Harnessing Flexibility in an Evolving Electric Power System

Prepared by

The GridWise Architecture Council

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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.

ACKNOWLEDGMENTS

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INTRODUCTION

The Third International Conference and Workshop on Transactive Energy brought together representatives of government, industry, utilities, vendor organizations and academia to advance understanding and implementation of transactive energy. The core principle of transactive energy is to combine economic and control techniques, leading to improvements in power grid reliability and efficiency. It encompasses techniques for managing the centralized and local generation, flow, and consumption of electric power within an electric power system through the use of market-based methods while maintaining grid reliability.

As a centerpiece of the recently completed Pacific Northwest Smart Grid Demonstration Project, transactive energy has left many in the industry eager to see where the technology will go next. The project highlighted the utility of communicating pricing signals and future load predictions, as well as underscoring the need for more evolution of the technology. TES2016 provided a forum where these lessons were discussed and digested, and ideas for the future of transactive energy germinated.

TES2016 built upon the success of the previous two conferences, offering a variety of worthwhile activities for energy professionals, policy makers and those seeking to enhance grid intelligence with a focus on value. The conference featured keynote talks from energy industry leaders, international expert panels, and presentations of selected papers on topics critical to the success of transactive energy. There were also four interactive workshops where attendees discussed and developed answers to important questions about the future of the intelligent electricity grid.

The 2016 conference continued a productive partnership between the GridWise® Architecture Council (GWAC) and Smart Grid Northwest. Support for this conference at the World Trade Center in Portland, Oregon, on May 17 - 19 2016 was provided by Portland General Electric and other industry leaders.

ABOUT SMART GRID NORTHWEST

Founded in 2009 as Smart Grid Oregon, Smart Grid Northwest has expanded the regional focus and impact of the organization with a mission to promote, grow and enable the smart grid industry and infrastructure in the Pacific Northwest. The organization has 70 member companies and growing, representing regional utilities, smart grid industry companies, major energy users (corporations), service firms, higher education groups, government agencies, non-profits, and other grid development stakeholders. Smart Grid Northwest's efforts to promote a cluster of smart grid related companies, while also working to enable deployment of smart grid solutions, focuses in three priority areas: education, policy, and planning. More details are available at SmartGridNW.org.

The World Trade Center, Portland, OR

About the GridWise Architecture Council

The GWAC was convened in 2004 by the U.S. Department of Energy (DOE), to promote and enable interoperability among the many entities that interact with the nation's electric power system, with PNNL providing administrative and technical support with DOE funding. As a volunteer council, the GWAC includes practitioners and leaders with broad-based knowledge and expertise in power, information technology, telecommunications, financial systems and other fields who are working together toward a coordinated GridWise vision—the transformation of the nation's energy system into a rich, collaborative network filled with decision-making information exchange and market-based opportunities.

DAY ONE

CONFERENCE WELCOME AND COMMENTS

SPEAKERS: RONALD B. MELTON, GRIDWISE ARCHITECTURE COUNCIL ADMINISTRATOR;
CHRIS IRWIN, US DOE,
JAMES MATER, GENERAL MANAGER, SMART GRID AND DIRECTOR, QUALITY LOGIC,
DAVID FORFIA, SENIOR DIRECTOR, INFORMATION TECHNOLOGY SERVICES,
LARRY BEKKEDAHL, PORTLAND GENERAL ELECTRIC VICE PRESIDENT, TRANSMISSION & DISTRIBUTION

SLIDES: CLICK HERE: LARRY BEKKEDAHL

The conference began with a welcome to Portland by Ron Melton and David Forfia on behalf of the GridWise® Architecture Council, and James Mater on behalf of Smart Grid Northwest. Ron Melton provided a brief history acknowledging the participants in the previous GWAC transactive energy workshops and conferences and thanking the sponsors of this conference and workshops. He outlined the theme of this year's conference which was "Transactive Energy Systems: Harnessing Flexibility in an Evolving Electric Power System." Larry Bekkedahl welcomed participants on behalf of Portland General Electric and provided background on related Portland General Electric activities.

KEYNOTE – NEW YORK'S REFORMING THE ENERGY VISION (REV) PROGRAM

BUILDING A CLEAN, RESILIENT AND AFFORDABLE ENERGY SYSTEM FOR ALL NEW YORKERS

SPEAKER: AUDREY ZIBELMAN, CHAIR OF NEW YORK STATE PUBLIC COMMISSION

Ms. Zibelman, chair of the New York state Public Service commission gave an overview of her efforts to change the state's energy regulations and outlined how utilities will operate under the Reforming Energy Vision (REV) initiative.

The effort will provide clean, affordable and reliable energy and will strengthen New York's electricity grid while encouraging strategic investments to create a sustainable clean-energy industry. New York is working to position itself as a national leader in transforming it's energy infrastructure for the 21st century.

GWAC FOUNDATIONAL SESSION

MODERATOR: DAVID FORFIA, GWAC CHAIRMAN, ELECTRIC RELIABILITY COUNCIL OF TEXAS

SPEAKERS: DON HAMMERSTROM, PACIFIC NORTHWEST NATIONAL LABORATORY,
PAUL DE MARTINI NEWPORT CONSULTING GROUP, LLC.;
JEFFREY TAFT, PACIFIC NORTHWEST NATIONAL LABORATORY;
DAVID FORFIA, ELECTRIC RELIABILITY COUNCIL OF TEXAS

The GridWise Architecture Council has identified four transactive energy related topics for presentation in the foundational session. The purpose of this session is to provide important background information to help establish common understanding of transactive energy system related topics for all conference participants.

The topics for TESC2016 are:

- **Transactive System Valuation** - how do we value or measure the impact of transactive systems in support of distributed energy resource integration?
- **Distributed Energy Resource Integration Challenges** - what are the key challenges faced by utilities with increasing levels of distributed energy resources?
- **Grid Architecture** - what are the current broad architectural concerns and considerations, and concepts that can facilitate migration to an electric power system supporting higher penetrations of distributed energy resources while maintaining reliability, resilience, and economic efficiency?
- **The GWAC Transactive Energy Decision Maker's Checklist** - what are key questions and considerations for executives, policy makers, regulators and other electric power system decision makers as they consider the investments in transactive energy systems?

Valuation of Transactive system services

SPEAKER: DON HAMMERSTROM, PACIFIC NORTH NATIONAL LABORATORY

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Dr Hammerstrom discussed his report about valuation methodology, focusing where transactive energy systems have been selected to coordinate the exchanges of value between actors. A guiding principle is that the interactions between a system's responses to the transactive energy system and incentivized objectives within the transactive energy system must be explicitly modeled, thus avoiding overly optimistic conclusions about the envelope of value that might be realized. Caution should be used in that relatively few objectives are explicitly incentivized by transactive energy systems. Some benefits accrue more passively and indirectly through their correlations with other impacts and benefits that are directly incentivized. This rigor is essential where different transactive energy system mechanisms are to be compared because the distinctions between alternative mechanisms can be subtle. A suitable valuation framework requires that a significant level of abstraction be maintained if it is to enable exploration of the diverse use cases that are being posed for transactive energy systems. And comparisons must be made against baseline scenarios to obtain meaningful valuation results.

Dr Hammerstrom proposes a methodology in which routine operations are separated from growth expectations and opportunities. The combination of growth and operational modeling inform a series of yearly costs and benefits, to which decision objectives (e.g., net present cost or low risk) may be applied. The recommended separations between the operational, growth, and economic treatments facilitate extensible insertion of methods later as they become realized and needed. Dr Hammerstrom suggests that this extensible valuation methodology may become the basis for the sharing of valuation tools and practices among a community of valuation developers (e.g., analysts) and consumers (e.g., states and regulators).

Dr Hammerstrom further proposes that standard visual modeling should accompany future valuation studies. In the transactive energy system domain, E3 Value diagrams, which may be represented as UML use case diagrams, offer a convenient mechanism for rendering a precise representation of the values being exchanged and the actors who exchange value. E3 Value diagrams show the exchange of business value in a way that is potentially foundational for valuation studies—they facilitate an assessment of fairness and net benefit for each stakeholder if all the various values entering and leaving an actor block are summed. E3 Value diagrams can be represented using UML use case diagrams, thus taking advantage of a well-accepted standard visual modeling tool.

Additionally, UML activity diagrams are proposed for the representation of individual operational models. Operational models, as used here, inform a specific impact or benefit during a given year. The UML activity diagrams are precise functional representations of the operational models, and they may be expanded to reveal additional detail, even individual computational steps. It is tempting to presume that all operational models will entail time-series simulation. In fact, operational models are found to be quite diverse. They may require time-series simulation, statistical treatment, or even game theory to inform impacts that will be needed to conduct valuations. Further, alternative operational models may reveal the same impact, where various alternatives might be acceptable as assumptions allow, or necessary as available data require.

The global world of operational models can be thought of as a wall of navigable flows between the operational models. The outputs of one model are inputs for others. There are perhaps innumerable possible paths through the wall. But at least one viable path must exist between available input data and needed impacts if a valuation study is to be completed.

This paper is based on project work that has been funded by the U.S. Department of Energy. Input has been sought from numerous practitioners, and interim results have been shared and discussed at two meetings of distributed energy resource integration valuation experts hosted by the GridWise Architecture Council.

Two Visions of a Transactive Electric System

SPEAKER: PAUL DE MARTINI, NEWPORT CONSULTING GROUP, LLC

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This session focused on discussions about a transactive grid and how the future of the electric industry abounds with terms like decentralized, market design, distribution system operator and distribution marginal pricing. However, less visible in these discussions is the emergence of two clearly distinct visions or paradigms for how a decentralized, transactive electric system with high penetration of distributed energy resources (DER) could be designed to operate. This session started from the operations perspective and described the two visions in some detail, comparing them and drawing implications for key design and regulatory questions being debated today. Operations, in this context, means reliable operation of the high-DER physical electric system as a whole, from the balancing authority area to the end-use customer, and thus entails operation of both the distribution and transmission systems as well as the interfaces between them.

One vision centers around a centralized, whole-system optimization performed by the transmission system operator (TSO), who may also operate wholesale spot markets as an independent system operator (ISO) or regional transmission organization (RTO). Under this model the TSO needs detailed information and visibility into all levels of the system, from the balancing authority area down through the distribution system to the meters on end-use customers and distribution-connected devices.

The other vision involves a decentralized, layered-decomposition optimization structure, for which optimization at any given layer of the system only requires visibility to the interface points with the next layers above and below, and does not need visibility to what's inside those other layers. The TSO under this layered optimization paradigm would see a single virtual resource at each transmission-distribution interface and would not need to be concerned with the individual DER or customers below the interface. This is not unlike the existing operational paradigm between balancing authorities, which primarily focuses on interchange flows between balancing authority areas.

Each of these visions can be used to characterize a different mature end state of the high-DER electric system. The two visions are deliberately drawn as conceptually distinct to reveal key operational design choices and derive some observations to help inform today's policy, market design and system architecture discussions. The choice of which vision to aim for in any jurisdiction will have major implications for specifying the complementary roles and responsibilities of the distribution system operator (DSO) and the TSO, and consequently for the business model of the distribution utility. The choice will also imply different directions on questions like the value of distribution-level locational marginal pricing, the optimal uses of markets and controls to maintain reliable system operation, and the benefits of decentralization for enhancing system security and resilience.

Perhaps surprisingly, both visions can fully support a transactive grid including distribution-level peer-to-peer transactions, assuming the regulators adopt regulatory frameworks to enable such transactions.

Framework and Transactive Grid Codes for DER Integration

SPEAKER: JEFFREY TAFT, PACIFIC NORTHWEST NATIONAL LABORATORY

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The use of grid codes is well understood for transmission level interconnection. The concept has recently been discussed in the context of DER integration at the distribution level, but for this purpose a grid code must necessarily involve more than the primary aspects of physical and electrical connection. The present focus on smart inverters is a part of the picture, but there is a still a very large element missing in these views. The gap is at the operational level and involves the emerging combined market-control aspects of distribution operations.

In this presentation Dr Taft showed how to use grid architecture methods, specifically layered decomposition, network of structures, and market-control constructs, to create a formal framework for DER integration. Such a framework ties together DSO concepts, distribution interaction with bulk energy systems, distribution operations, and grid control and distribution reliability management with the coordination of high penetration mixed DER, whether it is prosumer owned, utility owned, or merchant owned. This framework in turn informs the content of a transactive grid code for DER integration as well as the application of relevant interoperability standards.

Each utility will develop its own grid code for DER integration this work provides a simple stack model as a guide for the elements to include in such a code. The value of a transactive grid code for utilities, for prosumers, for energy services organizations, and for product/system developers is described in the presentation, and the relationship between the Transactive Grid Code Model and the GWAC Stack is noted, as is the impact of this framework on cyber security.

Transactive Energy Decision-Maker's Checklist

SPEAKER: DAVID FORFIA, ELECTRIC RELIABILITY COUNCIL OF TEXAS

DOCUMENTS: GWAC TE DECISION-MAKER'S CHECKLIST

David Forfia introduced an animated video presentation from Mark Knight, Emeritus Chair of GWAC, which discussed GWAC's TE Decision Maker's Checklist. This is a tool that uses thought provoking questions to assist a decision maker and decision making process in evaluating the potential use of transactive energy systems. Intended users of the Checklist include decision makers in utilities, vendors, regulatory bodies and other organizations considering investments or business decisions related to the use of transactive energy systems. This provided a brief overview of transactive energy and why the industry needs a decision maker's checklist.

The animation can be downloaded here. **Warning**: *it is approximately 50Mb*.

LUNCH KEYNOTE –ELLIOTT MAINZER, ADMINISTRATOR AND CEO, BONNEVILLE POWER ADMINISTRATION

OVERVIEW OF BPA'S TECHNOLOGY AND INNOVATION PROGRAM AND THE CURRENT STATUS OF ENERGY PRODUCTION IN THE PACIFIC NORTHWEST

SPEAKER: ELLIOT MAINZER, ADMINISTRATOR & CEO OF THE BPA

Elliott Mainzer described BPA's perspective on transactive energy, alternative energy, and goals for the future during his keynote speech at the 2016 Transactive Energy Conference.

> *"This is an interesting and transformative time. There are now limits on resources, and we as a Federal agency need to be smart about technology. Power loads in Portland, Oregon and Vancouver, Washington are really spiking and we need new tools. We need to look at every last solution for power congestion before building new lines,"* stated Mainzer.

Mainzer also discussed the many changes and challenges in his 14 years at BPA: the challenges of integrating a large portion of wind into the service area and how quickly that build-out outstripped the capacity of hydro to adjust to that variability. With additional wind development expected, BPA issued a Request for Offers for implementation ready solutions to meet this flexibility need. Mainzer noted that flexibility has become a highly desirable commodity for BPA, and BPA is following the evolution of Transactive Energy with great interest.

