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Energy
Framework

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About this Document

The GridWise Architecture Council (GWAC) was formed by the U.S. Department of Energy to promote and enable ***interoperability*** among the many entities that interact with the electric power system. This balanced team of industry representatives proposes principles for the development of interoperability concepts and standards. The Council provides industry guidance and tools that make it an available resource for smart grid implementations. Readers of this document should possess a good understanding of interoperability, familiarity with the GWAC Interoperability Context-Setting Framework, and knowledge of energy markets and their business models. Those without this technical background should read the *Executive Summary* for a description of the purpose and contents of the document. Other documents, such as checklists, guides, and white papers, exist for targeted purposes and audiences. Please see the www.gridwiseac.org website for more products of the Council that may be of interest to you.

GRIDWISE Architecture Council

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INTRODUCTION

The GridWise® Architecture Council (GWAC) hosted its fourth workshop on Transactive Energy at the Rose Center in Westminster, Calif., December 10–11, 2013. This workshop applied the Transactive Energy Framework document through the presentation and discussion of transactive energy case studies. The framework includes definition of attributes of transactive energy systems. Researchers and practitioners who have implemented transactive energy systems—or capabilities that may be used in implementing such systems—were asked to describe their results using a case study template based on the attributes defined in the framework document.

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OVERVIEW AND OPENING REMARKS

WORKSHOP LEADER: MARK KNIGHT, GRIDWISE ARCHITECTURE COUNCIL CHAIRMAN

The GridWise® Architecture Council (GWAC) recently published the Transactive Energy Framework (http://www.gridwiseac.org/pdfs/te_framework_report_pnnl-22946.pdf). This work will be revised during 2014 to reflect comments on the document and to possibly include additional material. Input from these workshop sessions will be used to help during this process.

A key element of the framework is an update to the definition of transactive energy and addition of a set of associated attributes. The definition now being used by GWAC is, *"A set of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter."* By adding a set of attributes, the council intended them to help the reader understand the boundaries of transactive energy, and to be used to discuss different approaches and implementations of transactive energy.

With that in mind these workshop sessions were intended to bring together experienced industry experts who have been doing work in areas considered to be transactive in nature, or who have plans in place for transactive energy systems. As more and more people start to use the term transactive energy, one of the council's goals in publishing the framework was to create common ground for all interested parties to discuss and advance this field. Since this was the aim of creating the transactive energy attributes, the presenters had been previously asked to complete a presentation template that used these attributes to describe their work. A key objective of the workshop sessions was to see how well the attributes worked in terms of providing common ground for comparing and contrasting different transactive initiatives.

To make it easy for attendees to compare how each session described the presenter's work in terms of specific attributes, the PointView website was updated to facilitate comparisons. For example, by clicking on the following URL (https://www.pointview.com/e/175#topics), you see a list of transactive energy attributes, and by clicking on an attribute you are taken to a page that describes that particular aspect of each presentation.

Since the council wishes to update the framework in 2014 and also to hold another transactive energy conference in December 2014, it is important to get feedback on whether the attributes work for the purpose that was intended.

Each session is planned for 45 minutes, with 30 minutes for presentation and 15 minutes for discussion.

Background

What is transactive energy?

The meaning of the term “transactive energy” has been under discussion and refinement at the workshops on this topic hosted by the GWAC and through related work of others. An early definition referred to techniques for managing the generation, consumption or flow of electric power within an electric power system through the use of economic or market-based constructs, while factoring in grid reliability constraints. The term “transactive” came from the consideration that decisions are made based on a value. These decisions may be analogous to—or literally—economic transactions.

More recently, as the GWAC prepared the Transactive Energy Framework document[1], the definition was refined to, *“A set of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter.”* An associated set of attributes of transactive energy also were developed. These attributes define dimensions of transactive energy and are intended to enable rich descriptions of transactive energy methods or systems and allow for comparison of different approaches.

An example of an application of a transactive energy technique is the double auction market used to control responsive demand-side assets in the GridWise Olympic Peninsula Project[2]. Another would be the TeMix work of Ed Cazalet[3]. Transactive energy techniques may be localized to managing a specific part of the power system—for example, residential demand response. They may also be proposed for managing activity within the electric power system from end-to-end (generation to consumption), such as the transactive control technique being developed for the Pacific Northwest Smart Grid Demonstration Project[4,5]. An extreme example would be a literal implementation of “prices-to-devices,” in which appliances respond to a real-time price signal.

The current situation is that dynamic pricing is widely used in the wholesale power markets. Balancing authorities and other operations such as hydro desks routinely trade on the spot market to buy or sell power for very near-term needs. In addition, dynamic pricing tariffs are being tried in a number of retail markets, for example, the PowerCentsDC dynamic pricing pilot[6].

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[1] GridWise® Architecture Council, “GridWise Transactive Energy Framework, Draft Version”, PNNL-22946, October 2013, Pacific Northwest National Laboratory, Richland, WA http://www.gridwiseac.org/pdfs/te_framework_report_pnnl-22946.pdf

[2] Hammerstrom, D.J., et al, “Pacific Northwest GridWise™ Testbed Demonstration Projects: Part I. Olympic Peninsula Project”, PNNL-17167, October 2007, Pacific Northwest National Laboratory, Richland WA

[3] Cazalet, E.G., “TeMIX: A Foundation for Transactive Energy in a Smart Grid World”, presented at Grid-Interop 2010, Chicago, IL http://www.pointview.com/data/files/2/1062/1878.pdf

[4] Hammerstrom, DJ, et al, “Standardization of a Hierarchical Transactive Control System”, in the Proceedings of Grid-Interop 2009, November 2009, Denver, CO, pp 35 – 41. http://www.gridwiseac.org/pdfs/forum_papers09/don-business.pdf

[5] http://www.pnwsmartgrid.org

[6] http://www.powercentsdc.org

PRESENTATIONS

For this workshop, each participant was required to give a presentation on their current work dealing with transactive energy and was specifically asked to describe their work using the attributes defined in the Transactive Energy Framework draft. They also were asked to submit a white paper on their presentation. The following are the abstracts, case studies, and links to the presentations.

CLOSING THE GAP BETWEEN WHOLESALE AND RETAIL

SPEAKER: JAMES MATER

Council Member James Mater kicked off the workshop with an overview of the Transactive Energy Framework first presented at the Peak Load Management Alliance (PLMA) Fall Conference in Atlanta, October 30, 2013. The overview included a discussion of the framework's attributes, and assessments of both OpenADR and transactive control based on the GWAC framework.

Closing the Gap between Wholesale and Retail Presentation

Questions, Comments, and Discussion:

- Difficult to identify and separate the notion of value from whatever mechanism (bid/offer, price, rate, etc.) is used to make a decision by a transacting entity
- OpenADR discussion within the context of transactive energy is correct, but the notion of prices that are used in OpenADR and what it means is not well understood
- Minimizing wholesale prices should not be objective; correct objective should be to minimize cost. The TEF document states optimizing, not minimizing prices.
- Transmission system gets mentioned quite a few times, but distribution-side benefits are not mentioned often
    - Part of transactive energy challenge is to connect retail with wholesale
- More discussion needed on the future roadmap and actionable plan for industry
    - Some risks exist in not laying out a roadmap; people will take their definitions of transactive energy and charge ahead with implementation plans
    - More discussion on the meaning of transactive is still required, in order to build some kind of consensus, before asking people to devise their solutions
- Implementation will require entities like National Association of Regulatory Utility Commissioners, Edison Electric Institute (EEI), etc., and policy makers to get moving
    - EEI coming out with a series of papers on how to advance transactive energy
- Framework is to evolve into a much larger body of work, including things like roadmap
- Doug Houseman suggested there may be a missing attribute
- Transactive energy is much more than energy [sales].

TRANSACTIVE ENERGY FRAMEWORK FOR BILATERAL ENERGY IMBALANCE MANAGEMENT

SPEAKER: FARROKH RAHIMI, OPEN ACCESS TECHNOLOGY INTERNATIONAL, INC. (OATI)

This case study was motivated by a number of parallel activities in the Western Electricity Coordinating Council (WECC) related to the development of Energy Imbalance Markets (EIM). The study is initiated and funded by Open Access Technology International, Inc. (OATI) in loose collaboration with several interested

WECC Balancing Area operators. The primary objective of the study is to demonstrate a novel approach to EIM based on transactive energy principles.

The high penetration of variable generation in the West, driven by Renewable Portfolio Standard mandates, is necessitating new operational practices to support ramping and flexibility needed to maintain power system's supply and demand balance at all times. Proposals have been put forward for a number of EIM designs to facilitate the supply of required balancing services, including a centralized—as well as decentralized—market-based framework.

This case study assesses requirements for system balancing when faced with high levels of variable generation. It includes review of emerging EIM structures, such as the California Independent System Operator (CAISO)-PacifiCorp model and alternative approaches, and discusses transactions required to support operations of retail resources and demand response to the centralized EIM. It also addresses the relative advantages and disadvantages of centralized EIM versus EIM-based on bilateral transactions. Transactive Energy constructs are mapped to the EIM market frameworks, with special emphasis on supply of ramping and flexibility reserves by demand response resources. These transactions cover the entire market lifecycle from bid to bill, with special emphasis on price signals and automated operations.

The study is ongoing. It includes application of the Transactive Energy Framework to EIM in both centralized EIM and decentralized EIM designs. The preliminary results indicate that proper application of the framework enables expeditious development of EIM, leveraging existing energy trading and risk management tools.

Case Study

Architecture

Both centralized and decentralized designs are considered and evaluated.

Extent

The transactive activities extend across two or more Balancing Authority (BA) areas in the Western grid (WECC). Transacting entities include asset owners/operators of conventional and distributed generation, storage, building energy management systems, microgrids, C&I prosumers, residential prosumers, distribution utility operators, and aggregators.

Transactions

The commodities transacted include primarily energy (kWh/MWh), but may also include capacity (kW/MW), conventional reserves (non-spinning, spinning, regulation), and new reserve products (flexibility reserves, ramping, load following, etc.). Transactions may involve different time horizons and temporal granularity, span across geographical/electric service territory boundaries, include schedules or price-quantity bids/offers, be financial or physical (include points of delivery and receipt), and involve two or more parties. Transactions may involve human interactions (negotiation) or use automated systems and infrastructure based on pre-defined rules and agreements.

Transacting Parties

Transacting parties may include human participants/actors or intelligent systems/nodes. Generally transactions with sub-hourly temporal granularity (e.g., 5 minutes) involve automated/intelligent systems.

Temporal Variability

The transaction time scales range from multi-day, multi-hour to sub-hourly (15 minute and 5 minute) temporal granularity. The deployment/delivery of the transaction may be time-triggered, event-triggered, or take place on demand. Generally in the sub-hourly time scale, transactions are effected based on pre-defined times or events.

Interoperability

Both technical and cognitive interoperability are addressed in the case study. Where relevant, standards are used to facilitate interoperability.

Value Discovery Mechanisms

The value discovery for forward (multi-day, multi-hour) transactions is affected either based on reference public prices (from organized markets or trading hubs) or through bilateral bid/ask mechanisms based on economic or engineering values. In the sub-hourly time frame, automated clearing/bid-matching mechanisms are used (e.g., EIM automated dispatch/clearing) for value discovery.

Value Assignment

The bids and offers used in the transactions reflect objective value assignments for transacted products and services. Subjective values may be incorporated in “priority” orders. In the context of the present case study (EIM), the latter apply to the type (e.g., firm or non-firm) of transport path (transmission or distribution) used for delivery.

Alignment of Objectives

The premise of EIM is based on a win-win outcome for transacting parties by pooling imbalances across footprints and pooling different resources within the footprints to mitigate the cumulative imbalance.

Stability Assurance

The system has been designed to ensure incentive-compatibility aligning economic objectives of the participating entities with security and stability of the physical grid. It is also designed with the stability of the market (EIM) as a primary objective. Specific protections are put in place (including physical modeling of technical constraints) to assure that the transactions do not introduce system or market instabilities. These include data collection and analysis by the EIM (in both centralized and decentralized designs) to monitor physical quantities (flows), bids and offers, prices, and relevant metrics.

Participating Agencies and Organizations

OATI has informal arrangements with some WECC entities; at this time, these discussions are ongoing.

References

OATI has made several presentations at EIM design meetings. OATI's contributions have been mainly to ensure distributed resources are included in EIM design.

Questions, Comments, and Discussion:

- Case study expresses a specific market design, which is based on the concept of cost rather than prices
- Some issues with characterization of centralized markets in the use-case;
    - cost of congestion built into the LMP itself
- In a centralized market, what is taken into account is only the bids/offers and congestion constraints to determines the LMPs, but interchange between BAs does not necessarily take into account the transmission charge in the dispatch process
- The seams issue between balance areas should handle the dispatch algorithm
- simple two-bus system (used to demontstrate the concept in the presentation) to a multi-bus system Use-case presents an example with various cost components, and not just energy cost, that must be presented to customers for them to be able to make rational choices
- Problems look harder because no distinction between spot market and forward market transactions.

Transactive Energy Framework for Bilateral Energy Imbalance Management Presentation

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HOMEOSTATIC UTILITY CONTROL IN RETROSPECT

PRESENTER: JAMES KIRTLEY

This was a prospective study on how electric utility systems might work in the "future;" in this case, the future was the year 2000 and beyond. The study was convened by Fred Schweppe, a visionary in electric power systems operation and control, and the developer of state estimation for electric power utilities.

Case Study

Architecture

Homeostatic Utility Control was envisioned as consisting of three basic parts, working together:

•For short-term control, it envisioned the Frequency Adaptive Power Energy Regulator (FAPER); this would replace or:

•For longer term control, Homeostatic Control envisioned real time pricing (RTP), to reflect actual costs of generation and distribution to customers.

•And to implement all of this, there would be the Marketplace Interface to the Customer (MIC), which would include communications of system price to the customer and a metering system that would properly reflect the customer's use of electric power and any customer generation that would be injected back into the utility system.

Transactions

In the Homeostatic Utility Control scheme, transactions would involve setting of price by the utility and the use of electric power by the customer. A FAPER would generate a discount for the customer by selling high frequency electricity at a lower price than low frequency electricity. Real-time pricing would enable customers to buy low and sell high. It is straightforward to understand that these elements would make the system work better and cheaper.

Transacting Parties

In the original notion of Homeostatic Control, the parties are the regulated utility system and its customers. Envisioned within the system are automated control systems that interact with pricing signals, attempt to make predictions of future prices and buy electric power accordingly. Some loads get rescheduled.

