# Transactive Energy Workshop Proceedings 2012

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**About this Document**

The GridWise Architecture Council 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. In the spirit of advancing interoperability of an ecosystem of smart grid devices and systems, this document presents a model for evaluating the maturity of the artifacts and processes that specify the agreement of parties to collaborate across an information exchange interface. You are expected to have a solid understanding of large, complex system integration concepts and experience in dealing with software component interoperation. 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 whitepapers, 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.

**DISCLAIMER**

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## INTRODUCTION

The goal of this workshop was to address different approaches to the use of variable pricing models throughout the power system - from generation through transmission and distribution to consumption. Techniques based on such approaches are called "transactive energy."

Transactive Energy Workshop Participants
March 28, 2012

## PARTICIPANTS

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## Overview and Opening Remarks

**Workshop Leader:** Ron Melton, Pacific Northwest National Laboratory

The GridWise® Architecture Council (GWAC) hosted its second workshop on transactive energy at IBM's T.J. Watson Research Center on March 28 – 29, 2012. This workshop expanded on the activities and results of the previous workshop held at OATI in May 2011. The objective of the previous workshop was to bring together a small number of people engaged in research and development of transactive energy techniques to share their approaches, discuss the nature of these approaches, identify opportunities for collaboration, and identify research and development needs. Each participant described their work through presentation to the group. Proceedings of the workshop have been published by the GWAC through Pacific Northwest National Laboratory (PNNL) on www.gridwiseac.org.

The 2012 Transactive Energy Workshop (TEW) engaged a broader group including researchers and others in the electric power industry with an interest in the topic. The first day of the workshop consisted of presentations from last year's participants providing an update on their ongoing work and presentations from new participants describing their work related to this topic. The second day consisted of working sessions to discuss the group's transactive energy white paper, discuss tutorial material on transactive energy, which will be presented at upcoming meetings, and to coordinate transactive energy panel sessions and tracks at meetings including Grid-Interop 2012 and the 2013 IEEE Innovative Smart Grid Technologies conference.

## Background

What is Transactive Energy?

The term "transactive energy" is used here to refer 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 considering grid reliability constraints. The term "transactive" comes from considering that decisions are made based on a value. These decisions may be analogous to or literally economic transactions. 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[1]. Another would be the TeMix work of Ed Cazalet[2]. 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[3],[4]. 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[5].

In addition to these practical applications, research is taking place on more sophisticated techniques such as the previously cited work on transactive control. The community of people performing this research has not had a focused opportunity to discuss their work – thus this workshop.

**2011 Workshop Participants**

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|---|---|
| Ron Melton, Pacific Northwest National Laboratory | Ali Ipakchi, OATI |
| Rob Pratt, Pacific Northwest National Laboratory | Farrokh Rahimi, OATI |
| Todd Halter, Pacific Northwest National Laboratory | Anna Scaglione, UC Davis |
| Chris Irwin, US Department of Energy | Mahnoosh Alizadeh, UC Davis |
| Terry Oliver, Bonneville Power Administration | Robert Burke, New England ISO |
| Ron Ambrosio, IBM T.J. Watson Research Center | Ed Cazalet, TeMIX, Inc. |

[1] 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
[2] 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
[3] 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
[4] http://www.pnwsmartgrid.org
[5] http://www.powercentsdc.org

## PRESENTATIONS

For this workshop, each participant was required to give a presentation on their current work dealing with transactive energy. They were also asked to submit a white paper on their presentation. The following are the abstracts on the presentations, and links to the slides and white papers.

## CLOSING THE GAP BETWEEN WHOLESALE AND RETAIL

**SPEAKER:** ROBERT BURKE, ISO NEW ENGLAND

The term "transactive energy" refers to the technique 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 considering grid reliability constraints. Presently, it is applied to the end-use customer level and not to the participants in the wholesale market. Transactive energy grew out of a pilot project to control responsive demand in the GridWise Olympic Peninsula Project.[6] Wholesale electricity markets operated by the Independent System Operators ("ISOs") ISOs and Regional Transmission Operators ("RTOs") in the United States do not operate on the transactive energy model. ISOs and RTOs are responsible for maintaining reliable bulk power system operations in real-time. These organizations provide critical reliability services including outage coordination, generation scheduling, voltage management, ancillary services provision, and load forecasting. The ISOs and RTOs may also be responsible for the longer-term forecasting of the system's ability to meet forecast loads.

To have value in the wholesale market, the resource must be able to provide a service that the ISO or RTO needs. Demand response, which could include transactive energy, empowers customers to reduce their electricity consumption in response to an emergency, peak-load, and appropriate wholesale or retail price conditions on the electricity grid. The wholesale markets operated by the ISOs and RTOs have successfully encouraged demand response by implementing programs and market designs that encourage the development and participation of demand response. FERC order 745[7] requires the payment of full locational marginal price ("LMP") to demand resources participating in the wholesale electricity market provided the demand resource can "balance supply and demand." Balancing supply and demand mean that the demand resource must be available for dispatch by the ISO or RTO.

This paper describes the general operation of the wholesale market and one possible method for transactive energy to be incorporated in the wholesale energy market in light of FERC order 745.

Closing the Gap between Wholesale and Retail [Presentation.](#)

[6] 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.
[7] FERC Order No. 745, Demand Response Compensation in Organized Wholesale Energy Markets (Issued March 15, 2011), 134 FERC ¶ 61,187. Available at URL: http://www.ferc.gov/EventCalendar/Files/20110315105757-RM10-17-000.pdf

## DEMAND RESPONSE: BRIDGING RETAIL TO WHOLESALE-PRICE SIGNAL PREDICAMENT

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

This presentation will address issues, challenges, and opportunities for closing the gap between wholesale and retail markets. It will also discuss the narrowing of the gap between bulk power and distribution grid operations. The role of transactive energy technics will be discussed along with a roadmap.

Demand Response: Bridging Retail to Wholesale-Price Signal Predicament
Presentation.

## TRANSACTIVE CONTROL AT THE RETAIL LEVEL

**PRESENTER:** ROB PRATT, PACIFIC NORTHWEST NATIONAL LABORATORY

Multiple Operational Objectives for Transactive Dispatch of Distributed Smart Grid Assets Select lowest cost resources from all smart grid assets Demand response (DR), distributed generation & storage (DG, DS) Respond to real-time (5-min.) wholesale LMP Manage capacity constraints at bulk level (gen./trans.) Manage capacity constraints at distribution level In the future: other value streams, other assets.

Transactive Control at the Retail Level Presentation.

