VOLTTRON™

Devices | Data | Decisions

Technical Meeting on the Software Framework for Transactive Energy: VOLTTRON™

Pacific Northwest NATIONAL LABORATORY

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U.S. DEPARTMENT OF ENERGY

PG&E Pacific Gas and Electric Company®

PG&E Pacific Energy Center | 851 Howard Street | San Francisco, CA 94103

Agenda		
May 16-17, 2017 **PG&E Pacific Energy Center | 851 Howard Street | San Francisco, CA 94103**		
Objectives: Build the User Community, Learn From Each Other, and Ensure VOLTTRON™ Meets the Needs for a Transactive Market		
DAY 1 – May 16, 2017		
EERE and Grid Integration: Role of Transactive-Based Control		
08:30	Welcome	Dennis Stiles, PNNL
	DOE/BTO Purpose and Context	Joseph Hagerman, DOE/BTO
	VOLTTRON™ – How far we have come!	George Hernandez, PNNL
VOLTTRON™ – Hardware		
9:30	Raspberry Pi, Intel NUC, etc.	Robert Lutes, PNNL
	Intwine Connected Gateway for VOLTTRON™ Applications	Ryan May, Intwine Connect
	The SkyCentrics SkySnap – Controls, Sensors, Metering & VOLTTRON™	Tristan de Frondeville, SkyCentrics
VOLTTRON™ – Applications		
11:00	Intelligent Load Control	Srinivas Katipamula, PNNL
	VOLTTRON™ Thermostat	Teja Kuruganti, ORNL
	Transactive Control and Coordination	Robert Lutes, PNNL
11:45	Discussion	Facilitator
National Laboratory Portfolio (Panel) – Working Lunch		
12:00	Clean Energy and Transactive Campus Project	Srinivas Katipamula, PNNL
	Connected Neighborhood	Teja Kuruganti, ORNL
	Connected Home Challenge	Jereme Haack, PNNL
	PG&E Demand Response Reference Platform	George Hernandez, PNNL
VOLTTRON™ Solutions		
01:30	Maalka: An Extensible Platform for VOLTTRON™- Enabled Visualizations, Analytics, Data and Program Management	Rimas Gulbinas, Maalka
02:15	VOLTTRON™ and Demand Response	Paul Lipkin, Kisensum
03:00	VOLTTRON™-Based Services	Terry Herr, Intellimation
03:45	Constant Commissioning (CCx) and Automated Demand Response (ADR) on VOLTTRON™	Zach Wilson, New City Energy

VOLTTRON™ Open Source		
04:30	VOLTTRON™ Foundation	Joseph Hagerman, DOE/BTO
05:00	Adjourn	
DAY 2 – May 17, 2017		
08:00	Summary of First Day	Facilitator
Technology Overview		
08:10	VOLTTRON™ History & New Features	Jereme Haack, PNNL
08:40	VOLTTRON™ Deployment Overview	Craig Allwardt, PNNL
09:00	Securing VOLTTRON™ and the Underlying System	Craig Allwardt/Bora Akyol, PNNL
09:45	Device Configuration and Interaction	Robert Lutes/Kyle Monson, PNNL
10:45	Historians and Data Storage	Kyle Monson/Craig Allwardt, PNNL
11:15	Deployment Management	Craig Allwardt/Jereme Haack, PNNL
VOLTTRON™ in Use Working Lunch		
12:00	VOLTTRON™ Applications	Andrew Rodgers, Intellimation Nigel David, SES Consulting Kevin Morrissey, UW Chris Winstead, ORNL Christian Kohler, LBNL
VOLTTRON™ Office Hours		
01:30	How do I do this in VOLTTRON™?	VOLTTRON™ Team
02:30	Open Discussion	Facilitator
03:30	Adjourn	

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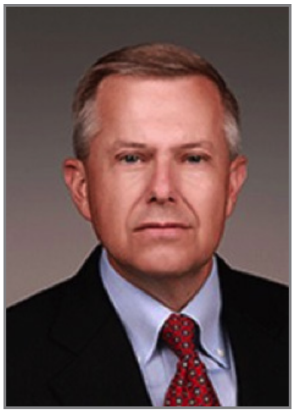
DAY 1

PNNL WELCOME

Dennis Stiles



Dennis serves as the Buildings Program Lead at Pacific Northwest National Laboratory (PNNL), working with the U.S. Department of Energy to define research that supports its goals for improving the efficiency of residential and commercial buildings, making buildings fully engaged in the larger energy system, and employing responsive building loads to support integration of renewable energy generation.

During his career at the Laboratory, Dennis has played a role in a number of research areas, most significantly in launching PNNL's biofuels and renewable chemicals research program, which resulted several commercial products and national awards. In other prior assignments, he served as a scientific co-director of the Oregon Nanoscience and Micro-Technologies Institute, as a senior project manager, as a technical group manager, and in various strategic planning roles.

Dennis has a Bachelor's degree in Industrial and Management Engineering from Montana State University and a Master's degree in Engineering Management from Washington State University.

DOE/BTO PURPOSE AND CONTEXT

Joseph Hagerman

Joe is a Senior Advisor at the U.S. Department of Energy's (DOE) Energy Efficiency and Renewable Energy (EERE) Office, where he focuses on building energy efficiency and new building technology development. He is at the forefront of the effort to develop clean, healthy, competitive building technologies for the 21st century – leading the Department's smart buildings, transactive controls, and building-to-grid research. Joe oversees various negotiated federal regulatory and new initiatives – including all activities related to connected equipment, building cybersecurity, interoperability, and connected equipment characterization. He also directs the Building Innovators program, which awards innovative graduate student teams to develop market-based technology solutions as well as VOLTTRON™ applications.