Temporal Variability

FAPERs operate on short time scales. Real-time pricing operates on longer time scales.

Interoperability

Information exchange is limited to prices that would be transmitted from the central utility system. Some level of reverse information flow was contemplated, but the very low bandwidth of the time (1979) was contemplated.

Value Discovery Mechanisms

This was a very early effort and no experiments were contemplated.

Value Assignment

The assumption was that those customers who decided to participate in the system (and not all customers would be required to) would benefit by being able to buy power at reduced rates. Customers who chose not to participate might benefit, but would not lose because of this arrangement, because the whole system would work more economically.

Alignment of Objectives

The assumption was that those customers who decided to participate in the system (and not all customers would be required to) would benefit by being able to buy power at reduced rates. Customers who chose not to participate might benefit but would not lose because of this arrangement, because the whole system would work more economically.

Stability Assurance

We had not thought this far.

Participating Agencies and Organizations

This was an activity wholly within the Massachusetts Institute of Technology, with no external support that I know of.

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•J.L. Kirtley, Jr., and T.L. Sterling, “Impact of New Electronic Technologies on the Customer End of Distribution Automation and Control.” IEEE Power Engineering Society 1979 Summer Meeting, Vancouver, B.C., July 1979.

F.C. Schweppe, R.D. Tabors, J.L. Kirtley, Jr., "Homeostatic Utility Control." A paper presented at the Distribution Automation and Control Working Group Meeting, Baltimore, Maryland, November 20-22, 1977.

Questions, Comments and Discussion:

- Paper from 35 years ago talks about all the issues that are absolutely relevant in today’s time; Jim Kirtley was asked what their thought processes were when writing this paper
    - Did the Public Utility Regulatory Policies Act (PURPA) influence a movement toward driving demand to be more elastic, which led to these papers?
- These papers came along with PURPA, and not post-PURPA. Utility industry at the time was very opposed to distributed generation, and a lot of what we are talking about today.

With PURPA and the deregulation of power system, the whole thought process in the industry has changed quite a bit today.

- Why did it take 35 years for the idea to gain more traction?
    - Didn't have much of the computing power to do what we want to do today
- Some concerns about automation software causing price-chasing behavior, and its impact on system stability.
    - Distribution systems will need to be more resilient, but not sure how and if control systems may co-operate to get desired results.
- Today there is more communications infrastructure, more CPUs in the field and a different political/regulatory climate, thus many barriers are less today than they were 35 years ago.
- Value discovery is important to transactive energy but value assignment depends on the transactor's role.

Homeostatic Utility Control in Retrospect Presentation

AEP GRIDSMART® RTP DEMONSTRATION

PRESENTER: STEVE WIDERGREN, PACIFIC NORTHWEST NATIONAL LABORATORY

The AEP gridSMART RTP demonstration is an ARRA project sponsored by AEP Ohio and the Department of Energy. It deploys a transactive coordination and control system that coordinates the responses of smart grid assets on a 5 minute basis to participate in achieving several operational objectives, including reducing the cost of electricity purchases based on market price fluctuations, distribution feeder congestion management, peak load management, and the potential provision of ancillary services (such as spinning reserves). Several hundred residential customers in the northeast Columbus, OH area were recruited and over 200 home energy manager (HEM) were installed to examine how real-time pricing (RTP) mechanism can engage HVAC loads to lower energy bills and earn incentives for the customers by changing their energy use-patterns. The customers control their HEMs and smart thermostats by setting their comfort and schedule preferences, which automate HVAC operational response to real-time energy prices. Commissioning of the residential systems occurred in the spring of 2013 and the preliminary tests started in early June 2013. Households were added to the RTP system through the summer and information is collected through the end of 2013.

Case Study

Architecture

The system implements a distributed, multi-agent architecture, where the agents coordinate by bidding into a centralized market clearing mechanism. The transactional participants (agents) are spread across about 200 residences on four distribution feeders in the northeast Columbus area of Ohio and operated by AEP Ohio. While the market clearing is centralized for each feeder, the decision-making is distributed to the participants.

Extent

The RTP system runs a retail electricity market on each of four distribution feeders operated by AEP Ohio. The four markets run simultaneously, engaging residential HVAC load to provide demand response service based the 5 minute, varying cost of electricity. The PUC of Ohio approved an RTP residential tariff that includes a dynamic real time price derived from PJM's 5 minute wholesale energy market and adjusted by the locational marginal price (LMP) of energy at the PJM LMP node that services these feeders. The RTP system also responds to feeder capacity constraints that engage the household resources to reduce energy to mitigate capacity violations. The feeder capacity value can be manually adjust so that resources can be engaged to shift peak feeder load for local needs or to address an AEP or PJM system issue, much like critical peak pricing attempts to engage loads. In this way, the loads are engaged at various levels of the system: PJM transmission system needs, AEP transmission system needs, and AEP distribution feeder needs.

The technique of using a market exchange to coordinate decisions from multiple agents can also be applied within a building or with the transmission and distribution infrastructure itself.

Transactions

Within each home is a programmable thermostat communicating with a heating and ventilation air conditioning (HVAC) unit. The thermostat runs an agent that bids the price it is willing to pay for electricity for the next 5 minutes into the feeder's RTP market and receives the market clearing price of electricity. If the clearing price received by the agent is less than the bid, the HVAC unit runs. If it is greater than the bid the unit does not run. The bid is updated every 5 minutes based on the residents' desired temperature set-point and their preference setting for more comfort or more savings. More savings translates to greater temperature setting flexibility by the thermostat to run or not run, based on price fluctuations. Maximum comfort translates to no price flexibility and the thermostat will operate as a regular thermostat. Every 5 minutes, the thermostat sends the desired quantity of power and the price it is willing to pay as part of its transaction with a home energy management system (HEM). The HEM can aggregate bids (quantities and prices) from multiple devices in the household and send these as a transaction to the RTP market clearing subsystem located in the AEP Ohio operations center using a cellular connection.

The market clearing system assembles the bids from all households on the feeder along with the market price for supplying electricity as determined by the RTP tariff (based on the LMP at the local PJM load bus) for electricity in the feeder's service area. The dispatch system clears the market based on where supply and demand bid curves intersect. The clearing price is broadcast to all homes, where the smart thermostat adjusts HVACs temperature set-point. The clearing price is also sent to the service provider's operations system for billing. The billing system exchanges information with the smart meter at the home to obtain the energy used during the 5 minute interval so the bill can be calculated. The consumer display is part of the smart thermostat. It displays the estimated billing price for energy so the consumer can participate with other energy saving actions, should they be monitoring the system.

Transacting Parties

(Describe the parties taking part in the transactions. These may be intelligent systems and nodes, or human participants)

The end-use loads in participating households are HVAC systems controlled by thermostats, which are enabled to (1) change their energy consumption based on the cleared market price, (2) determine the price they are willing to pay for electricity, and (3) bid their desired demand. The residential customers are required to only enter (1) their desired temperature set-points and (2) comfort/economy settings for the scheduled periods of operation (home, away, sleep, etc.). The participating households transact with the distribution utility by providing demand response based services. The incentives for providing these services are based on real-time market prices.

Temporal Variability

The participating households' HVAC systems submit demand bids every five minutes through the HEM. The bid is in the form of a price-quantity pair, expressing a household's willingness to consume a given quantity if the market price is below its bid price. Real-time retail price (base price, the formula for which has been approved by the PUC of Ohio) that results from market clearing is calculated as a function of PJM's wholesale energy price. In case of distribution feeder becoming capacity constrained, i.e., periods of feeder congestion, the cleared retail price can deviate from the base price. When the resources are engaged to respond to feeder capacity constraints or if the capacity limit is adjusted so that the resources can provide ancillary services, any corresponding increase in price due to the imposed constraint is rebated back to the customer. If a household responds to an imposed constraint, they will also be provided an incentive payment calculated in proportion to their level of participation and the amount of energy shifted.

Interoperability

The smart thermostats, the HEMs, and the RTP market clearing system where developed under subcontracts to AEP Ohio so that the interoperability concerns were within the management purview of AEP Ohio. The thermostat and HEM manufacturers implemented messages based on communications standards, developed information models of price-quantity bids and resulting clearing price from the real-time double auction markets. The business processes associated with the exchange of information between the transacting parties were also specified. This include situations such as what to do if the latest PJM price was not available or if bids were not received from a household within the allotted time. Various vendors could conceivably provide products that enable customer participation; however, the information specification were developed for the demonstration and are not part of an open standard at this time.

Value Discovery Mechanisms

The demonstration's transactive control and coordination mechanism utilizes a double auction market as the means for the coordination of demand and supply in a distributed manner. There are multiple households participating in each feeder's double auction market. In each market, the households (through their HEMs and programmable thermostats) submit demand bids into the double auction market, and upon market clearing, receive a real-time price based on which they adjust their energy consumption. A demand bid submitted by a HEM consists of a price-quantity pair, expressing its willingness to consume. The real-time prices received by the HEMs are a function of the PJMs wholesale energy prices (LMP) reflected in the real-time electricity tariff (adders to real-time prices).

With this market-based mechanism, "control" objectives are achieved by engaging household resources that respond to fluctuations in the real-time electricity market prices, as opposed to direct load control. In this scheme, each participating household can have resources, such as HVAC units and electric water heaters, who bid their willingness to consume electricity in the form of a price/quantity pair. The market aggregates the information from all parties and determines the clearing point of price and quantity where the supply and demand curves intersect.

The double auction is a market mechanism that can be described as a two-way market, where both suppliers and end-use loads submit offers and bids, to sell and buy energy respectively, into a single energy market. The auction resolves the supply and demand bids into a common cleared market price and quantity, and delivers this information back to the participants. This approach is highly scalable, and allows all parties to participate and achieve their objectives in a distributed manner.

Value Assignment

Within each household, the HEM uses the occupant's configuration of comfort/economy level and desired temperature set-point to determine the price that they are willing to pay as a function of energy consumption, and this is bid into the double auction. This value is reflected in an actual, 5 minute financial transaction that results in the on/off operation of the equipment and whose price for energy used is accumulated into the household's monthly bill. In addition, if the HVAC turns off due to high prices that result from feeder capacity constraints, the households are provided financial incentives for the provision of demand response service to the system, and these are also accumulated into their monthly bills.

Alignment of Objectives

The RTP system provides incentives to the end-use resources that are time flexible in their use of energy thus allowing these resources to participate in the balancing of supply and demand. The added flexibility in operations generates shared value streams for the service provider and RTP customers. For the customer, they are able to reduce their monthly electric bill. For the service provider, value streams include energy purchase benefits (reducing wholesale purchases in PJM's real-time market), capacity cost benefits due to deferment of capital investments, and potential for additional ancillary services. The transmission system and the system operator (PJM) benefit from provision of energy balance and ancillary services from demand side resources that are less expensive than traditional generation resources.

Stability Assurance

A primary motivation for the demonstration is to observe and analyze the stability of the RTP system. Analysis is underway; however, under the operating conditions witnessed, the automation systems appear to behave in a stable manner. In a system with large amount of participating loads, occasional non-compliance of HVACs to price signals (either due to loss of communication or manual intervention) should not cause system-wide disturbances as long as the probabilistic nature of these occurrences are taken into account in the design and maintenance of the system.

Manipulation of the agents could cause poor market performance and the potential for financial imbalances between the service provider and the customers. Gaming by consumers also deserves study, especially over longer periods than are available in the demonstration time frame. Cybersecurity concerns where address by AEP's cybersecurity reviews and guidelines; however, manipulation of the market or other parts of the system by cyber-attack also deserves further study. More work will be needed to ensure proper performance of the system and to consider appropriate safe guards.

Participating Agencies and Organizations

American Electric Power (AEP) Ohio leads the demonstration project.
Pacific Northwest National Laboratory specified the requirements of the transactive control system, market mechanisms, and the agents. They also participated in the tariff design and are involved in the analysis of the system.
Battelle Memorial Institute designed and built the RTP system.
Vendors were contracted to provide the hardware, do the installation, recruit customers for the program, and survey the RTP customers.
The Public Utilities Commission of Ohio approved the RTP tariff.

References:

- PNNL-SA-77870
- PNNL-SA-86100

Questions, Comments, and Discussion:

- Derivation and approval process of the real-time retail pricing tariff
- Use of price as a control signal to engage responsive load
- Mechanism used to incent customers to participate in the program
- Level of customer participation and satisfaction with the gridSMART program
- Outcomes and success metrics
- Performance of communications systems.

AEP GridSmart RTP Demonstration Presentation

TEMIX TRANSACTIVE ENERGY AND INTEROPERABLE TRANSACTIVE RETAIL TARIFFS

PRESENTER: ED CAZALET, TEMIX INCORPORATED

TeMix Transactive Energy (TTE) engages customers and suppliers as participants in decentralized markets for energy transactions that strive toward the three goals of economic efficiency, reliability, and environmental enhancement.

Interoperable Transactive Retail Tariffs are an application of TTE to the interface between all retail customers and decentralized generation and storage.

The development of TTE was initiated by the Smart Grid Interoperability Panel (SGIP) under the direction of the Priority Action Plans, 03 and 09. The development of the standards was carried out by the Organization for the Advancement of Structured Information Standards (OASIS), a non-profit consortium that drives the development, convergence and adoption of open standards for the global information society. The TTE standards developed by OASIS have been approved by the SGIP for entry into the SGIP Catalog of Standards. These standards are free and open to all.

An implementation of a general platform for deployment of TTE has been developed by TeMix Inc. using the OASIS standards.

The SGIP is currently working on a specific application of TTE to an Interoperable Transactive Retail Tariffs (ITRT). The ITRT is the critical interface between retail customers and the distribution entity and energy retailers. The ITRT is simply an application of TTE to this interface. Beginning an implementation of TTE with an ITRT can be the best way to make significant contributions because most retail tariffs are based on flat or tiered rates and provide little opportunity for parties to transact to improve each other's benefits.

Case Study

Architecture

All transactive energy tools and methodologies are described as constituents or subsystems of a system architecture. A key distinction is whether the architecture is centralized, distributed, or a combination of the two:

The architecture of TTE is decentralized. The framework, as currently published does not encompass a decentralized architecture. It is focused on centralized and distributed control. True distributed control involves breaking a massive control problem down into a set of smaller problems, and solving the smaller problems on typically a physically separated set of computing elements. Next, integrate all of the sub-problem results together to obtain the solution to the original large-scale problem.