He noted that this is a National and Global effort, evidenced by multi-national audience. New York and Hawaii will bear close attention. Regulators are starting to grow engaged – but many questions remain, especially in the 'value proposition': How does this benefit rate-payers universally? How is Reliability addressed? Is there truly a Resiliency dividend? Is this the best approach for emphasis as we de-carbonize the energy sector?

Mainzer agreed with comments and concerns expressed at the conference and would like regulators and utility representatives to answer these questions:

- How do you build a reliable DER supply?
- What are various pricing algorithms for short term distributed energy?
- How do you aggregate the technology?
- What are the best controls and pricing structures for distributed energy resources?

One take away: This can have great benefit for BPA customers if it facilitates de-carbonizing transportation by providing a new revenue recognition mechanism.

Panel Session I – Technology I

Moderator: James Mater, QualityLogic, Inc.

Slides: Click Here

Panelists: Linda Rankin, V-Squared,
Farrokh Albuyeh, OATI,
Bruce Nordman, LBNL,
Don Hammerstrom, Pacific Northwest National Laboratory

James Mater discussed how transactive energy systems offer a platform for harnessing flexibility through the coordination of the behavior of all the assets connected to the distribution system. But which technologies best enable Transactive energy systems with the opportunity to deliver tangible benefits that provide flexibility to deal with near time opportunities and also provide the ability for the Transactive system to adapt to the continued evolution of the power system?

This session featured discussions of lessons from bulk power systems for Transactive Energy systems at the distribution level; a review of the results and lessons of the largest Transactive energy experiment to date, the PNW Regional Demonstration Project; a proposed architecture for Transactive systems within the building and lessons learned from the internet; an analysis of the Internet of Things and how it may enable Transactive Energy systems and finally, a description of an experiment to demonstrate how IoT may support specific Transactive Energy messaging requirements.

The panel session included question and answer time as well as preparation for the following workshop that worked with the panel information to consider further the issues the technical side of Transactive Energy.

Transactive Systems and IoT: Leveraging the IoT Platform

SPEAKERS: LINDA RANKIN, V-SQUARED

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When the electrical utility industry began seriously implementing strategies to enable consumer participation in a "smarter grid", the initial focus was on smart meters that would include the capability to exchange information with devices or an energy management system in a residential or commercial building. This led to the Zigbee Smart Energy Profile 1.0 (SEP 1) that is currently installed in over 50 million smart meters worldwide (among other solutions). These solutions required both dedicated hardware and communications capabilities as well as software applications to monitor, communicate and coordinate, and then manage the energy consumption of the devices.

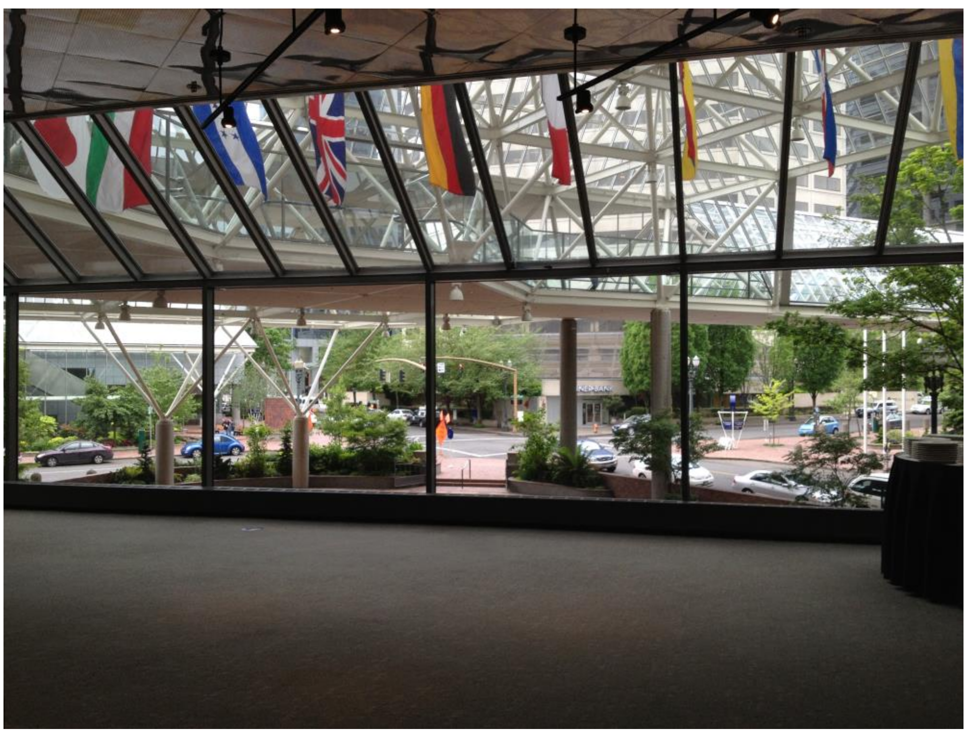
However, soon after the mass deployment of smart meter capabilities started in the mid-2000s, a distinctly different path to "smart homes" and "smart buildings" evolved via cloud services and the explosive growth of IP connect smart phones. This coupled the proliferation of low cost IP addressable microcontrollers in everyday home devices, what we now call the internet of things (IoT), provides an alternative way fulfilling the vision SEP 1. The simple idea is that every device or "thing" from a refrigerator to a light bulb to a doorbell to a thermostat would be connected over an IP network. Once this new "connected home" or "connected building" technology got started, the value of using a smart meter with unique firmware and associated systems in buildings for dedicated communications and control about energy management became obsolete. Why build a separate communications systems and require devices to have dedicated energy management capabilities – i.e., dedicated hardware and software - when you could use a lower cost, ubiquitous communications platform that enabled multiple different applications from entertainment to home security to remote monitoring and control to also hosting applications for energy management on top of such a platform? By using the scale and breadth of different applications on a common platform, the costs of any single application, such as energy management, are drastically reduced. This is essentially the vision of the Internet of Things as applied to buildings.

Linda Rankin discussed how, from a Transactive Energy perspective, a critical factor in enabling such systems is the ability to exchange information quickly, efficiently and cheaply. This enables the planning and financial markets required to allow for truly Transactive systems to operate efficiently. Why couldn't the IoT platforms being deployed today by consumers be utilized for

Transactive energy applications? What is required of the IoT to enable such applications? How would utilities interface their Transactive systems (which may look like advanced Demand Response and/or DER integration systems) to the emerging IoT platform?

The objectives of Linda Ranin's paper and presentation were to:

1) assess the current state of IoT platforms to meet the requirements of Transactive Energy systems (one of which is to provide efficient, interoperable communications protocols)
2) discuss how utilities would interface the evolving applications and communications protocols for Transactive Energy, demand response and DER integration with the IoT platforms and what challenges would be encountered
3) describe a specific demonstration of integrating the OpenADR 2 protocol into a popular IoT platform and the resultant ability to impact energy demand through an IoT communications platform.



Applying Lessons Learned from Transmission/Bulk Power De-regulation to Transactive Energy at the Distribution/Retail Level

SPEAKER: FARROKH ALBUYEH, OATI

As the concept of Transactive Energy at the retail/distribution level takes shape, there are a number of parallels that can be drawn between the de-regulation of the wholesale/transmission sector in the mid-1990s and the opening up of the distribution grid to accommodate the increasing proliferation of Distributed Energy Resources (DER) including Demand Response (DR) and Renewable/Variable Energy resources. As a result of opening up the transmission grid and creating various electricity markets, Balancing Area (BA) operators saw a need for tools to monitor and control flows in their transmission system resulting from transactions external to their system. This resulted in the development of Electronic Tagging (e-Tagging) systems and procedures to provide the required visibility and control. Participants in the electricity markets required the development of a transmission capacity reservation system in order to guarantee their transactions could be implemented, resulting in the development of the Open Access Same-Time Information System (OASIS). The concept of contract path versus physical path gave birth to the development of congestion management systems like Interchange Distribution Calculator (IDC) in the Eastern Interconnection, webSAS in the Western Interconnection, and other methods implemented by Independent System Operators (ISO)/Regional Transmission Operators (RTO). Various methods for commitment and scheduling of resources, market transactions, and transmission scheduling were tried with mixed results. The demise of the California Power Exchange is only one example of a failed attempt.

With the proliferation of various forms of DERs, the concept of Transactive Energy is finding its way into the distribution sector. The proposed Distribution System Platform (DSP) construct in the east, and the Distribution System Operator (DSO) in the west promise wider incorporation of DERs and in larger scales. Both constructs propose opening the distribution grid and providing access to various users and participants. The same issues already dealt with on the transmission side are now facing distribution system and market designers and operators. The DSO/DSP operator needs to have visibility and control to transactions and resulting flows in the distribution grid. Congestion in the distribution grid needs to be dealt with. Participants need guarantees for available transport capacity for their intended transactions. Participants, or “prosumers,” require the ability to transact with one another or to offer energy and services in support of distribution grid operations as well as in support for system-wide operations. Retail energy and grid service markets are somewhat simpler in nature than their counterparts at the wholesale level but with larger dimensionality.

Dr. Albuyeh’s presentation presented parallels between the deregulation and opening of the transmission sector with that of the distribution system. This presentation also presented some of the tools and methods developed in the wholesale side and how these, with some modification, can be applied in the distribution side.

Using Internet Design Principals to Inform Transactive Energy Architecture

SPEAKER: BRUCE NORDMAN, LBNL

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Dr. Nordman described how there are many similarities between our communications systems and our electricity systems – plus a few important differences. With the Internet arguably the most successful new technology of the last half century, it makes sense to identify all applicable lessons it may hold to redesigning our electricity systems, including how to incorporate principles of transactive energy (TE). This presentation identified key Internet design elements and proposed an architecture of technology and policy for power distribution that fulfills these principles. The scope is transactions (of money and electricity) that occur at the building meter, or inside buildings transactions between grid entities are not addressed. The proposed architecture diverges from traditional TE approaches in several respects it merits consideration for its many advantages.

Internet principles applied include: beginning with a clear layered model isolating complexity into layers and services ensuring that technologies are universal and independent of scale intensively embracing simplicity not being impaired by legacy technology considerations and constructing the system on a network model.

Key architectural components of Local Power Distribution (LPD) are:

- Prices at the building meter are highly dynamic (no restriction on how much or how fast prices change) price forecasts are non-binding and prices for buying utility power may be higher than for selling.
- Buildings are only price-takers and do not directly communicate with the utility grid (vehicle charging may be an exception).
- Utility prices may vary locally to account for T&D losses and capacity constraints.
- The utility grid has no visibility inside of buildings, including even the presence of local generation and storage.
- Within buildings, power is segmented into networked domains - nanogrids - that contain local storage and have distinct power availability and so local price.
- Nanogrid controllers, including local generation, negotiate with each other for power exchanges based on their own local prices. Many will be direct current. End-use devices are price-takers.

As out of scope, negotiations among entities whose primary function is to generate or store electricity for the grid may use traditional TE forward and spot markets.

Dr Nordman explained how the LPD architecture has many advantages over other approaches. Utilities can deploy dynamic pricing without interacting with customer devices and so do so quickly and inexpensively. Customers can deploy LPD technology without interacting with an outside entity (other than eventually receiving a one-way broadcast of meter prices), and do so quickly and inexpensively. Privacy and security are maintained for both sides as there is no communication other than the price signal. LPD technology can be deployed incrementally and organically, and provides additional benefits such as energy savings and local reliability. By separating the meter relationship from technology inside of buildings, different locations can have varying meter relationships due to regulation or other reasons and still utilize the same internal technology. Buildings can use TE internally even if not implemented by the utility.

Dr Nordman concluded by saying that LPD is a practical and efficient way to move TE forward, and its availability as a core element could give modern power distribution an appeal akin to that provided by Internet technology.

Retrospective on the PNWSGD Transactive Energy System Experience

SPEAKER: DON HAMMERSTROM, PACIFIC NORTHWEST NATIONAL LABORATORY

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The Pacific Northwest Smart Grid Demonstration provided an opportunity to design and implement a transactive energy system over a grid region that encompassed multiple states and utilities. The system operated for two years. Now, a year after the conclusion and dismantling of that transactive energy system, it is time for retrospection. Dr. Hammerstrom addressed the following questions in his presentation: How did the system work? What was the system meant to accomplish? What worked well? What aspects would be improved if the opportunity were to occur again?

PANEL SESSION II – TECHNOLOGY II

MODERATOR: RON AMBROSIO, IBM SMARTER ENERGY RESEARCH

PANELISTS: CHAD CORBIN, PACIFIC NORTHWEST NATIONAL LABORATORY,
ANNABEL PRATT, NREL,

NARAYANAN RAJAGOPAL,TATA CONSULTANCY SERVICES,
AMRO FARID, THAYER SCHOOL OF ENGINEERING AT DARTMOUTH

Transactive energy systems offer a platform for harnessing flexibility through the coordination of the behavior of all the assets connected to the distribution system. But which technologies best enable Transactive energy systems with the opportunity to deliver tangible benefits that provide flexibility to deal with near time opportunities and also provide the ability for the Transactive system to adapt to the continued evolution of the power system?

This technical session had a strong focus on microgrids and Transactive Energy. The sessions included simulation of microgrids using decentralized multi-agent control constructs; a multi-campus Transactive Energy project underway to serve regional grid needs and provided a research platform for Transactive energy experiments; a look at the potential for engaging residential resources responding to pricing signals and simulations of engaging residential appliance as grid optimization resources.

Finally, the panel concluded with a presentation of using dynamically configured microgrids in a Transactive Energy system. The panel session included question and answer time as well as preparation for the following workshop that worked with the panel information to consider further the issues the technical side of Transactive Energy.

Regional Transactive Campus Testbed - Design and Initial Results

SPEAKER: CHAD CORBIN, PACIFIC NORTHWEST NATIONAL LABORATORY

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The Clean Energy and Transactive Campus project connects the PNNL, UW, and WSU campuses to form a multi-campus test bed for transaction-based energy management. Chad Corbin described how the project builds on the foundational transactive system established by the Pacific Northwest Smart Grid Demonstration (PNWSGD), to construct a test bed as both a regional flexibility resource and well as a platform for R&D on buildings/grid integration and information-based energy efficiency. This presentation reviewed progress towards this effort, the methods employed, and initial findings from the transactive experiments conducted. Future plans for expanding the project were also discussed.

Transactive residential electricity supply

SPEAKER: ANNABEL PRATT, NREL

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The approximately 100 million single family homes in the United States account for 36% of the electricity load. Annabel Pratt described how residential electricity supply is a key area to address in a transition of the power system from its traditional structure to a transactive system. Consumer adoption of home automation products is increasing, thus paving the way for the implementation of more sophisticated technologies ready for transactive systems. This presentation presented the capabilities and structure of one of those technologies – home energy management system (HEMS) algorithms that can react to a price signal return information, e.g., a power profile forecast back to a central controller and automatically act on behalf of the homeowner. The central controller may be either a utility or a third party provider, e.g., an aggregator. The proper design of the price signal will lead to the realization of a more flexible power system through the provision of grid services by buildings. These HEMS algorithms determine the optimal operational schedules of residential appliances including heating, ventilation and air conditioning (HVAC) systems, electric water heaters, refrigerators, residential batteries, electric vehicles, standalone micro combined heat and power (CHP) generators, dishwashers, washer dryers, and pool pumps, in order to meet the homeowner's objectives. Multiple objectives can be specified, including a reduction in cost, energy use and/or peak demand. A stochastic, multi-objective optimization using a Model Predictive Control framework is used that accounts for consumer preferences, electricity price and weather forecasts, and forecasts of rooftop PV power generation.