## CLOSING THE GAP BETWEEN TRANSMISSION AND DISTRIBUTION ON THE PACIFIC NORTHWEST SMART GRID DEMONSTRATION PROJECT

**PRESENTER:** RON MELTON, PACIFIC NORTHWEST NATIONAL LABORATORY

This paper summarizes a technique referred to as transactive control that has been developed as a means of coordinating the response of smart grid assets at all levels of the power system. In simple terms transactive control may be thought of as extending the notion of locational marginal pricing throughout the power system from generation to end-use. The transactional nature of the technique, however, introduces a new element in the use of a pair of signals to implement an equivalent to market closing distributed in space and time.

The first of these signals, referred to as the transactive incentive signal (TIS), represents to cost of electrical energy delivered to any specific point in the power system. This signal includes both the current cost and a forward projection of estimated future cost. Following the flow of power through the system, the value of the TIS is updated at each point in the system where a constraint may exist or a decision about the flow of power through that point can be made.

The second of these signals, referred to as the transactive feedback signal (TFS), represents the estimated behavior of loads or other responsive elements in the power system. This signal is aggregated upwards in the system at nodes serving the loads. As with the TIS, the TFS includes both the current load and a forward estimate of the load.

At points in the power system where the flow of power may be affected, referred to as nodes, control elements, referred to as transactive control nodes, are created. The transactive control nodes have several functions: blending incoming TIS values to create a composite representing the inputs (assuming more than one source of power into the node); aggregation of TFS values to create an aggregated result representing the estimated future behavior of assets served through the node; analyzing the TIS, TFS and local conditions to make decisions affecting the behavior of responsive assets attached to the node; and adjusting the future estimates of TIS and TFS based on consideration of each with respect to the other taking into account local information. This latter function causes the overall transactive control system to be a closed loop system with the closure distributed in both space (because it is happening at each of the topologically distributed nodes) and time (because it is based on consideration of the future values of each of the two signals with respect to each other.)

This paper will summarize the basic principles of the technique and then discuss some of the challenges in applying the technique in the Pacific Northwest Regional Smart Grid Demonstration Project. This project is applying the technique in a five state region (Washington, Oregon, Idaho, Montana and Wyoming) through the participation of eleven utilities.

Closing the Gap between Transmission on the Pacific Northwest Smart Grid Demonstration Project Presentation.

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## PRICING DEFERRABLE ELECTRIC POWER SERVICE

**PRESENTER:** ELIYAN BITAR, CORNELL UNIVERSITY

In an effort to combat the onset of global warming, 30 of the 50 states in the USA have adopted Renewable Portfolio Standards (RPS) that mandate load serving entities to increase the percentage of renewable energy used to serve their demand[8]. While wind and solar resources are plentiful in raw energy availability, the inherent variability in their power output will pose serious challenges to their large scale assimilation into the electric grid. Even at today's modest levels of penetration, the added variability due to wind results in systemic operational problems[9]. The impact of intermittency and inaccurate forecasting on reserve margins will only become more pronounced as wind energy penetration increases. For example, the 2010 EWITS report[10] by NREL projects that regulating reserve requirements will increase by 1500 MW (on average) under a 20% percent wind energy penetration scenario in the PJM interconnection. Such an increase in reserve requirements is unacceptable, as regulating reserves are normally supplied by fast-acting, fossil fuel based resources such as natural gas fired generators – mitigating the net greenhouse gas benefit of renewable energy. As wind and solar energy penetration increases, how must the assimilation of this variable power evolve, so as to minimize integration costs,

[8] M.J. Beck Consulting, The RPS Edge, http://mjbeck.emtoolbox.com
[9] E. Ela and B. Kirby, "ERCOT event on February 26, 2008: Lessons learned," NREL Technical Report, NREL/TP-500-43373, July 2008.
[10] EnerNex Corp., "Eastern Wind Integration and Transmission Study," National Renewable Energy Laboratory, Report NREL/SR-550-47078, January 2010.

while maximizing the net environmental benefit? One option is to harness the flexibility in consumption on the demand side.

Today, the demand side is largely treated as inelastic. However, the power requirements of many commercial and residential loads are such that a fraction of power demand at any given moment is inherently deferrable in time subject to a deadline constraint on the total energy supplied. Examples include thermal systems such as refrigerators, water heaters, HVAC systems, data centers, and, assuming mass adoption of plug-in electric vehicles, batteries. Clearly, there is an opportunity to transition from the current modus operandi to one in which demand is capable of reacting to variability in supply if properly incentivized.

The majority of demand response mechanisms generally fall into one of two categories: (1) those relying on consumer-based control in response to a signal from the supplier (e.g. dynamic pricing[11]) and (2) those involving direct-load control capabilities, where the supplier purchases the right ex-ante to remotely interrupt the load under a set of pre-specified contingencies (e.g., interruptible load contracts [12,13]). Dynamic pricing mechanisms have gained substantial support from industry and government in recent years [14]. They aim to replace conventional flat-rate tariffs – reflecting the "average system marginal cost" for energy – with time varying rates (e.g., critical peak pricing, time-of-use pricing, real-time pricing[15] ) that more accurately represent the true system marginal cost as a function of time. The hope is that consumers will reduce or shift their consumption when faced with higher than average prices during peak periods. However, as these mechanisms rely on consumer-based control, the inherent uncertainty and delay in consumer response limits market opportunities for the DR provider to peak shaving. Moreover, exposing a wide range of consumers to real-time prices may lead to an increase in variability of aggregate load beyond that of the current baseline patterns.

Enabling the DR provider to extract revenue from additional markets (e.g., ancillary service markets) not accessible by dynamic pricing mechanisms will require the inception of incentives that induce consumers to cede partial control of their individual resources to a DR provider (or aggregator) who can then reliably coordinate their aggregate response on the time scales required of various ancillary service products. From the perspective of the system operator, the load bus will appear as a dispatchable resource – not unlike a conventional thermal generator. Forward contracting mechanisms will be essential to realizing benefits achievable through coordinated demand response. The key enabling elements are: (a) (Lead Time) The lead time on delivery afforded by forward contracts enables the DR provider to access markets with lead times beyond the real time spot market (e.g., hour ahead, day ahead, etc.). (b) (Firm Load Response) By procuring the right to schedule in real time the delivery of energy to the individual consumer resources subject to forward contract constraints (e.g., an energy quantity and delivery deadline), the DR provider can ensure a firm load response upon request. This increased certainty in demand response minimizes quantity 1 risk exposure to the DR provider when offering this aggregated capacity in transmission side markets.