The key point is that there is no overall control or optimization problem for the economy or for the electric power systems consisting of homes, buildings, factories, electric cars, generators, storage and transport (T&D) infrastructure.

Control and optimization (including distributed control and optimization) may be needed or useful within (T&D) infrastructure, but the natural structure of this ecosystem is decentralized data, development, evolution, and operational control that is constrained by natural and artificial regulations.

It has to be that a key distinction of the transactive energy architecture is decentralized control and coordination of each party's electric energy-related planning and operating decisions using engineered protocols in the same way that the Internet protocols support the massive complexity of the decentralized Web.

Extent

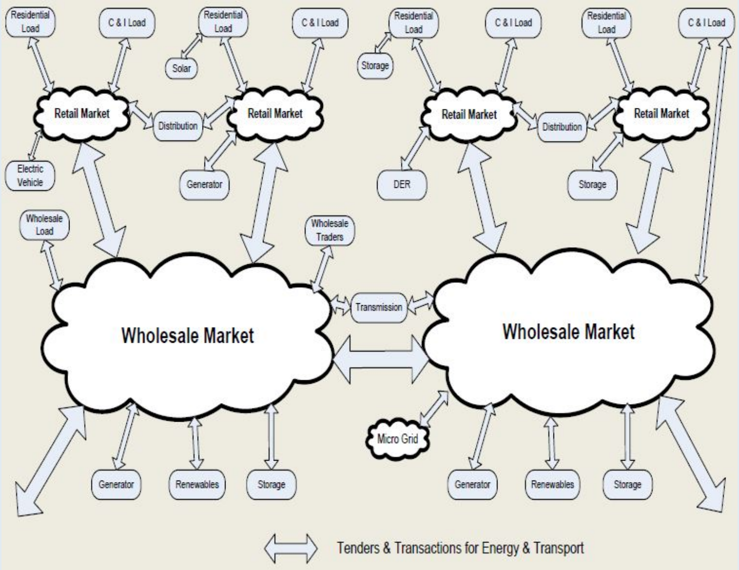
An implementation of transactive energy technology will typically apply within some geographic, organizational, political, or other measure of extent. A geographic extent, for example, might be within a region and apply across multiple participating entities. An extent may be described organizationally, for example, if an implementation is intended for use within a single utility, building, or campus. Likewise, a transactive technique may apply across political boundaries with different regulatory or policy constraints. Extent may also be considered relative to the topology of an electrical infrastructure including end users.

Thus, a transactive technique may apply in transmission, distribution, or both; it may also be useful for managing energy within buildings or by end-users of electrical energy.

TTE as a decentralized architecture applies anywhere on the grid. There is no boundary to the TTE transactions: any party can transact with any other party, subject to the physical limits of the grid and policy and regulatory limits.

For a centralized or distributed architecture that seeks to optimize an objective function, the extent should be clearly defined; TTE does not need such a restrictive specification of extent.

The following figure illustrates the extent of TTE:



Transactions

A transaction is simply a negotiated exchange of things. This applies in transactive energy also, where it is a communicative activity involving two or more parties that reciprocally affect or influence each other through a formal mechanism in order to reach an agreement. These agreements must not be one-time agreements, but must be subject to continuous review, and multiple agreements that may take place as frequently as sub-second timing. Rules need to be specified for every transactive system such that interdependent operations on the system are either all completed successfully or all canceled successfully. In other words, the transaction is the central mechanism by which transactive energy systems achieve their objectives; by linking multiple individual operations into a single, indivisible transaction, which optimizes the objectives and ensures that all operations in the transaction are completed without error.

TTE defines a transaction as a binding exchange of a quantity of an energy product for currency.

•TTE has two basic products:

–Energy delivered at an interface over an interval of time

–Transport that moves energy from one interface to another over an interval of time.

TTE offers call options on the two products that act like capacity and ancillary service products

Environmental certificates products are transacted where they are not internalized in the energy product.

Transacting Parties

Fundamentally, transactive energy involves transacting parties. In most cases these will be automated systems, possibly acting as surrogates for human parties. In some cases humans may be in the loop. A transactive energy mechanism must be explicitly describable by the entities that are parties to transactions. Because a transactive energy system will provide services to different parties, its success in delivering these services will depend in part on the expectations and needs of each group and in part on the qualities of the delivered service.

The parties taking part in TTE transactions are:

- End users owning energy use devices, storage and generation (including DER);

- Central generation and storage owners

- Distribution and transmission grid operators

- Intermediaries – retailers, marketers, exchanges, etc.

Temporal Variability

Transactive elements interact across multiple time scales. For example, transactions within a single system may range from sub-second to five minutes or to some longer periodicity. It is also possible for transactions to be event-driven. In characterizing a given transactive approach, the time scale(s) of transactive interactions need to be specified and analyzed for compatibility.

TTE transactions are carried out over time-scales of years to seconds. Transactions are carried out on standard, nested delivery intervals of a year, month, day, hour, 15 minutes, 5 minutes, 1 minute and 4 seconds, for example, for each market. Standard market intervals enhance transaction liquidity because parties do not need to negotiate on the definitions of the intervals.

TTE transactions are primarily forward transactions carried out at various times ahead of delivery. Several forward transactions (buy or sell) may result in a net position for a delivery interval. Such transactions may occur at any time for any reason including as a result of events.

Interoperability

Transactions are enabled through the exchange of information between transacting parties. There are two elements to consider here: technical interoperability and cognitive (semantic) interoperability. The systems have to be able to connect and exchange information (emphasizing format and syntax), and they have to understand the exchanges in the context that was intended in order to support workflows and constraints. For any given transaction, the information exchanged during a transaction must be explicitly identified. Furthermore, one should be able to explain how interoperability has been addressed in support of the information exchanges, specified and analyzed for compatibility.

TTE achieves interoperability by applying OASIS TE Standards

–OASIS Energy Market Information Exchange (EMIX) for TE Information Model

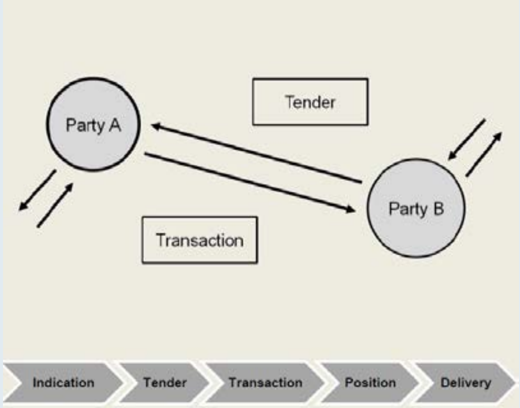
–OASIS Energy Interoperation for TE Messaging

–Standards were developed openly under SGIP PAP oversight; free and open to all; in SGIP Catalog of Standards.

Value Discovery Mechanisms

A value discovery mechanism is a means of establishing the economic or engineering value that is associated with a transaction. The value discovery mechanism is a key element of value-driven multi-objective optimization. Value realization may take place through a variety of approaches including an organized market, procurement, tariff, an over-the-counter bilateral contract, or a customer's or other entity's self-optimization analysis. Value discovery mechanisms should include considerations of economic incentive compatibility and acceptable behavior.

TTE allows values to be private information of the transacting parties. There is no concept of value discovery required. Parties may participate in transactions with other parties using a variety of processes and mechanisms that are outlined in the **following diagram**:



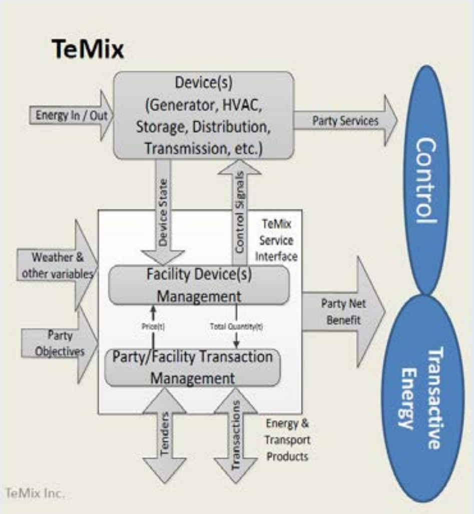
Indication: 1) a request for a tender, 2) a forecast of usage or supply, or 3) a forecast of price for an interval.
Tender: A price and quantity for a transaction with an expiration time
Transaction: Formed by accepting all or part of a tender
Position: Net quantity and net cost for a sequence of buy and sell transactions for an interval
Delivery: The metered quantity delivered.

Value Assignment

Assignment of value is fundamental to value discovery. For sub-elements of a transactive energy mechanism, a means may be needed to assign value for those objectives that cannot be addressed through a discovery mechanism, values that are needed by the discovery mechanism, or for values that do not have a common dimension that can be used for valuation.

With TTE, a party's determination of value, subjective or otherwise, is a private process and decision. A party only needs to consider the tenders from others and make tenders to others that would be acceptable to them.

The following diagram illustrates the general TeMix service interface for a party at a facility. The party controls devices within the facility and carries out transitions with others outside the facility. How the party controls devices within the facility and what process the party might use to evaluate tenders or make tenders is private. However, the party can choose an optimization approach to control devices to maximize the party's net benefit given the forward prices of the tenders expressed to the party by others, or the party's own forecasts of forward prices.

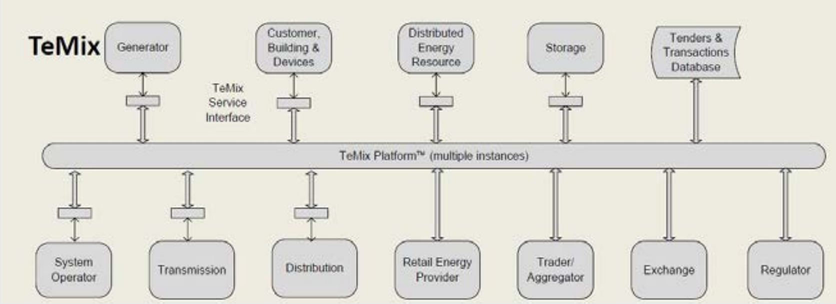


Alignment of Objectives

A key principle in transactive energy is the continuous alignment of multiple objectives to achieve optimum results as the system operates. This alignment enhances the economic and engineering impacts of the dynamic balance(s) achieved by transactive energy. Note that optimal relates to balance of the entire transactive system, and to achieve an optimum balance it is necessary to optimize objectives, variables, and constraints. It is important to understand that optimization doesn't simply add intelligence to existing business processes. It changes business practices.

The concept of alignment of objectives to optimize objectives, variables and constraints is a centralized, control concept that has no place in TTE. Public policy on environmental and safety standards, bulk power reliability standards, renewables portfolio standards, prevention or mitigation of market abuse and monopoly power, contract law, granting and regulation of monopoly franchises are the forum to constrain voluntary transactions among parties in a TTE market.

Within these public policy constraints, TTE can use multiple instances of platforms that support the communication and recording of tenders and transactions among the parties **as illustrated below**.



Stability Assurance

Transactive energy systems through their integration of both engineering and economic operational objectives are a form of control system. As such, the stability of a specific transactive energy system must be considered. The stability of grid control and economic mechanisms is required and must be assured. Considerations of stability must be included in the formulation of transactive energy techniques and should be demonstrable. Unfortunately, there are no public benchmarks for stability, and during numerical optimization minor errors can build on each other, and sometimes spiral out of control. It is important to mitigate optimization instabilities because grid stability may be compromised by poor value optimization techniques.

Stability in a TTE implementation can be designed for. For example, primary frequency regulation (generator governor and other frequency responsive devices) will need to be a connection requirement where appropriate and economic. Any power system, with or without TTE, needs to assure stability on this time scale

Transactions for secondary frequency response can be carried out by TTE either as conventional AGC regulation up and regulation down products that in TTE are call options on the energy product, or by TTE tenders and transactions on four-second intervals, for example. Generally, a balancing operator's automatic system under operator supervision would perform this role.

Forward transactions at the 5-minute, 15-minute, hourly and longer interval made between parties are within conservative grid operating constraints and stability margins.

Transaction stability is enhanced by forward transactions, position limits, tender size limits, and near-continuous clearing with operator and regulatory market oversight.

Participating Agencies and Organizations

TeMix Inc., NIST and SGIP

References

Toby Considine, William Cox, and Edward Cazalet, "Understanding Microgrids as the Essential Smart Energy Architecture," in Grid-Interop, 2012, available from Grid-Interop.

Edward Cazalet and Chellury Ram Sastry, "Transactive Device Architecture and Opportunities," in Grid-Interop, Irving TX, 2012.

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OASIS, "Energy Market Information Exchange Version 1.0," January 11, 2012. [Online]. http://docs.oasis-open.org/emix/emix/v1.0/emix-v1.0.html.

Questions, Comments, and Discussion:

- Definitions in the TEF should be more succinct and concise
- Difference between GWAC and TeMix definitions of Architecture
    - GWAC talks of centralized, distributed and combination, while TeMix talks of decentralized architecture
    - Despite differences there are many similarities
    - TeMix is essentially a subset of the GWAC definition because it is broad.
- Difference in definition of a transaction between GWAC and TeMix
    - GWAC's definition sounds like a barter, and the concept of value may be too vague for readers
    - TeMix defines a transaction over two basic products (energy and transport)
    - There is a fundamental question to resolve over definitions of transacting parties and whether they are people, devices or both.
- The extent as described in TeMix allows for anybody to transact with anyone else
    - TEF describes a big optimization problem across whatever is the extent of the system
- Value discovery mechanism in TeMix works as a bid/offer (negotiation) process
- Instead of doing everything in spot transactions, allow forward transactions providing utilities with long-term revenue streams
    - Customer buys some baseline amount in the forward market at the forward rate
    - In spot market, customer pays or gets paid at the spot price above or below the amount bought in the forward market
    - Potentially obviates the need for more complex, wide-ranging utility DR programs.
- Use concepts that have already been implemented in transmission system to manage physical constraints in the distribution system.

TeMix Transactive Energy and Interoperable Transactive Retail Tariffs Presentation

MICROGRID TRANSACTIVE OPERATION

PRESENTER: BILL COX, COX SOFTWARE ARCHITECTS

This case study describes aspects of an approach to managing energy flows in and among microgrids.

Several themes address transactive energy, and are used to evaluate the case study information template 20131024.

This is in part derived from a research proposal for mixed commercial and industrial microgrids in 2012; objectives included use of transactive techniques to manage demand thresholds and energy costs, using standardized interoperation and locally scoped markets.