Before joining DOE, Joe was the project manager for the Building Technologies group at the Federation of American Scientists,where he conducted research in new building technologies while demonstrating these technologies in the public sector. His efforts helped address environmental and energy injustices in energy-efficient, affordable housing.

Joe received his Bachelor of Architecture from Mississippi State University and his Masters in Civil Engineering at the Fu Foundation School of Engineering at Columbia University. His academic work focused on engineering mechanics and construction technology.

Abstract

Transaction-based controls are "a means of executing transactions through automatic control of the operating state of building equipment and other energy systems in response to data and value streams." Pacific Northwest National Laboratory (PNNL) and two other DOE national laboratories, through extensive modeling, have showed that proper use of transaction-based controls can achieve 20-30% energy-efficiency savings in small office buildings through the deployment of controls, control strategies, and control applications/algorithms. Investing in applied research and development (R&D) reduces the "figure it out tax" for the industry, which includes:

- Sensors
- Plug and play capabilities
- Self configuration, start-up, and automatic fault detection and diagnostics
- Complex control methods
- Others identified in the Sensor and Control Roadmap.

Another promising concept, Complex Control Theory, is expanding through conversations about, research into, and implementations of transactive energy that can enable control aggregation to deliver the myriad of services that end-use equipment can provide for market-based service solutions; for example, does the market prefer the aggregation of commercial rooftop units across fleets of big box retailers to deliver end user and grid services, or do owners and operators prefer to manage buildings within the property boundaries? Aggregation is but one important topic to Complex Control Theory. By using an incentives-based approach, rather than direct utility "Command and Control," customer choice is respected in the use of their assets while enhancing their options for direct and remunerative participation, and they are offered the satisfaction of helping to reduce the region's carbon footprint.

Several campus testbeds will further be specialized as a platform on which additional R&D will be conducted to advance the state of knowledge in three key areas of critical interest to DOE team members:

- PNNL - transactive energy management systems for campuses and buildings.
- University of Washington - smart campus and building information systems that provide energy-efficiency benefits and support the integration of photovoltaic systems with distribution.
- Washington State University and the University of Washington will use the testbed and associated R&D activities to develop new, multidisciplinary curricula that combine the disciplines of information and control technology, distribution systems engineering, building systems engineering, and energy economics.

Transactive controls research and development represents an opportunity for DOE's Building Technologies Office (BTO) program to fully realize the benefits that whole building system integration can provide to the grid at different scales and for different, yet regionally specific, economic drivers.

BACKGROUND

BTO has established a vision of transaction-based controls that first, and foremost, benefits the owners and operators of buildings through the delivery of energy efficiency. Transaction-based controls are a means of executing transactions through automatic control of the operating state of building equipment and other energy systems in response to data and value streams. Furthermore, PNNL and two other DOE national laboratories, through extensive modeling (following DOE's Codes Determination Methodology), have showed that proper use of transaction-based controls can achieve 20-30% energy-efficiency savings in small office buildings through the deployment of controls, control strategies, and control applications/algorithms. This important policy finding estimated through modeling has raised the awareness of building controls as a concentration area across DOE. In addition to energy-efficiency savings, transaction-based controls can benefit system efficiency of the electricity grid by delivering traditional grid services such as direct load control, ancillary services via an aggregator, and others as outlined in the grid services use cases developed for BTO. In the marketplace, even commercial programs such as U.S. Green Building Council's Leadership in Energy and Environmental Design program recognizes and incents buildings that have installed demand response-enabled control systems (but does not require those buildings to be enrolled in any demand response utility program). Therefore, the marketplace is beginning to recognize and value transaction-based controls.

TRANSACTION-BASED CONTROLS

In the publication "Transaction-Based Building Controls Framework, Volume 1: Reference Guide," PNNL specified four service classes that transaction-based controls could deliver;

1. **User services** (e.g., energy-efficiency measures, diagnostic and automated commissioning services)
2. **Energy market services** (e.g., variable rate utility tariffs, real-time price, future tariffs for emerging technologies)
3. **Grid services** (e.g., traditional demand response and, in the future, other ancillary services or load management)
4. **Societal services** (e.g., services society has deemed important through policies or regulations – such as those to reduce emissions of greenhouses gases or to improve air quality via reduction of smog-forming pollutants).

This spectrum of services includes a non-exhaustive list of use cases for each of the four categories of services.

Fundamentally, transaction-based controls require the commingling of energy data and information. In the "controls" market today, several vendors claim to provide this type of solution, but they are proprietary, expensive, and narrowly focused on one or two systems (typically only heating, ventilation, and air conditioning, or those systems and lighting). Because DOE is technology neutral in the selection or award of proprietary solutions and needs to support the larger discipline of transaction-based controls, in 2011 DOE adopted PNNL's innovative distributed control and sensing software "platform" (VOLTTRON™) as the flexible, open-source solution to accelerate the development of its controls program and simplify the technology transfer process.

VOLTTRON™ was developed by PNNL as part of the Future Power Grid Initiative using Laboratory-Directed Research and Development funding, a five-year project established in 2011 designed to deliver next-generation concepts and tools for grid operation and planning and ensure a more secure, efficient and reliable future grid. However, the initial VOLTTRON™ platform was distribution grid focused, so in 2012 DOE began to enhance the solution to extend functionality to include buildings-specific control strategies and fully released the solution (and future solutions) as open source. The solution has been tested at utility scale, certified in PNNL's PowerNET Testbed, and includes cyber security features that have been tested through various events. Furthermore, to support other solutions (and continue to "not pick a winner"), BTO commissioned to PNNL to develop Volume 2 of the 'Transaction-Based Building Controls Framework,' a specification document defining the architecture of transaction-based control systems and related IT.