Annabel Pratt also presented the capabilities of a co-simulation platform, the Integrated Energy System Model (IESM) that simulates transactive energy systems. The IESM is a co-simulation framework – it brings together the capabilities of multiple simulators in a shared execution environment and manages time and data exchange between them. The IESM currently links HEMS controllers and GridLAB-D, an event based distribution feeder and load simulator developed by PNNL. GridLAB-D includes physics-based models for buildings as well as a number of specific end use appliance models including dishwashers, refrigerators, clothes washers and dryers. It also models photovoltaic (PV) systems, battery systems, and electric vehicles. In the IESM, consumer behavior is modeled as preferences programmed into the HEMS controllers. Variability is introduced across the population through randomization of HEMS preferences and appliance operations. Results were shown from a large scale simulation with hundreds of homes on a feeder with each using a HEMS to manage appliance operations. The HEMS co-optimizes occupant comfort and energy cost. The simulations were performed on NREL's high-performance computer, Peregrine.

Finally, a smart home test bed that is under development was presented. It couples the IESM co-simulation platform with physical appliances by applying hardware-in-the-loop techniques. The test bed will accelerate and reduce the cost of technology evaluation by combining large-scale software simulation with hardware evaluation of a small set of representative systems. In addition, hardware operations will be evaluated and the data used to refine the simulation models. Results from a simulation linked to air conditioner and thermostat hardware were also presented.

Integration of a Dynamic Microgrid Configurator into the Transactive Energy Framework

SPEAKER: NARAYANAN RAJAGOPAL, TATA CONSULTANCY SERVICES

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Network Resilience is one of the main objectives of the conceptual architecture required to implement Transactive Energy (TE) Framework. During network contingencies the system should be able to operate with minimal service disruption and restore normal operations at the earliest. Microgrids are a key element to build higher resilience into the distribution network. The presentation described a novel method to intelligently honeycomb (irregular honeycombs) the Utility's territory into numerous Microgrid cells linked together by smart technology to be effective in:

- Maximizing the number of customers served under all conditions (including major contingencies)
- Effective / Enhanced utilization of distributed green energy resources
- Implementation of a Microgrid Based Operation (MGBO) model for the Utility’s service area will require the following:
  - A Dynamic Microgrid Configurator (DMC) that will serve as an effective tool to the dispatcher to dynamically honeycomb the entire service area into a number of contiguous Microgrids based on network conditions existing
  - An MGBO controller which will be a part of the Control Center to initiate control actions required for dynamic operation of the service area based on the dynamic honeycomb
  - A Market platform with necessary interfaces to include the elements of MGBO as part of the market context – essence of the TE Framework

It was described how the DMC needs to be well integrated into the TE architecture through mature interfaces based on standards such as Energy Interoperation (EI). This presentation proposed an interface model of the DMC to the other systems whereby the Distribution System Operator can interact with the entities involved (Customers, Aggregators, Other Microgrid Operators, and other Market facing entities) to effectively operate and manage the entire territory (distribution service area).

The DMC will need to have the following set of Energy Services Interfaces (ESI):

(1) Interfaces to receive the information on Contingency Events – time ahead planned events and emergency events from the system operations and planning functions
(2) Interfaces to communicate the optimal Microgrid configuration. This will be required (by the MGBO controller) to initiate control actions - market systems will also require the configuration information to apply the changes needed in the market mechanism and communicate to the market participants

Interoperability requirements of the DMC will be tested through simulated TE scenarios and the results will be analyzed to enhance the design. Energy Interoperation defines the message structure to communicate reliability, and emergency condition information - the message structure will be adapted with necessary extensions to realize the MGBO.

The ESI will serve as the main interface of the DMC and will serve as the node of connectivity to the other systems in the architecture. The ESI is the point of communication whereby the relevant entities such as Distribution System Operator, Market Platform, etc. interact.

Microgrids as a Key Enabling Transactive Energy Technology for Resilient Self-Healing Power Grid Operation

SPEAKER: AMRO FARID, THAYER SCHOOL OF ENGINEERING AT DARTMOUTH

SLIDES: CLICK HERE

Microgrids have often been proposed as a key enabling technology to enable greater consumer and prosumer engagement with respect to the supply and demand of their energy choices. They support the integration of distributed energy resources and demand response which motivate the need for new coordination and control approaches. Within their scope, they are often installed with centralized energy management systems which also have the high potential for future distribution into transactive energy control approaches. This presentation looked beyond the scope of a single microgrid to address its role with utilities and other microgrids so as to support resilient and self-healing operation. Dr Farid presented a novel multi-agent system coordination approach representing multiple microgrids. An architecture composed of physical agents is presented on a dual platform of JAVA-JADE and MATLAB. The MATLAB simulation implements a transient stability simulation keeping track of generator angles and speeds. The JADE microgrid agents implement behavior which allows them to connect and disconnect depending on the need for mutual cooperation. The resilience of multiple microgrids was then demonstrated in relation to three types of disturbed operations: (i) highly variable net load, (ii) net load ramp events and (iii) net load changes during high load levels. The results show that a decentralized multi-agent system can be used to control different power system areas under the jurisdiction of entirely different organizations. Furthermore, the presented architecture allows for the agile development of more complex transactive control strategies.

WORKSHOP SESSION 1 – TECHNOLOGY I

MODERATOR: JAMES MATER

This session continued the discussions from Panel Session 1: Technology. It explored how technology enables the participation of consumers/prosumers and discussed the lessons learned from the bulk power system for distribution Transactive Energy systems. It also explored how to bring utilities and customers together through technology, especially with the emerging IoT platforms, and looked at which technologies make TES easiest to embrace for customers by exploring the emerging technical solutions for TES.

WORKSHOP SESSION 2 – TECHNOLOGY II

MODERATOR: RON AMBROSIO

This session continued the discussions from Panel Session 2: Technology and explored which field technologies utilities need to be looking at to stimulate more involvement at the engineering and planning level in TES. This workshop examined:

- How technology enables the participation of consumers / prosumers
- How utilities can balance wires and non-wires solutions
- How to bring utilities and customers together through technology
- Which technologies make TES easiest to embrace for customers

DAY TWO

PLENARY KEYNOTE: THE ELECTRIC INDUSTRY - KEY ISSUES SHAPING THE TRANSFORMATION

SPEAKER: DAVID OWENS, EXECUTIVE VICE PRESIDENT, BUSINESS OPERATIONS, EDISON ELECTRIC INSTITUTE

SLIDES: CLICK HERE

These are exciting times for the electric power industry. The need for modernization, shifts in the energy supply mix, changing regulations, and new and emerging technologies are transforming our industry. David Owens discussed his ideas for improving sustainability, affordability, and reliability and how taking positive steps in these areas can help shape the future of the electric power industry.

Utility Plenary Panel

Moderator: Heather Sanders, Principal Manager, Integrated Grid Strategy & Engagement

Panelists: Duke Oishi, Senior Associate General Counsel, Hawaiian Electric,

Robert Sherick, Principal Manager, Renewable Integration, Southern California Edison,

Darren Murtaugh, Portland General Electric,

John Gibson, Manager, Distribution System Operations and Engineering Technical Services Manager, Avista.

Slides: Click here for: Duke Oishi, Robert Sherick, Darren Murtaugh, John Gibson

Increasing levels of variable generation challenge bulk power and distribution system operations, and the increased use of distributed energy resources (DER) threaten traditional utility business models. Expert panelists discussed the challenges and opportunities awaiting utilities and offered ideas on how they can manage and thrive –under a new paradigm.

Utilities today face a challenging operating environment. How are utilities to adjust – and thrive – under a new paradigm? This session addressed potential solutions under a Transactive paradigm such as leveraging demand-side capabilities for provision of grid services to enhance bulk power reliability and economic operations. It also addressed the need for, and potential of, the increased role of distribution system operations to harness – and 'dispatch'- the flexibility of consumer/prosumer systems under a transactive set up to manage the distribution grid reliably and cost-effectively.

The blurring of seams between bulk power and distribution operations and the need for secure information exchange between bulk power/energy markets, distribution operations/retail markets, and consumers/prosumers was also included in the scope of this sessio

Panel Session III – Utility Experience

Moderator: Gerald Gray, Technical Executive at the Electric Power Institute

Panelists: Ed Cazalet, TeMIX Inc.,

Fred Fletcher, Burbank Power and Water,

Ted Glauthier, Stem,

Bill Kallock, Integral Analytics

As a part of the Utilities track this panel session explored topics similar to those discussed in the Utilities plenary panel.

Considerations for Transactive Grids, Microgrids and Utilities

SPEAKER: ED CAZALET, TEMIX INC.

SLIDES: CLICK HERE

Ed Cazalet's presentation described some important considerations for applying transactive energy to microgrids and grids. Dr Cazalet started with a brief survey of transactive energy with references.

Thinking about grids raises some interesting issues:

(1) We can consider buildings as microgrids, neighborhoods as microgrids, devices as microgrids, utilities as microgrids, grids as microgrids
(2) Hierarchical decomposition as used in demand response differs from transactive energy in significant ways—i.e. the separation into Virtual Top Nodes and Virtual End Nodes (VTNs and VENs) implies control paths and limitations on potential trading partners. Transactive energy does not.
(3) Cross a boundary (market domains, management domain, ownership domains, etc.) and you can't assume the same objective for the parties.
(4) The decoupling of grid implementations from each other makes easier integration and evolution
(5) In a transactive system separating transport products from electricity products makes both simpler—complexities of control can be limited and supplanted by reachability considerations

Ed also discussed key implications, including:

(1) Microgrids do not have to be treated as virtual power plants.
(2) Aggregation for buying and selling is not necessary for microgrids, but can be used.
(3) The concept of "the next level" is more fluid than commonly thought-approaches such as dynamic fault resilience rely on that fluidity (Cox, ISGT 2014)
(4) Decoupling hierarchical organization a "transacts with" relation improves flexibility, economic value, and resilience
(5) Designing for fluidity allows us to build more robust and more scalable systems using transactive energy
(6) Building a transactive microgrid by scoping markets to match physical systems is a practical first step but severely limits value

With transactive microgrids, anybody inside or outside can transact energy with anyone else, using one or more market contexts.

Virtual Top Nodes and Virtual End Nodes, standardized in OASIS Energy Interoperation and IEC 62746-3 and IEC 62746-10-1, are a demand response concept. Avoiding restrictions as to potential buyers and sellers drives greater value to the grid edge nodes and customers.

End-to-End Power System Operation under the Transactive Energy Paradigm

SPEAKER: FRED FLETCHER, BURBANK POWER AND WATER

SLIDES: [CLICK HERE]

Fred Fletcher's presentation explored how the Transactive Energy framework, in conjunction with the emerging Distribution System Operator (DSO) construct, can be used to advantage to ensure customer-side resources, including intelligent devices stay connected to the utility as viable prosumers to the mutual benefit of the utilities and customers/prosumers.

The presentation also discussed an illustrative use case based on progress at a vertically integrated utility in California which uses a combination of Transactive Energy and DSO concepts coupled with utility-owned energy storage to allow the use of low cost renewable energy, as well as community based solar generation deliver such energy over its current transmission and distribution facilities, match its power supply with its net load in near Real-Time, improve its system load factor, and provide a foundation for increased energy sales and to accomplish all of this economically, while facilitating peer-to-peer Transactive exchanges among consumers/prosumers, building energy management systems, community based resources, and microgrids.

Customer-Sited Storage as a Grid Resource: Best Practices

SPEAKER: TED GLAUTHIER, STEM

SLIDES: [CLICK HERE]

Today's electric grid is fundamentally changing from a centralized system to one that is distributed, complex and self-combatting. For utilities and grid operators, adapting to these changes is essential for survival. As the rate of renewable energy adoption continues to increase, organizations around the world are looking for new ways to manage grid stability and ease resiliency concerns.

Intelligent energy storage company Stem is at the forefront of this solution, helping utilities and businesses unite to balance the grid through behind-the-meter resources. Stem's Vice President of Hawaiian Operations, Ted Glauthier, described how customer-sited energy storage systems supported by intelligent software can have a major impact on grid operations. He drew on insights from three of Stem's partners—the Hawaiian Electric Company, Southern California Edison and CAISO—to show how software-guided storage systems augment grid resiliency and capacity, while also helping utilities achieve legislative targets for renewable energy and energy storage.

Intelligent storage systems benefit business customers, incorporating weather pattern information as well as customers' past energy usage data and rate information to predict when electricity use will peak at a given site. This software can signal battery storage hardware to rapidly respond to spikes in customers' electricity use, drawing on stored power to reduce the demand charge portion of monthly electricity bills.

Ted Glauthier described how distributed storage programs can benefit both utilities and grid operators. For example, the Hawaiian Electric Company partnered with Stem to bring 1 MW of intelligent energy storage to businesses on Oahu to help stabilize loads and better manage variability from distributed solar. Showing early data from Stem's system at Oahu-based Wantanabe Floral, Mr. Glauthier will highlight how this program is simultaneously reducing electricity bills for businesses and supporting grid operations.

Stem's upcoming 85 MW deployment with Southern California Edison—the largest of its kind—Ted described how Stem was the first intelligent storage provider to successfully bid into the California Independent System Operator (CAISO) day-ahead and real-time markets, aggregating capacity from as many as six customer sites to use as a rapid-response resource.

Best Practices in Measuring Net Metering Impacts of Distributed Energy Resources (DER's)

SPEAKER: BILL KALLOCK, INTEGRAL ANALYTICS

SLIDES: CLICK HERE

As the cost and efficiency of distributed energy resources (DER's) improve and smart grid infrastructure deployed enabling consumer engagement and energy awareness, the need for utility wide integrated planning across traditional utility silos will become increasingly necessary. Several regional planning areas have recently identified the need for distribution level integrated planning, combining the cost effective capital investment with programs and services designed to lower the overall cost of delivering energy while maintaining reliability and security[1].

Bill Kallock described how recent studies including those by EISPC[2] and NARUC[3] have focused on state-of-the-art concepts and tools for states, planning coordinators and others to assist in the forecast of load growth and load modifying resources, and the impact of these on the distribution network. Together, these studies recognize the importance of load forecasting in capital planning as the fundamental business problem in the utility industry. In this presentation this research was extended by highlighting important methodology considerations crucial to achieving accurate, usable resource plans including:

- The use of actual, granular data and hierarchies such as geographic, temporal and sub-regional. The accuracy gained at a granular level is translated to the enhanced forecasts at the aggregated levels enabling top down and bottoms up analysis emerging DER technologies and utility services.
- Consistency with proven methods and adherence to best practices in order to establish the credibility in load forecasting and the impact of net metering.
- Recognition that long-term load forecasts based on deterministic, ex ante point forecasting is inappropriate, but rather forecasts for resource planning should be based on probabilistic characterization of risk using actual load history, weather data and prices.
- Properly and fully accounting for granular avoided costs, when calculating the appropriate fixed charge for net metering.