At Grid-Interop 2012 we introduced the concept of a micromarket to locally balance supply and demand.

Case Study

Architecture

Scalable software systems typically use an approach similar to the distributed control described in the draft framework. Architectural requirements include focus on external interactions such as buying and selling of energy or related services, decoupling the interchanges from the implementations of the participants; and minimal knowledge of counterparty internals (including decisions, optimizations, and operations).

So-called optimization strategies are private to the actor doing the optimization; it's a very different game when others know your strategies. A sequence of buy/sell operations does not directly review private and proprietary information to potential competitors.

This architectural approach, of building from independent actors to aggregations as microgrids, is enabled by transactive techniques. The actors are inherently independent, and hence decisions are distributed. In a very useful set of cases, the actors are microgrids, themselves recursively composed of microgrids. In others, devices are the transacting parties that will be composed.

It's critical to consider transactive mechanisms apart from the market mechanisms and clearing that's needed to balance supply and demand. One must avoid combinatoric expansion in the architecture description; a factored and/or layered architecture is beneficial. Good flexion points are critical.

Extent

The proposal addressed heterogeneous ownership, geographically close facilities, within a two-square-mile campus, with external connections to multiple transmission and distribution lines.

Transactions

Economic communication would use prices of energy bought and sold, complicated by less dynamic contracts. This is similar to the subscription approach discussed by Ed Cazalet and others in papers and in the Transactive Energy Association on LinkedIn.com. The Semantics of Price are complex, and "value mechanisms" disconnected from price are problematic.

Transacting Parties

The parties are independent businesses within an office and industrial park. Facility automation provides the “Energy User Agent” (viz. X.400 and IETC mail services) in the general case through a standardized gateway.

A SOA approach limits the service interactions required, and simplifies implementation and evolution. The variability is in the data in the service requests describing energy products, with a minimal and universal set of transactive services (Quote, Tender, Transaction, Delivery) supported by OASIS Energy Interoperation/OpenADR2 transactive services (under discussion).

Temporal Variability

For liquidity, most energy markets and transactive implementations use fixed length and synchronized time intervals. The time intervals would be adjusted to address the necessary demand shaping by transactive techniques.

Interoperability

By using OASIS Energy Interoperation, Energy Market Information Exchange [10], and their Transactive EMIX (TEMIX) profiles, both semantic and technical interoperability were assured. The definition of products to be transacted requires some care, but the product definitions are self-descriptive to ease interoperation and evolution. The more interesting question is how a facility management system through the Energy Services Interface makes decisions; this cannot be a monoculture, though some consistency in information models is useful.

See other references for models and discussion of price responsive facilities and devices. An interesting recent area of work is in stitching together microgrids with transactive techniques, and allowing dynamic reconfiguration and fault recovery and an accepted ISGT 2014 paper.

Micromarkets address limited scope and size markets for specialized purposes. A micromarket might be deployed to address microgrid-to-microgrid energy transfers.

Value Discovery Mechanisms

The value depends, ultimately, on the value received by the transacting parties. Since actual energy cost is for specific products (e.g., 10kWh from 2-3 p.m. tomorrow), the complexity presumed by the description of value discovery is not beneficial, and seems to presume an overarching optimization process that cannot function correctly under heterogeneous ownership.

Value Assignment

In this case study, the value to the parties is determined by the parties themselves by their private processes. There is no value and a great deal of harm that may come from overextended and distributed knowledge of private processes and value functions.

Alignment of Objectives

Participants buy and sell energy products in fulfillment of their private objectives. An interesting study proposal would have examined monitored transactions in detail.

Stability Assurance

There have been millennia of technologies and approaches to increase stability of markets, controlled interactions (such as power grids), and more. Market rules are a key technique, and have evolved in many markets in varying ways. Standard approaches include limits on price transitions, and market monitoring for health and stability. Liquidity appears to be a more significant issue for markets.

Management of electrical grids typically has techniques that are one step removed from transactive ones—buying regulation services or demand response, effectively as options for later call. A hybrid approach appears necessary, as a transactive system may have similar issues to non-transactive systems. Recovery is an important area not addressed here; transactive systems allow dynamic reconfiguration and recovery, increasing availability.

Participating Agencies and Organizations

Proposal; not applicable.

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Toby Considine, William Cox, and Edward Cazalet, "Understanding Microgrids as the Essential Smart Energy Architecture," in Grid-Interop, 2012, available from Grid-Interop and authors' web sites.

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In addition to references above, there is a body of work on transactive techniques for energy. For a partial annotated bibliography see the author's web site at: http://www.coxsoftwarearchitects.com/Pages/C_New.html. An architectural overview of transactive energy from the spring 2013 Transactive Energy Conference is available there and from the GridWise Architecture Council site at http://www.gridwiseac.org/historical/tec2013/tec2013.aspx.

Questions, Comments and Discussion:

- EMix and OpenADR allow transactions in any currency
- What is the technique to hide business processes?
    - Only concentrating on transactive features such as tender, buy/offer would enable private information to not be revealed
    - The question is how much process information should be exposed, and is it required to identify value?
    - Value is internal, price is external. Issue for discussion.
- Private and proprietary information on value of energy is not going to be shared by companies
- There is a problem with the term "value discovery mechanism" because value is a private information, whereas price is the public information which encapsulates private value
- OpenADR is not a price *discovery* mechanism, but a price *communication* mechanism
- Long-term energy subscription model helpful for utilities to do long-term planning
    - Spot markets only used to manage deviations from the forward contracts, which are financially binding
    - May be used by microgrids to manage energy flows, using "micro-markets"

- Grid resilience can be achieved to micro-markets and dynamic reconfiguration of the grid
- Most presentations talked about engineering solutions, but what is the role of public officials in this discussion?
  - Transactive tariff would be highly beneficial to businesses and customers.

SOUTHERN CALIFORNIA EDISON'S TRANSACTIVE ENERGY PROJECT

PRESENTER: BOB YINGER

Southern California Edison (SCE) is in the process of testing and demonstrating the building blocks for a transactive energy project to be architected and implemented using EPIC funds with planning starting in 2014. Present work taking place under the American Reinvestment and Recovery Act (ARRA)-funded Irvine Smart Grid Demonstration has started a two-year operation period concluding in mid-2015. Work is also under way with the assistance of the California Institute of Technology (Caltech) to build adoption models that can feed the simulations and prepare a high-level project plan for the future demonstration project. In addition, work is underway to build models of distribution circuits including details down to loads inside of customer facilities. These models, running under GridLAB-D software, will be used to test various transactive energy systems and determine what will be implemented in the field demonstration.

Case Study

Architecture

This system needs to be hierarchical in nature so that real-time decisions can be made locally with overall strategies being set through a more centralized control system.

Extent

The present Irvine Smart Grid Demonstration includes four blocks of homes and the distribution system near the University of California-Irvine. The future field pilot demonstration is expected to extend across a single community. This would include customers being served out of a single distribution substation on multiple distribution circuits. Selection of this area will be made using these criteria:

- High solar PV penetration in an area with favorable solar resource
- High adoption of PEV, DR, EE and home automation systems
- Community interest in smart grid technologies.

Transactions

The transactions are expected to be price signals sent to customers that would interact with their automation systems to control load, generation and storage.

Transacting Parties

The transacting parties are expected to be commercial and residential customers. These transactions could be either done manually or through automation systems.

Temporal Variability

The timing of intervals will be determined as an output of the Caltech work.

Interoperability

SCE is in favor of using standards where ever possible. Examples of these standards are SEP 2.0 and IEC 61850. New standards will have to be developed for many of the transactions being contemplated.

Value Discovery Mechanisms
SCE expects values to be determined through market mechanisms. Details of how this might work should come from the Caltech work.

Value Assignment

These values are to be determined as part of the Caltech work.

Alignment of Objectives

Participant objectives are to be explored as part of the Caltech work.

Stability Assurance

SCE contemplates the use of Centralized Cyber Security System to prevent outside influences on the market. Specific control system stability cannot yet be evaluated because of the early design phase of the project. System design will need to be robust enough to avoid market manipulation or market power issues.

Participating Agencies and Organizations

- ISGD project – UC-Irvine, General Electric, Space-Time Insight, SunPower, USC ISI, and EPRI
- California Institute of Technology
- Demonstration project – TBD

Comments, Questions, and Discussion:

- ISGD is mostly a hardware-related project
- Transactive energy concepts not included in the current demonstration plan
    - SCE is contemplating a transactive energy pilot in the future.

Southern California Edison’s Transactive Energy Demonstration Project Presentation

PACIFIC NORTHWEST SMART GRID DEMONSTRATION

PRESENTER: RON AMBROSIO, IBM RESEARCH

The Pacific Northwest Smart Grid Demonstration, (PNW-SGDP) is developing a transactive coordination and control system to continuously coordinate the responses of smart grid assets to meet a wide range of operational objectives and achieve benefits both locally and across the entire Pacific Northwest.

The project kicked off its five-year journey in February 2010. The project is one of sixteen regional smart grid demonstrations funded by the American Reinvestment and Recovery Act (ARRA). The budget is $178 million total with $89 million from the U.S. Department of Energy and the remainder from project participants (meeting a minimum of 50% cost share). The participants include 11 utilities and five technology providers. The scope of the project includes about 60,000-metered customers across five states (Idaho, Montana, Oregon, Washington, Wyoming). The PNW-SGDP is the largest of the ARRA-funded smart grid demonstration projects in the nation.

The primary objectives of the project are to:

- Develop a communication and controls infrastructure using incentive signals to engage responsive assets including distributed generation, storage and demand assets

- Facilitate the integration of renewable resources

- Validate new smart grid technologies and business models

- Quantify smart grid costs and benefits

- Advance standards for interoperability and cyber security.

Over 60 megawatts of total assets are engaged in the project. Assets are organized into asset systems and grouped into three categories of smart grid test cases: transactive control, conservation and efficiency, and reliability. The project has 33 transactive control test cases involving 8 different types of asset systems (conservation voltage reduction, building and commercial demand response, in-home displays, programmable thermostats, distributed generation, battery storage, residential demand response, and plug-in hybrid electric vehicle charging).

The project is implementing transactive control at the interface between transmission and distribution (T&D) to test the ability of responsive asset systems to respond to changes in an incentive signal representing operational needs of the bulk power system. Though the demonstration project is focused at this interface between T&D, the technique is a general technique intended for application throughout the system from generation through intermediate control or constraint points in T&D, to end-uses. The incentive signal represents to forecast cost of power delivered at any given point in the system. A corresponding feedback signal provides a forecast of net load to be served from any given point in the system.

Case Study

Architecture

Transactive control is a distributed architecture matching the topology of the power system. In general, transactive control nodes, the name for the distributed control points, will have a mesh architecture in the bulk power system and a hierarchical architecture corresponding to the typical radial topology of distribution systems below that. For more complex distribution systems, including micro-grids, the architecture will correspondingly be a form of mesh network.

Extent

The transactive control technology is designed for implementation across any extent from use by a local utility, even just on a single feeder, to regional deployment across multiple utilities. The technology may be applied from end-to-end, spanning generation, transmission, distribution, and end-use. It may be applied in both structured and unstructured markets, and in markets with unbundled service providers.

Within the PNW-SGDP, 27 transactive nodes are implemented, 14 of which are transmission zones representing large regions of the Northwest transmission system, while the remaining 13 are utility-site nodes. Any two transmission zone nodes, connected by transmission lines, are obligated to exchange transactive signals that describe the predicted exchange of energy between the nodes.

Transactions

PNW-SGDP’s transactive control system (TCS) utilizes an engineering-economic value-based transactive signal, the transactive incentive signal (TIS) and a corresponding transactive feedback signal (TFS)—as the primary basis for the coordination of supply and in a distributed manner. The TIS is a price-like signal that represents the unit cost of power delivered to any given point in the system, taking into account factors including, for example, location, time, transmission congestion, and the transmission losses. The TFS represents the plan for consumption of power desired by nodes served from the node receiving the TFS. To clarify this last aspect—each transactive control node sends and receives both TIS and TFS with all immediately neighboring nodes.

All transactive feedback signals are forecasts of future local power needs at the transactive nodes, expressed in kilowatts or megawatts. Together with bulk power generation projections, renewable energy forecasts and other values, the TFS then allows for computation of an incentive signal at the neighboring transactive nodes, which is sent back to the nodes. This TIS is expressed in cents per kilowatt hour and informs the transactive nodes about the cost of delivering power to that node.

This approach maintains fidelity to the actual value/cost of grid operations while also providing transparency and a level playing field. By using such a signal, the information exchange is simplified, can be made able to integrate more resources at different operating levels of the system, and provides a higher level of robustness by allowing healthy parts of the system to adapt in response to system component constraints or failures. The PNW-SGDP is testing transactive control with more than 20 types of responsive smart grid assets applied to residential, commercial, industrial, and irrigation customers.

Transacting Parties

The transacting parties in this approach are the transactive control nodes. For the PNW-SGDP, the utility-site nodes create at least one transactive node, which includes information of included circuits, and the responsive assets to be managed by the utility. Transactive signals at present are not sent to actual distributed assets in most cases, and hence, the utilities are free to devise control mechanisms of these assets. In principle however, transactive nodes may be disaggregated so that transactive signals are potentially exchanged between distributed assets directly, enabling more local information to be part of the TCS.

Temporal Variability

Transactive signals (TIS and TFS) are exchanged with immediate neighbors at least every five minutes. The signals themselves cover a 72-hour forecast period with variable granularity. For the first 12 intervals, values are forecast for every 5-minute interval; for the next 20 intervals they are forecast every 15 minutes; for the next 18 intervals, every hour; for the next four intervals, every six hours; and for the last two intervals, every day. This is a total of 56 intervals. A formal model of this interval structure is defined. A formal transactive node object model is defined including temporal behavior.

Interoperability

Interoperability is supported at multiple levels. A reference implementation of the transactive control system has been created using the IBM Internet Scale Control System (iCS) tool, compliant with the ISO/IEC 18012 interoperability standard. This reference implementation addresses basic physical and logical connectivity.

Information interoperability is addressed through the formal definition of the structure of TIS and TFS using XML schemas. A test harness and tools have been implemented for interoperability testing of transactive control nodes for proper formation and exchange of transactive signals.