Transaction-based controls allow buildings and connected equipment in buildings to perform four primary functions:

1. **Supply** - Generate power to avoid, minimize, or shift larger system distortions from renewable assets like photovoltaic and wind. Example solutions include economic dispatch of fuel cell technologies.
2. **Consume** – Regulate, change, or alternate operation to optimize or reduce large system distortions. Example solutions include the control of end-use loads to manage whole building site usage to a fixed amount or quantity.
3. **Regulate** - Transfers loads between two or more devices to optimize the larger electricity system. Example solutions include load management to extend or reduce a transformer's design capacity or lifetime.
4. **Store** – Applications of functions necessary to store or stage energy. Example solutions include physical storage like batteries or management of buildings and connected equipment to provide "virtual battery storage."

DOE'S TRANSACTIVE CONTROL PROGRAM VISION

DOE's collection of controls projects and activities has garnered widespread industry support and collaboration through multiple public engagements because the comprehensive program was built on three key principles defining DOE's role:

1. DOE should invest in comprehensive applied R&D in the fundamentals of sensors and controls in areas such as plug and play, large-scale complex control methodologies, and agent-based control theory, which encompasses multiple solutions and cuts across many industry entities.
2. DOE should continue development of an open source, transaction-based controls platform and related tools (e.g., VOLTTRON™ Core and VOLTTRON™ EIS) so everyone has equal access to the research, findings, and applications (whether or not industry participants ultimately adopt VOLTTRON™ or simply incorporate features and code found in VOLTTRON™).
3. DOE should continue to stimulate the market, fund the development of market-based solutions, and promote market successes only after careful scoping studies are completed that describe the use cases, business case, and market justification with the industry through direct industry engagement.

In each of these areas, DOE programs (including BTO and other EERE offices) have key roles to play. For example, previous Recovery Act investments funded municipalities and cities to install and deploy clean energy technologies. However, in many of those communities, the projects only deployed the technologies – such as electric vehicles, smart meters, or building-located photovoltaics. Therefore, integration opportunities remain to realize the full benefit of clean energy technologies at scale – which can help a utility increase and enhance their service offerings rather than impede their operations.

DOE has a clear and present role across EERE to help these communities realize these projects' full potential by lessening any transmission and distribution power quality issues caused in whole or in part by clean energy technologies and, more importantly, to sustain or create opportunities for continued investment in the energy and information sectors. DOE's roles are best characterized by:

1. **Investing in applied R&D** that reduces the "figure it out tax" for the industry, including:
   - Sensors
   - Plug and play capabilities
   - Self configuration, start-up, and automatic fault detection and diagnostics
   - Complex control methods
   - Others identified in the Sensor and Controls Roadmap.
2. **Convening the industry** to discuss and work out institutional issues that benefit the greater good, including:
   - Interoperability
   - Cyber security
   - Characterization of assets.
3. **Developing an open source software solution** that is easily adoptable (by all of DOE) and contains proof-of-concept, bench-top examples, and extensible solutions of transaction-based controls at the scale of:
   - User services (energy efficiency)
   - Energy market services
   - Grid services
   - Societal services.

4. **Stimulating the market** through the development of demonstrations that are small-scale implementations of real market solutions (based on carefully constructed reference documents with deep industry input and comment).
    - Residential solutions
        - o Whole home energy management
        - o Fully integrated solutions for traditional (e.g., water heater, air conditioning) and emerging (e.g., heat pump, water heater, photovoltaic, electric vehicle, battery) equipment as well as sensors for "quality of life."
    - Commercial Solutions
        - o Sector based, such as small and medium buildings controls platforms and other sector solutions (e.g., convenience stores, supermarkets).
        - o Equipment and component based, such as building to vehicle integration, municipal pumps and water control solutions, and other market-based solutions.

RELATED CONTROLS CONCEPTS

Another promising concept, Complex Control Theory, is expanding through conversations about, research into, and implementations of transactive energy (and related transaction-based controls) that can enable control aggregation to deliver the myriad of services that end-use equipment can deliver for market-based service solutions; for example, does the market prefer the aggregation of commercial rooftop units across fleets of big box retailers to deliver end user and grid services, or do owners and operators prefer to manage buildings within the property boundaries? Aggregation is but one important topic to Complex Control Theory. As these fundamental issues and market opportunities are explored, DOE must continue and track the maturity of controls versus the services that can be delivered. This is particularly relevant as more building-located devices and assets are becoming "connected" thanks in part to the Internet of Things movement (and the trivial cost of adding connected features and capabilities during the manufacturing of these devices).

This "mapping" of the equipment's ability to deliver each or multiple services type (or the lack of the ability) is a key goal of characterization. Whereas DOE has explicitly stated that it won't label or rate products, it is recognized that other groups may need ratings and labels to satisfy their constituents, as a means of educating consumers/buyers, or to more narrowly specify the performance required in a specification of bid (thereby supporting competitive markets rather than vendor-driven solutions). Using its convening abilities, DOE has recognized that characterization is one of the important pillars for success. Internally to DOE, EERE may consider rating or mapping project activities to they are diverse in its investment in opportunities.