[1] For example, the California PUC recently required all IOU's to submit DRP's detailing the circuit level impacts of DER on the distribution system

[2] EISPC, Eastern Interconnection States' Planning Council

[3] NARUC, National Association of Regulatory Utility Commissioners

Panel Session 4 – Regulatory / Environmental / Governmental

Moderator: Carl Zichella, Natural Resources Defense Council

Panelists: Jason Salmi Klotz, Oregon Public Utility Commission,
Alexi Miller, New Buildings Institute,
Gary Radloff, Wisconsin Energy Institute,
Tom Sloan, State Representative, Kansas House Of Representatives

As the electrical system evolves from a central station, baseload system with discrete bulk and distribution components to a more integrated system in which interoperability and market signals govern how flexibility is obtained and used (otherwise referred to as transactive energy) across these systems, the role of regulation must also evolve. This panel session explored regulatory topics.

Transactive Energy Suggestions Fitting Into the Regulatory Environment

Speaker: Jason Salmi Klotz, Oregon Public Utility Commission

Transactive energy, as conceived, requires a significant regulatory paradigm shift. Current regulatory practices have developed over decades to protect retail electric ratepayers from the dynamics of electric markets and thus have evolved to present ratepayers with a stable, affordable, non-interactive system. Mr. Salmi Klotz explained how transactive energy is inherently dynamic yet potentially offers ratepayers a more transparent, engaging marketplace capable of offering the end user the ability to control costs.

Currently, regulators, both at the federal and state level, are reacting to swift technological changes that are enabling customers, with greater visibility and control and empowering them to require change in grid operations, resource availability and regulatory constructs. Transactive energy incorporates these new technologies to bring markets, visibility, consumer control and interaction into a framework which could potentially address the challenges currently faced by regulators. However, there are concept adjustments, maturity of practice and market transformation which needs to take place.

The first part of this presentation briefly reviewed the concept and current demonstrations of transactive energy. This same section drew comparisons to current regulatory practices. The second part proposed, from the perspective of the regulatory community, the current short comings of the transactive energy concept. The final and third part of the presentation suggested practices and model frameworks to move transactive energy into a position where its benefits, structure and operation become part of a more dynamic regulatory paradigm.

Zero Net Energy Buildings and the Grid: Designing for Success on Both Sides of the Meter

Speaker: Alexi Miller, New Buildings Institute

As zero net energy (ZNE) buildings and other low-energy buildings become increasingly common Alexi Miller described how it is important to consider how different ZNE strategies can interact with local electricity grids. The electricity grid was built as a one way street, with energy flowing from the power plant to buildings. But widely distributed renewable energy systems and other cutting-edge building technologies will change that equation as the grid transitions to two-way energy flows. Demand response (DR) technologies and grid-sensitive design features in ZNE buildings will be critical to enabling the integration of these facilities into the grid at a large scale.

Alexi Miller described three tiers of DR and renewable energy technology integration in commercial buildings:

1. Conventional buildings with one-way energy flows or conventional net metering
2. Moderately responsive buildings with interactive demand response capacity
3. Fully grid-integrated buildings with active and passive efficiency and demand response features, often with on-site renewable energy

This third tier represents the buildings of the future. These buildings integrate grid-sensitive design features, fully dispatchable DR across major end-uses in the building, and carefully designed and installed renewable energy technologies that are intended to improve the relationship between the building and the electricity grid.

These buildings of the future, whether operating at a ZNE level or not, must be explicitly designed with both active and passive features and technologies to optimize the interactions between buildings and the utility grid. Passive design strategies, such as building orientation, daylighting, and passive space conditioning, are the foundational step and should be implemented as much as practicable. Active strategies such as night ventilation, thermal storage, or DR will also be instrumental and can allow buildings to be used when necessary as storage for the grid.

Renewable energy systems should be carefully chosen and designed to interact well with the grid. For example, wide adoption of east-west oriented solar PV systems could provide significant benefits to grid operators where the onsite generation load shape better matches the grid demand load shape. This presentation described a framework for employing design strategies and measures that ensure buildings of the future can benefit from, and support, the grid modernization efforts that will occur throughout the life of the buildings. Finally, policy recommendations based on past, present, and future policy needs were presented.

Dynamic Distribution and Dynamic Markets: Understanding how TE success is tied to new energy architecture, business models, and policy change

SPEAKER: GARY RADLOFF, WISCONSIN ENERGY INSTITUTE

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The Dynamic Distribution System (DDS) is an architecture that can serve as a vector point for the ongoing thinking about the electric grid of the future. Architectures represent functions, structures, and interactions in mappings, standards, and models that permit large complex systems to be designed and evolved in effective and valuable ways. The key is designing a transformational pathway to the future making sure to set the end goal of growing the value proposition giving fair opportunity – to the utility customer, third party energy businesses and the utilities – so that the best of the legacy grid can mesh with entrepreneurial and innovative new business models and solutions. Designing a new energy architecture must simultaneously include fashioning adaptable policies along with setting the standards and rules for operations of transactive energy markets with the purpose of evolving the legacy energy system, including recognizing transitional phases of development, all while making sure the lights remain on.

In this session, Gary Radloff outlined present and future research on DDS architecture and preliminary modeling and findings on a dynamic market and tariffs. Further, a framework was presented identifying future research to evolve the next generation of architecture, markets, and policy. The organization of this research recognizes the need to use a systems approach looking at technology, system architecture, economic and environmental functions simultaneously to achieve a future distribution grid and market. This bottom-up design approach of DDS features cooperative and autonomous control functions, scalability, greater utilization of DERs, increasing renewable energy generation, and the highest levels of efficiency and resilience of the system.

The DDS does not specify a marketplace design, but rather identifies a reference architecture framework that can accommodate various market designs without degrading the ability of the entire system to accomplish and improve upon the goals of all stakeholders. In making the case for a flexible architectural approach, Gary Radloff identified three key concepts.The marketplace should:

- enable energy transactions at the local level,
- provide an equitable marketplace for investment, and
- facilitate intrinsic stability and optimization.

The marketplace should support three other components of DDS deployment: power systems controls, revised utility business models, and updated regulatory policies. The modeling for the marketplace will demonstrate key answers on goal and principles of operation, proposed rules, and concepts for capturing externalities, how actors will participate in the marketplace, and tariff design.

Policy and regulatory reforms will help to shape the design of new energy architecture, market, and business models. It will be critical that policy, regulation, and standards work in several dimensions as it guides the evolution of the current electric utility industry, while helping to integrate and grow DERs, including allowing greater market participation for non-utility businesses and consumers. Gary Radloff highlighted the various stages of policy that complement redesign of energy architecture, market and business models.

The Chemistry of Transactive Energy Systems

SPEAKER: TOM SLOAN, STATE REPRESENTATIVE, KANSAS HOUSE OF REPRESENTATIVES

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Representative Sloan's presentation took an unconventional and entertaining look at the evolving energy system in which utilities, customers and third parties have opportunities to monetize their products and services because of technological and communication improvements. Tom Sloan described how the transactive energy framework published by the GridWise Architecture Council provides four different ways to categorize transactive energy systems. When each of the subcategories is represented as a rectangular block, the assembled subcategories can be arranged so as to roughly resemble the periodic table of elements.

This presentation took that comparison further by discussing transactive energy systems like chemical formulae in a way that did not overwhelm with control theory or market based economics. Instead it focused on the significance of the "transactive energy periodic table blocks" and how the blocks may be combined to describe potential transactive energy systems in terms that will resonate with utility executives, regulators and policy-makers, consumers, and entrepreneurs.

INTERNATIONAL PLENARY PANEL

MODERATOR: STEVE WIDERGREN, PRINCIPAL ENGINEER, PACIFIC NORTHWEST NATIONAL LABORATORY

PANELISTS: THOMAS BAKKER, COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION (CSIRO)

ALEXANDER KRSTULOVIC, ALLIANDER

DAVID KIM, GRIDWIZ

SLIDES: CLICK HERE FOR: THOMAS BAKKER, ALEXANDER KRSTULOVIC, DAVID KIM

A TE View from the Netherlands and Europe

ALEXANDER KRSTULOVIC, ALLIANDER,

A TE View from South Korea

DAVID KIM, GRIDWIZ

A TE View From Downunder – An Electricity Transformation Roadmap

THOMAS BAKKER, COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION (CSIRO)

Day Three

Plenary Keynote

Speaker: Travis Kavulla, Montana Public Service Commission, NARUC

Travis Kavulla started with a brief political economic history of the regulatory model with regulators setting prices to recover the cost of doing business. Even so, the regulated monopoly has 2 major processes that require a great deal of discretion: first, cost allocation and, second, rate design. So how should the so-called “fixed costs” of the grid be assigned? And once those costs are assigned to the appropriate customers, do you collect those costs?

A few “past precedents” gesture to regulatory attempts to accommodate technologies that cut against the grain of what was typical but new technologies are cutting across the different functions of the integrated grid. Cost allocation is a good jumping off point to the debate that our country is having about how the Grid & Distributed Energy Resources should be valued.

Kavulla quoted Alfred Kahn who stated that “The longer the time perspective of the costing process, the greater the proportion of costs that become variable.” He also mentioned that NARUC’s Cost Allocation Manual provides a good conceptual example of a long-run approach, which treats essentially everything as a variable cost. He referred to one recent case where a customer advocate argued that no more than 10-25% of distribution system costs were what would be required for a “minimum system” while the utility claimed about 85% of the costs would have had to be incurred regardless.

So how do you address DER? Kavulla asked. It’s a chicken-and-egg problem when it comes to the debate of short- vs. long-run marginal cost pricing and it’s appropriate to take a view of DERs in the sense of the value they provide to the grid, including not just energy & capacity but also with respect to the benefits and costs vis-à-vis the grid.

Kavulla identified three important principles to keep in mind:

1) The purpose and role of utility regulators in a more transactive grid.
2) The diversity of service territory in the USA
3) The need for valuation of DERs to be a practical & non-discriminatory exercise

The discussion concluded with Kavulla stating that it is essential that valuation capture only those benefits and costs that actually realize a value elsewhere in the marketplace. Doing otherwise risks having the political economy of regulation unmoored from the prices people actually pay for similar or the same goods elsewhere.

Regulatory and Policy Plenary Panel

Moderator: Chris Villarreal, Minnesota Public Utilities Commission

Panelists: Matthew McDonnell, Hawaii Public Utilities Commission,
Jason Salmi Klotz, Oregon Public Utility Commission,
Jorge Camacho, Public Service Commission of the District of Columbia,
Rao Konidena, Midcontinent Independent System Operator

SLIDES: NO SLIDES WERE USED DURING THIS PANEL SESSION.

Chris Villarreal described how each state is different with different regulatory constructs, different types of utilities, and different statutory guidance. However, each regulatory body does ascribe to a similar set of principles on rate design, including affordability, reliability, resilience, and availability of electricity supply. Where is the future of regulation going? This is one of the central questions posed by NARUC President Travis Kavulla noted in his remarks last November: "What we should do, I believe, is focus on making sure that whatever future is the most affordable and reliable will ultimately prevail in the regulatory setting we create. That system of regulation should be durable enough to accommodate either future. And that consideration leads us to ask questions that may be applied to new circumstances, but are not exactly new themselves." In addition, where do RTOs fit in this discussion? In this panel the audience heard regulatory staff from around the United States and a representative from an RTO discuss these questions and how it impacts TE in their respective states and markets, regulatory and market challenges associated with implementing TE, and the future role of DER and TE in the distribution grid and bulk power market.

Hawaii

SPEAKER: MATTHEW MCDONNELL, HAWAII PUBLIC UTILITIES COMMISSION

Matthew Mcdonnell noted that the island grids are not connected; 70% of generation is from oil, resulting in high prices; lots of solar and wind potential. Policies have driven recent growth in renewables. Now 1 in 3 residential homes have rooftop PV. There is a 100% target for renewables in Hawaii. With respect to energy metering, it is not currently designed to operate at Hawaii scale, as it does not give correct price signals. Customers are a mixture of grid supply and customer self supply. There is ongoing rate design to deal with all the changes. Hawaii is looking at customer-side resources (storage, vehicles) with respect to demand response. They need to define services in a technology-neutral manner.The longer strategic vision is to allow DER to fulfill the role conventionally provided by large-scale generation.

Oregon

SPEAKER: JASON SALMI KLOTZ, OREGON PUBLIC UTILITY COMMISSION

Jason Salmi Klotz noted that electricity rates are lower in the Pacific Northwest due to the Columbia River, so they are behind on DER. DER is topic of discussion for the Oregon PUC at present. SB 1547 requires divestment of coal in near term, and RPS increased to 50%. The PUC is also contemplating net energy metering. There are two ideas for the proposed resource value of solar: one similar to net metering, the other, if you want to sell you can, but requiring submetering to do so. EVs are being considered under the heading of climate change. The PUC is also considering TOU rates. How do you balance the equity of non-EV with EV? Also need to consider how to value energy efficiency. The Power Council has released the 7th power plan, including at least 600 MW of DR. The Pacific Northwest is behind but catching up with Hawaii and other states. Need to provide benefits with equity across all rate ratepayers.

District of Columbia

SPEAKER: JORGE CAMACHO, PUBLIC SERVICE COMMISSION OF THE DISTRICT OF COLUMBIA

Some of the ares discussed included: community renewable energy facilities and their Applicability to high-density urban areas, and substation applications in Washington DC. The PSC is trying to bring utilities, technologists, city personnel to the table to discuss these issues. The PSC is also attempting to reduce waste, reduce costs, and give consumers more control. Third party providers can now provide services traditionally handled by utilities which creates a diffusion of responsibility for reliability.

Midcontinent Independent System Operator

SPEAKER: RAO KONIDENA, MIDCONTINENT INDEPENDENT SYSTEM OPERATOR

MISO includes a large expanse from Manitoba in the North to New Orleans in the South. On the way to significant amounts of wind power and also PV. MISO also has phase shifters in Michigan. TE is not significant at MISO. MISO needs to integrate distribution and generation to unlock potential of TE.

TRANSACTIVE ENERGY CHALLENGE WORKING GROUP PLENARY PANEL

MODERATOR: DAVID HOLMBERG, NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

PANELISTS: JOHN CALDWELL, EDISON ELECTRIC INSTITUTE,
WILLIAM COX, COX SOFTWARE, ARCHITECTS, LLC,
JENNIFER WORRALL, ITEROS, INC,
ROLF BIENERT, OPENADR ALLIANCE,
ALEXANDER KRUSTULOVIC, ALLIANDER,
HIMANSHU NEEMA, VANDERBILT UNIVERSITY,
CHIN YEN TEE, CARNEGIE MELLON UNIVERSITY

OVERVIEW: CLICK HERE

The NIST TE Challenge is working to advance modeling and simulation for TE while more generally working with industry stakeholders to better understand TE and how to implement it. Participants work together to create and demonstrate modeling and simulation platforms while applying transactive energy approaches to real grid problems. The goal is to provide technical results to guide utilities, regulators, and legislators in applying TE. In this session, the TE Challenge teams presented reports and status from their team efforts.