Value Discovery Mechanisms

Value discovery is achieved through a negotiation process involving the exchange of TIS and TFS between neighboring nodes. As a simple example involving two nodes—a supply node and a consumer node—the supply node sends a TIS with its forward forecast of the cost of power. The consumer node sends a TFS with its forward forecast of planned consumption. The supply node analyzes the TFS and responds with a new TIS representing changes in the cost of power delivered given the forecast of consumption. This change would be driven by changes in cost due, for example, to a constraint in ability to meet the forecast of consumption. The consuming node in turn responds to the change in TIS forecast by updating its consumption plan – if the new forecast of cost is not acceptable. The algorithms for updating the TIS and TFS must be constructed to drive to convergence, otherwise oscillations may occur in this series of interactions.

As implemented in the PNW-SGDP, the technique is applied at the interface between transmission and distribution. Further, the TIS for the transmission system is based on a synthetic result. The utility nodes are implemented at the boundary of the utility and the transmission system. There are a limited set of nodes associated with avoiding demand charges that have the “negotiation” interaction with interaction between the TIS and TFS within the transactive control node.

In summary, the TCS employs an implicit control mechanism, where the actual control of the grid is attained by continuous negotiations between neighboring transactive nodes. The transactive signals TIS and TFS are continuously updated and exchanged between neighboring transactive nodes until a settlement is reached. The emergent TIS and TFS represent delivered cost of energy and average rate of energy flow between the two transactive nodes, respectively. The mechanism allows for dispatch of grid assets to occur in a distributed manner while respecting the physical grid constraints and maintaining supply-demand balance.

Value Assignment

Value assignment is the translation of engineering state into economic terms representing the cost of power. For example, if a distribution transformer is overloaded, algorithms regarding transformer service life can be used to calculate the cost of the overloaded state.

In the PNW-SGDP, value assignment is implemented for a variety of conditions modeled within the bulk power system and for the implementation of demand charge avoidance. Value assignment is implemented in a class of transactive control node functions referred to as “resource” functions.

Alignment of Objectives

Transactive control aligns objectives through correspondence of the transactive control node topology with the electric power system topology. Owners of system elements (assets) are enabled to affect the cost of power (TIS) or consumption of power (TFS) through the transactive control nodes deployed at the points in the topology corresponding to their ownership of assets. The term asset is used broadly here to represent any generation, transmission, distribution, or consumption element. The focus of action is local – at each transactive control node the objective is to achieve local optimization through action based on a combination of global information in the TIS and TFS and local information from that location’s assets.

In the PNW-SGDP, the TIS associated with the transmission system represents the needs of the bulk power system, for example, supporting wind integration, to the local utility. The local utility then introduces its own needs, for example, avoiding demand charges, and the resulting TIS drives asset system responses.

Stability Assurance

At this stage in the research, specific analysis aimed at the impact on overall grid or market stability has not been performed. The transactive control system is expected to be stable through the incorporation of the two signals—TIS and TFS. The use of the two together represent a form of closed-loop control. There is still, however, a requirement that the decision-making algorithms be designed to include functionality equivalent to damping to help assure system stability.

Participating Agencies and Organizations

Battelle Memorial Institute is leading the project and collaborating with 11 Northwest utilities and the Bonneville Power Administration (BPA) to perform the transactive control system design, configuration and testing, as well as the data analysis. On the technical side, the PNW-SGDP has aligned Alstom Grid for operations software, real-time dynamic pricing, and renewable energy management. IBM contributes with distributed control software, servers, middleware, and cyber security solutions. 3TIER, Inc., a Seattle-based forecasting company, provides renewables and hydropower forecasting. Netezza Corp., which was subsequently acquired by IBM, provides highly parallel data storage. QualityLogic, Inc., is the organization in charge of interoperability testing, standardization, and conformance certification.

Questions, Comments, and Discussion:

- Do signals originating at a node propagate throughout the system; how fast would a signal due to generator going propagate throughout the system?
- Are there requirements and design documents on this project?
    - Implementation of this design in other parts of the country shouldn't re-invent the wheel
- Are there metrics being generated to measure success of the project?
- How do TE systems deal with commodity surpluses versus shortages?

Pacific Northwest Smart Grid Demonstration Presentation

TRANSACTIVE ENERGY FRAMEWORK FOR CENTRALIZED IMBALANCED MARKET

PRESENTER: ALI IPAKCHI, OPEN ACCESS TECHNOLOGY INTERNATIONAL, INC. (OATI)

This case study presents transactive energy-based constructs required to supply of ancillary services, load following and balancing energy products from demand response (DR) and distributed energy resources (DER) to support both system reliability and power supply economics. The case study addresses transactive operations needed to link end-use consumers and their qualified resources, including microgrids, to the power system chain of operations, including curtailment service providers (CSP), utility distribution companies (UDC), load serving entities (LSE), energy traders, balancing authorities (BA) and energy markets (ISO/RTO). It covers full operational life-cycle from registration and qualification to forecasting, scheduling, dispatch and controls to measurement, as well as verification and settlements. It should be pointed out that many of the ancillary services (reliability products) are "must have" products with resource adequacy obligations.

The high penetration of variable generation in the West, driven by Renewable Portfolio Standard mandates, is necessitating new operational practices to support ramping and flexibility needed to maintain power system's supply and demand balance at all times. Various regulatory and operational initiatives are being considered to significantly enhance the integration of DR and DER into system operations, especially for provision of flexibility reserves and ancillary services needed to mitigate the impact of variable generation. These initiatives span from centralized market concepts to distributed and bilateral constructs. This case study focuses on the latter, the bilateral and distributed operations.

The study identifies technical, operational and regulatory requirements for supply of ancillary and balancing services, and maps transactive techniques to these requirements. Transactive techniques are contrasted against the existing operational practices and techniques, and recommendations for use of transactive techniques for integration of DR and DER for supply of ancillary and balancing services in system operations are made.

Open Access Technology International, Inc. (OATI), has been actively involved in all aspects of these transactions, and the case study will map the transactive techniques to the existing operational practices, identify gaps and opportunities and recommend action plans for a broad deployment of transactive techniques for end-to-end power system operations.

Case Study

Architecture

Distributed architecture with bilateral transactions connecting various business and operational entities – supported by a common information and transactional model for an end-to-end operation.

Extent

The case study covers end-to-end power system operations from demand-side resources to bulk power markets, including all intermediary entities—CSPs, UDCs, LSEs and merchant and grid operators. It also covers the life-cycle phases from registration, to forecasting/bidding, scheduling, dispatch/control, measurement, verification, and settlements.

Transactions

The commodities transacted include primarily energy (kWh/MWh), but may also include capacity (kW/MW), conventional reserves (non-spinning, spinning, regulation) and new reserve products (flexibility reserves, ramping, load following, etc.). Transactions may involve different time horizons and temporal granularity, span across geographical/electric service territory boundaries, include schedules or price-quantity bids/offers, be financial or physical (include points of delivery and receipt) and involve two or more parties. Transactions may involve use of automated systems and infrastructure based on pre-defined rules and agreements.

Transacting Parties

Transacting parties may include human participants/actors or intelligent systems/nodes. The case study covers end-use retail customers, including residential, commercial and industrial users, microgrids, as well as business and operational entities including CSP/DRPs, UDCs, LSEs, energy trading and merchant operations, transmission operators and balancing authorities and, finally, wholesale market operators.

Temporal Variability

The transaction time scales range from multi-day, multi-hour to sub-hourly (15 minute and 5 minute) and real-time temporal granularity. The deployment/delivery of the transaction may be time-triggered, event-triggered, or take place on demand.

Interoperability

Technical, Informational and organizational interoperability are addressed in the case study. Where relevant, standards are used to facilitate interoperability.

Value Discovery Mechanisms

The value discovery is based on the services offered to affect power system reliability and economics, both at the retail power/distribution level and at bulk power/transmission operations level. Distributed and demand-side resources can provide significant value in mitigating the impact of variable generation both at distribution and transmission levels. The value discovery is affected either based on reference market of hub prices (organized or bilateral markets) or through bilateral bid/ask mechanisms based on local economic or reliability values. Various options are elaborated.

Value Assignment

The bids and offers used in the transactions reflect objective value assignments for transacted products and services. Subjective values may be incorporated in “priority” orders.

Alignment of Objectives

By defining required characteristics of energy and capacity products for mitigating the impact of variable generation to be supplied, and creating a clearing process for such products, the objectives could be aligned with the requirements.

Stability Assurance

The system has been designed to ensure incentive-compatibility aligning economic objectives of the participating entities with security and stability of the physical grid. Through deployment a distributed architecture, and establishment of life cycle operational and temporal rules, e.g., qualifying, forecasting and publishing (supply and demand), scheduling (bilateral self-supply), bidding with established hierarchical market clearing times, and penalties for lack of performance, operational stability can be assured.

Participating Agencies and Organizations

OATI has working relationships with many utilities at retail and bulk power levels.

Questions, Comments and Discussion:

- Different processes in power markets happen at various timescales, which have become routine business practices
    - Transactions can happen at any of these timescales
- The TEF as it is written includes the possibility of all kinds of transactions to be supported
- Intermittent resources are increasing, and at the same time gas-fired plants are retiring in California
    - Need for fast ramping flexible resources is imminent (duck curve)
- Storage mandates in California (1.3 GW) change the dynamics of demand-side management
    - Change in dynamics depends on whether the deployment is in bulk or distribution system

  - It is not clear how control of storage gets installed on customer premises—and that's where GWAC and groups like this can help in showing how these resources can be used to provide grid and other services. Things like tariff, etc., are still unknown
  - Good part of new renewables (solar) are on the distribution side, and so if storage comes at the distribution level, and even though it may not be completely controllable to provide bulk grid services, it can still help to mitigate imbalances at the distribution level, which would help to change the shape of the duck curve
  - 15-minute storage is not going to help with the level of annual imbalance that will be created because of the renewables
- Load shape can be changed with energy efficiency and time-of-use incentive programs, but grid services to maintain reliability require resources that are dispatchable, controllable, etc.
  - Demand side resources aspiring to provide these services face uphill challenges
  - Command and control programs are still needed to provide services at shorter timescales
- Technical requirements for transactive energy include things like telemetry, and there needs to be a discussion on
  - Whether telemetry from aggregated resources is enough, or is telemetry needed from each individual household?
- There are additional questions that need to be addressed on the new processes that are required to accommodate demand-side resources, at a large scale (e.g. how does unit-commitment process change?)
- Inter- and intra- domain transactions and interactions need to be modeled, and may require formal processes to be designed
- Where does transactive energy intersect with true organizational transactions along the supply-chain?
  - Don't need settlement from business transaction sense within a single organization, but some way of measurement and validation
- Value most likely comes from bulk power markets and gets trickled down to the end customers
  - Benefits are obtained through end-to-end and operational life-cycle management
- If through transactive signals we are able to change load shape, then we might be able to reduce the need for grid services like frequency regulation, etc.
- PJM's price responsive demand program is setup to be reliable, controllable, and available when asked to respond, and it can also set prices.

Transactive Energy Framework for Centralized Imbalanced Market Presentation.

TRANSACTIVE CONCEPTS FOR A NETWORK OF ROOFTOP HVAC UNITS

PRESENTER: ROB PRATT, PACIFIC NORTHWEST NATIONAL LABORATORY

Today's buildings do not participate significantly in the energy market or provide services to power system operators. However, new smart grid technologies are creating a significant potential for buildings to participate in energy markets by providing ancillary services to power system operators. Communication networks and advanced control systems are a necessary enabler of this new potential, and the proposed research provides building owners with information needed to invest in the improvement of their communication and control capabilities. First-year proof-of-concept with existing tools and building systems is needed to establish a baseline of potential savings in out-year deployment. Deployment of advanced control systems for grid integration is expected in the next 5-8 years.

The initial target market is all existing packaged air conditioners and heat pumps that are installed on commercial buildings. These units contribute to 60 percent of air-conditioning consumption, which is roughly 571 trillion BTUs of site electricity and 1.8 quads of source energy annually.

Use of advanced controls and self-correcting controls on existing RTUs will result in significant energy and cost savings and also enhanced maintenance by introducing condition-based maintenance practices and targeting maintenance when needed. The potential savings based on average savings per RTU of 30 percent are roughly 171 trillion BTUs of site electricity and 531 trillion BTU's of source energy annually.

This project began in FY13 and is continuing in FY14. It aims to improve efficiency and maintenance of RTUs, and will also make RTUs more grid responsive, so that they can interact with the grid and provide demand response and ancillary services benefiting both the owner/customer and the utility.

In addition, this project will demonstrate the utilization of RTUs for providing energy services to utilities using autonomous controllers. The goal is to develop next-generation control strategies and validating the strategies by:

- Quantitative analysis of the RTU energy management opportunities within buildings

- Design, prototype, and analysis of the advanced controller strategies for RTUs

- Design and analysis of communication network within building and external interfaces to utility communication networks

- Economic analysis of control strategies.

The rate and granularity of the control for the RTUs determines the types of utility services that can be provided.

Case Study

Architecture

Each RTU location uses independent VOLTTRON™ platforms. Some applications running on these platforms are purely autonomous, while others interact across the RTU platforms. Future development is expected to involve applications that control multiple devices within a premises. The platforms may interact in a hierarchy or they may do so in a peer-to-peer fashion.

Extent

Trading Capacity Rights use case: The interactions and exchanges all take place within a building or facility. The concept of managing a set capacity across assets may be extended to populations of buildings with the coordination and reconciliations occurring at the level of an aggregator, feeder, substation, or utility.

Diagnostics Services use case: The building or facility transacts with a third party provider for monitoring and diagnostic analyses, conducted remotely over the network.

Transactions

Trading Capacity Rights Use Case: Total capacity rights of a building or facility are distributed across RTUs at the site through negotiated transactions between the RTU units. This enables optimization of the simultaneous operation of RTU units, while still achieving the occupant comfort objectives.

Diagnostics Services Use Case: Here, the transactions are at a contractual rather than real-time operational level. A service contract defines the monitoring and diagnostic services that a customer receives over time from a third party service provider.

Transacting Parties

Trading Capacity Rights Use Case: The RTU platform nodes trade capacity rights through asynchronous, bi-lateral, peer-to-peer transactions with each other based on quantity (kW) and ”need” based on excursion from the targeted temperature set point.

Diagnostics Services Use Case: A contract is established between the owner or operator of the building or facility, and the third party service provider.

Temporal Variability

Trading Capacity Rights Use Case: Rights are traded for relatively short periods of 5-15 minutes, as relevant to occupant comfort control, but trading for longer-term capacity rights could also take place.