Specific to buildings, BTO specified the following needed efforts to scale controls:

- "Common definitions and data formats to facilitate scalable, lower-cost solutions that will enable building and building-to-grid optimization." (Responding to interoperability needs.)
- "Smart building solutions, including automated controls to provide faster response and support greater penetration of end-use solutions to U.S. energy, demand, and grid regulation needs (i.e., <50 msec response to better enable ride-through capabilities)." (Responding to outstanding core, foundational R&D needs.)
- "Greater utilization of smart meter data to enable and appropriately value energy savings and building/component response." (Responding to the outstanding needs to leverage data and to commingle that data with the electricity itself to enable transaction-based controls and the larger, emerging field of transactive energy.)
- "Further U.S. innovation and leadership focused on new innovations and solutions to support greater cost-effective energy efficiency and energy demand savings, renewable penetration, and grid support from the end use and building level." (Responding to the need to stimulate the market through programs with clear reference documents specifying the characteristics of market solutions, the business case, and use case.)

VOLTTRON™ – HOW FAR WE HAVE COME!

George Hernandez

George joined Pacific Northwest National Laboratory in 2009 and works in the Electricity Infrastructure & Buildings division. He is a Technical Advisor and senior demand-side management professional. Working under the support of Joe Hagerman, he has co-authored the "High Performance RTU Challenge," "Buildings Performance Database, the Low Cost Wireless Metering Challenge," "Energy Information Handbook," "Portable Sensor Suitcase," "Open Source Small Building Control System," and "Transactional Network" project. Most recently, he has championed development and commercialization of an open source software platform called VOLTTRON™, used to deploy transactional control strategies for buildings-to-grid integration. He has extensive knowledge, skills, and capabilities derived from a substantial career in demand-side utility management across a wide variety of commercial and industrial sectors and utilities as both a corporate employee and an independent consultant. George received his B.S. in Mechanical Engineering from California State University and his Masters in Mechanical Engineering from the University of California at Berkeley. He is a Licensed Professional Engineer by the State of California.

Abstract

It hard to see the future, maybe impossible, but every once in a while you find a gem in the rough. VOLTTRONTM started as an idea by three PNNL researchers to enable Transactive Energy and has rapidly developed into a software platform that truly has endless possibilities. Let's take a trip down memory lane and dream about a future so bright, you will definitely need shades!!

RASPBERRY PI, INTEL NUC, ETC.

Robert Lutes

Robert is an engineer in Pacific Northwest National Laboratory's Advanced Building Controls group. Since joining the Laboratory in 2012, Robert has supported research related to the development of software tools to promote energy efficiency, improved operations, and building-to-grid integration. Robert's research interests include automated fault detection for building heating, ventilation, and air conditioning (HVAC) systems, transactive controls, and development of non-conventional control techniques for built up HVAC systems and rooftop air conditioners.

Abstract

VOLTTRON™ can run quite effectively on inexpensive hardware with limited computational power. This talk will highlight the current hardware in use for the PNNL campus deployment and will focus on popular single board computers (e.g., Raspberry Pi). Quantification of platform performance for various hardware will be presented.

INTWINE CONNECTED GATEWAY FOR VOLTTRON™ APPLICATIONS

Ryan May

Ryan joined the Intwine Connect team in 2015 as chief engineer. He is responsible for leading the engineering team as well as heading the development of algorithms to enhance the functionality of the end-to-end system. He is currently working on his PhD in Controls Engineering on the topic of highly distributed control for electric power systems. Ryan has previously worked at the National Aeronautics and Space Administration's Glenn Research Center and Bendix Commercial Vehicle Systems developing control systems for automotive, aeronautic, and space applications.

Abstract

Intwine Connect has been manufacturing and selling multi-protocol routers for IT/Internet of Things applications. We've been involved with VOLTTRON™ since version 2 and offer our routers with VOLTTRON™ pre-installed. This provides companies/researchers the ability to integrate VOLTTRON™ agents with many different communication protocols, including ZigBee HA1.2, BLE, Bluetooth 2.0, WiFi b/g/n, RS232, RS485, Ethernet, and any other interface that is developed! The routers can provide a cellular 4G LTE connection to enable high availability and reliability connectivity options.

THE SKYCENTRICS SKYSNAP – CONTROLS, SENSORS, METERING AND VOLTTRON™

Tristan de Frondeville

Tristan is a senior executive with over 20 years of experience in product management, software development, information management, internet sales and distribution, and manufacturing. Tristan has been managing the SkyCentrics' technology development for over six years to bring the promise of the Internet of Things to commercial buildings and utilities.

Abstract

SkyCentrics will be demonstrating its new SkySnap line of VOLTTRON™ hardware. This 5.5" x 5.95" x 1.9" device "plugs into the wall" like a night light, provides a Bluetooth low energy sensor platform that can also sub-meter up to seven circuits, control two relays, and provide 0-10V dimming and RS-485 connections to legacy building management systems. While supporting VOLTTRON™, SkyCentrics also has a complete stack of building management tools with web and mobile apps for monitoring, trending, alerting, and controlling building assets.

INTELLIGENT LOAD CONTROL

Srinivas Katipamula

Srinivas is a Staff Scientist at Pacific Northwest National Laboratory (PNNL). For over 25 years, Srinivas' career has focused on improving the operating efficiency of commercial buildings. Prior to joining PNNL, he led the analytics group at Enron Energy Services, where is managed the analytics group. He also worked at Energy Systems Laboratory at Texas A&M University, where he developed a number of measurement and verification techniques to measure energy savings from retrofits. He has extensive technical experience in the evaluation of advanced design concepts for heating, ventilation and air-conditioning systems; development of automated fault detection and diagnostic techniques; self-correcting controls; building and energy system simulations; analysis and evaluation of new energy-efficient technologies; and development and use of analytical modeling techniques.

At PNNL, Srinivas leads a number of research projects in advanced building controls, automated fault detection and diagnostics, and building operations. He also leads building-grid integration research, development and deployment activities. His major responsibilities include development of transaction-based controls for commercial and residential buildings. He also manages or contributes to a number of Grid Modernization Laboratory Consortium Category 1 and 2 research topics related to this area. One of these projects is a multi-campus research and development effort on Clean Energy and Transactive Campus. He also manages all the application development of the open source software platform VOLTTRON™.

