

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

Hosted by the Virginia Tech Advanced Research Institute
900 Glebe Rd., Arlington, VA 22203
July 23-24, 2015

Welcome

The Department of Energy Building Technologies Office and the Virginia Tech Advanced Research Institute (ARI) would like to welcome you to the 2nd annual meeting on VOLTTRON! I would like to thank you for attending and for your active participation and also thank Virginia Tech for graciously hosting these meetings and discussions.

At DOE, we continue to support a transactive energy ecosystem capable of meeting all clean energy demands and capacity requirements from generation to buildings end-use. This vision would allow the millions of sensors, meters, smart appliances, connected equipment, loads, and distributed generation assets to seamlessly communicate and coordinate, to the benefit of both building owners and the grid. We believe this includes VOLTTRON™, a transaction based software platform and an open source software environment for developing and deploying a variety of market driven applications.

Over the next day and a half, we will discuss current and future applications that utilize the VOLTTRON platform to demonstrate transactive energy principles in buildings, outline use cases of the technology, and showcase several building/grid applications to improve, such as building energy efficiency, electric vehicle charging, or integration of renewable energy.

It is my hope that this meeting will inspire stakeholders - including industry members, university and other researchers, software developers and practitioners – to engage in the crafting of a shared vision for realizing transactive energy. And I hope everyone understands our demonstration of transactive energy through VOLTTRON demonstrates how buildings can act as dynamic, self-optimizing participants in the power system. This meeting is about realizing a future and more importantly capitalizing on the opportunities leveraged through controls.

Thanks again for your time. We look forward to a productive and stimulating meeting.



Joe Hagerman

Senior Policy Advisor

DOE/Building Technologies Office

Purpose

This meeting continues the dialogue started last year at Case Western Reserve University on a transactive energy software framework known as VOLTTRON™.¹ The meeting will provide an overview of the VOLTTRON™ platform, present new developments and uses, discuss advancement of the Transactional Network concept, and build and expand the user community around this technology.

Presentations at the meeting will provide an overview of the Transactive Energy concept, describe current and future applications of VOLTTRON™, outline use cases of the technology, and showcase VOLTTRON™'s potential to address several buildings-related services, such as buildings' energy efficiency, electric vehicle charging, or integration of onsite renewable assets, among others.

DOE-BTO aims to broaden the applications of transactive energy (TE) and foster a community of VOLTTRON™ users, leading to outcomes including the following:

- A catalog of real-world TE applications related to buildings.
- Discussion on development of VOLTTRON-based products/services by industry.
- A reference TE platform supported by the community participants.
- TE applications developed on the reference TE platform for demonstration purposes.
- An interoperability testing and certification suite to ensure multi-vendor interoperability.
- Multiple demonstration facilities to help evangelize TE applications for buildings.
- A software repository to store TE applications, the reference platform and test suites, and an associated bug tracking and enhancement request.
- A peer-to-peer technical support forum for fostering discussions and answering questions.
- How-to documents to help build various TE applications on commonly encountered and readily available hardware.
- A forum to track and discuss bugs, enhancements of the TE platform, and the various applications.

The community will also contribute to the wider application of TE in buildings by addressing research gaps in the area of sensors, control technology, data mining and modeling standardization.

Background

The term "transactive energy" is used here to refer to techniques for managing the generation, consumption or flow of electric power within an electric power system through the use of economic or market based constructs while considering grid reliability constraints and building energy efficiency. The VOLTTRON™ platform facilitates such transactions by allowing third-party developers to deploy energy efficiency services and to deploy applications that respond to price or other signals by altering demand for energy services through control of many disparate building equipment and systems.

The U.S. Department of Energy's Building Technologies Office (DOE-BTO) is supporting research on transactive energy for buildings as part of its mission to improve energy efficiency and facilitate the integration of renewable energy. DOE-BTO is increasing the awareness of VOLTTRON™ and the Transactional Network concept by convening stakeholders from the buildings and the grid sector - including industry members, researchers, software developers and practitioners - to build a community of early adopters. While this technical meeting will include discussions about the capabilities, supported devices, and hardware/software requirements of VOLTTRON™, the objective is to attract a wide audience to further advance the concept of transactive energy and the potential of the VOLTTRON™ platform among interested parties.

¹ Presentations and other materials from that meeting are available from DOE's Buildings-to-Grid website at <http://energy.gov/eere/buildings/downloads/technical-meeting-software-framework-transactive-energy>

VOLTTRON™

VOLTTRON™ is a DOE-BTO funded platform for transactive energy applications that allows sensing and control actions to take place as close to devices as possible. Designed to support modern control strategies, including use of agent-based and transaction-based controls, VOLTTRON™ enables mobile and stationary software agents to perform both information gathering, processing, and control actions. VOLTTRON™ has been used in the Transactional Network project²; a multi-lab effort between Oak Ridge National Laboratory (ORNL), Lawrence Berkeley National Laboratory (LBNL), and Pacific Northwest National Laboratory (PNNL) examining the role transactive networks could play in optimizing commercial building energy use.