[11] A. Faruqui, R. Hledik, and J. Tsoukalis, "The power of dynamic pricing," The Electricity Journal, April 2009.
[12] H.P. Chao and R. Wilson, "Priority service: pricing, investment, and market organization," The American Economic Review, Vol. 77, No. 5, Dec. 1987
[13] C.W. Tan, and P.P. Varaiya, "Interruptible electric power service contracts," Journal of Economic Dynamics and Control 1993.
[14] S. Borenstein, M. Jaske, and A. Rosenfeld, "Dynamic pricing, advanced metering, and demand response in electricity markets," Technical Report, University of California Energy Institute, UC Berkeley, 2002.
[15] A. Faruqui, R. Hledik, and J. Tsoukalis, "The power of dynamic pricing," The Electricity Journal, April 2009.

Essentially, the DR provider must procure “flexibility” in the delivery of energy to participating resources. Flexibility can be defined in various ways – e.g., interruptibility, deferability, storage capability. A couple of basic questions that we will attempt to answer are: (1) how does a DR provider structure and price forward contracts for flexible energy service and (2) how does the DR provider schedule in real-time the delivery of variable renewable energy to participating resources to maximize expected profit while satisfying contractual constraints associated with a certain “quality of service”?

Much of the existing literature on pricing flexible service contracts centers on the concept of reliability differentiated interruptible power contracts [16,17], where consumers take on risk of load curtailment in exchange for a lower price for energy. When faced with a random source of generation, such contract mechanisms eliminate the need for reserves and attenuate price volatility when compared to spot pricing mechanisms [18]. There are several drawbacks however. (a) Such mechanisms are difficult to audit, resulting in potential moral hazard on the supply side. (b) To the extent that consumers purchase less-than-reliable power in a forward contract, they take on quantity risk in exchange for price risk and are thus faced with the complex challenge of planning future consumption in the face of uncertain supply.

To alleviate these difficulties we propose an alternative forward contracting mechanism that provides a guarantee on the aggregate quantity to be delivered by a consumer-specified deadline. In this way, the supplier still maintains flexibility in energy delivery, while the consumer faces no quantity risk in the metric of interest (e.g., probability of meeting its task energy requirement). Here, the supplier is able to manage variability in supply by scheduling the delivery of energy to resources consenting to deferrable service.

Specifically, we propose a novel forward market for deadline-differentiated contracts for energy, where consumers consent to deferred service of pre-specified loads in exchange for a reduced per-unit price for energy. Such a market would naturally complement the proliferation of plug-in electric vehicles (EV) in the US transportation fleet. Consider the following motivating example. Upon plugging her EV into a smartcharger, the EV owner is presented with a menu of contracts – each of which stipulates a per-unit price for energy and an associated service deadline. Faced with such choices, how does the EV owner decide upon a bundle of contracts? How does the provider set the deadline-differentiated prices? What if the supply is random? Can one characterize a set of prices yielding an efficient competitive equilibrium? Using a stylized market model, we answer these and other questions.

Pricing of Deferrable Electric Power Service Presentation.

[16] H.P. Chao and R. Wilson, “Priority service: pricing, investment, and market organization,” The American Economic Review, Vol. 77, No. 5, Dec. 1987.
[17] C.W. Tan, and P.P. Varaiya, “Interruptible electric power service contracts,” Journal of Economic Dynamics and Control 1993.
[18] E. Bitar, P. Khargonekar, K. Poolla, R. Rajagopal, P. Varaiya, and F. Wu, “Selling random wind,” 45th Hawaii International Conference on System Science (HICSS), 2012.

## Energy Micromarkets

**Presenter:** William Cox, Cox Software Architects LLC

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

- High scalability
- Low overhead
- Low barriers to participation
- Ability to delivery energy bought and sold

These features allow application to large sets of participants, from the devices in a facility to microgrid (and district energy) participants, and from small-scale localized markets to larger and possibly more dispersed markets. Local knowledge is used to interact with local markets.

Requirements for interactions with small-scale localized markets are the next step. We want micromarkets that can be implemented with a variety of transactive techniques and standards. While we are agnostic with respect to market design and rules, nonetheless, we explore the minimal set of capabilities that energy micromarket deployments must support to meet our goals.

We address scaling in two dimensions:
- by aggregation of small-scale markets and
- by expanding individual markets that meet the requirements

and describe how the scaling can be accommodated.

It is common to transact forward contracts for planned energy use. We examine implementation in micromarkets, including techniques for composition of transactions, including both a pure TeMIX approach for interaction and a distributed transaction-processing approach building on distributed agreement protocols, examining the complexity and characteristics of both solutions.

We conclude with design considerations for a standards-based micromarket deployment.

Energy Micromarkets Presentation.

## THE TEMIX PLATFORM™ FOR "TRANSACTIVE ENERGY" APPLICATIONS AND DEMONSTRATION

**PRESENTER:** ED CAZALET, TEMIX INCORPORATED

Transactive Energy is a business process for energy transactions. A Transaction is an exchange among parties of a product for a price. Transactive Energy is most useful in decentralized competitive electric energy markets, but it has applications in centralized dispatch, vertically integrated electric utilities, and microgrids.

Automation of electric energy transactions enables a more efficient and customer friendly electric grid. Transaction automation also supports increased variable renewables on the grid with fast response. Transactive Energy Market Information Exchange (TeMIX) is a methodology to support automated energy transactions and decentralized management of energy use and supply on a smart electric grid. Using TeMIX, customer devices such as air conditioners, plug-in vehicles, distributed generation and storage automatically interact with distribution grids, transmission networks, and central generation and storage.

The TeMIX standard is a profile (subset) of transactive energy standards by (OASIS) Organization for the Advancement of Structured Information Standards. In its ideal implementation, TeMIX uses frequent communication of small tenders and transactions for products. TeMIX has just two products; Energy and Energy Transport, and Call and Put Options on these. Parties to transactions may be (1) owners of end-use devices, generation, and storage with interval meters, (2) financial parties providing risk management with no intention of delivery, (3) suppliers and consumers of physical energy transport services, or (4) suppliers and consumers of financial transport hedges. A Party may take the buy or sell side of a transaction. A consumer can sell by reducing a purchased position or by self-generating. A supplier can buy back from a sold position.

The TeMix Platform[tm] for "Transactive Energy" Applications and Demonstrations paper.