Diagnostics Services Use Case: Contracts terms would be for specified time periods such as monthly or yearly. The diagnostic evaluations and reporting would take place over shorter actionable time periods such as daily (while considering longer historical operational baselines) to identify equipment malfunctions and degradations.

Interoperability

Trading Capacity Rights Use Case: Interoperability is required between the node platforms within the building or facility, whether this is available through an open standard or through a single vendor using a proprietary communications protocol. Extending the concept to populations of separate customers would require more formal interoperability standards between remote platforms.

Diagnostics Services Use Case: If the services are cloud based, they are likely to use communications for the exchange of monitoring and diagnostics data, and reporting that are proprietary to the service vendor.

If the services are all locally provided within the facility domain, conformance with the platform nodes standards would be required.

Value Discovery Mechanisms

Trading Capacity Rights Use Case: The coordinating platform node for the building or facility discovers the value of the comfort/consumption trade-offs from the buy/sell bids received from the RTU platform nodes.

Diagnostics Services Use Case: The value of monitoring and diagnostic services is discovered through experiential market information regarding what customers are willing to pay for avoided energy and operational maintenance costs.

Value Assignment

Trading Capacity Rights Use Case: The RTU platform nodes assign value for the capacity they are willing to buy or sell by combining forecasted load requirements with comfort objectives indicated by user preferences and configurations.

Diagnostics Services Use Case: Value discovery and assignment are not as separable for this kind of service. Customers assign value based on their particular operational costs and benefits, and service providers assign value based on maximizing their business profits and the market.

Alignment of Objectives

Trading Capacity Rights Use Case: The objectives of the utility are met through customers avoiding unnecessary peak load demands. The objectives of the customers are met by optimized distribution of the operation of RTU units and reduction of utility charges.

Diagnostics Services Use Case: : The objectives of the utility are met through customers avoiding prolonged operation of inefficient equipment. The customers meet their objectives by reducing operational costs and maintaining efficiency. Societal objectives are addressed through greater energy efficiency (through better performing equipment)

Stability Assurance

Trading Capacity Rights Use Case: System of capacity rights (with aggregated RTU capacity limits operating under the total capacity limits of the building/facility) ensures stability with respect to peak load management objective.

Diagnostics Services Use Case: Stability is not an issue in this use case, as it does not involve an control objective.

Participating Agencies and Organizations:

The project is funded by the DOE Office of Energy Efficiency and Renewable Energy’s Building Technologies Office for FY13–FY14. PNNL previously developed VOLTTRON™ platform and PNNL, ORNL, LBNL are developing applications. PNNL is performing RTU control demonstrations and ORNL and LBNL are involved in other related RD&D work.

Questions, Comments and Discussion:

- Communication platform across RTUs can provide better control
- Open source software can support communication and transactions across the RTU network
- No transactions in the system yet that would be deemed transactive
- Two transactive concepts presented:
  - Trading capacity rights
    - Peak load management targets (for a building) and allocate certificates to each unit. Units can then trade the capacity rights/certificates.
    - Each unit would have some notion of the flexibility/comfort requirements of the building inhabitants.
  - Diagnostic services
    - Third-party providing diagnostic services for building maintenance.
    - Downloads applications on the platform or stores in a cloud to perform diagnostics
    - No real control action happening, and only financial transactions of contractual type with nothing to do with the grid, except only tangentially.
- The concepts presented in the use-case could potentially fall under the definition of transactive energy.
  - PGE might start a program for car charging along the lines of capacity trading example that was described in the use-case
- What does VOLTTRON™ run on?
  - Message bus that runs on Linux or other platforms on a given node
- How is the commercial world being engaged using this project?
- Has VOLTTRON™ adopted existing standards?
  - PNW project uses a platform that uses a different standard, and using another platform with different set of standards might create problem from interoperability perspective.
- What percentage of RTUs have variable speed drives?
- In a world with good dynamic prices, such as in PJM, demand charges should not be used to manage demand.

Transactive Concepts for a Network of Rooftop HVAC Units Presentation

TRANSACTIVE APPLICATIONS OF OPENADR

PRESENTER: MARY ANN PIETTE, DRRC RESEARCH DIRECTOR, LAWRENCE BERKELEY NATIONAL LABORATORY

In this case study template, we summarize several projects and programs that have demonstrated transactional elements of OpenADR. The term “projects” refers to demonstration projects that involved one or several buildings to demonstrate a concept. The term “programs” refers to utility programs with transactional elements that use OpenADR. The following projects and programs will be presented:

- Taco Bell—small commercial building demonstration project (2009) -Office Building
- Participating Load Pilot Project (2009)
- Price Response in NY-Automated Demand Bidding Program (PG&E and SCE) -Automated Capacity Bidding Program (PG&E, SCE and SDG&E)

The primary objective of the study was to show that a small commercial site could maintain its demand reduction based on instructions from the utility without a human in the loop. The project was implemented in 2009 and funded by Southern California Edison (SCE). The results showed that small commercial buildings could respond to demand reduction signals and maintain the reduction in response to signals from the utility. The utility was interested in a system with the same functionality at a fraction of its cost.

Case Study

Architecture

The project used a client/server architecture. Server is operated by a utility and the clients are located at each site. Generally, in OpenADR implementations, price, reliability and demand response event parameters are communicated to each facility using OpenADR as the information exchange model and the Internet as the communication medium. In this case, a certain percentage of reduction from the baseline was being communicated to the site.

Extent

This transactive activity was between a utility and its customers. If all the chains participated, it could extend across geographic domains.

Transactions

In this transaction, the utility requested a certain percentage of decrease from the customer baseline and the customer provided this reduction in exchange of pre-negotiated amount for each kWh. The customer's baseline was calculated by the utility and made available to the customer a day in advance. Customer participated in this transaction in a fully-automated fashion without a human in the loop.

Transacting Parties

The parties involved in the transactions were a server representing a utility and a client embedded in a thermostat representing the customer end-use. This was a totally machine-to-machine communication without a human in the loop.

Temporal Variability

The transaction was event driven, based on the system's need for additional capacity on hot summer days and had hourly granularity. Meaning, the customer had to deliver the percent reduction from the baseline each hour.

Interoperability

The system used OpenADR 1.0. The customer using OpenADR received the instructions and feedback on the electricity usage was provided back to the utility automation server using the same information exchange model and communication link.

Value Discovery Mechanisms

The value of the transaction was at a fixed cost per kWh determined by an agreement between customer and the utility prior to customer's participation in the project.

Value Assignment

The value was negotiated between the participant and the utility and agreed upon before the participant participated in the transaction. For the customer, they weighed the cost and benefits of their decision.

Alignment of Objectives

For the customer, the disruption was minimal and not noticeable. For the utility the potential benefit of having all the Taco Bells in their service territory deliver demand response was perceived to be beneficial.

Stability Assurance

The system was not designed or optimized for stability. It was assumed that the utility systems would use these resources to implement their stability capabilities.

Participating Agencies and Organizations

Demand Response Research Center/LBNL

Southern California Edison Akuacom

References

Kiliccote, S., M. A. Piette, J. H. Dudley, E. Koch, D. Hennage. Open Automated Demand Response for Small Commercial Buildings. July 2009. LBNL-2195.

Questions, Comments, and Discussion:

- OpenADR case studies show how automation can be used to different transactive energy applications
    - Presented four different real-world examples of OpenADR being used for demand response applications
- Published a report on Any Time DR, which looks at demand response from any and all resources to make it look like grid-scale storage
- OpenADR in over 1,300 facilities and 250 MW in Southern California
    - Signal sent through OpenADR is percent kilowatt reduction in baseline

- Baseline using 10/10 rule or 3/10 rule are not custom baselines, and regression-based baselines might be used in future
- What are the key challenges for demand response to become reality in future?
    - Any time a utility does EE using a control system, they should also do demand response automation
    - Automate once and use many times – requires huge training program for buildings and facilities managers
    - Wholesale/retail market design is a challenge in CAISO
    - Getting low-priced telemetry equipment is a challenge
    - Communicating savings to customers is not a very transparent process
- Most buildings can respond dynamically to prices, and RTP-based programs would work fine, obviating the need for more complex programs.
    - SCE has an RTP-based program where prices increase with temperature and large C&I customers can take advantage by responding to those.

Transactive Applications of Open ADR Presentation

TRANSACTIVE CONTROL OF A LARGE CORPORATE CAMPUS

PRESENTER: ERICH GUNTHER, ENERNEX, CORPORATION

This case study describes the high-level design of a microgrid for a large corporate campus. The mantra for the overall project is "Achieve business continuity with a system that pays for itself and supports environmental stewardship." Other guiding principles for the project include:

•100% renewable energy from onsite generation preferred

•Onsite solar and onsite fuel cells fueled with biogas

•Remaining power supplied by offsite renewable energy

•Microgrids/storage/responsive loads/offsite renewables used to balance load

•Direct access is preferred method of purchasing renewable

•Design for all revenue opportunities (e.g. peak shaving, ancillary services, storage-based arbitrage, demand charge management, renewable energy to grid on weekends—participate in all potential markets wholesale, retail, insale)

•Extremely high energy supply reliability required—campus resiliency

•High hourly employee productivity/revenue generation

•Self-generation needed in event of utility outage (3 weeks plus capable)

•Increased operational flexibility—resiliency to regulatory uncertainty

•High power quality required—including during islanded operation

•Computer and prototype manufacturing equipment sensitive to momentary conditions (sags, swells, transients, momentary interruptions)

•Critical labs and loads have specific concerns.

This is a new campus—a "green field" opportunity to implement new concepts for energy management when running in the on-grid and off-grid mode. There were no requirements to apply the concepts of transactive energy in this design. Our team decided to develop a high-level architecture and design specifications for the microgrid in such a way that a transactive energy-based implementation is possible. It will be up to the successful bidder for the microgrid controller and related components to actually implement the system using transactive energy concepts. To facilitate the successful bidder in supporting transactive energy, use cases were developed to describe a vision for how a transactive energy-based solution might operate.

Case Study

Architecture

For this project, we identified high-level requirements and architectural elements that are capable of supporting transactive control. In this case, it is anticipated that there will be a combination of centralized and distributed control. There will be a microgrid controller to orchestrate the overall operation of the microgrid. In addition to the centralized controller, there will be multiple building automation controllers, numerous sensors, and power system equipment that have local sensing and decision making capabilities based on information available locally and from the microgrid controller. The precise design will be left to the successful bidder.

Extent

The unique aspect of this application of transactive control is that it primarily operates entirely within the confines of the campus. There is no interaction with outside markets other than being aware of external energy procurement costs and using that information to optimize the operation of the various devices (controllable loads, generation and storage) in the campus.

Transactions

The following scenario summary is an example as to the types of information exchanges and transactions that the implemented system is anticipated to support:

- Pre-condition: Bright but puffy cloud day
- Local PV generation providing bulk of instantaneous energy demand
- Cloud transients causing increasingly deep voltage sags
- Controller asks connected devices in manufacturing area cost of sags to current processes running and those expected to run for the day

  - Response is $12,000 in QC rejected widgets per sag. Also responds with alternate offer that there is no impact if sags kept to no lower than 80 percent of nominal
  - Controller queries Dynamic Voltage Restorer (DVR) on operational cost to mitigate voltage during sags to ensure never less than 80 percent for predicted number (20) of cloud transients expected today
  - DVR responds $1,000 per sag
  - Controller evaluates cost of doing nothing, or operating DVR and commands DVR to operate at 80 percent level rest of day
  - Controller also calculates cost of reducing PV utilization and buying more renewable via direct access, or dispatching storage, or using fuel cells
  - Controller decides to dispatch DVR to mitigate sags
  - DVR operates autonomously using local sensor data
  - Logger captures actual operations and costs for controller to use in future decision-making.

Transacting Parties

There are several systems that have been identified as “actors” or transacting parties in the architecture for this campus energy system. They include:

- PV Panels and associated inverters and controls

- Fuel Cells, associated controls, fuel source, metering

- Large Energy Storage System, associated inverter and controls

- Small UPS systems and associated controls and metering

- Fast-start reciprocating machine generators

- Building and utility switchgear

- Branch circuit voltage, current, power, energy, and quality monitoring

- Utility interface metering

- Building Automation System(s)
  - Lighting control system
  - Presence detection system
  - HVAC control.

Temporal Variability

The use case scenario described earlier reflects relatively short time scales (milliseconds to seconds) once in an operating mode—quickly responding to cloud transients to manage voltage quality—but longer time scales leading up to arming that operating mode (minutes to hours). In general, the big picture and longer time frames are evaluated and managed by the centralized microgrid controller whereas faster decision making based on local information once in a specific operating mode is handled by the edge devices.

Interoperability

The requirements described in the procurement documents specify that information exchanges at well-defined points of interoperability utilize standards-based communication technologies. Examples include the use of BACNet for building automation, TCP/IP-based communications for the network layer, and IEC CIM and 61850-based information models for semantic interoperability.

Value Discovery Mechanisms

As described in the simple scenario above, each of the controllable devices used in the system can be queried for metadata on operational costs for various modes. This information is used along with external cost factors such as the cost of external energy procurement options and payments for ancillary services to make the big picture decisions and operational action plan in the microgrid controller.

Value Assignment

In addition to the deterministic, objective cost optimization of this system, a guiding principal for the overall project is to support environmental stewardship. In this system, much of that goal is achieved through the selection and initial sizing of the various components such as the roof-top solar plant. The microgrid controller will have rules to minimize the facility carbon footprint once all other constraints are met (business continuity, employee productivity, product quality, etc.).

Alignment of Objectives

In this closed system, the relationship of actions between the transacting parties is mostly deterministic. However there is the potential for some unintended consequences of various operations—especially with respect to power quality impacts. The goal is to ensure that the transactive control optimization strategy takes these interactions into account either through direct prediction (the deterministic aspect) as well as by reacting to measurement of key system operation metrics (quality, cost, carbon, etc.).

Stability Assurance

Unlike a transactive control system implemented on the bulk system involving T&D assets over a large area and interacting with energy markets, this campus system is much more deterministic in its operation with fewer opportunities for emergent chaotic control behaviors. For the high-level requirements design, several simulations were performed in electrical and control domains to verify that the overall concept was feasible. It is anticipated that upon project award we will end up developing a detailed model of the successful bidder’s proposed solution to verify operating modes, control strategies, and discover the potential for abnormal control operation.

