. This work is very preliminary, but does not reveal insurmountable barriers at this time.

9. THE PATH FORWARD

BPA is participating with many of its Customers and Regional stakeholders in the Pacific Northwest Smart Grid Demonstration Project, coordinated by Battelle. Assisted with ARRA funding, a wide-variety of potential demand response solutions are being investigated, including the previously mentioned project with Ecofys to store surplus wind generation as domestic hot water

The larger the service area for this product, the greater the potential benefits. This suggests that as we gain experience we should pursue building a unified ‘market’ for the transactive Signal that will be implemented across multiple BA’s.

Finally, more extensive research into potential impacts on transmission system Reliability – both positive and negative – is prudently required and will be a factor in the PNW Smart Grid Demonstration Project. This will inform the Region on the best implementation strategy – and guide the rate of adoption.

10. SUMMATION

Early results of applying the Transactive Signals to affect electricity use demonstrated the potential for impressive gains. Our opportunity is the potential to achieve significant savings by eliminating or delaying the need for substantial utility system infrastructure. It also provides a potential schema to accomplish the integration of large amounts of variable renewable energy. In addition, the transactive control system can potentially aid transition from the historical operating method of generating and distributing power to follow load, to one where electricity use is optimized for the generation available.

The potential value of the Transactive Signal could conceivably increase as dependency on the electric utility grid grows to meet new demands such as wide use of electric vehicles and needs to meet these as transparently and economically as possible. It also establishes a platform that can more easily integrate highly distributed local generation, incorporate increasingly sophisticated local management networks, and support new operational tools such as micro-grids, intentional islanding, and promotion of ‘net-zero’ buildings.

Perhaps the most important promise of the Transactive Signal is as a founding transition tool to migrate from the electric infrastructure of today to that of the next generation. The ‘classic’ grid, devised to serve loads by dispatching generation resources is now confronted with the conundrum of *non-dispatchable* generation, such as wind or solar generation that supplies power only when the energy source is available. The elegant resolution is dispatchable *loads.* Introducing a new dimension to manipulating loads to satisfy needs of the greater grid is not only using the tools to reduce load (yielding the same result as INCreasing generation) but to increase loads when presented harvestable renewable generation.

The flexibility and versatility of pursuing Transactive Signal tools and standardization compliment the growing penetration of distributed generation. Taking that evolution another step into the future will be the widespread introduction of distributed storage. Already, ‘pallet-ready’ technology is commercially available to provide integrated distributed generation *and* distributed storage *and* distributed control tailored to the specified preferences of the end-users and responding to information delivered by the internet. And gaining greater confidence and developing increased applicability of the Transactive Signal across the electrical network will simplify and smooth the way for the inevitable transitions in how energy is transmitted and used. Comprehending the potential impacts and benefits will require carefully considered and committed resolve to adopt a new paradigm with challenges but also great promise to fundamentally enhance and optimize the grid, providing substantially increased capacity while better preserving reliability. The technology is maturing rapidly but substantial work remains before it is proven and confidently implemented in the power system.

National efforts to keep standards and interoperability at the forefront of these discussions are essential. The industry and our customers can realize substantial benefit not only from the effective and wide-spread adoption of the Transactive Signal to facilitate integration of non-dispatchable renewable energy, but also from the savings presented by non-wires alternatives to large new transmission construction. Gaining the flexibility and resilience that a smart electrical grid with distributed-control will deliver may provide the ability needed to effectively adjust the operation of the entire system to minimize congestion, aid in balancing load and generation, and shifting peak electricity use to reduce energy costs and increase reliability. It also provides a platform for taking full advantage of new thinking, operating theory, and technology integration on the electric grid. The Transactive Signal is an enabling technology that can make the transition to new energy systems attainable and help us avoid significant negative impacts and disruptions.

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