## Distributed Energy Resource Integration – Lessons Learned from U.S. case Studies

Presenter: Alan Rourke, KEMA

Growth in investments in distributed energy resources – renewable distributed energy generation, demand response (DR), energy storage, and plug-in electric vehicles (PEVs)

1) Determining market impacts
- Short term forecasts to create visibility
- Longer term indirect control of resources
- Determining Operational Reserve requirements

2) Communication infrastructure for Distributed Energy Resources
3) Incenting asset investment

Results from two case studies will be discussed

Findings highlight the fact that data can play an important supporting role in both electricity grid and market operations and indicate the need for additional research.

Distributed Energy Resource Integration – Lessons learned for U.S. Case Studies Presentation.

## The Pacific Northwest Smart Grid Demo: Transactive control Implementation

Presenter: Ron Ambrosio, IBM T.J. Watson Research Center

The Pacific Northwest Smart Grid Demonstration is a large-scale project involving a five state region (Washington, Oregon, Idaho, Montana and Wyoming) with eleven utilities. The project is led by Battelle Memorial Institute, Northwest Division, and includes Bonneville Power Administration, IBM Research, Alstom Grid, Quality Logic and 3-Tier. The primary objective of the project is to create a large-scale implementation of Transactive Energy Management.

This presentation will provide a brief overview of the project, and then begin to dive down through the design and implementation layers of the system to illustrate key design points related to interoperability, introduce the primary application programming and interoperability framework being used (ISO/IEC 18012), and provide details of the internal structure of the Transactive Control Node implementation being used on the project.

The presentation should give the audience a clear understanding of one approach to Transactive Energy Management that is using a highly distributed design to achieve maximum scalability and resiliency to single points of failure.

The Pacific Northwest Smart Grid Demonstration: Transactive Control Implementation Presentation.

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## Lessons Learned from Wholesale Transactive Techniques and their Applications to Retail Transactions

### Presenter: Ali Ilpackchi, Open Access Technology International, Inc. (OATI)

The advent of Smart Grid and increased attention to climate related issues brings along the need for coordinated management of a large number of distributed and demand-side resources while maintaining a high degree of grid reliability and improving operational economics. This requires information exchange among many entities, systems, devices, and users for enrollment, scheduling, monitoring, and control. It involves information exchange between demand response resources, intermittent renewable generation, storage devices, grid monitoring and control devices, and micro-grids. It also requires information exchange between markets, utility operations, customers and service provides. New methods are needed for end-to-end management and real-time operation of such complex system.

To address these challenges, one need not start from scratch. Many tools and techniques have been developed over the last two decades for the management of bulk power operations and wholesale energy markets based on transactions among various entities. These include scheduling, pricing, transmission capacity reservation and auctions, congestion management, and many others both in bilateral and centralized market environments. Lessons learned from bulk power operations and wholesale energy markets can be applied to distributed resources, demand response, retail markets, and distribution system operations under the Smart Grid paradigm. Below we briefly review four examples of existing bulk power transactive practices and their possible use when dealing with retail markets and distributed resources.

1. Scheduling and Dispatch of Demand-Side Resources

The Smart Grid infrastructure can provide for multi-level hierarchical information exchange and control. It may be used to aggregate, schedule and dispatch demand-side resources in a way that, from a system or market operator's point of view, looks similar to scheduling and dispatch of conventional generation resources. Dispatchable demand-side resources include Direct Load Control (DLC), Distributed Generation, Distributed Storage, and Electric Vehicles. The central idea here is to aggregate these distributed assets in the form of Virtual Power Plants (VPPs) with characteristics similar to conventional power plants, while taking into account the temporal and geographical attributes and constraints of these resources as well as any distribution system constraints, and contractual limitation related to demand-side programs implemented by Load Serving Entities, Curtailment Service Providers, Distribution Utilities, Balancing Authorities, and/or Market Operators.

The parameters of a VPP change with time frequently compared to those of a conventional generation resource. For example, the Net Dependable Capacity (Pmax) of a conventional power plant changes seasonally, whereas that of a VPP may change hourly or even sub-hourly. As another example, a VPP comprised of a large number of residential electric water heaters may have a high Pmax in the morning hours but a low Pmax during the work hours of a weekday. The same may apply to other parameters such as Pmin, ramp rate, etc. The scheduling and dispatch of a VPP must take these variations into account but will otherwise be similar to that of conventional resources.

2. Distribution Congestion Management and Capacity Reservations

Congestion management is central to transmission open access. Under bilateral market paradigm the control area operator (Balancing Authority) must resort to schedule curtailments to manage transmission congestion. Transmission capacity reservation with different priority levels provides the mechanism for congestion management. Similar concepts may be applied to the distribution system. For example, with the emergence of plug-in electric vehicles (PEV), a distribution circuit may not be able to serve all electric vehicles in a neighborhood simultaneously. Distribution capacity reservations with different priority levels provide the means for the distribution system operator to manage congestion. Priorities may be established based on various criteria such as reservation time, reservation fee, etc.

3. Distribution Capacity Auction to Hedge Against Limited Distribution Capacity

Using organized wholesale markets (facilitated by ISOs/RTOs) as a model, a distribution capacity auction mechanism may be put in place whereby limited distribution capacity is auctioned on a seasonal, monthly, and possibly daily basis. Such local distribution capacity markets may not be as liquid as their wholesale counterparts, however. To avoid hording of limited distribution capacity, eligibility to participate in such auctions may be restricted to certain users. The auction winners may then bilaterally trade the capacity. For example a PEV owner may bid to buy capacity during evening peak hours of the weekdays for a month in the auction and when the PEV is charged (or idle) sell the excess capacity to others using the same circuit elements.

4. Variable Generation Balancing using Demand-Side Resources

Variable generation (wind, solar, etc.) is volatile and unpredictable. Fast dispatchable Demand Response resources (Virtual Power Plants) may be used as part of scheduling and dispatch processes to mitigate variable generation by utilizing them as a source of ramping and balancing energy.

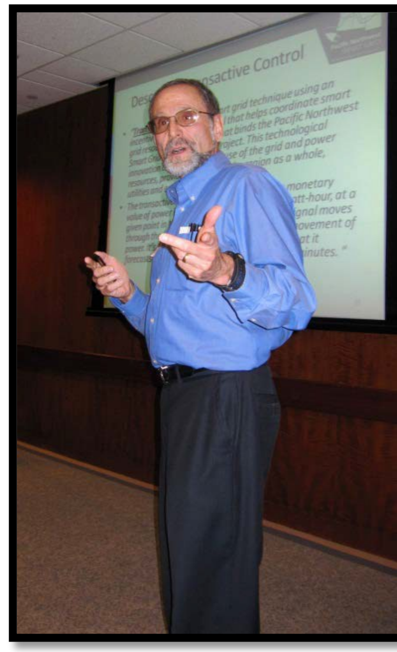
## Lessons Learned from Wholesale Transactive Techniques and their Application to Retail Transactions Presentation.