Alternative Transactive Electricity Market Models

SPEAKER: JOHN CALDWELL, EDISON ELECTRIC INSTITUTE

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The evolution of the U.S. electricity system to a transactive network is already under way, with the growing presence of responsive demand and distributed energy resources. But to enable a complete transition to such a system, viable business models by both incumbent electricity providers and third parties will have to be developed, along with new regulatory and legislative paradigms to support a decentralized, transactive electricity grid. This presentation explored alternative business, legislative, and regulatory models for transactive electricity, discussed their relative merits and shortcomings, as well as potential challenges that would have to be addressed if each were adopted, and also discussed the transitional milestones that will have to be crossed to reach these end states.

As a part of this examination, the presentation identified key participants in the transactive network, their corresponding roles, and how they would interact. It also discussed the positive impacts of such a fully realized network on the overall economy, the environment, and the electricity system itself. While the focus of the presentation was on the economic and regulatory features of each model, technical aspects of the electricity grid which must be addressed to support each model were also described, at a high level.

The presentation drew on much of the latest thinking that has evolved on the subject of transactive energy models, for example in the GridWise Architecture Council, the OASIS transactive energy standards work for the Smart Grid Interoperability Panel, and models currently under discussion in state regulatory/legislative initiatives such as the New York REV, categorizing where necessary the alternative approaches already being explored. It also described parallel activities going on in other countries. But it also added new variants and novel approaches to be considered for achieving a fully functional transactive electricity grid.

John Caldwell noted that wherever possible, however, variants and approaches will be subsumed under larger categories, leaving a small set of general alternative models to be summarized, compared, and evaluated.

Common Transactive Services Report

SPEAKER: WILLIAM COX, COX SOFTWARE ARCHITECTS, LLC

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The Common Transactive Services Team in the NIST Transactive Energy Challenge examined the range of significant transactive systems and selected a minimal set of Common Transactive Services that enable interoperability between transactive systems.

A primary goal was to describe a simple complete set of transactive services that map well to most transactive systems to allow simpler simulation, modeling, and integration. This means that a project in any of these environments may benefit by using the Common Transactive Services to extend its reach and engage more transactive parties.

Simplicity, working with the products being used, and being adaptable were among the requirements developed. In addition, a Service-Oriented Architecture approach was used, which permits independent evolution through loose coupling of standardized environments.

The transactive systems of interest were:

1. Energy Interoperation, an OASIS Standard progressing in IEC
2. IEC Markets, largely based on the IEC 62325 family and 61968-100
3. The Pacific Northwest Smart Grid Demonstration Project
4. PowerMatcher, used for integrating devices in a market-driven manner
5. TEMIX, a profile of both Energy Interoperation and EMIX product definition intended for large scalable markets

Transactive Energy for Energy Management in Systems of Microgrids

SPEAKER: JENNIFER WORRALL, ITEROS, INC.

SLIDES: CLICK HERE

There has been extensive work in the abstract TE model as well as other standards based on Energy Interop, such as the Transactive Energy Market Information Exchange (TeMix). However, we have yet to see a pilot demonstration that proves the efficacy of this mechanism.

The output of this team's work in the TE Challenge is the framework for an open-source, open-standards Java-based implementation of the TeMix platform, from use cases and requirements to a sample architecture for both market participants and a market facilitator. Jennifer Worrall explained how this will provide the basis for a live implementation of the Transactive Energy concepts in the next phase of the Transactive Energy Challenge.

Transactive ADR Team

SPEAKER: ROLF BIENERT, OPENADR ALLIANCE

SLIDES: CLICK HERE

PowerMatcher IoT Team

SPEAKER: ALEXANDER KRSTULOVIC, ALLIANDER

SLIDES: CLICK HERE

A Reusable and Extensible Web-Based Co-Simulation Platform for Transactive Energy Systems

SPEAKER: HIMANSHU NEEMA, VANDERBILT UNIVERSITY

SLIDES: CLICK HERE

Rapid evolution of energy generation technology and increasing usage of distributed energy resources (DER) is pushing utilities to adapt and evolve business models that are aligned with these changes. Energy pricing is becoming rather competitive and transactional, needing utilities to increase flexibility of grid operations and incorporate transactive energy systems (TES). However, a huge bottleneck is to ensure stable grid operations while gaining efficiency.

A comprehensive platform is therefore needed for grid-scale multi-aspect integrated evaluations. For instance, cyber-attacks in a road traffic controller's communication network can subtly divert electric vehicles in a particular area, causing surge in the grid loads due to increased EV charging and people activity, which can potentially disrupt, an otherwise robust, grid. To evaluate such a scenario, multiple special-purpose simulators (e.g., SUMO, OMNeT++, GridlabD, etc.) must be run in an integrated manner. To support this, Himanshu Neema described the development of a cloud-deployed web- and model-based simulation integration platform that enables integrated evaluations of transactive energy systems and is highly extensible and customizable for utility-specific custom simulation tools.

Simulation Based Transactive Energy - Spot, Forward and Investment Decisions

SPEAKER: CHIN YEN TEE, CARNEGIE MELLON UNIVERSITY

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With the increasing level of uncertainties brought about by evolving grid technologies, investment in the electricity grid has become increasingly risky. In order to harness the value of distributed technologies and to better manage and distribute risk among market stakeholders, a paradigm shift needs to occur in electricity regulatory and market design. Various transactive energy market designs, such as the TeMix framework proposed by Ed Cazalet and the double auction market design (used by the Gridwise Olympic Peninsula Project), have been proposed in recent years. Most of these work are still on the conceptual or experimental level, and the efficiency, effectiveness and implementability of these different market designs have yet to be fully understood. As the industry works towards developing a standard for transactive energy markets, we need a methodology to efficiently and effectively test different market design in order to better understand the potential effects and externalities of different market frameworks.

In this talk, Chin Yen Tee discussed how simulation platforms such as the CMU-NIST Smart Grid in a Room Simulator can be a useful tool to allow us to test novel transactive energy market designs under different assumptions. The SGRS is designed with distributed decision making and multi-timescale modeling capabilities, both of which are important aspects of transactive energy markets. An overview was provided of the SGRS and it was illustrated how multi-timescale transactive energy markets can be simulated on the SGRS. It was further demonstrated how spot and forward markets, along with generation and transmission investment decision making can be simulated on the SGRS. Through a simple case study, Chin Yen Tee demonstrated how the results can be used to explore the impact of different market design on generation and transmission investments, and reveal potential problem areas for further evaluation.

TE Challenge Next Steps

SPEAKER: DAVID HOLMBERG, NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

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TRANSACTIVE ENERGY IN PRACTICE: HOW READY ARE WE?

MODERATOR: BRUCE YONKER

PANELISTS: ERIK GILBERT, NAVIGANT CONSULTING,
MARTIN FORNAGE, ENPHASE ENERGY,
THIERRY GODART, ENERGY SOLUTIONS

Wrapping up the Conference this session explored transactive energy efforts that are up and going. Leading industry innovators shared how TE is working in practice in the marketplace and the benefits these efforts are bringing. The discussion also delved into how ready TE is for wide spread deployment and how to move the ball forward.

TRANSACTIVE ENERGY: NEXT STEPS

The growth in attendance, active discussions, and response to the call for abstracts indicate a growing community of interest and practice for the topic of transactive energy systems. The International Panel provided a valuable perspective of the global nature of the challenges facing the industry which transactive energy systems can address. The applicability of transactive energy systems was described for both green field efforts in developing countries such as India and in mature economies in Europe and Australia, reinforcing the flexibility for the applications of these systems. The expanding deployment of diverse mixes of resources and the growing deployment of intelligent devices and systems within both the power systems and end uses of electricity call for these new approaches to coordinating supply and demand.

In spite of this growth in interest and activity there is much work to be done. This challenging work is interdisciplinary and cuts across traditional stovepipes within the electric power system industry, the end uses of electricity, and between the two.

With that in mind we look forward to continued activity and progress and your participation in the 4th International Conference and Workshop on Transactive Energy in 2017.

Closing Comments & Special Thanks

The GridWise® Architecture Council and Smart Grid Northwest thank all of the speakers, session leaders, student volunteers and sponsoring organizations. Last, but not least, we thank the participants. The event brought together representatives of government, industry, utilities, vendor organizations and academia who have an interest in advancing transactive energy. The discussions and exchanges of ideas and experiences during the course of the conference and the workshop sessions are very valuable in helping the Transactive Energy Systems community to grow. We would especially like to thank Portland General Electric for making the facilities available for the conference.

Organizers

The Council organized this International Transactive Energy Conference and Workshop as part of its mission to further advanced thinking about the guiding principles, or architecture, of a highly intelligent and interactive electric system.

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APPENDIX A – REFERENCE MATERIAL

Advanced Grid Planning & Operations
http://www1.eere.energy.gov/solar/pdfs/advanced_grid_planning_operations.pdf

AEP Demonstration Project website
http://www.smartgrid.gov/project/aep_ohio_gridsmartsm_demonstration_project

A Foundation for Transactive Energy in a Smart Grid World
http://www.pointview.com/data/files/2/1062/1878.pdf

Bain & Co. Distributed Energy Business Models
http://www.bain.com/publications/articles/distributed-energy-disrupting-the-utility-business-model.aspx

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Cisco Ultra Large-Scale Power System Control Architecture
http://www.gridwiseac.org/pdfs/cisco_control_architecture_white_paper.pdf

Control of the Grid in 2020, and How Economics Can Help Us
http://www.newton.ac.uk/programmes/SCS/seminars/2013042409301.html

DOE Building Technologies Office
http://www1.eere.energy.gov/buildings/index.html
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http://www.edisonfoundation.net/iee/Documents/Fox-Penner_IEE_071510_Final.pdf

Energy Interoperation Version 1.0
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Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide
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Green Button
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http://www.gridwiseac.org/pdfs/tew_2012/tew_2012_proceedings.pdf

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http://www.gridwiseac.org/pdfs/gwac_tec_052313/tec_2013_proceedings_pnnl_sa_96361.pdf

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http://www.gridwiseac.org/historical/tec2013/tec2013.aspx

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http://www.gridwiseac.org/pdfs/te_framework_report_pnnl-22946.pdf

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http://www.gridwiseac.org/pdfs/te_principles_slide_pnnl_sa_103625.pdf

Integrated DER Pricing & Control
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LBNL CERTS Distributed Resource Integration Website
https://certs.lbl.gov/research-areas/distributed-energy-resource-0

Navigant - Potential Use of IOU Demand Response Programs for Integration of Wind and Solar Energy Needed to Achieve California's Renewables Portfolio Standard
http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=7066

Pacific Northwest Demonstration Project website
http://www.pnwsmartgrid.org/publications.asp

Potential Role of Demand Response Resources in Maintaining Grid Stability and Integrating Variable Renewable Energy
http://www.calmac.org/publications/7-18-12_Final_White_Paper_on_Use_of_DR_for_Renewable_Energy_Integration.pdf

Renewable and Distributed Power in California
http://media.hoover.org/sites/default/files/documents/energy-policy-tf-grueneich-study.pdf

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http://www.energy.ca.gov/2012_energypolicy/documents/2012-11-07_workshop/2012-11-06_Resnick_Institute_Report-Grid_2020_Towards_a_Policy_of_Renewable_and_Distributed_Energy_Resources_TN-68383.pdf

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http://collaborate.nist.gov/twiki-sggrid/pub/SmartGrid/SGIPCommitteeProductsSGAC/Smart_Grid_Conceptual_Model_20100420.pdf

Southern California Edison’s Approach to Evaluating Energy Storage
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Transactive Device Architecture and Opportunities
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Appendix B – Agenda

TUESDAY MAY 17, 2016		
Time		**Session**
8:00am	8:30am	Registration and Networking
8:30am	9:00am	Welcome and Opening Remarks
9:00am	9:45am	Opening Keynote - Audrey Zibelman
9:45am	10:00am	Networking Break
10:00am	12:00pm	GWAC Foundational Session
12:00pm	1:30pm	Lunch and Keynote - Elliot Mainzer
1:30pm	3:00pm	Panel Session 1- Technology
1:30pm	3:00pm	Panel Session 2 - Technology
3:00pm	3:30pm	Networking Break
3:30pm	5:00pm	Workshop Session 1 - Technology
3:30pm	5:00pm	Workshop Session 2 - Technology
5:00pm	7:00pm	Networking Reception

WEDNESDAY, MAY 18, 2016		
Time		**Session**
8:00am	8:30am	Registration and Networking
8:30am	9:15am	Plenary Keynote - David Owens
9:15am	10:10am	Utility Plenary Panel
10:10am	10:30am	Networking Break
10:30am	12:00pm	Panel Session 3 - Utility Experience
10:30am	12:00pm	Panel Session 4 - Regulatory / Environmental / Governmental
12:00pm	1:30pm	Lunch and Keynote - Christopher Irwin
1:30pm	3:00pm	Workshop Session 3 - Utility Experience
1:30pm	3:00pm	Workshop Session 4 - Regulatory / Environmental / Governmental
3:00pm	3:30pm	Networking Break
3:30pm	5:00pm	International Plenary Panel

THURSDAY, MAY 19, 2016		
Time		**Session**
800am	8:30am	Registration and Networking
8:30am	9:15am	Plenary Keynote - Travis Kavulla
9:15am	10:15am	Regulatory and Policy Plenary Panel
10:15am	10:30am	Networking Break
10:30am	12:00pm	Transactive Energy Challenge Working Group Plenary Panel
12:00pm	1:30pm	Lunch and Keynote - David Forfia
1:30pm	2:30pm	Transactive Energy in Practice: How Ready Are We
2:30pm	3:00pm	Closing Plenary

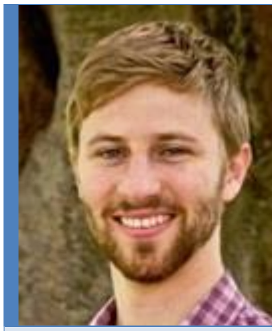
Appendix C – Speaker's Profiles

Farrokh Albuyeh

Senior Vice President, Smart Grid Projects
OATI

Farrokh Albuyeh received his B.S., M.S. , and Ph.D. degrees in Electrical and Computer Engineering, with emphasis on Power Systems, from the University of Wisconsin-Madison. He is currently Senior Vice President, Smart Grid Projects at Open Access Technology International (OATI), where he is involved in the development of software solutions and products for Smart Grid as well as for energy markets.