VOLTTRON™ is equipped to communicate with building systems (e.g. MODBUS or BACnet devices) and external services, has a built-in data historian and weather service, supports OpenADR 1.2., has a flexible messaging system (publish/subscribe), as well as utility and supporting classes to simplify application development, and logging service for saving application results and logging information. More broadly, it is a highly interoperable reference platform for transactive energy applications, enabling the integration of buildings and the grid.³

² For more information about this project, please see <http://transactionalnetwork.pnnl.gov/index.stm>

³ For a 3 minute video on VOLTTRON's capabilities, please see <http://transactionalnetwork.pnnl.gov/volttron.stm>

Logistics Information

Meeting Location

Virginia Tech Research Center - Arlington
Ballston Room, 2nd Floor
900 Glebe Rd., Arlington, VA 22203
<http://www.ncr.vt.edu/Arlington/index.html>

Parking

There is underground parking at the meeting location.

Contact Information

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Hotel Options

- The Westin Arlington Gateway, 801 N Glebe Rd, Arlington, VA 22203 (this is the closest hotel - 390 feet)
- Holiday Inn Arlington At Ballston, 4610 N. Fairfax Dr., Arlington, VA 22203 (0.2 mile)
- Comfort Inn Ballston, 1211 N Glebe Rd, Arlington, VA 22201 (0.3 mile)
- Hilton Arlington, 950 N Stafford St, Arlington, VA 22203 (0.4 mile)
- Residence Inn Arlington Ballston, 650 N Quincy St, Arlington, VA 22203 (0.5 mile)

Walking Directions from Ballston Metro Station

- Walk 0.3 mile west on N Fairfax Dr.
- Turn left onto N Glebe Rd.
- VTRC is across the street from P.F. Chang's restaurant.

You can also refer to the directions available here: <http://www.ncr.vt.edu/Arlington/Directions.html>.

Table of Contents

- Welcome 2
 - Purpose 3
 - Background..... 3
 - VOLTTRON™ 4
- Logistics Information..... 5
- Agenda: Thursday, July 23 7
- Agenda: Friday, July 24..... 8
- Day 1 9
 - DOE Welcome and Keynote Presentation..... 9
 - DOE/BTO Purpose and Context..... 10
 - Motivation for the Transaction-Based Reference Platform..... 12
 - Where We’ve Been and Where We are Going – VOLTTRON™ 1.0 to 3.0..... 13
 - VOLTTRON™ Technical Overview and Features 14
 - VOLTTRON™ Scalability Testing..... 15
 - VOLTTRON™ Platform Security and Hardening 16
 - BEMOSS Open Source Controls for Small Buildings 17
 - Energy Efficiency and Grid Services for Small and Medium-Sized Commercial Buildings..... 18
 - VOLTTRON™ Transactional Node 19
 - Unified HVAC and Refrigeration Control for Small Footprint Supermarkets..... 20
 - Automatic Fault Detection and Diagnostics for Air-Handling Units 20
- Day 2..... 21
 - Key Meeting Takeaways from 2014 Meeting at Case Western and Changes made to VOLTTRON™ in Response 21
 - VOLTTRON™ Development Primer: How to Use the New Features in Version 3.0..... 22
 - VOLTTRON™ Enabling Vehicle-to-Building Integration..... 22
 - Transaction-Based Operation of Resource Constrained Systems..... 23
 - Energy Efficiency and Grid Services for C-Stores and Supermarkets 23
 - Innovation Challenge using VOLTTRON™ 24