## Transactive Energy Communications to Consumers

Presenter: James Mater, QualityLogic, Inc.

A key objective of developing and implementing a transactive energy system is to enable much more active engagement by consumers and commercial customers in the management of electricity consumption and reliability. Yet consumers have been insulated from the reality of electric system operation for generations and view low-cost, reliable power as a given of our modern society. For the most part, consumers have little if any understanding of the varying costs of delivering electric power in a day nor have they had any tools for monitoring or managing their own demands on the system. Further, only about 50% of consumers in the US are even familiar with the terms smart grid and smart meters and a good percent of those have little understanding of their meanings (SGCC Consumer Pulse Wave 2, January 23, 2012). When it comes to implementing a transactive energy system that enables consumers to not only understand their electrical usage on a granular basis (5, 10, 15 minute intervals versus monthly) but to actually implement an automated demand management plan to optimize their own economic benefits while simultaneously benefiting the larger grid, the past relationships with the system and their utilities are wholly inadequate. There are many examples of attempts by utilities to engage customers on the relatively simple technology of smart meters: some successful and some dismal failures. But engaging consumers on discussions about transactive energy presents a much more daunting challenge. The PNW Regional Demonstration Project has 11 utilities, each with their own approach to engaging consumers on transactive energy. This paper will summarize the different approaches and the early indications of lessons learned in these consumer engagements.

Transactive Energy Communications to Consumers [Presentation.]



## TRANSACTIVE ENERGY ROADMAP

This year's presentations and follow on discussion, as with last years, showed the need for a common vision of what transactive energy means, what it will look like in the future, and how it will benefit society. Currently, there are many definitions for transactive energy, theoretical ideas, and practical implementations of transactive energy methodologies. As a group, it was decided that a transactivity energy roadmap is needed to focus the group's efforts in this domain and to communicate to intention of the group to others.

The roadmap will envision an evolutionary process from today's grid to a mature transactive energy grid of the future. Understanding that different regions and elements of the grid evolve at different paces, the roadmap will need overlapping ranges of dates for each stage in the roadmap to accommodate this evolution process. The roadmap will be broken into 4 stages starting in 2011 (with current grid) and ending in 2050 (with a fully implemented/mature transactivity energy grid). Also, the roadmap needs to be a living document to be updated as technology, policy, etc. changes in the future.

To ensure the progress of the roadmap, a small roadmap committee was formed and with a plan to have weekly web meetings to develop and refine the roadmap.

**Vision**

In order to develop the roadmap, a common vision of transactive energy now and in the future is needed. The following is a rough draft of the Vision, which will continue to be refined by the roadmap committee.

In a mature transactive grid, optimization and control is largely decentralized and is associated with the parties, devices and systems at the edges and intermediate elements of the grid. Coordination is largely through economic signals communicating the needs and opportunities within the system. There are several different approaches to formulating these signals and taking operational actions based on them.

One approach, for example, is to implement high-speed, priced micro-tenders (buy or sell offers) and micro-transactions for both energy and transport (T&D). Any party can transact with any other party including intermediaries. Transport operators and transactions for transport rights enforce grid constraints. The approach also addresses transactions for environmental commodities created through public policy. Other approaches more explicitly consider the use of economic signals as a means to control and/or coordinate the behavior of distributed energy resources throughout the grid through the monetization of cost of generation and transport throughout the system from generation through distribution to end-use points.

Evolution of current market structures and creation of new market structures and activities will be required. Transactive grid custodians such as today's federal, state and local regulatory agencies and grid operators enforce market rules, grid security, reliability and grid standards and collect, analyze and publish information on grid constraints and capabilities to all parties. Structural market changes evolve through more customer participation in the markets, more distributed generation, transitions to competitive markets, and reductions in any market power. Coordination of changes in retail, distribution, transmission and wholesale markets will be helpful and often necessary.

Transactive approaches should provide new opportunities for all grid elements. Generation, storage and energy using devices and systems may become more self-managed in response to near continuously updated real-time and forward priced bids and offers among the parties. In a grid with increasing penetration of renewables, distributed generation, storage and smart devices the balancing of supply and demand using transactive techniques can efficiently accommodate high levels of renewables. Transactions can be designated as either financial or physical. Physical transactions are intended to schedule physical generation and load delivery. Financial transactions are forward hedges settled against physical delivery prices. Transactive Energy can be applied both in cost-of-service franchise markets and open or partially open competitive markets and markets that are transitioning to more open competitive markets.

**Benefits**

The roadmap will also need to define why is transactive needed/necessary. To this end, a benefits section will need to be included in the roadmap, and evolved to guarantee that transactive energy is helping all parties involved. The following benefits statement is a draft to be refined by the roadmap committee.

The benefits of transactive energy accrue to society at large. The benefits result from efficiency gains in investment, operation and consumption. Public policy (1) sets standards, (2) implements environmental policy by constructing environmental commodities such as renewable and carbon certificates, and (3) influences the sharing of the cost and benefits among parties by explicit subsidies and taxes. Consumers benefit from the lower costs and the use of automation to manage electricity usage and further reduce costs. Producers, wires owners and intermediaries benefit by transparent, stable long-term and spot markets for their products to support investment recovery and profits.

The roadmap will be available 4Q 2012 on the GWAC website.

## TRANSACTIVE ENERGY WHITEPAPER

A whitepaper summarizing the vision of work on transactive energy has been under development since the first workshop in May 2011. Creating this whitepaper has been a challenging task. Discussions on the whitepaper continued during the March 2012 workshop.

A key challenge is succinctly explaining the vision and intent of transactive energy techniques. The current set of techniques represent a diverse set of approaches. While there is common ground between them, summarizing them is challenging.

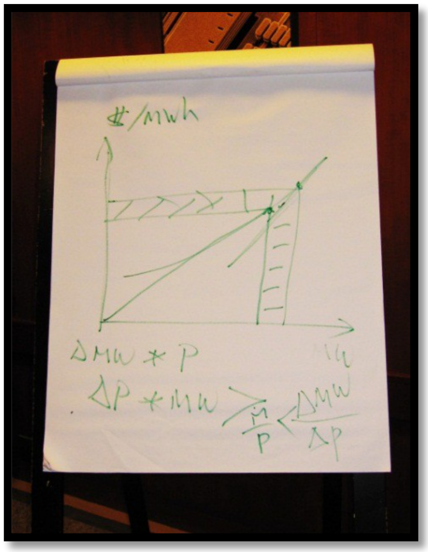
The efforts of the group are now focused on a shorter whitepaper, 3 – 4 pages, building on the previous work and the vision and benefit statements above.