Srinivas is a fellow of the American Society for Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) and the American Society of Mechanical Engineers. He currently serves on the ASHRAE Standards Committee and several other ASHRAE technical committees. He is a former editor of the American Society of Mechanical Engineers Journal of Energy Resources Technology.

Abstract

Stabilization of base load relies on automated dynamic load shaping of the electricity consumption in a building, a group of buildings (campus), or a neighborhood. Intelligent Load Control (ILC) uses VOLTTRON™ and a set of algorithms (v-agents) to manage electricity load shape in buildings, while concurrently maintaining occupant comfort. Available building loads need to be prioritized for curtailment for three reasons:

1. To support transactive energy services generally.
2. To mitigate short- or long-term imbalances between supply and demand.
3. Tto manage building peak load under traditional utility rate structures.

To accomplish this, ILC draws upon the Analytic Hierarchy Process, a proven business process for analyzing complex decisions, which can help determine whether shutting down or turning on devices in a certain sequence will achieve optimum load shape. The ILC process was developed and initially tested in a simulation environment to control a group of rooftop units to manage a building's load shape while keeping zone temperatures within acceptable deviations. After successful testing of the algorithms in a simulation environment, it was successfully deployed on several buildings on the Pacific Northwest National Laboratory campus in Richland, Washington. The test

demonstrated how the ILC algorithm could reshape the load profile while maintaining satisfactory comfort no matter if that load shape benefits dampening of the renewables or firming of base load. Currently, ILC supports three use cases:

1. To manage billing peak under a traditional utility rate case.
2. To manage building load to meet capacity building program objectives.
3. Dynamically changing the shape of the building load in response to a transactive signal.

This presentation will highlight how one would configure and run ILC to meet one of the three use cases.

VOLTTRON™ THERMOSTAT

Teja Kuruganti

Teja is Senior Research and Development (R&D) staff member in the Computational Sciences and Engineering Division at Oak Ridge National Laboratory (ORNL), where he has worked since 2003. He currently leads ORNL activities in developing novel sensors and controls for improving energy efficiency of buildings and novel techniques for enabling grid-responsive building loads. His research interests include wireless sensor networks, communications systems, control systems, and novel sensor development. Teja received an R&D 100 award in 2012 for co-developing an electromagnetic wave propagation simulation engine for harsh environments. He earned M.S. and PhD degrees in Electrical Engineering from University of Tennessee, Knoxville and a B.E. in electronics and communication engineering from Osmania University. He is a member of the Institute of Electrical and Electronics Engineers and International Society of Automation (ISA). He is currently the director of the ISA Test and Measurement Division.

Abstract

Reducing peak power demand in a building can reduce electricity expenses for the building owner and contribute to the efficiency and reliability of the electrical power grid. Similarly enabling coordination of loads, with minimal retrofit control hardware, by connecting loads using VOLLTRON™-enabled thermostats has potential to generate desired load shapes responsive to grid needs. Oak Ridge National Laboratory developed a VOLTTRON™-based thermostat (VStat) along with agents required for transitive control of arbitrary number of heating, ventilation, and air conditioning units. Several VStats across a building or multiple buildings can be networked to form a connected network of loads. This presentation describes the hardware and software required for deploying the network of thermostats to perform load coordination.

TRANSACTIVE CONTROLS AND COORDINATION

Robert Lutes

Abstract

Transactive control technology enables the devices and systems within buildings that provide cooling, heating, lighting and other functions to work in concert with the power grid. Through transactive applications, electricity supply and demand can be automatically balanced at the lowest cost to customers through the continuous control of building assets. The grid will become more resilient and reliable, and existing energy resources will be used more efficiently. Transactive control and coordination (TCC) uses the VOLTTRON™ platform to essentially create markets within different building zones and devices as part of an automated, real-time process. For example, an air handling unit (AHU) obtains electricity at a certain cost and then sells its product—cool air—to zones within the building that electronically "bid" on the cooling capacity based on price and desired occupant comfort levels.

Under this approach, the AHU or other controllable loads, such as water heaters, respond to a price-temperature curve that essentially relates the current energy price to the predetermined comfort expectations of building occupants. The curve influences AHUs to either reduce power load to balance cost and comfort objectives, or in cases of abundant, economical electricity, perhaps increase consumption to perform tasks in advance, such as pre-cooling a building. TCC has been initially tested in a simulation environment (VOLTTRONTM and EnergyPlus). After successful testing in the simulation environment, it was deployed on several buildings on the PNNL campus. This presentation will highlight how one would configure and run TCC in buildings.

CLEAN ENERGY AND TRANSACTIVE CAMPUS PROJECT

Srinivas Katipamula

Abstract

Vast opportunities for improved reliability, consumer benefits, and energy efficiency exist at the buildings-to-grid nexus. Realizing those benefits, however, requires research, development, and testing of transactive controls for energy management. Greater understanding and implementation of transactive controls at the single building, single campus, multi-campus, and community microgrid scale will help lead to a more reliable, resilient grid.

Pacific Northwest National Laboratory (PNNL) is leading a six-campus project with Washington State University, University of Washington, Case Western Reserve University, University of Toledo and National Aerospace and Space Administration, Glenn Campus. This is the first time researchers will test the use of demand-side transactive controls ("behind the meter") at this scale, involving multiple buildings and devices.

Another key objective is the establishment of a transactive energy system test bed. The partners will examine how the test bed can be operated as both a flexibility resource to help manage electricity loads and bring intermittent renewable energy onto the power grid, and as a platform for future research and development in the emerging buildings-grid discipline.