Participating Agencies and Organizations

The client has not given permission to allow their name to be disclosed. EnerNex is a subcontractor to the client's A&E firm and is responsible for developing the overall concept, high-level architecture, system requirements, and other content for use by the A&E firm to produce bid documents.

Questions, Comments, and Discussion:

- Would these transactive techniques be applied in grid connected or islanded mode?
    - The system will be designed to operate and optimize in all modes
- Two independent microgrids with controllers transacting with devices to achieve coordination
    - Negotiations and transactions done by monetizing the different constraints and objectives
    - No energy market involved, and it is purely a transactive control problem
    - Use-case specifies centralized controller with some distributed functions
- How well do clients understand the concept of transactive energy?
- How do you convert transactive energy attributes into RFP, without really designing a system?
    - Challenge is to come up with standard boilerplate language to write these procurement documents that lends itself naturally to a transactive energy solution, without specifically asking for one
- Clients in these projects can have overriding objectives, and providing grid services, etc., might not even be on the radar screen
- The ability to dynamically adapt and operate may be the key to specifying procurement requirements.

COMBINED DISCUSSION OF USE CASE PRESENTATIONS

Following the presentations and their associated discussions, the workshop conducted two discussion sessions during which the attendees were split into four groups for the purpose of active conversation on two main topics. These topics were: 1) the effectiveness of the transactive energy attributes for communication of transactive concepts, and their effectiveness at being a catalyst for comparison of different use cases; and 2), what is the path forward for transactive energy?

In order to permit comparison of the breakout groups' activities, with a view to focusing on enhancements to the Transactive Energy Framework, the groups were provided with questions to focus the discussions. The instructions to the groups emphasized the objective of assessing the suitability of the transactive energy attributes for this purpose. The groups were asked to consider factors such as: Did they help the presentations? What could be changed? Could the template be improved even if the attributes are fine? Are there any attributes that are missing or others that are related to those already listed? How might the definitions be modified? How does each attribute translate into Request for Proposal requirements to help the industry adopt common approaches to requesting bids where transactive energy is viewed as a solution?

The scope of the path forward discussion was broader and more exploratory. For example, what does "path forward" even mean? Is the biggest value on transmission or distribution? Who are we "selling" to, i.e., who is the next group to get involved in transactive energy and what do they need to help them?

Breakout Team 1 Members:
Lincoln Wood, Bob Yinger, Doug Houseman, Mary Ann Piette, Farrokh Rahimi, and Steve Widergren

Question 1: Transactive Energy Framework areas for possible improvement

- Define the commodity being transacted.
- The "temporal variability" attribute is hard to understand. Choosing another title for the attribute could help.
- The attributes can be used to outline a use case, but what are the criteria to be transactive?
  - Perhaps the framework should support a scale of more or less transactive.
  - What conditions or characteristics make something more or less transactive?
- Use cases need to describe the assumptions they have about how the value of the electric system infrastructure is addressed.
- Reconsider the title for the "value discovery." Value is really not discovered, as different entities value things differently. However, in a market, we do have price discovery.
- Most if not all transactive energy use cases touch the end-user, but that is not in the attributes. Consider adding something regarding the voluntary participation of end-use systems and something on distributed decision-making that should be involved in transactive energy.
- The framework needs to mention the context of the Transactive Energy Framework with respect to the overall objectives of the GWAC on this topic. It is unlikely that the framework is an end in itself.

Breakout Team 2 Members:
Andrew Steckley, James Mater, Ward Camp, Heather Sanders, Stephen Knapp, Chris Knudsen, Erich Gunther, and Ali Ipakchi

- ”What is the outcome/conclusion message of the report? What do we want people to do?"
- Order the attributes more in line with the GWAC Stack
  - Alignment of Objectives
  - Value Discovery
  - Values Assignment
  - Transacting Parties.
- Architecture: No comments.
- Extent:
  - Not clear
  - Physical, business (operational), regulatory boundaries (and interfaces).
- Transactions: No comments.
- Transacting Parties: No comments.
- Temporal Variability:
  - (Probably wrong title) temporal and spatial variability
  - Flexible accommodation of timescales and locations.
- Interoperability: No comments.
- Value Discovery Mechanisms:
  - Value determination mechanisms
  - Understandable, consistent, and fair set of rules for discovering value
  - There needs to be a way for the system to reveal the real transaction costs and benefits of options to a participant.
- Value Assignment: No comments.
- Alignment of Objectives:

  - Best results for the most number of stakeholders
  - Best chance of everyone getting what they want
  - Multi-objective optimizing
  - Transactive energy allows local, regional and global optimizations.
- Stability Assurance
  - Control stability (can signals get "out of control" or be sent as "incorrect")
  - Grid (physical) stability
  - Market stability.

Breakout Team 3 Members:
Ken Wacks, Bill Cox, Ed Cazelet, Abhishek Somani, Jim Kirtley, Mark Kerbel, Tracy Markie, and Dave Mollerstuen

- General
  - The terms "tools" and "techniques" are used variably and inconsistently
  - The list in Section 3.2 is a set of definitions.
- Architecture
  - Ed Cazalet was concerned about distributed versus decentralized. Need clarity with precise definitions
  - Should align with commonly used software descriptive architecture
  - Bill Cox is concerned about reference to definition of the grid as an ultra-large scale system. Can refer to systems-of-systems.
- Extent: No comments.
- Transactions
  - Why do the order of terms in Section 3.2 and the template differ?
  - Should we use commonly accepted definition of transaction?
  - The text after the first sentence should be deleted?
- Transacting Parties
  - Parties are legal entities who may be represented by devices. Devices may have proxies that act on their behalf
  - Entire paragraph, or at least the 5th sentence needs to be rewritten.
- Temporal Variability
  - Re-title: "Time Scale."
- Interoperability
  - Edit and simplify.
- Value Discovery Mechanism
  - Ed said that parties discover their own values during a transaction. The dollars attached to the transaction reveal the value
  - Values may not be easy to represent in dollars
  - Bill said that value is out of scope of transactive energy.
- Value Assignment
  - Ed, Bill, and Jim Kirtley said this should be deleted
  - Tracy Markie said we need a concept of value. Each stream needs a concept of value, perhaps different for each stream (pairs of interacting parties). Value could be expressed in dollars or kWh, etc.
- Alignment of Objectives
  - Bill said the Transaction Energy Framework is muddled and needs rethinking
  - Jim said this system should not promote rent-seeking behaviors. (Rent-seeking means trapping people into a transaction not desired)
  - Bill said the work promotes a centralized view

  - Bill said to delete from the third sentence to the end.
- Stability Assurance
  - Bill said this should be changed to “Design for Stability”
  - Bill recommended deleting from “Unfortunately” onward.
- Reviewed all comments.
- Debated the motivation for transactive energy:
  - To maintain grid stability
  - To lower energy cost through distributed generation versus centralized
  - To involve more entities in power systems.

Breakout Team 4 Members:
Rob Pratt, Susan Covino, Tom Sloan, Gordon Mathews, and David Forfia

- Reorder the attributes
- Stability assurance: How does the approach address the following?
  - Physical reliability
  - Market reliability: gaming
  - Graceful failure
- Describe how short-term operational planning relates to long-term capacity planning
- Some illustrative examples would help the reader.

PATH FORWARD DISCUSSIONS

Breakout Team 1 Members:
Lincoln Wood, Bob Yinger, Doug Houseman, Mary Ann Piette, Farrokh Rahimi, Steve Widergren

Question 2: What are the top problems to realize the transactive energy future?

- Lacks an energy policy that accommodates transactive energy approaches. If TE was understood and embraced more broadly, special regulatory rulings would be reduced and incentives would be coordinated to achieve multiple objectives
- How should policy and regulation be set up to determine the price of electricity?
- Customers and regulators need TE education to become more acceptable.

Question 3: What can we do to address these problems?

- Communicate the value of TEC in clear, concise, and compelling ways to regulators and decision-makers
- Organize pilots and demonstrations to help communicate the TE points
- Create a TE roadmap for setting the context in which the initial steps to advance TE can be recommended
- Identify “no regrets” steps to advance TEC and support the roadmap mentioned in the previous bullet as well as the objectives of TE.

Breakout Team 2 Members:
Andrew Steckley, James Mater, Ward Camp, Heather Sanders, Stephen Knapp, Chris Knudsen, Erich Gunther, and Ali Ipakchi

Question 2: What are the top problems to realize the TE future

- What we do should enable and provide predictive, reliable ROI for all potential entrants
- Nobody is listening because it is not a priority
  - Utilities are too busy with other things, and hence, TE is barely on their radar screens

    - TE needs to provide demonstrable improvement (cost, operations) to get their attention
- Regulatory policy: rate design, jurisdictional boundaries, retail/wholesale integration
- Regulatory uncertainty.

Question 3: What can we do to address these problems?

- We are not collectively solving the problem
- We are instead introducing a new market concept to enable solutions to come forward
- We are not proposing solutions, but rather a framework for common dialog and collaboration
- The framework should provide a context and vocabulary to identify the issues that can be either beneficial or detrimental that need to be addressed (by policymakers, utilities, vendors, consumers) and the relationships between them.

Breakout Group 3 Members:

Ken Wacks, Bill Cox, Ed Cazalet, Abhishek Somani, Jim Kirtley, Mark Kerbel, Tracy Markie, and Dave Mollerstuen

Question 2: What are the top problems to realize the TE future?
- Regulatory and legislative framework is not in place
- Financial structures are not determined
- Education of parties at all levels is needed
- We do not understand system elasticity
- "What in it for me?"
- How do we adjust the business models of utilities and encourage new entrants?

Question 3: What can we do to address these problems?
- Need a set of common terminology; document needs more work
- Ed said the definition of TE is too broad
- Need more real-world demonstration projects
- Need incremental implementation
- TE needs hardware that does not exist until there is a substantial market; need energy management systems and smart appliances
- Need derivative documents from TE Framework tailored to various audiences
- Need an executive champion for TE (like the U.S. CTO pushed Green Button)
- We are optimistic that we can agree on a common model.

Breakout Team 4 Members:
Rob Pratt, Susan Covino, Tom Sloan, Gordon Mathews, and David Forfia

Question 2: What are the top problems to realize the TE future
- Too many regulatory regimes – one size TE approach does not fit all those regimes
- Need interoperability standards for TE (utility paralysis contributes)
- Lack of integration of wholesale and (new) retail value streams/prices
- How do we encourage good TE concepts, schema, and designs to float to the top?

Question 3: What can we do to address these problems?
- Regarding the multiplicitous regulatory regimes: F amily or toolkit or TE, at least one each for market- and non-market based approaches

- Combine wholesale prices (value streams) of different commodities (energy and ancillary services) into a simpler blended price/signal at retail level
- DOE, maybe partnering with FERC, should develop
  - models/simulations that utilities and regulators can use to evaluate TE proposals or designs for their states
  - Test pieces and parts of TE solution in the field at a reasonable cost without risking the grid as a whole.

FUTURE TRANSACTIVE ENERGY WORKSHOPS AND 2014 CONFERENCE

The group generally agreed that future workshops should be held with the intent to continue to expand the number of participants.

Workshops have been planned for March 12-13 and at the fall 2014 GWAC meeting to be held in August or September 2014. These upcoming workshops will be focused on development of a GWAC Transactive Energy Roadmap. Through participation in these meetings the Council seeks to get broad stakeholder involvement in the development of the roadmap, which will expand on the existing framework document.

The Council plans to roll out the roadmap in late 2014 at the 2nd International Conference and Workshop on Transactive Energy. This conference will once again be hosted by Smart Grid Oregon and organized by the Council. The location for the conference will once again be Portland, Ore., and the tentative dates are December 10 –11, 2014.

TRANSACTIVE ENERGY WORKSHOP CLOSING COMMENTS & SPECIAL THANKS

Ron Melton, *GWAC Administrator, PNNL*
Mark Knight, *GWAC Chairman*

On behalf of the GridWise Architecture Council I want to thank the participants in this year's workshop for the time they spent preparing for and participating in the workshop. The discussions were lively, thoughtful and thought provoking.

This workshop continued the efforts of the Council to build a community of interested regulators, policymakers, researchers and practitioners around the topic of transactive energy. This effort has come a long way from the handful of participants in the 2011 workshop to where we find ourselves today with broad recognition of this topic across the industry. The Council invites all interested parties to join the further discussions, to provide feedback on the draft "Transactive Energy Framework" document released by the Council in November 2013, and to join the council in expansion of that document to include a roadmap describing work to further develop this area.

Finally, the Council would like to specially thank Southern California Edison (SCE) for hosting this meeting. The willingness of organizations such as SCE to support the work of the council is greatly appreciated.

GWAC Transactive Energy Framework
Proceedings of past transactive energy workshops and conferences.
http://www.gridwiseac.org/historical/tew2011/tew2011.aspx
http://www.gridwiseac.org/historical/tew2012/tew2012.aspx
http://www.gridwiseac.org/historical/tec2013/tec2013.aspx
To learn more, please visit
http://www.gridwiseac.org/about/transactive_energy.aspx

REFERENCE MATERIAL

Important Links

During the course of the workshop participants brought up related material that may be of interest to the broader community. Links to that material are included here.