## PLANNING FOR CONFERENCE SESSIONS AND TUTORIALS

There are events in 2012 and 2013 that the group agreed to target for tutorials, panel session, and mini-workshops. This follows on from activities in 2011 and early 2012. A panel session was organized at Grid-Interop 2011 featuring several of the May 2011 workshop participants. Information about this session is included in the Grid-Interop 2011 proceedings that are available at the GridWise Architecture Council website (http://www.gridwiseac.org/historical/gridinterop2011/default.aspx .)

The group also participated in the IEEE Power and Energy Society's 2nd Innovative Smart Grid Technologies conference held in Washington, DC in January 2012. A plenary panel and regular technical panel included participants from the May 2011 workshop and others doing related work.

For the remainder of 2012 and early 2013 the group agreed to target the same meetings. Discussions were held on organizing activities as a part of Grid-Interop 2012 scheduled for early December in Irving, Texas and for the 3rd IEEE Innovative Smart Grid Technologies conference to be held in early 2013.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## FUTURE TRANSACTIVE ENERGY WORKSHOPS

The group generally agreed that future workshops should be held with the intent to continue to expand the number of participants. In two or three years the number of participants should be approaching 50 people and it may make sense to attach the meeting to an existing conference as a track or other focused activity.

## TRANSACTIVE ENERGY WORKSHOP SUMMARY

**Ron Melton**
*GWAC Administrator, PNNL*

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.

We have had a diverse set of participants in both workshops with representatives from academia, the national laboratory community, government, industry and regional power system operators. We have yet to directly engage the utility owner-operators. Their involvement will be key to practical progress in the coming years.

Though only a subset of the Council has been directly involved in these workshops, the rest of the Council has been paying careful attention to the work. The Council sees new approaches such as these transactive techniques as a key to the modernization of the power system and looks forward to on-going efforts in this area.

The summary of the workshop is addressed in the workshop's whitepaper.
http://www.gridwiseac.org/historical/tew2011/tew2011.aspx

To learn more, please visit
http://www.gridwiseac.org/historical/tew2011/tew2011.aspx

## Closing Comments & Special Thanks

We would like to thank all the participants, IBM Thomas J. Watson Labs, and the Department of Energy for another very successful workshop. The workshop resulted in a focused discussion on transactive energy that will be fully described in a white paper to be released in the summer of 2012.

# 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 Workshop**
http://www.gridwiseac.org/historical/tew2011/tew2011.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

**Knowledge Problem Links**
http://knowledgeproblem.com/2012/02/15/video-regulating-monopolies/

http://knowledgeproblem.com/2012/02/17/new-video-richard-epstein-on-simple-rules/

http://knowledgeproblem.com/2012/03/21/learn-liberty-video-should-government-regulate-monopolies/

# Appendix A - Agenda

**Wednesday, March 28, 2012**

| | |
|---|---|
| 9:00 – 9:15 am | **IBM Welcome**<br>*Ron Melton & Ron Ambrosio* |
| 9:15 – 9:45 am | **Review of last year's workshop**<br>*Ron Melton* |
| 9:45 – 10:00 am | **Discussion of workshop objectives**<br>*Ron Melton* |
| 10:00 – 10:30 am | **Closing the gap between wholesale and retail**<br>*Robert Burke* |
| 10:30 am – 11:00 pm | **Demand Response" Bridging Retail to Wholesale-Price Signal Predicament**<br>*Farrokh Rahimi* |
| 11:30 – 12:00 pm | **Closing the Gap Between Transmission on the Pacific Northwest Smart Grid Demonstration Project**<br>*Ron Melton* |
| 12:00 – 1:00 pm | **Retail-level Transactive Control Linked to Wholesale LMPs**<br>*Rob Pratt* |
| 1:00 – 2:00 pm | **Lunch** |
| 2:00 – 2:30 pm | **Pricing Deferrable Energy**<br>*Eliyan Bitar* |
| 2:30 – 3:00 pm | **Energy Micromarkets**<br>*Bill Cox* |
| 3:00 – 3:30 pm | **The TeMix Platform™ for "Transactive Energy" Applications and Demonstrations**<br>*Ed Cazalet* |
| 3:30 – 4:00 pm | **Distributed Energy Resource Integration – Lessons Learned from U.S. Case Studies**<br>*Alan Rourke* |
| 4:00 – 4:30 pm | **The Pacific Northwest Smart Grid Demo – Transactive Control Implementation**<br>*Ron Ambrosio* |
| 3:30 – 4:00 pm | **Lessons Learned from Wholesale Transactive Techniques and their Applications to Retail Transactions**<br>*Ali Ipakchi* |
| 4:30 – 5:00 pm | **Transactive Energy Communications to Consumers**<br>*James Mater* |
| 5:00 pm | **Adjourn** |

**Thursday, March 29, 2012**

| | |
|---|---|
| 9:00-11:00am | **Discussion of Day 1 presentations**<br>*Ron Melton* |
| 11:00-12:00am | **Transactive Energy Whitepaper**<br>*Ron Melton* |
| 12:00-2:00pm | **Planning for Conference Sessions and Tutorials**<br>*Ron Melton* |
| 2:00pm-3:00pm | **Wrap-up, Assignments, Next Steps**<br>*Ron Melton* |
| 3:00pm | **Adjourn** |

# APPENDIX B – PARTICIPANTS' PROFILES

**Ron Ambrosio**

*Global Research Executive, Energy & Utilities Industry, IBM T.J. Watson Research Center*

Ron Ambrosio oversees IBM's Energy & Utilities Industry activities in its eight world-wide Research Laboratories. Ron joined IBM in 1981 at the T.J. Watson Research Center, working in a variety of areas including embedded operating systems, distributed application frameworks, and pervasive computing environments, ultimately focusing on networked embedded computing with particular emphasis on what he coined "Internet-scale Control Systems" – the interoperability of sensor networks and control systems with enterprise systems and business processes. He helped establish IBM's activities in both Intelligent Utility Networks and Sensors & Actuators.

**Eilyan Bitar**

*Assistant Professor, Cornell University*

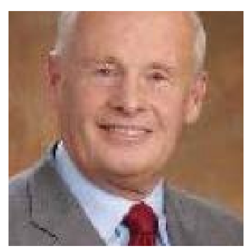
Eilyan Bitar (Ph.D., UC Berkeley) is currently an Assistant Professor at Cornell University in the Department of Electrical and Computer Engineering. Dr. Bitar is an expert on stochastic optimization and control of complex networks with research centering on the redesign of electric grid operations and markets to facilitate the deep integration of renewable energy.