Using transactive controls to manage devices, data, and decision-making, buildings will automatically adjust energy loads based on predetermined criteria such as cost, essential services, and comfort levels. Knowledge gained from this activity informs responsive load management, energy conservation, and future grid modernization decision-making, regionally and nationally. This is a key step forward in achieving a more modern, efficient, and reliable power grid.

This presentation will provide an overview of the project, PNNL research focus, results from the first year's effort, and planned activities for the coming year.

CONNECTED NEIGHBORHOOD

Teja Kuruganti

Abstract

Oak Ridge National Laboratory is partnering with Southern Company, Alabama Power, and Georgia Power on two connected neighborhood research platforms for developing and validating at-scale, transactive energy and control solutions. Two neighborhood architectures are currently under construction. The first architecture will examine a transactive market with distributed energy resources (e.g., solar photovoltaic, electric battery storage, and backup generator) deployed at each house (Georgia Power), while the second will examine distributed energy resources aggregated at the neighborhood scale (Alabama Power). The purpose of this experiment is to develop, implement, and evaluate VOLTTRON™-based algorithms to co-optimize cost, comfort, environment, and reliability by controlling home owner end devices and grid generation assets through transactive control. In this presentation, we describe the use of VOLTTRON™ at a neighborhood scale to manage demand and integrate with a microgrid controller for optimizing energy use.

CONNECTED HOME CHALLENGE

Jereme Haack

Jereme is a Senior Research Scientist at Pacific Northwest National Laboratory (PNNL). For the past four years he has been a co-lead for the VOLTTRON™ platform, which enables deploying agent-based solutions at the edges of the smart grid and in buildings to improve energy efficiency and load responsiveness. This platform serves as an integration point for devices, remote resources, and agent applications, greatly decreasing the amount of effort to move research from simulation to actual deployment. Other agent research is the application of bio-inspired solutions to cyber security as part of PNNL's Digital Ants project, which has been covered in Scientific American and National Public Radio, among others. Jereme has also been researching how computer science solutions can best assist information analysts through evaluating their effect on the information analysis process. As part of this research, he has been involved in the VAST Challenge, producing datasets with ground truth and evaluating software used to discover the hidden threat. These datasets have become an open resource for research and university courses in the infoviz field. Jereme holds a B.S. in Computer Science and Mathematics from Doane College, Crete, Nebraska, and a Graduate Level Certificate in Intelligence Studies from Mercyhurst College.

Abstract

This talk will present key feedback from the judges and other attendees of the Connected Buildings Challenge (CBC) Demonstration. Five Challenge teams presented solutions of remarkable sophistication despite the relatively short duration of the challenge. The demo served as a networking event for the sponsors, Pacific Northwest National Laboratory (PNNL), CBC partners, and other key players in the connected buildings space, particularly in the Pacific Northwest region. Subsequent to the demonstration, the PNNL project team also set up five follow-up calls with the participating teams to gather their feedback and discuss their future plans.

PG&E DEMAND RESPONSE REFERENCE PLATFORM

George Hernandez

Abstract

The U.S. Department of Energy (DOE) has developed an open source, secure platform, VOLTTRON™, which is capable of supporting Pacific Gas and Electric Company's (PG&E's) Automated Demand Response (ADR) Program. VOLTTRONTM can support existing customer building automation system equipment and facilitate expanded customer and grid functionality such as energy efficiency, demand response (DR), optimal renewable utilization, grid-responsive loads, and ancillary services. This proposed effort will develop, test, and demonstrate an open-source reference design for a demand response automation server (DRAS) using the VOLTTRONTM platform. This reference design can be used as a target procurement specification to be met by suppliers of DRAS. This will widen the supplier base for such automation systems and potentially reducing the cost of operating the ADR program and simultaneously facilitate the deployment of intelligent algorithms for improving energy efficiency.

The demonstration will include the use of small- and medium-size commercial buildings (<100,000 sf) for ADR using heating ventilation and air conditioning (HVAC) lighting and refrigeration systems. Advanced control strategies to manage the HVAC loads to provide the capacity bid will be deployed. Additional loads such as lighting and scheduling of the defrost cycles may also be deployed. In addition to making the buildings more grid responsive, energy efficiency measures such as automate fault detection and diagnostics for RTUs can also be deployed.

MAALKA: AN EXTENSIBLE PLATFORM FOR VOLTTRON™ ENABLED VISUALIZATIONS, ANALYTICS, DATA AND PROGRAM MANAGEMENT

Rimas Gulbinas

Rimas is the Chief Executive Officer and Co-Founder of Maalka, Inc. Prior to starting Maalka, he researched and developed applications to engage commercial building occupants with data-driven insights to inform positive behavior change. His work has been published in leading international peer review publications, including *Institute of Electrical and Electronics Engineers Smart Grid*, *Applied Energy*, *Energy and Buildings*, *and Journal of Computing in Civil Engineering*. Maalka was founded to scale his research across communities, cities, and countries. Maalka has emerged as a leader in smart cities and open software architecture, with the mission of spreading best practices across public and private domains. Rimas is responsible for coordinating with the U.S. Department of Energy national laboratories for integrating emerging open-source technologies onto the Maalka platform and working with international partners to scale Maalka's services.

Abstract

The Maalka team engaged with Pacific Northwest National Laboratory (PNNL) engineers to develop a highly dynamic and responsive tool for managing VOLTTRON™ services across a campus of buildings. Rimas will discuss the underlying technology that enables dynamic management of VOLTTRON™ data and will provide sample visualizations from the tool deployed across a small portfolio of buildings at the PNNL campus. A discussion about the scalability and extensibility of the tool for enabling reporting, benchmarking, and other customizable services will also be introduced.