Prior to joining OATI in 2004, he worked for AREVA T&D as the Director, Market Participants, where he was involved in the development of products and solutions for participants in energy markets. From 1985 to 1999 he worked for ABB as the Director, Product Development and Marketing where he was involved in the design and implementation of advanced transmission system analysis, and generation scheduling applications for Energy Management Systems and market applications for ISOs and RTOs.



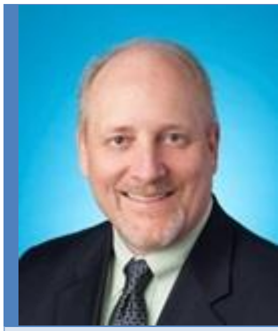
Thomas Bakker

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Tom is the Technology Lead on the Network Transformation Roadmap Project at CSIRO, Australia's national science agency in Partnership with the Energy Networks Association (ENA – Australia's peak network representative body).

His role is to lead and support key technical work streams including; beneficial integration of DER; grid side capabilities and technology; and, transactive energy market and automation futures. This role sees Tom engaging with a diverse range of CSIRO and Network experts to ensure the program capitalises on all relevant expertise and bodies of knowledge.

Tom is an experienced Power Systems Engineer with a keen interest in the integration of renewable energy technology and utility business transformation, having previously worked on a wide variety of complex projects of both a technical and business nature for Australian Distribution Network Service Provider, Energex.



Larry Bekkedahl

Vice President, Transmission and Distribution
Portland General Electric

As vice president, transmission and distribution, Larry Bekkedahl is responsible for PGE's transmission and distribution engineering and operations functions. He oversees the company's Transmission and Reliability, Engineering and Design, Distribution Services, Asset Management, System Control Center and Dispatch, and Substation Operations sections. He joined PGE in 2014.

Bekkedahl was previously senior vice president for transmission services at the Bonneville Power Administration, and has held other leadership and management positions at BPA, Clark Public Utilities, PacifiCorp and Montana Power Company.

He holds a Bachelor of Science degree in electrical engineering from Montana State University, and serves on the Electric Power Research Institute's transmission executive committee, as a U.S. board member for the International Council on Large Electric Systems (CIGRE), and on the member's advisory committee for Peak Reliability, the reliability coordinator for the western grid. He is a strong supporter of technological innovation and has led efforts to deploy smart grid technologies, road maps, and wide-area visualization tools.

Bekkedahl also has international utility experience gained by participating in a six month exchange program with Hokuriku Electric Power Company in Toyama, Japan, developing hydro projects in the Philippines, and participating in United States Agency for International Development (USAID) exchange projects in Bangladesh, the Republic of Georgia, and the Philippines.

Rolf Bienert

Technical Director
OpenADR Alliance

Rolf Bienert is the Technical Director of the OpenADR Alliance. In this capacity, Rolf oversees the technical developments and the certification program of the Alliance. Before going independent, Rolf was the Technical Manager for Telecom and the Global Competence Center for emerging communication protocols at TUV Rheinland. In this role at TUV, Rolf was involved in many international standardization efforts and guided the company's efforts in these areas. Rolf has been an active member of the NIST SGTCC, OpenADR Alliance, USNAP Alliance, SunSpec Alliance, ZigBee Alliance, and other organizations driving the development of new technologies with a specific focus on certification and interoperability.

Anto Budiardjo

CEO
PointView, Inc.

Mr. Budiardjo is a serial entrepreneur with numerous companies where he was responsible for product development, management and marketing communications. His rare combination of marketing and technology practices has enabled him to fine tune and soften the challenging task of transitioning the product development process from an engineering-centric focus to a market-centric focus.

As a founder of PointView, Inc., Mr. Budiardjo is responsible for conceptualizing the PointView collaboration portal, working with event attendees and organizing experts to execute a decade of successive truly-awesome conferences, using PointView.

John Caldwell

Director of Economics
Edison Electric Institute

Conducts a variety of policy studies using econometric models, including estimation of commodity demand and supply curves, portfolio analysis, and advanced linear regression techniques. Principal area of research has been the development of new business and regulatory models for electric utilities to support grid modernization, improved system resiliency, and the development of a cleaner energy portfolio.

Provides written testimony on critical industry filings in the areas of FERC and legislative policy involving transmission, demand response, integration of renewable resources, and grid modernization.

Regularly speaks at industry conferences to explain industry trends and developments, to share the results of recent research, and to represent policy views advocated by EEI and its membership.

Jorge Camacho

Infrastructure and System Planning
Public Service Commission of the District of Columbia

Jorge currently leads the Office of Infrastructure and System Planning at the Public Service Commission of the District of Columbia and its initiative to modernize how energy is delivered in Washington. He started his career with Entergy maintaining the underground electric distribution system of downtown New Orleans, he then moved with DoD to Washington, DC to support the Intelligence Community.

He holds bachelor's and master's degrees in electrical engineering (Tulane University, U of Florida) and completed his doctoral coursework in power engineering (LSU). He is a registered professional engineer and a senior member of the IEEE serving in the National Electrical Safety Code and the IEEE 1547 Conformity Assessment committees.

Ed Cazalet

CEO
TeMIX Inc.

Ed is CEO and Founder of TeMIX Inc, a transactive energy services provider, and VP and Co-founder of MegaWatt Storage Farms, Inc., a storage advisory and project development firm.

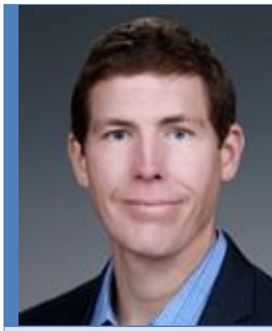
An internationally recognized electric industry expert, Dr. Cazalet is a leader in the analysis and design of markets for electricity. For his industry contributions, Public Utilities Fortnightly magazine named Dr. Cazalet "Innovator of the Year".

Dr. Cazalet has over forty years of electric power and related experience as an executive, board member, consultant, and entrepreneur.

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.



Chad Corbin

Engineer
Pacific Northwest National Laboratory

Dr. Corbin is an Engineer in the Advanced Building Controls Team at the Pacific Northwest National Laboratory in Richland, WA.

William Cox

Principal
Cox Software Architects LLC

Bill is a leader in commercial and open source software definition, specification, design, and development. His work combines business experience with his deep and practical understanding of software architecture and technologies including XML, Web services, Service-oriented architectures, Energy, eBusiness, Networking and system software to lead standards and project definition and execution.

Much of his work since 2009 has been in collaborative energy, including service-oriented interactions and transactive energy.

Bill is past Chair of the Organization for Structured Information Systems (OASIS) Technical Advisory Board, the leading XML and Web services standards organization in the world. He has completed major standards projects in

OASIS, the Object Management Group, and IEEE.

He chairs the OASIS Energy Interoperation Technical Committee which is producing the interoperation standard for the smart grid and facilities (including OpenADR 2.0), and the OASIS Energy Market Information Exchange Technical Committee which has completed version 1.0 of information models for energy market communications (completing SGIP Priority Action Plan 3). He is a member of the OASIS WS-Calendar TC which has delivered the Common Calendar and Scheduling Model 1.0 for the Smart Grid (completing SGIP Priority Action Plan 4).

Bill is a member of the Smart Grid Architecture Committee, and participates in IEC and in ASHRAE SPC201P for facility information models for energy usage and load.

Paul De Martini

Managing Director Newport Consulting Group LLC

GWAC

Paul De Martini provides advisory services to utilities, technology firms, policymakers and research institutions regarding the integration of distributed energy resources, market designs and related business models. He is also a Senior Fellow at ICF International. He co-leads California's More Than Smart initiative and is lead facilitator for the NY REV Distribution System Implementation Plan Stakeholder Engagement. Paul is also an industry advisor to Chrysalix Energy Venture Capital and several cleantech start-ups.

Paul was previously Chief Technology & Strategy Officer for Cisco's global Energy Networks business unit. Earlier he was VP, Advanced Technology at Southern California Edison where he led SCE's $2 billion grid modernization, distributed energy resource and transportation electrification efforts. Prior to SCE, he led ICF International's Energy Strategy practice.

Paul is a visiting scholar at the Resnick Sustainability Institute at Caltech and a practitioner-in-residence at the Pardee RAND Graduate Public Policy School. He holds an MBA from the University of Southern California and a BS, Applied Economics from the University of San Francisco.

Amro Farid

Associate Professor of Engineering Thayer School of Engineering at Dartmouth

Prof. Amro M. Farid received his Sc. B. in 2000 and his Sc. M. 2002 from the MIT Mechanical Engineering Department. He went onto complete his Ph.D. degree at the Institute for Manufacturing within the University of Cambridge (UK) Engineering Department in 2007. He has varied industrial experiences from the automotive, semiconductor, defense, chemical, and manufacturing sectors. He is currently an assistant professor of Engineering Systems & Management at the Masdar Institute of Science & Technology in Abu Dhabi, UAE and leads the Laboratory for Intelligent Integrated Networks of Engineering Systems (LIINES). The laboratory maintains an active research program in Smart Power Grids, Energy-Water Nexus, Energy-Transportation Nexus, Reconfigurable Manufacturing Systems, Sustainable Systems.

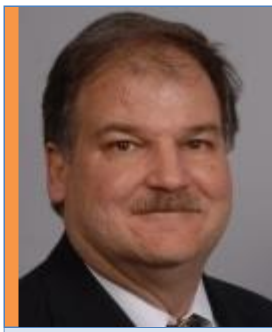
He is also a visiting scientist at the Massachusetts Institute of Technology – Technology and Development Program. He has made active contributions to the MIT-Masdar Institute Collaborative Initiative, the MIT Future of the Electricity Grid Study, and the IEEE Control System Society Smart Grid Vision.

Fred Fletcher

Assistant General Manager
Burbank Water & Power

Fred Fletcher has led electric utility planning, operations, and engineering from metering through distribution protection, substation, switching stations, transmission lines, energy control centers, power plants, power trading, risk management, and project finance for many years. He started his career in South Dakota, first with Black Hills Power and then as part of the first management team of Missouri River Energy Services. In 1986 he became Assistant General Manager at Burbank Water and Power. He focuses on the operational and the creative approaches of business development in publicly owned electric utilities.

Since 2006 he has been addressing the challenges of renewable energy and demand control/management/response. He was the first chair of the BWP Smart Grid Network Council. In 2010 he took a leave from BWP to work in private industry in developing advanced solutions for demand control and integration for a year. His experience in private industry helped him better understand how to apply these new tools. So he has re-doubled his efforts and is in the midst of revamping Burbank power system so that it incorporates these new tools and takes advantage of these new options.



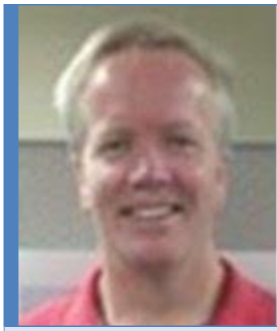
David Forfia

Director, Enterprise Architecture & IT Transformation
Electric Reliability Council of Texas

GWAC

David Forfia is Director of Enterprise Architecture and IT Transformation at the Electric Reliability Council of Texas, or ERCOT, where he is responsible for the architecture for the systems which operate the Texas electric grid operations and implementing the programs that transform the delivery of IT services to ERCOT's stakeholders. During his tenure at ERCOT, he has served in many roles including Director of Infrastructure & Operations, Director of Application Services and multiple roles on the Texas Nodal implementation.
He has more than 25 years of experience in the industry, and began his career at Austin Energy in 1987. Forfia received his bachelor's from the University of Texas and MBA from St. Edward's University, both in Austin. Forfia is PMP certified and currently serves on the Smart Grid Interoperability Panel Board of Directors

where he Chairs the Nominating and Governance Committee and serves on the Executive, Technical and Audit committees.



John Gibson

Manager of the Distribution System Operations and Engineering Technical Services
Avista

Mr. Gibson holds a Bachelor of Science degree in electrical (BSEE) and civil engineering (BSCE) from Gonzaga University and a Masters in Engineering Management from Washington State University. He is a registered professional engineer in the State of Washington and has worked in the electric utility industry for over twenty years. Mr. Gibson's experience in the electric utility industry consists of electric distribution planning, distribution system efficiencies and reliability programs. Mr. Gibson was Avista's project manager for the Smart Grid Investment Grant project as well as program consultant for the Turner Vanadium Flow Battery project. Currently, Mr. Gibson is the manager of the Distribution System Operations and Engineering Technical Services group responsible for the day to day operations of Smart Grid Technologies and Distributed Energy Resources on Avista's Distribution System.

Erik Gilbert

Director
Navigant Consulting

Erik Gilbert is a Director with Navigant's Energy Practice. His focus is on grid modernization and DER program analysis and technology strategy, including cost-benefit assessment. Mr. Gilbert has over twenty years of experience in developing and managing complex products and market programs as well as performing program evaluations and assessments. He is a member of the GridWise Alliance Board of Directors.

Prior to joining Navigant, Mr. Gilbert served as Director of smart-energy products for residential energy management system vendor Tendril Networks, Inc., where he defined and executed their hardware roadmap, including in-home energy displays, IP-to-HAN gateways, AMR/ERT-to-ZigBee bridges and other products.

Previously, Mr. Gilbert held various management positions at Cisco Systems, Inc., as well as several years of technology strategy development with Ernst & Young Management Consulting. Mr. Gilbert began his career as a design engineer. He holds BS in Electrical Engineering and Computer Science from the Massachusetts Institute of Technology and an MBA from the University of California at Berkeley.

Tad Glauthier

VP of Hawaii Operations
Stem

Tad Glauthier is a founding business development and operations executive of Stem, a Silicon Valley-based energy software company and the leading firm in the growing advanced energy storage industry. Tad serves as Stem's Vice President of Hawaii Operations, where his responsibilities include utility relations, customer development, regulatory affairs, and integrated market-and-product strategy for the Hawaiian market. Tad serves as the Vice President of the Distributed Energy Resources Council of Hawaii, which works to shape policies and programs for customer-side resources to connect and participate on the grid. Mr. Glauthier earned a BA from Stanford University and an MBA from the Graduate School of Business at Stanford.

Thierry Godart

General Manager, Energy Solutions
Intel

Thierry Godart joined the Internet of Things Group (IOTG) of Intel Corporation as General Manager of Energy Solutions in July 2015 to develop and deliver IoT solutions for the Power and Oil & Gas industry. The goal of Energy IoT is to implement an optimum energy value chain with reduced environmental impact in real-time. The scope of Energy IoT includes generation, transmission and distribution and consumption of electricity as well as the efficient extraction and refinement of oil and gas products.

Thierry is working with the ecosystem of equipment manufacturers, automation and software vendors, as well as utilities, oil & gas producers and service providers to develop and deploy ubiquitous connected devices, edge platforms and cloud architectures for operational excellence and transformative businesses.

Thierry has 25 years of experience providing advanced solutions to the global energy industry. At Schneider Electric, he was responsible for selling the complete set of Schneider offerings to electric utilities worldwide. Prior to his tenure at Schneider, Thierry led the Smart Grid Division of Siemens in North America. He has also held leadership positions at Areva T&D, ABB and GE.