Transactive Energy Framework Draft
http://www.gridwiseac.org/pdfs/te_framework_report_pnnl-22946.pdf

Transactive Energy 2013 Conference
http://www.gridwiseac.org/historical/tec2013/tec2013.aspx

Transactive Energy Workshops
http://www.gridwiseac.org/historical/tew2011/tew2011.aspx
http://www.gridwiseac.org/historical/tew2012/tew2012.aspx

GridWise Architecture Council
http://www.gridwiseac.org/

National Institute of Standards and Technology
http://www.nist.gov/smartgrid/

Pacific Northwest National Laboratory/Energy and Environment Directorate
http://energyenvironment.pnl.gov/

Pacific Northwest Smart Grid Demonstration
http://www.pnwsmartgrid.org

APPENDIX A - AGENDA

Tuesday, December 10, 2013

8:00 – 8:15 am	**Continental Breakfast**
8:15 – 8:30 am	**Welcome and Introductions** *Mark Knight, GWAC Chairman, Jeff Gooding*, GWAC Member
8:30 – 9:15 am	**Closing the Gap Between Wholesale and Retail Pacific Northwest Smart Grid Demonstration** *James Mater, QualityLogic*
9:15 – 10:00 am	**Transactive Energy Framework for Energy Imbalance Management** *Farrokh Rahimi, Open Access Technology International, Inc. (OATI)*
10:00 – 10:45 am	**Homeostatic Control** *James Kirtley, MIT*
10:45 – 11:30 am	**AEP gridSMART® RTP Demonstration** *Steve Widergren, Pacific Northwest National Laboratory.*
11:30 – 12:15 pm	**Lunch**
12:15 – 1:00 pm	**Southern California Edison** *Doug Kim, Southern California Edison*
1:00 – 1:45 pm	**Interoperable Transactive Retail Tariffs** *Ed Cazalet, TeMix*
1:45 – 2:30 pm	**Microgrid Transactive Operation** *Bill Cox, Cox Software Architects*
2:30 – 3:15 pm	**Southern California Edison's Transactive Energy Demonstration Project** *Bob Yinger, Southern California Edison*
3:15 – 4:00 pm	**Transactive Energy Framework for Supply of Balancing Ancillary Services** *Ali Ipakchi, Open Access Technology International, Inc. (OATI)*
4:00 – 5:00 pm	**Recap of the day** *Mark Knight GWAC Chairman*
5:00 pm	**Adjourn**
5:00 – 6:30 pm	**Evening Reception**

Tuesday, December 10, 2013

8:00 – 8:30 am	**Welcome and Recap** *Mark Knight, GWAC Chairman, Jeff Gooding, GWAC Member*
8:30 – 9:15 am	**Concepts for an RTU Transactive Network** *Rob Pratt, Pacific Northwest National Laboratory*
9:15 – 10:00 am	**Open ADR or TE Topic** *Mary Ann Piette, LBNL*
10:00 – 10:45 am	**Cupertino Campus** *Erich Gunther, EnerNex*
10:00 – 10:45 am	**Discussion of the Use Case Presentations** *Mark Knight, GWAC Chairman*
11:30 – 12:15 pm	**Pacific Northwest Smart Grid Demonstration** *Ron Ambrosio, IBM Research, Ron Melton, PNWSGD Project Director*
12:15 – 1:00 pm	**Lunch**
1:00 – 3:30 pm	**Discussion of the Use Case Presentations, continued** *Mark Knight, GWAC Chairman*
3:30 – 4:30: pm	**Path Forward Discussion** *Mark Knight, GWAC Administrator*
4:30 pm	**Adjourn**

APPENDIX B – SPEAKERS' PROFILES

Ed Cazalet

CEO, The Cazalet Group

An internationally recognized electric industry expert, Dr. Cazalet is a leader in the analysis and design of markets for electricity and the analysis of transmission, generation and load management investments. For his industry contributions, Public Utilities Fortnightly magazine in 2000 named Dr. Cazalet "Innovator of the Year". He is also Vice President and Co-founder of Megawatt Storage Farms, Inc., storage advisory and project development firm. He formerly was a Governor of the California Independent System Operator, and founder and CEO of both Automated Power Exchange, Inc. (APX) and Decision Focus, Inc. (DFI). He has a Ph.D. from Stanford in Engineering-Economic Systems. Dr. Cazalet is co-chair of the OASIS Energy Market Information Exchange (eMIX) Technical Committee, and a member of the OASIS EnergyInterOp and WS-Calendar Technical Committees.

William Cox

Principal, Cox Software Architects, LLC

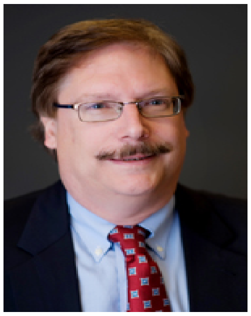
William Cox is a leader in commercial and open source software definition, specification, design, and development.

He is active in the NIST Smart Grid Interoperability Panel and related activities and contributed to the NIST conceptual model, architectural guidelines, and the NIST Framework 1.0.

Bill is co-chair of the OASIS Energy Interoperation and Energy Market Information Exchange Technical Committees, past Chair of the OASIS Technical Advisory Board, member of the Smart Grid Architecture Committee, and the WS-Calendar Technical Committee.

Bill has developed enterprise product architectures for Bell Labs, Unix System Labs, Novell, and BEA, and has done related standards work in OASIS, ebXML, the Java Community Process, Object Management Group, and the IEEE, typically working the boundaries between technology and business requirements.

He earned a Ph.D. and M.S. in Computer Sciences from the University of Wisconsin-Madison.



Erich Gunther

Chairman & Chief Technology Officer, EnerNex Corporation

Erich Gunther is the Chairman and Chief Technology Officer for EnerNex Corporation in Knoxville, Tennessee, where he helps EnerNex clients define their strategic direction in basic R&D, technology, and product development.

Mr. Gunther has over 20 years of experience in design and development of innovative solutions to a wide array of power system problems, most notably ways to take advantage of communications networks and technology to improve the efficiency, operating practices, and security of the electric power system. He played a key role in the development and implementation of the Power Quality Data Interchange Format (IEEE 1159.3), the Utility Communication Architecture (now IEC 61850) and is a key team member on the EPRI IntelliGrid Architecture and related projects. He also serves on the board of directors for the Utility Communications Architecture International Users Group.

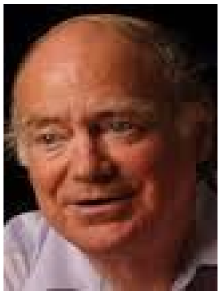
He is presently consulting with the California Energy Commission and Southern California Edison on matters related to the development of a widely deployed advanced metering and demand responsive infrastructure in California, and is working with the Tennessee Valley Authority to develop a comprehensive security policy for their IED data communications infrastructure.

Ali Ipakchi

Vice President of Smart Grid and Green Power, OATI

Dr. Ipakchi has over 30 years of experience in the application of information technology to power systems and electric utility operations. As the Vice President of Smart Grid and Green Power at OATI, he is responsible for growth of the business in these emerging areas. Prior to OATI, he was Vice President of Integration Services at KEMA, assisting utility clients with roadmaps, specifications, and business and implementation strategies for automation and technology projects. Prior to KEMA, Dr. Ipakchi held various senior management positions at leading vendors supporting power application development and system solutions delivery to the power industry.

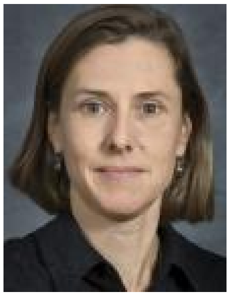
He has led new business-line and organizational development initiatives, and has managed product development and delivery teams. His areas of experience include Smart Grid, utility automation, power systems operations, enterprise and operational IT systems, systems for ISOs/energy markets, utility control centers, trading floors, power generation, distribution operations, and advanced metering. He holds a Ph.D. from University of California at Berkeley, and is co-holder of three US patents on power systems applications and instrument diagnostics.



James L Kirtley Jr.

Professor of Electrical Engineering, Massachusetts Institute of Technology

James L. Kirtley Jr. is Professor of Electrical Engineering at the Massachusetts Institute of Technology. He has also worked for General Electric, Large Steam Turbine Generator Department, as an Electrical Engineer, for Satcon Technology Corporation as Vice President and General Manager of the Tech Center and as Chief Scientist, and was Gastdozent at the Swiss Federal Institute of Technology. He continues as a Director for Satcon. Dr. Kirtley attended MIT as an undergraduate and received the degree of Ph.D. from MIT in 1971. Dr. Kirtley is a specialist in electric machinery and electric power systems. He served as Editor in Chief of the IEEE Transactions on Energy Conversion from 1998 to 2006 and continues to serve as Editor for that journal and as a member of the Editorial Board of the journal Electric Power Components and Systems. Dr. Kirtley was made a Fellow of IEEE in 1990. He was awarded the IEEE Third Millennium medal in 2000 and the Nikola Tesla prize in 2002. Dr. Kirtley was elected to the U.S. National Academy of Engineering in 2007. He is a Registered Professional Engineer in Massachusetts.



Marry Ann Piette

Research Director, Lawrence Berkeley National Laboratory

Mary Ann Piette is the Head of the Building Technology and Urban Systems Department and has been at LBNL since 1983. She is also the Director of the Demand Response Research Center (DRRC). The DRRC develops DR technology and the Open Automated Demand Response standard, which is a key element of the NIST Smart Grid standards. OpenADR is being deployed to deliver over 250 MW of DR in California and throughout the U.S. Ms. Piette develops and evaluates low-energy and demand response technologies for buildings. She specializes in commissioning, energy information systems, benchmarking, and diagnostics.

She has authored over 100 papers on efficiency and demand response. In 2006, Ms. Piette received the Benner Award at the National Conference on Building Commissioning for contributions to making commissioning “business as usual”. Ms. Piette completed her undergraduate work at UC Berkeley in Physical Science. She has a Master’s of Science Degree in Mechanical Engineering from UC Berkeley and a Licentiate in Building Services Engineering from the Chalmers University of Technology in Sweden.

Rob Pratt

Pacific Northwest National Laboratory

Rob Pratt manages PNNL's Smart Grid R&D program activities for the U.S. Department of Energy. He leads the GridWise™ initiative, which spawned a new DOE program and an industry alliance that both share a vision of an information-rich future for the power grid. He heads a team with a focus on communications architecture, advanced control technology, and simulation and analysis of the combined engineering and economic aspects of the future grid.

Mr. Pratt also leads a PNNL initiative that recently commissioned the new Electricity Infrastructure Operations Center, a fully-equipped grid control center capable of serving as a back-up center, with live phasor data resources from around the U.S. and state-of-the-art analysis tools. It serves as a unique technology development, valuation, training, and technology transfer platform. The initiative is currently developing advanced grid control and situational awareness technologies and watershed/hydro system management capabilities.

Mr. Pratt received his B.S. in Ocean Engineering from Florida Atlantic University and an M.S. in Mechanical Engineering from Colorado State University.

Farrokh Rahimi

Vice President of Market Design and Consulting, Open Access Technology International, Inc. (OATI)

Farrokh Rahimi is Vice President of Market Design and Consulting at Open Access Technology International, Inc. (OATI), where he is currently involved in analysis and design of power and energy markets and Smart Grid solutions. He has a Ph.D. in Electrical Engineering from MIT, along with over 40 years of experience in electric power systems analysis, planning, operations, and control, with the most recent five years in the Smart Grid area. Before joining OATI in 2006, he collaborated with California ISO, Folsom, CA for eight years, where he was engaged in market monitoring and design. His prior experience included eight years with Macro Corporation (subsequently KEMA Consulting), five years with Systems-Europe, Brussels, Belgium; one year with Brown Boveri (now ABB), Baden, Switzerland; ten years, as a university professor, researcher, and consultant in power and industrial control systems, and two years with Systems Control, Inc. (now ABB Systems Control, Santa Clara, CA), where he started his professional career.

Dr. Rahimi is a Senior Member of IEEE, and a number of Smart Grid task forces and committees, including NERC Smart Grid Task Force, NAESB Smart Grid Task Force, WECC Variable Generation Subcommittee, and Open Smart Grid Users Group

Mark Knight

Executive Consultant, CGI

Mark Knight is Chair of the GridWise Architecture Council and is an experienced consultant with deep expertise in utility companies. Mark's background, spanning 25 years, has included a mix of information technology work and business process work both as a consultant and as a utility employee in the U.K. and the U.S. and has spanned several areas including distribution, transmission, metering, systems integration, and restructuring.

He draws upon extensive experience to deliver business solutions that leverage the integration of people, business (processes, systems, data), and technology to support innovative, effective, and practical solutions for clients. He believes that smart grid is not about the technology; it is about leveraging data and policy to create better understanding of both business and operational issues so as to improve efficiency, share knowledge and maintain/increase security.

James Mater

Director, QualityLogic, Inc.

James Mater founded and has held several executive positions at QualityLogic, Inc. from June 1994 to present. He is currently Co-Founder and Director, working on QualityLogic's Smart Grid strategy, including work with the GridWise Architecture Council, the Pacific Northwest Smart Grid Demonstration Project, the Test and Certification Committee of the Smart Grid Interoperability Panel and giving papers and presentations on interoperability standards and challenges.

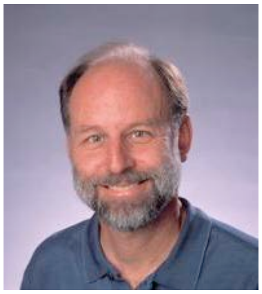
From 2001 to October, 2008, James oversaw the company as President and CEO. From 1994 to 1999 he founded and built Revision Labs, which merged with Genoa Technologies in 1999 to become QualityLogic. Prior to QualityLogic, James held Product Management roles at Tektronix, Floating Point Systems, Sidereal and Solar Division of International Harvester. He is a graduate of Reed College and Wharton School, University of Pennsylvania.

Steve Widergren

Principal Engineer, Pacific Northwest National Laboratory

Steve Widergren contributes to new solutions for reliable operation of electric power systems. Common throughout his career is the application of information technology to power engineering problems, including simulation, control, and system integration.
Mr. Widergren is a principal engineer at Pacific Northwest National Laboratory (PNNL) and is the 2010/2011 Plenary Chair for the Smart Grid Interoperability Panel, a group established by the National Institute of Standards and Technology to advance interoperability of smart grid devices and systems through the coordination of standards and best practices. He was recently Administrator for the GridWise Architecture Council a group formed to enable interoperability of automated systems related to the electric system.

Before joining PNNL, Mr. Widergren was a corporate engineer at ESCA, now AREVA T&D, an electricity control center supplier. He previously worked at American Electric Power and interned at Pacific Gas and Electric. In these positions, he engineered and managed energy management systems products for electric power operations and supported power system computer applications. Application areas include information modeling, SCADA systems, and power system reliability assessment tools.



Bob Yinger

Consulting Engineer, Southern California Edison

Bob Yinger is a Consulting Engineer working in the Advanced Technology Group of the Transmission and Distribution Business Unit at Southern California Edison. The group is responsible for researching and bringing into use new technologies for SCE.

In his 33 years with SCE, Bob has been involved in a wide range of research and development activities including system planning, solar and wind energy development, power quality, communications technology development, electronic metering systems, and substation/distribution automation. His present work is focused on planning the scope and implementation for the Smart Grid at SCE. He is also involved in investigation of the effects of air conditioner stalling on system voltage recovery, new automation technologies for substations and the distribution system, and use of SCE’s Smart Connect advanced metering system to obtain benefits for the distribution system.

Bob graduated from California State University, Long Beach with a degree in Electrical Engineering. He holds a Professional Engineer license in electrical engineering from the state of California and is a member of the IEEE.