VOLTTRON™ AND DEMAND RESPONSE

Paul Lipkin

Paul is co-founder of Kisensum and functions as both Chief Operating Officer and project lead for many of Kisensum's innovative energy storage projects. He led implementation activities at the Los Angeles Air Force Base, which was the first electric vehicle fleet traded in the California Independent System Operator regulation market. Paul has served in senior and executive roles in operations and software development in energy, health, banking, and geospatial markets. Prior to Kisensum, Paul was at Honeywell developing and supporting product operations for demand response solutions. Honeywell had acquired Akuacom, the company for which he served as Vice President of Operations, which pioneered automated demand response. He previously led operations at Tele-Atlas, Kivera, and TRW, and also founded the healthcare startup iKnowMed with Bob Barcklay. Paul received a BS in Computer Science from the University of California at Berkeley.

Abstract

Pacific Gas and Electric Company (PG&E) has asked Pacific Northwest National Laboratory to develop an automated demand response implementation of their Capacity Bidding Program (CBP) product leveraging the VOLTTRON™ platform. This talk will provide an overview of the PG&E CBP, discuss the approach taken to solve this problem for PG&E, and summarize implementation plans. This project will leverage previous work performed to automate demand response controls in buildings by incorporating an OpenADR Virtual End Node Agent into the VOLTTRON™ open source repository. This talk will also describe the application that was built to capture event information and transmit it to the VOLTTRON™ building management systems at the various sites.

VOLTTRON™-BASED SERVICES

Terry Herr

Terry is the founder and principal of Intellimation LLC. He has 30 years of experience in the building automation industry, with 26 of those years as the owner of a building automation / systems integration firm. Recently, Intellimation's focus has been exclusively on deploying automated fault detection and diagnostics / buildings analytics software tools. Intellimation uses this new class of software for data-driven retro and ongoing or continuous commissioning. He is a licensed master electrician and earned a B.S. in Physics from Lebanon Valley College.

Abstract

In order to extract value from a growing list of automated fault detection and diagnostics (AFDD) or building analytics software tools coming onto the market, one must first connect to, trend, archive, meta tag, and make building automation system (BAS) and meter data easily available to these new applications. VOLTTRON™ can be this enabling middle ware technology platform, and Intellimation is testing the use of VOLTTRON™ for this purpose.

CONSTANT COMMISSIONING (CCX) AND AUTOMATED DEMAND RESPONSE (ADR) ON VOLTTRON™

Zach Wilson

Zach Wilson has been creating new technology businesses and innovative IT solutions to improve process efficiency and sustainability for 14 years. He is currently developing a data-driven energy management ecosystem for the city of Washington, DC. Zach leads a team of twenty project managers, systems integrators, software developers, and mechanics, and facilitates organizational improvements for the Portfolio, Energy, Facilities, Construction, and Finance Divisions of the DC Department of General Services. Previously, Zach managed a consulting practice that provided data strategy, economic and sustainability analysis, and custom multimedia and communications to large multinational clients. Earlier in his career, he cofounded a 3D-mapping software startup and created a green building division for a conventional design/build firm. Zach's work is anchored in his passion for sustainability and his excitement for making innovation tangible.

Abstract

For four years, the Department of General Services (DGS) of DC has been developing frameworks, data flows and an integrated IT platform to support constant commissioning for a large municipal buildings portfolio (~30M SqFt). VOLTTRON™ is at the center of this project, which intends to allow DGS to perpetually verify and manage HVAC performance using BAS trend logs. With approximately one billion annual BAS data points and a broad range of integrated systems, spanning from PV arrays to VRF systems, DGS aims to be one of the largest pioneers of transactive energy.

VOLTTRON™ FOUNDATION

Joe Hagerman

Abstract

DOE's vision of VOLTTRON™'s future. How do we get VOLTTRON™ to be a the standard for interoperability such that all ends of the spectrum are engaged in its success; from laboratory research projects to small business products and services to a holistic ecosystem for secure efficient data collection, edge computing, and big data analytics.

DAY 2

VOLTTRON™ HISTORY & NEW FEATURES

Jereme Haack

Abstract

Developed with support from the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy's Building Technologies Office, VOLTTRON™ provides a reference platform for the development of transactional energy, demand response, fault detection, and other building applications. This presentation will discuss the history of the platform and provide an overview of the latest and upcoming features. It will provide the background for the more focused presentations which follow.

VOLTTRON™ DEPLOYMENT OVERVIEW

Craig Allwardt

Craig is a Software Engineer in Pacific Northwest National Laboratory's Software Engineering and Architecture group. He is the technical team lead and a core developer for the VOLTTRON™ platform.

Abstract

This session provides an introduction to the components in a typical VOLTTRON™ deployment. Participants will follow along to set up a simple multiple instance VOLTTRON™ deployment where data is collected on one platform and displayed in the management console on another. This session sets the stage for further in-depth sessions.

SECURING VOLTTRON™ AND THE UNDERLYING SYSTEM

Craig Allwardt

Bora Akyol

Bora is a Senior Research Scientist in Pacific Northwest National Laboratory's (PNNL's) Data Intensive Scientific Computing group, conducting research and development in network security, information sharing protocols, and Smart Grid. He also serves as cyber security lead for the Pacific Northwest Smart Grid Demonstration project as well as the Principal Network Engineer for PNNL's Chief Information Officer. He earned both his M.S. and Ph.D. in electrical engineering from Stanford University.