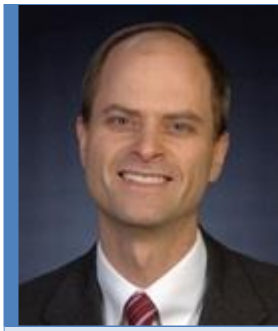
Thierry holds a Ph.D. in Electrical Engineering and Master's degrees in Applied Mathematics and Electrical Engineering, all from Georgia Tech (Atlanta, GA). He is a SUPELEC (Paris, France) Engineer.

Donald Hammerstrom

Senior Research Engineer
Pacific Northwest National Laboratory

Dr. Hammerstom is a Senior Research Engineer for Energy Technology

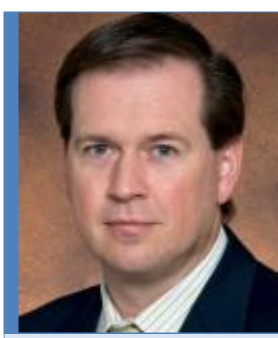
Development at the Pacific Northwest National Laboratory in Richland, Washington. He received his Ph.D. in Electrical Engineering from Montana State University in 1994.



David Holmberg

Mechanical Engineer, Engineering Lab NIST

David Holmberg serves as a mechanical engineer in the NIST Engineering Laboratory, Energy and Environment Division. His work focuses on building integration with the Smart Grid, looking at building system operation in a transactive energy environment. He is currently the leader for the NIST TE Modeling and Simulation Challenge for the Smart Grid. He serves as secretary of the SGIP TE Coordination Group. In addition, David represents the buildings community on the NIST Smart Grid team, serving as convener of the Smart Grid Working Group of the ASHRAE BACnet committee and co-convener of the IEC PC118 Smart Grid User Interface WG2 Power Demand Response.



Christopher Irwin

Smart Grid Standards and Interoperability Coordinator U.S. Department of Energy

Christopher Irwin has spent over 17 years in a diverse spectrum of high technology fields from HVAC to III-V semiconductor manufacturing, and most recently in communication networks for advanced metering (AMI) and Smart Grid infrastructure. He is a member of the Department of Energy team administering the Smart Grid Investment Grants, and is responsible for standards and interoperability activities, including participation in the NIST-led Smart Grid Interoperability Framework.

Prior to joining the Department of Energy, he served as Director of Products at an AMI communications vendor, also participating in Technology Discovery and Business Development. In that role, he gained a full market perspective on the electric energy sector, as well as natural gas and water infrastructure. This experience, combined with his semiconductor and satellite communications background, contributes to a unique perspective on the US energy business under transformation. Chris holds a B.S. in Mechanical Engineering from the University of Maryland, College Park, and an M.B.A. from the W.P. Carey School of Business at Arizona State University.

Bill Kallock

VP Grid Analytics Integral Analytics

Bill Kallock has over 25 years of experience in the energy efficiency, demand side management (DSM), and renewable energy industries. Mr. Kallock has consulted for energy utilities throughout North America designing and evaluating energy efficiency, demand response and renewable energy programs. He has also worked directly with residential, commercial and industrial customers to design and implement energy efficiency projects. As a result of his experience Mr. Kallock has in-depth knowledge of the energy efficiency market from the perspective of both the consumer and the energy provider.

As Vice President of Grid Analytics at Integral Analytics, Mr. Kallock is working with clients to develop solutions to optimize the distribution grid, and in particular integrating renewable energy sources. IA's granular load forecasting tools provide the distribution-level cost signals for utilities to deploy distributed energy resources, like PV and storage, in the right location, at the right amount and managed at the right time to optimize the distribution grid.

Mr. Kallock holds a MBA from the University of Michigan and a Bachelor of Science Mechanical Engineering from Cornell University.

Travis Kavulla

Montana Public Service Commission

Travis Kavulla represents the Montana Public Service Commission's geographically largest district. In November 2010, he was elected by a 28-point margin, the largest of anyone facing an election contested by both major parties since the modern commission's inception in 1974. He was re-elected in 2014 in an uncontested race.

Additionally, Mr. Kavulla is the President and Chairman of the Board of Directors of the National Association of Regulatory Utility Commissioners (NARUC). He is a member of the Advisory Council of the Electric Power Research Institute

He also serves as co-chairman of the Northern Tier Transmission Group (NTTG) Steering Committee and is a member of the California ISO's Energy Imbalance Market (EIM) Transitional Committee. Mr. Kavulla previously has led Western state utility regulators' efforts on the creation of efficient wholesale markets, emissions allowance trading, and the reliability of the bulk electric system.

David Kim

CEO
GRIDWIZ

David Kuhwan Kim is CEO and founder of GRIDWIZ Inc. providing smart energy services and solutions based on international standards.

David Kim works as standardization delegate for KATS (Korean Agency for Technology and Standards) in the area of Smart Grid and EV/EVSE.

GRIDWIZ is a leading company in the domains of Demand Response, Micro Grid, Smart Factory, EV Charging System based on OpenADR2.0, IEEE 2030.5 (SEP2.0), and ISO/IEC 15118.

Prior to forming GRIDWIZ, David Kim has co-founded WIZNET Inc., a semiconductor company enabling small devices Internet-connected. He also has worked as general manager of smart energy planning department at ILJIN Electric.

David Kim received his degrees in computer engineering from Busan National University, South Korea.

Rao Konidena

Principal Advisor, Policy Studies
Midcontinent Independent System Operator

Rao Konidena is Principal Advisor at MISO. Rao began his work with MISO in the areas of resource adequacy and transmission planning . He and his team developed demand side and clean technology options as alternatives to generation in the 20 year long term transmission expansion planning process. Rao is currently involved in the development of a comprehensive approach towards implementing state and federal policy objectives around increased penetration of energy storage and renewables. Rao has an MBA from University of MN and MSEE (Master of Science in Electrical Engineering) from University of Texas at Arlington. Rao is a Board member of Finnish American Chamber of Commerce - Minnesota and volunteers at City of Roseville, MN on the Finance Commission.

Alexander Krstulovic

Alliander

I am currently involved in shaping the future of the PowerMatcher, a disruptive transactive smart energy technology. Previous work has included the development of a trading platform based on PowerMatcher technology that can unlock and trade flexibility. With a mechanical engineering background and wide interest ranging from fields such IT security to Transportation and Logistics and Entrepreneurship I aim to add a wide skill base and innovation activation to give pragmatic shape to the energy transition.

Elliot Mainzer

Administrator & CEO
Bonneville Power Administration

Elliot Mainzer is the Executive Vice President for Corporate Strategy at the Bonneville Power Administration. In this capacity, Mainzer has responsibility for developing agency strategy on critical regional and national issues including climate change, renewable resource integration, regional transmission planning and market design.

Mainzer has held a variety of positions within BPA. Most recently, he served as the Manager of Transmission Policy and

Strategy where he led the development of BPA's Network Open Season. In 2006-2007, he led the development of the Northwest Wind Integration Action Plan in cooperation with utilities, developers and policymakers throughout the Pacific Northwest. He also has served as trading floor manager and manager of pricing and transaction analysis in the agency's power business line. Prior to joining BPA, Mainzer established and managed Enron's renewable power desk in Portland.

A native of San Francisco, Mainzer earned his MBA and Master of Environmental Studies degrees from Yale University. He enjoys skiing, hiking and reading history. He also plays jazz saxophone. Mainzer and his wife have two sons, twins.

James Mater

General Manager, Smart Grid and Director
QualityLogic, Inc

GWAC

James Mater co-founded and has held several executive positions at QualityLogic from June 1994 to present. He is currently Co-Founder and General Manager of QualityLogic's Smart Grid business. He is a member of GWAC and Chair of Smart Grid NW. He was an original member of the SGIP Test and Certification Committee, and has been giving papers and presentations on smart grid standards and interoperability since 2009. Prior to QualityLogic, James held Product Management roles at Tektronix, Floating Point Systems, Sidereal and Solar Division of International Harvester.

Mater holds a bachelor's degree in physics from Reed College, Portland, OR and an MBA from the Wharton School, University of Pennsylvania.

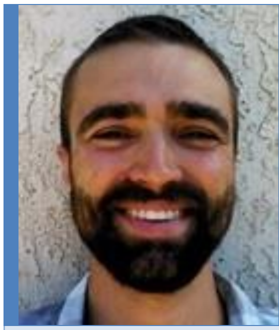
Matthew McDonnell

Commission Counsel
Hawaii PUC

Matthew T. McDonnell serves as Commission Counsel at the State of Hawaii Public Utilities Commission, where he supports numerous efforts, including integrated demand-side management, energy efficiency, community solar, and other DER-related issues. Mr. McDonnell's experience in energy consulting and electric utility regulation has focused on DERs and the development of new utility regulatory and business models.

As a consultant, Mr. McDonnell has advised clients on a variety of energy projects including independent review of generation options analysis, as well as, regulatory issues involving the transmission and sale of electricity. Mr. McDonnell's clients have ranged from municipalities and energy firms, to public utilities and stakeholder groups.

Mr. McDonnell has authored numerous publications on diverse topics including Section 111(d) of the Clean Air Act, Renewable Energy Credits in Arizona, and business models that engage and empower consumers. Mr. McDonnell earned his Juris Doctor from the University of Arizona and a B.A. in Finance from Michigan State University.

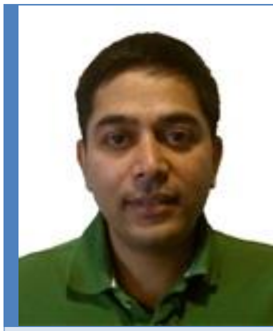


Alexi Miller

Senior Project Manager
New Buildings Institute

Alexi Miller is a Project Manager at NBI. He brings information and insights about cutting-edge technologies and strategies to diverse stakeholders as part of a wide-ranging effort to improve the energy performance of the built environment. As a technical resource he supports various projects including Getting to Zero, FirstView® and the NBI Building Information Network. His analysis supports projects having to do with zero net energy and high-performance buildings, evaporative cooling, deep energy savings retrofits, energy modeling software, emerging technologies, building codes, and more.

Prior to joining NBI in 2013 he spent six years at The Cadmus Group and worked on local, state, regional and international projects. Alexi has extensive knowledge of energy savings measures, energy metering and energy modeling. A graduate of the University of Colorado with a BS in Environmental Engineering, Alexi is a registered Professional Engineer in Mechanical Engineering, LEED-AP+ accredited and a PSAT (Pumping System Analysis Tool) Qualified Specialist. He is fully fluent in Spanish and conversationally fluent in Portuguese.



Himanshu Neema

Senior Staff Engineer
Vanderbilt University

Himanshu Neema is currently working as a Senior Engineer at Institute for Software-Integrated Systems at Vanderbilt University and holds a MS in Computer Science.

His primary research interests include Modeling & Simulation, Model-Integrated Computing, Distributed Simulations, Smart-Grids, Transactive Energy, Artificial Intelligence, Constraint Programming, and Planning & Scheduling.

He has 18+ years of experience in research, development, and managing of software applications covering a variety of areas such as Model-driven development, Simulation and Analysis of Transactive Energy Systems and Smart-Grids, High-level Architecture, Road & Railway Simulations, Cloud Computing, Functional Mock-up Interface, Service-Oriented Architectures (SOAs), Mobile Ad hoc Networks (MANETs), Resource Allocation, Semantic Web, and Automated Document Analysis & Classification.

Bruce Nordman

Research Scientist
LBNL

Bruce Nordman is a researcher in the Building Technology and Urban Systems Division, with principal focuses on energy use and savings in electronics and in networks. He works with the technology industry and standards organizations to develop new technologies to save energy in electronics and networks, and is often invited to speak domestically and internationally on this topic. He has worked on make Ethernet technology much more energy efficient, and enabling networked devices to sleep without sacrificing network connectivity. He also works on low-power mode energy consumption, on user interface issues for electronics power control and lighting, and on miscellaneous energy use, and on developing network architecture concepts for future building networks. Nordman has a BA in Architecture and MA in Energy & Resources, both from the University of California, Berkeley.

Duke Oishi

Senior Associate General Counsel
Hawaiian Electric

Duke T. Oishi is Senior Associate General Counsel at Hawaiian Electric Company, Inc. (Hawaiian Electric). Hawaiian Electric and its electric utility subsidiaries Maui Electric and Hawai'i Electric Light serve approximately 95% of Hawaii’s 1.4 million residents on the islands of O'ahu, Maui, Hawai'i Island, Lana'i and Moloka'i. Mr. Oishi joined Hawaiian Electric in 2013. His focus areas include regulatory proceedings before the Hawai'i Public Utilities Commission, renewable energy acquisition, power purchase agreements, and business and commercial transactions. In private practice prior to joining Hawaiian Electric, Mr. Oishi represented numerous developers of utility scale renewable energy projects through various phases of development, including project acquisition, negotiation of power purchase agreements, permitting and entitlement, and regulatory proceedings. Mr. Oishi received both his B.B.A (finance/international business) and J.D. from the University of Hawai'i.

David Owens

Executive Vice President, Business Operations
Edison Electric Institute

David K. Owens is Executive Vice President, Business Operations Group and Regulatory Affairs, of the Edison Electric Institute (EEI). EEI is the association that represents all U.S. investor-owned electric companies. Its members provide electricity for 220 million Americans, operate in all 50 states and the District of Columbia, and directly employ more than 500,000 workers. With $100 billion in annual capital expenditures, the electric power industry is responsible for millions of additional jobs. Safe, reliable, affordable, and clean electricity powers the economy, and enhances the lives of all Americans.

In his capacity as the first African American to hold an officer title at EEI, Mr. Owens has significant responsibility over a broad range of issues that affect the future structure of the electric industry and new rules in evolving competitive markets. He has responsibility over the strategic areas of energy supply and finance, environment, energy delivery, energy services, state regulatory issues, and international affairs. He also spearheads efforts to enhance the public policy climate for investments in America's electric infrastructure with emphasis on the role of new technologies to address climate change, and to enhance energy efficiency through smart buildings, smart appliances, smart meters, and smart electric grids.

Mr. Owens has frequently appeared before U.S. Congressional Committees, testified in more than 50 proceedings on energy issues before state bodies, lectured at universities across the nation, made hundreds of presentations in business forums, and frequently appears on television and radio. He is recognized as one of the foremost authorities on electric utility issues and industry restructuring. He has been at EEI for more than 29 years, starting his EEI career as Director, Rates and Regulation.

He is a graduate of Howard University with a Bachelor and Masters of Engineering degrees. He also has a Masters in Engineering Administration from George Washington University, and has attended executive courses at Howard University, the University of Pennsylvania, and Michigan State University.
Mr. Owens has distinction in Who's Who Among Black Americans, Who's Who In The Government, and has been honored as Outstanding Leader in the Utility Industry. He is the recipient of the James E. Stewart Award, the highest distinction for an American Association of Blacks in Energy (AABE) member, and he was awarded the President's Cup by AABE for his leadership on public policy matters. Mr. Owens sits on the Boards of the National Academy of Sciences, serves as Chair of the IDEA Public Charter School Board of Trustees, Chairman of the National Institute of Standards and Technology Smart Grid Advisory Committee, and is an active member of a number of professional and community-based organizations.