**Robert Burke**

*Markets Development Principal Analyst, ISO New England*

Mr. Burke is a Principal Analyst in Market Development with ISO New England (the Regional Transmission Organization "RTO" for the New England control area). He has thirty-five years of experience in the energy industry. Since joining ISO-NE, he has held various positions and been involved with the development and subsequent on-going improvement of the wholesale energy markets, and worked with market participants regarding demand resource integration issues. In his present position, he works on development of market rule changes for all areas of the New England wholesale markets and their FERC fillings. Mr. Burke has a B.E. in heat and power from Stevens Institute of Technology, and an MBA and MS in Computer Science from Rensselaer Polytechnic Institute. He has furthermore completed all examination requirements in Connecticut for a CPA.

He is a member of IEEE, and since 2009 working on smart grip interoperability as a member of the GridWise Architecture Council. He has made presentations at over three-dozen panel discussions and technical seminars, and authored or coauthored more than a dozen technical papers.



**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". Ed is also VP 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 PhD 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**

*Principle, 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.

**Dario Gil**

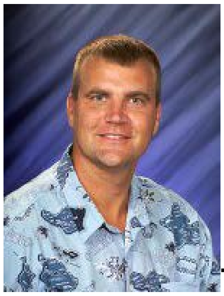
*Program Director for Smarter Energy, IBM T.J. Watson Research Center*

Dr. Dario Gil is the Program Director for Smarter Energy at the T.J. Watson Research Center, where he is responsible for leading IBM's worldwide Energy Research efforts. Dr. Gil also serves as the IBM Research Program Coordinator of the Computational Center for Nanotechnology Innovations (CCNI) at Rensselaer Polytechnic Institute. Prior to his current position Dr. Gil was a Program Manager in the office of the Vice President of Science and Technology, where he was responsible for working with executives to develop the Science and Technology Strategy for IBM's laboratories. Dr. Gil is a frequent speaker at international conferences, universities, research institutions and foundations. His research results have appeared in over 20 international journals and conferences and he has numerous patents in the field of lithography and nanofabrication. Dr. Gil, a member of the IBM Academy and Technology, received his Ph.D. in Electrical Engineering from the Massachusetts Institute of Technology (MIT).

**Soumyadip Ghosh**

*IBM Thomas J. Watson Research Center*

Soumyadip Ghosh is a Research Staff Member of the Mathematical Sciences Division at IBM T.J. Watson Research Center, Yorktown Heights, NY. He holds a BTech from the IIT Chennai, India, an MSE from the University of Michigan at Ann-Arbor and a PhD from Cornell University. This core research interests include theoretical developments in simulation-based stochastic optimization techniques, queuing theory, as well as accurate statistical modeling of complex systems using stochastic simulations. His research interests in the practice of Operations Research methods include smarter energy management, supply-chain analysis, scheduling of large-scale production systems. He can be contacted at ghoshs@us.ibm.com https://researcher.ibm.com/researcher/view.php?person=us-ghoshs



**Todd Halter**

*Scientist, Pacific Northwest National Laboratory*

Todd Halter has over 20 years' experience in the Computer Science, Physics, Mathematics, and Chemistry. Since 1998, Halter has been working on the Department of Energy's Atmospheric Radiation Measurement (ARM) Program as a value added products and data system developer and project manager collaborating closely with atmospheric scientists to obtain a thorough understanding of the data management requirements within atmospheric sciences. Mr. Halter has served as a group manager, project manager, system architect, and developer with experience in all aspects of project management (budget, schedule, resource, and risk analysis), architecture and system design, coding, testing, installation, and maintenance.

**Ali Ipakchi**

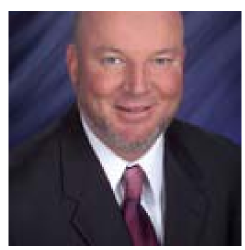
*Vice President of Smart Grid and Green Power, OATI*

Dr. Ipakchi has over 30 years of experience in the application of information technology to power systems and electric utility operations. As the VP 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 PhD from University of California at Berkeley and is co-holder of three US patents on power systems applications and instrument diagnostics.

**Ronald Melton**

*Administrator, GridWise Architecture Council, Pacific Northwest National Laboratory*

Ron Melton is the administrator of the GridWise Architecture Council (GWAC) and a senior power systems engineer at Pacific Northwest National Laboratory. He is also Project Director for the Pacific Northwest Smart Grid Demonstration Project, managed by the Pacific Northwest Division of Battelle. Dr. Melton has over 25 years of experience in systems engineering applied to interdisciplinary problems. He received his BSEE from University of Washington and his MS and PhD in Engineering Science from the California Institute of Technology.



**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 5 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**

*Director of Grid Applications, KEMA*

Mark Knight is a member of the GridWise Architecture Council and is Director of Grid Applications at KEMA. 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 UK and the US and has spanned several areas including distribution, transmission, metering, systems integration, and restructuring. He is a member of the GWAC team working to develop the Interoperability Maturity Model. 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.

**Dave Hardin**

*Senior Director of Smart Grid Standards, EnerNOC*

Dave Hardin is Senior Director, SmartGrid Standards at EnerNOC in Boston, MA. He has more than 25 years of experience architecting, constructing and managing real-time automation and information management systems for energy and manufacturing. Dave specializes in software and communication architectures with a focus on systems integration and interoperability spanning from intelligent devices to enterprise business systems. Mr. Hardin holds a Bachelor of Electrical Engineering from the University of Delaware. He is a Registered Professional Engineer (DE/MD), an IEEE Certified Software Development Professional and a PMI Project Management Professional.

**Pavithra Harsha**

*Research Staff Member, Council / IBM T.J. Watson Research Center*

Pavithra Harsha is a Research Staff Member in the Business Analytics and Mathematical Sciences group at IBM T.J Watson Research Center. She received her Ph.D. in Operations Research from the Massachusetts Institute of Technology (MIT) in 2008. Prior to joining IBM, she was a postdoctoral associate at MIT for two years and worked as a scientist at Oracle Retail for a year. Dr. Harsha's research focuses on problems in the pricing and optimization domain with applications to energy, retail and transportation. Her work received honorable mentions in two dissertation award categories at INFORMS 2009: Aviation's Application Dissertation Prize, and Transportation Science and Logistics Dissertation Prize.