Before joining PNNL in 2009, Bora was a technical leader at Cisco Systems, where his work involved service blades for the Catalyst 6500 Series switches, 1250 and 1140 Series 802.11n access points, and Internet Key Exchange and Internet Protocol Security protocols, as well as next-generation, identity-based networking products. He has published two Internet Engineering Task Force (IETF) Requests for Comment and holds 15 patents in the areas of wireless and Ethernet networks, network security, congestion control, and software engineering. He is a longtime active member of both IETF and the Institute of Electrical and Electronics Engineers.

Abstract

Securing a VOLTTRON™ deployment depends on the interaction of multiple components: VOLTTRON™, the underlying hardware, and the network. This session will cover how to utilize the security features of VOLTTRON™ and make recommendation for securing the resources it interacts with.

DEVICE CONFIGURATION AND INTERACTION

Robert Lutes

Kyle Monson

Kyle heads the Python Users Group at Pacific Northwest National Laboratory (PNNL) and is a lead developer on the VOLTTRON™ project. At PNNL, Kyle has worked in building energy codes, theoretical biochemistry, and on the Digital Ants project. Before joining PNNL, Kyle worked as a software developer at Flying Lab Software, producing video games.

Abstract

Simplifying device configuration has been a focus for VOLTTRON™ development this year. The current best practices and lessons learned for device configuration will be demonstrated at this session as will the new web UI for BACnet-based device discovery and configuration.

HISTORIANS AND DATA STORAGE

Kyle Monson

Craig Allwardt

Abstract

The VOLTTRON™ historian framework provides numerous options for data storage. Existing options for data storage will be discussed as well as their strengths and weaknesses. This session will provide a hands-on example of developing a new historian to demonstrate how the community could develop new historians to meet their needs.

DEPLOYMENT MANAGEMENT

Craig Allwardt

Jereme Haack

Abstract

PNNL's local VOLTTRON™ campus deployment will be presented as an example of how deployments can be set up and managed. This session includes a walkthrough, allowing participants to set up a small-scale demonstration on their laptop.

VOLTTRON™ IN USE WORKING LUNCH

During this working lunch, we will hear from speakers who have built applications on the base provided by VOLTTRON™. They will discuss their use case, how they accomplished their goals, and their experience with the platform. This session presents practical examples of the platform in use and provides an opportunity for participants to discover potential collaborators.

Andrew Rodgers, Intellimation

Andrew brings technology strategy and implementation experience from across many sectors to bear on the challenges of creating sustainable systems architectures for Internet of Things applications. Working with Intellimation and New City Energy, he is creating the technical infrastructure for an enterprise-scale Smart Building Management platform based on the VOLTTRON™ ecosystem. With over ten years of experience in the industrial automation and information technology sector, Andrew has led problem-solving initiatives in each of the projects he has supported. He brings deep knowledge of the implementation of both physical and logical topologies of various communications, networking, and fieldbus technologies, combined with an ability to communicate critical aspects of deeply technical subject matter at all levels of an organization. A native of Huntsville, Alabama, Andrew relocated to Chattanooga, Tennessee, in 2010. He is an active member of the local developer community and passionate about improving technical education in Chattanooga and across the country

Nigel David, SES Consulting

Nigel enjoys building data pipelines across British Columbia and Canada that allow SES's Consulting engineers to quickly and continuously deliver energy-efficiency solutions. He leads the research and development activities that complement SES's core engineering services. Nigel comes from a background of experimental physics and hydrogen fuel cell research. His current research interests include the "internet of things," integrated energy systems, and the VOLTTRON™ platform. When not wrangling data, he can be found wandering the British Columbia trails and beaches with his family.

Kevin Morrissey, University of Washington

Kevin is a Master's student in the University of Washington's Department of Electrical Engineering, and is a member of the Electrical Energy and Power Systems research group. Kevin will graduate in June 2017 and will defend a Master's thesis covering his work with photovoltaic generation smoothing in VOLTTRON™. Kevin also spent Summer 2016 as a master's intern for VOLTTRON™ software development at Pacific Northwest National Laboratory, developing a driver for the OpenEVSE vehicle charging platform. He will be starting a position at Smarter Grid Solutions in July 2017, working as a research and development engineer. Previously, Kevin obtained his Bachelor's degree in electrical engineering from Tufts University, and worked as a consultant at Navigant in establishing and revising federal energy efficiency standards. Kevin enjoys rock climbing and hiking in his spare time.

Chris Winstead, Oak Ridge National Laboratory

Chris Winstead is a Modeling and Simulations Software Engineer in the Computational Sciences and Engineering Division at Oak Ridge National Lab (ORNL). At ORNL, Chris' primary research interests include control applications for energy efficiency and reliability. Additional interests are reduced order modeling and test case generation via data science and machine learning. From Memphis, TN, Chris graduated with a BS in Electrical Engineering from the University of Tennessee in 2014, and with an MS in Electrical Engineering in 2016.

Christian Kohler, Lawrence Berkeley National Laboratory

Christian is the deputy department head for Building Technologies at Lawrence Berkeley National Laboratory (LBNL). Since 2012, he has been working on the integration of sensors and controls into windows and building facades. For more than 20 years, he has been the involved in the experimental work, validation and development of highly insulating and dynamic windows, as well as all aspects of software development in the Windows and Envelope Materials Group for various tools such as THERM, WINDOW, and Optics. His activities include the development of embedded controllers as well as algorithm development, user support, and training. Prior to that he was working at the LBNL Infrared Thermography research facility. He received his Master's degree in Building Physics in 1997 from Eindhoven University of Technology in the Netherlands.

VOLTTRON™ OFFICE HOURS

PNNL's VOLTTRON™ development team

VOLTRON™

Devices | Data | Decisions

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