Annabelle Pratt

Senior Engineer
NREL

Annabelle joined NREL in 2014 with 14 years of industrial research and development experience, most recently as a research engineer for the corporate research and development division of Intel Corporation. During her tenure at Intel, Annabelle worked in the areas of automated energy management, microgrid energy management, advanced digital control of voltage regulators, direct current power delivery for data centers, and high-efficiency server power supplies. Prior to Intel, Annabelle spent five years as a design engineer and project manager at power conversion equipment manufacturer Advanced Energy.

Gary Radloff

Researcher
Wisconsin Energy Institute

Gary Radloff is a researcher at the University of Wisconsin-Madison and the Director of Midwest Energy Policy Analysis for the Wisconsin Energy Institute (2009 to present). He is an Honorary Associate/Fellow with the Nelson Institute, Center for Sustainability and the Global Environment (SAGE). Radloff has also served as the Interim Director with the Wisconsin Bioenergy Initiative at the University of Wisconsin.

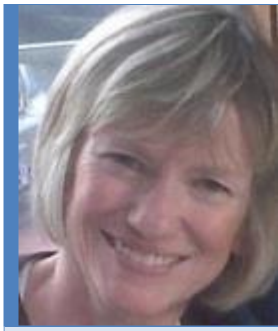
He is the lead author or co-author of the following reports: Policy Strategies to Catalyze the Energy Technology Innovation System in Wisconsin and the United States (2015); Transforming the Grid from the Distribution System Out (2014); How to Keep Wisconsin and the U.S. Competitive in a Changing Energy World (2013); Wisconsin Strategic Bioenergy Feedstock Assessment (2012); The Biogas Opportunity in Wisconsin (2011); and the Guidelines for Sustainable Planting and Harvest of Nonforest Biomass in Wisconsin (2012).

Radloff is the former Director of Policy and Strategic Communications at the Wisconsin Department of Agriculture, Trade and Consumer Protection (2004 to 2009). Past activities include helping to coordinate policy initiatives such as the Governor's Consortium on the Biobased Industry and the Working Lands Initiative.

Narayanan Rajagopal

Senior Scientist
Tata Consultancy Services

Narayanan Rajagopal has over 25 years' experience in the area of power system. As a Senior Scientist in TCS, he is engaged in Smart grid solutions conceptualization, analytics development, and evaluation of smart grid technologies. He is a certified SGMM Navigator. He has earlier worked in product development, system application, test system development, customer training, application engineering of substation and distribution automation systems (SA and DA). He is actively engaged in forums such as IEEE, Power and Energy Society, Smart Grid Interoperability Panel and Bureau of Indian Standards. He is a senior member of IEEE and member of IET, UK.



Linda Rankin

President
V-SQUARED

Computer and system architect specializing in energy and industrial Internet of Things applications and embedded systems. Technical leadership and project management skills in delivering world class products and solutions.

More than 40 patents/patents pending domestically and internationally including areas of security, thermal management, reliability.

Expert on smart grid and grid friendly applications, including transactive energy management services.

Jason Salmi Klotz

Oregon Public Utility Commission

Jason R. Salmi Klotz holds a J.D. and Masters of Environmental Law and Policy from Vermont Law School. Jason has worked for the Vermont Public Service Board, the Federal Energy Regulatory Commission, and the California Public Utility Commission. For these entities he worked on wholesale market development, demand side management, facilities siting and greenhouse gas regulation. Jason worked for Bonneville Power Administration where he was responsible for the initiation of the Pacific Northwest Smart Grid Demonstration Project.

Prior to his current role as climate change lead for the Oregon PUC, Jason worked for the Northwest Energy Efficiency Alliance as their Senior Policy Advisor. Jason is a published author of several papers on the nexus of environmental concerns and energy regulation. Jason is also currently an Adjunct Instructor of energy policy and law at the University of Oregon School of Law in Eugene, Oregon.

Heather Sanders

Principal Manager, Integrated Grid Strategy & Engagement
Southern California Edison
GWAC

Heather Sanders joined Southern California Edison (SCE) in August 2015. Within electric system planning, her team is focused on strategic direction and engagement to realize the 21st century integrated grid. Before joining SCE, she held multiple roles at the California Independent System Operator (ISO) in regulatory policy and smart grid technology and strategy. While at the ISO, she jointly led several road mapping efforts with the CPUC and CEC. These roadmaps outline needed actions to advance California energy and environment objectives with publications focused on Energy Storage, Demand response and Energy Efficiency, and Vehicle Grid Integration. Heather holds a BS in Electrical Engineering from South Dakota School of Mines & Technology and a MBA from the University of Utah.

Robert Sherick

Principal Manager, Renewable Integration
Southern California Edison

Robert Sherick, Principal Manager, Renewable Integration in Southern California Edison's Advanced Technology division, oversees engineering professionals who analyze and develop solutions for the next generation transmission and distribution grid. The group is currently engaged in evaluating telecommunications and controls systems, assessing the impacts from high penetration Solar PV and Storage, determining equipment needs for transmission stability, and demonstrating smart grid technologies on SCE's distribution system.

Mr. Sherick has worked in power operations, energy trading, and software development over his career with utilities, as a management consultant and as a software product manager. He holds a Masters in Electrical Engineering from USC and an MBA from the Drucker Management School and is a registered Electrical Engineer in the State of California.

Tom Sloan

State Representative Kansas House of Representatives

GWAC

Rep. Sloan is serving his eighth term in the Kansas House of Representatives and is Chairman of the Vision 2020 Committee (House "long-range planning committee), as well as a member of the Energy & Utilities and Government Efficiency & Technology Committees. He is a leading legislative voice on Kansas' electric, natural gas, telecommunications, and water policies. He is a member of the National Wind Coordinating Committee's Steering Committee; Vice Chairman, Council on State Government's Energy & Environment Task Force; member, U.S. Dept. of Energy's Electricity Advisory Committee.

Rep. Sloan has organized 12 Summits on renewable energy/transmission lines; reservoir sustainability; rural broadband; and health-care research at which the Chairmen/Commissioners of FERC/FCC; Administrators of NIH/FDA; and Assistant Secretary of the Army joined Kansas and regional stakeholders to promote increased collaboration.

Dr. Sloan is Chairman of Douglas County Rural Water District #1, former member of the Lower Republican Basin Advisory Committee, and the only state legislator to serve on the Kansas Water Authority, the state's water planning body. He was Assistant Professor of Political Science at Kansas State University and continues to teach on public policy formation at Kansas University and private colleges.

Dr. Sloan is President of Sloan & Associates, a firm that facilitates strategic planning and general communications with the client's customers, employees, and other targeted audiences. The firm has advised and assisted small businesses in Kansas and regional professional associations in the mid-west since 1995. With his wife, Gail, he owns a registered sheep farm with non-irrigated corn, soybean, and hay production.

Dr. Sloan earned a A.B. from Syracuse University, M.A. from Michigan State University, and a PhD from the University of North Carolina at Chapel Hill. He has held management positions in the private and not-for-profit sectors. He was an Assistant Professor at Kansas State University, served as Chief-of-Staff for the President of the Kansas Senate, and has held other positions in Kansas' state government.

Jeffrey Taft

Chief Architect
PNNL

GWAC Emeritus

Jeff is the Chief Architect for Electric Grid Transformation at the Pacific Northwest National Laboratory. As a member of the Energy and Environment Directorate, he is responsible for development and articulation of large scale architecture for grid modernization, as well as support of many cross-cutting activities at the Laboratory, including the Future Power Grid Initiative, advanced computing, and the Control of Complex Systems Initiative. He began working in the grid modernization area in 2001 and has held smart grid chief architect roles with Cisco, Accenture, and IBM. Jeff formerly worked for Westinghouse and has participated in several key smart grid projects since he first began to develop sensor architectures and analytics for distribution grids, and then became involved in the larger issues of end-to-end grid integration and control. Jeff earned a PhD in Electrical Engineering from the University of Pittsburgh with a dual specialization in digital signal processing and digital control systems in 1986. He is a member of the IEEE Power and Energy Society, an emeritus member of the GridWise Architecture Council and is the holder of 31 patents in control systems, signal processing, and grid modernization.

Chin Yen Tee

PhD candidate
Carnegie Mellon University

Chin Yen Tee is a PhD candidate at the Department of Engineering and Public Policy at Carnegie Mellon University. Prior to this, she received a Master of Science in Engineering and Public Policy from Carnegie Mellon University in 2015 and a BA in Engineering and Economics form Smith College in 2011. Chin Yen is a member of the Electric Energy System Group at Carnegie Mellon University. She is interested in energy issues at the intersection of engineering, policy, and economics. Her most recent research focus is on electricity market design for the future electricity grid.

Chris Villarreal

Director of Policy
Minnesota Public Utilities Commission

Chris Villarreal is Director of Policy for the Minnesota Public Utilities Commission. In his role at the Minnesota PUC, he provides policy perspectives on a number of issues before the Commission, including grid modernization, utility resource planning, dynamic pricing, energy storage and data access and privacy. Before joining the Minnesota PUC, he spent 9 years with the California Public Utilities Commission in the Policy and Planning Division as a Senior Regulatory Analyst. Before that he was a Paralegal in Washington, D.C., primarily focused on energy matters before FERC. He has a BA in History from Baylor University.

Steve Widergren

Principal Engineer
Pacific Northwest National Laboratory

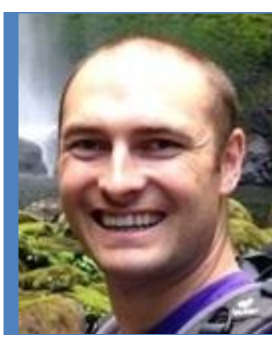
GWAC Emeritus

Steve Widergren is a principal engineer at the U.S. Department of Energy's Pacific Northwest National Laboratory where he directs electric power research projects. He is a member of the board of the Smart Grid Interoperability Panel and was the founding administrator for the GridWise Architecture Council – both groups formed with the mission to enable interoperability of automated systems related to the electric grid. His industry experience includes working at utilities and with an energy management system supplier. Applications include information modeling, SCADA systems, and reliability assessment tools. He received his BS and MS degrees in electrical engineering from the University of California, Berkeley, and is an active member of IEEE.

Jennifer Worrall

CTO
Iteros, Inc.

Jennifer Worrall is currently the President and Chief Technical Officer for Iteros, Inc., which is an enterprise software company specializing in energy systems. She was previously the Director of Information Engineering CleanSpark LLC, responsible for the design and implementation of their Enterprise Architecture and SCADA system as well as cybersecurity policies and procedures. She also is a team lead in the NIST TE Challenge or the group "Transactive Energy Control for Systems of Microgrids." At her prior position at Southern Company Transmission, she was a Senior Technical Architect for their Energy Management System and related applications. She brings her knowledge of the energy utility industry and large transmission grid implementations to the CleanSpark team. Ms. Worrall also has experience as a Development Team Lead and Program Manager for a large client implementation while consulting for Accenture, and as a software engineer at large Internet-based companies like About.com.



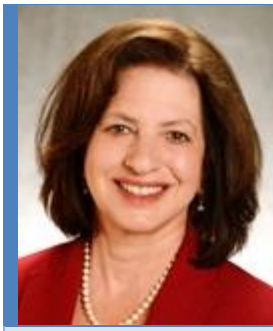
Bryce Yonker

Executive Director
Smart Grid Northwest

At Clean Edge I lead the development of the company through managing client relationships and ensuring that firm's offerings address the needs of the clean-tech community. We are helping key clean-tech industry firms track activity and apply market insights in the clean energy, advanced transportation, grid intelligence, water technology, green building, and energy efficiency sectors through a variety of indexing, benchmarking, and custom research offerings. As with the last handful of years, 2014 and beyond is sure to be an exciting time for renewables and other clean technologies.

In 2014 I took on the role to head up Smart Grid Northwest as its first Executive Director. I have been involved since the initial meeting in 2008 when we brainstormed the need to create an organization dedicated to supporting the development of grid technology in the region. With the mission to promote, grow and enable the smart grid industry and infrastructure in the Pacific Northwest we will be starting and expanding a number of initiatives focusing on education, policy, and planning.

Specialties: business development, product development, strategic initiatives and partnerships, client and relationship management, strategic planning, value creation, prospect outreach, sales management, marketing initiatives, proposal and RFP creation, sponsorship packages, event planning, presentations and public speaking, customer retention, business operations, financial planning and analysis, utility strategy and business models, smart grid insights, clean energy trends



Audrey Zibelman

Chair
New York State Public Service Commission

Audrey Zibelman was confirmed as a Commissioner of the New York State Public Service Commission on June 19, 2013, and was named Chair on September 3, 2013. Her term turns through February 1, 2018.

Ms. Zibelman has extensive experience in the public, private and not-for-profit energy and electricity sectors. She is a recognized national and international expert in energy policy, markets and Smart Grid innovation.

As PSC Chair, she is Chair of the New York State Board on Electric Generation Siting and the Environment. She also sits on the State Energy Planning Board; the board of the New York State Energy Research and Development Authority (NYSERDA), the board of the Regional Greenhouse Gas Initiative Inc. (RGGI), the Audit Committee of RGGI, the New York State Disaster Preparedness Commission, and the Bureau of Ocean Energy Management Task Force. Ms. Zibelman was appointed to the National Association of Regulatory Utility Commissioners (NARUC) Board of Directors, and is a member of NARUC Committee on Electricity. She is a member of the U.S. Department of Energy's Electricity Advisory Committee; a member of Lawrence Berkeley National Laboratory’s Future Electric Utility Regulation Advisory Group. She is also a board member of the Advanced Energy Research and Technology Center (AERTC).

Ms. Zibelman is a Founder and past President and Chief Executive Officer of Viridity Energy, Inc., which she formed after more than 25 years of electric utility industry leadership experience in both the public and private sectors. She has participated as both counsel and expert witness in numerous electric utility proceedings before state and federal regulatory and legislative bodies on topics such as the benefits of power markets and Smart Grids to consumers. Ms. Zibelman also has served on the boards of organizations responsible for assuring the security and reliability of the nation's power system, including Reliability First, the GridWise Alliance, and the Midwest Reliability Organization.

Previously, Ms. Zibelman was the Executive Vice President and Chief Operating Officer of PJM, a Regional Transmission Organization that operates the world’s largest wholesale power market and serves 14 states throughout the eastern United States. Ms. Zibelman also held executive positions at Xcel Energy, served as General Counsel to the New Hampshire Public Utilities Commission, and as Special Assistant Attorney General in the Minnesota Attorney General’s Office.

Ms. Zibelman received her B.A. from Pennsylvania State University and her J.D. from Hamline University School of Law.