**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.

**Mark Yao**

*Research Scientist, IBM*

Dr. Mark Yao is a research scientist and senior software architect at IBM T.J. Watson Research Center. His research work and interests focus on embedded control & computing, distributed middleware, cyber-physical system (CPS), and integration of CPS with business information system. Dr. Yao was one of original designer and lead author/developer of Internet-scale Control System (iCS), a development tool and runtime platform for large scale distributed cyber-physical control system and interoperability enablement for heterogeneity of applications and systems. Currently, Dr. Yao is part of Smart Energy Research team and one of lead architects of IBM Research team participated in Pacific Northwest Smart Grid Demonstration Project. Mark was also the lead software architect and developer in DoE Olympic Peninsula GridWise Test Project.

**Al Roark**

*Risk Assessment Manager, KEMA*

Al Roark has 22 years of modeling, planning, risk measurement, regulation, compliance with market rules, wholesale power and other energy market experience. Mr. Roark helps clients ranging from RTO/ISOs, transmission owners, end users and utilities to find software solutions, market and risk valuations and forecasting energy impacts.

Mr. Roark has specific experience in identifying, measuring and managing wholesale energy portfolios and in forecasting wholesale energy market prices and impacts. In addition to designing and approving models and developing software solutions to measure unbundled energy, ancillary services and congestion portfolios across five RTOs, Mr. Roark led involvement with the Committee of Chief Risk Officers and ethics and regulatory training. Mr. Roark has designed and implemented risk management programs for over 30 power, gas and oil clients. While working at Exelon, Avista and Destec, Mr. Roark was responsible for setting up and approving Board Level Risk limits, risk management, portfolio measurements and compliance associated with wholesale operations. In addition to writing and approving financial report sections on market risk, Mr. Roark certified reports to credit agencies and third parties.

Mr. Roark has worked as a senior economist with WEFA, providing forecasting and energy consulting for various international clients. Mr. Roark developed and maintained various energy models measuring the impact of energy policies. Mr. Roark is a former Commodity Trading Advisor and held System Operator Certification at NERC.

**Pam Sporborg**

*Analyst, Office of Energy Policy and Innovation at the Federal Energy Regulatory Commission*

Pam Sporborg is an analyst in the Office of Energy Policy and Innovation at the Federal Energy Regulatory Commission. Prior to joining FERC, Pam was the Load Management Lead at the Bonneville Power Administration, overseeing planning, implementation, and R&D activities for BPA's Demand Response programs. In 2010, her project, the BPA/Seattle City Light OpenADR Project received the PLMA Innovative Application of Technology Award. In 2008, Pam was awarded a Presidential Management Fellowship with the US Department of Energy, which enabled her to spend six months researching the integration of renewable energy through automated demand response at Lawrence Berkeley National Lab. Prior to discovering her fascination with all things electricity, Pam was a Microfinance Research Fellow at Mann Deshi Mahila Bank in Mhaswad, India. Pam received a Bachelor of Science from Cornell University and a master's in public administration from Portland State University. When not debating the future of the electric grid, Pam enjoys hiking, backpacking, cooking, and traveling.

**Michael Valocchi**

*Vice-President/Partner, IBM Global Business Services*

Michael is currently the Global Energy and Utilities Industry Leader for IBM Global Business Services. In that role, he is responsible for the development and execution of the industry strategy to delivery consulting services as well as the development and direction of the Industry thought leadership and solutions strategy. Michael is a member of IBM's Integration & Values Team, which includes the top 300 leaders from across the company. He is one of member of the IBM Industry Academy. Prior to this position, Michael was a Business Strategy Partner with IBM Global Services and PricewaterhouseCoopers Consulting.

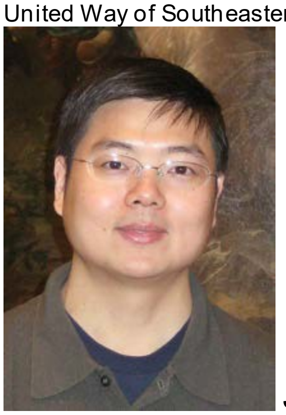
Michael has 26 years experience serving energy and utility clients, has proven leadership skills and expertise in financial, strategic, operational and regulatory issues, and has directed, managed and delivered solutions to complex business problems and issues. Michael is an accomplished business strategist with deep experience in leading complex client projects in the areas of financial, operational and regulatory strategy with specific expertise in smart grid strategy, policy and regulatory strategy and large scale technology implementation. He successfully delivered projects in the areas of mergers and acquisitions, trading and risk management, cost control, financial re-engineering, asset strategy, regulatory strategies and market entry studies. Michael has in-depth financial and accounting experience in areas of mergers and acquisitions, financial reporting, control structures, cost allocation and rate structures.

He is recognized for deep industry knowledge, being responsible for the development of industry point of views and various thought leadership pieces. He has been a thought leader in the area of consumer empowerment and business model transformation and has authored the following papers in the last 3 years: Switching Perspectives: Creating New Business Models for a Changing World of Energy, Lighting the Way: Understanding the Smart Energy Consumer, Plugging in the Consumer and a CEO Survey Perspective.

Earth2Tech ranked Michael on The Networked Grid 100 list, a compiling of the top 100 "Movers and Shakers" of the Smart Grid. Michael is a frequent speaker at industry events around the world and is regularly quoted in major publications, including The Wall Street Journal, NY Times, Fortune, USA Today, Public Utilities Fortnightly, Electric Light & Power, LP, Platts and The Financial Times. He has also appeared in numerous television programs including CNBC and satellite media channels discussing Smarter Energy and Smarter Cities topics. Michael serves on The Energy and Utilities Project Executive Board for Kyoto Publishing and the Interconnectivity

Committee and the Patrons Committee of the World Energy Council.

Michael holds a BS in Accounting from Saint Joseph's University in Philadelphia, PA and is a Certified Public Accountant. He is on the Board of Directors of the United Way of Southeastern Pennsylvania.



**Jinjun Xiong**

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Dr. Jinjun Xiong is a Manager and Research Staff Member at the IBM Thomas J. Watson Research Center, working in areas of large-scale electrical grid modeling, simulation, data analytics, and optimization. He has published more than 60 technical papers in refereed international conferences and journals. He has also filed more than 20 U.S. and world-wide patents. He was the PI for the U.S. Department of Energy (DOE) Project, Request for Information on Computation Needs for the Next-Generation Electric Grid from 2010 to 2011. He is also a member of the Pacific Northwest Smart Grid Demonstration Project, one of the largest U.S. DOE Smart Grid Demonstration projects.