Agenda: Thursday, July 23

Time	Topic	Presenter
7:30 am	Registration	
8:00	Agenda Review, Ground Rules and Introductions	Facilitator
EERE and GRID INTEGRATION: The role of Transaction-Based Controls		
8:10	DOE Welcome and Keynote Presentation	R. Risser, DOE
8:30	DOE/BTO Purpose and Context	J. Hagerman, DOE
8:50	Motivation for the Transaction-Based Reference Platform	G. Hernandez, Pacific NW National Lab
9:10	Discussion	Facilitator
POWERING TRANSACTION-BASED CONTROLS: The Open Source Solution - VOLTTRON		
9:30	Where we've been and where we are going - VOLTTRON™ 1.0 to 3.0	J. Haack, PNNL
10:00	Discussion	Facilitator
10:20	VOLTTRON™ Technical Overview and Features	B. Carpenter, PNNL
11:00	VOLTTRON™ Scalability Testing	T. Kuruganti, ORNL
11:20	VOLTTRON™ Platform Security and Hardening (Working Lunch)	B. Carpenter and B. Akyol, PNNL
VOLTTRON™ IN THE REAL-WORLD: Deployment of Applications and Lessons Learned		
1:00	BEMOSS Open Source Controls for Small Buildings	S. Rahman, VA Tech
1:40	Energy Efficiency and Grid Services for Small and Medium-Sized Commercial Buildings	Justin Sipe, Transformative Wave
2:20	VOLTTRON™ Transactional Node	Linda Rankin, Quality Logic
3:00	Discussion	Facilitator
3:20	Unified HVAC and Refrigeration Control for Small footprint Supermarkets	T. Kuruganti, ORNL
4:00	Automatic Fault Detection and Diagnostics for Air-Handling Units	J. Wen, Drexel University
4:40	Discussion	Facilitator
5:00	Adjourn	
5:00	Optional Tour: Virginia Tech's BEMOSS Lab (Load controllers -- monitor, control, user interface, and security features)	M. Pipattanasomporn, VA Tech

Agenda: Friday, July 24

Time	Topic	Presenter
7:30 am	Registration	
8:00	Agenda Review, Ground Rules and Introductions	Facilitator
WE'VE HEARD YOU: A Recap		
8:10	Summary from first day	Facilitator
8:20	Key Meeting Takeaways from 2014 Meeting at Case Western and Changes Made to VOLTTRON™ in Response	S. Katipamula
8:40	Suggestions/ideas for VOLTTRON™ community development & future development of VOLTTRON™ platform	Facilitator
USING VOLTTRON™ 3.0		
9:00	VOLTTRON™ Development Primer: How to use the new features in Version 3.0	J. Haack, B. Carpenter, PNNL
THE LOW HANGING FRUIT: Opportunities for VOLTTRON™ Applications		
9:45	VOLTTRON™ Enabling Vehicle-to-Building Integration	R. Pratt, PNNL
10:20	Transaction-Based Operation of Resource Constrained Systems	R. Brown, Lawrence Berkeley National Lab
10:55	Energy Efficiency and Grid Services for C-Stores and Supermarkets	John Wallace, Emerson Climate Technologies
11:30	Innovation Challenge using VOLTTRON	G. Nelson, Massachusetts Clean Energy Center
Noon	Adjourn	
Noon	Optional Tour: Virginia Tech's BEMOSS lab (Load controllers -- monitor, control, user interface, and security features)	M. Pipattanasomporn, VA Tech

Day 1

DOE Welcome and Keynote Presentation



Roland Risser is the Director of the Building Technologies Office (BTO) in the Office of Energy Efficiency and Renewable Energy (EERE) at the U.S. Department of Energy (DOE), where he directs the work to help create a self-sustaining market for building energy efficiency. BTO is focused on achieving a 50% reduction in energy use in buildings by optimizing energy-saving opportunities and creating a self-sustaining market for building energy efficiency. BTO is developing advanced building-related technologies and cost effective technical and market solutions for highly efficient buildings and homes, as well as accelerating the speed and scale of cost effective codes and standards. During his tenure, BTO has achieved 30% increased energy savings in residential and

commercial building energy codes and is on the path to deliver 4 quads of energy savings through standards.

Prior to DOE, he served as the Director of Customer Energy Efficiency for Pacific Gas and Electric Company (PG&E), where he directed its energy efficiency and demand response programs; assessed, developed and deployed new technologies and programs; managed building and appliance codes and standards work; and oversaw PG&E's Pacific Energy, Energy Training, and Food Service Technology Centers. He was a member of the National Action Plan for Energy Efficiency Leadership Group (now SEE Action), Chairman of the Consortium for Energy Efficiency, and a board member of the American Council for an Energy Efficient Economy. Currently, he is the Chairman of the Technical Committee to the International Standards Organization for ISO 50001, a new Energy Management Standard.

He holds a Bachelor of Science from the University of California, Irvine, a Master of Science from the California Polytechnic State University, San Luis Obispo, and is a graduate of the Haas School of Business Executive Program at the University of California, Berkeley.

DOE/BTO Purpose and Context



Joseph Hagerman is a Senior Advisor at the U.S. Department of Energy’s (DOE) Energy Efficiency and Renewable Energy Office focusing 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. Mr. Hagerman oversees all of BTO’s grid integration activities, various negotiated federal regulatory and related matters, and new initiatives for the program – including all activities on smart and connected equipment, cybersecurity in buildings, and interoperability.

Before joining DOE, Mr. Hagerman was the project manager for the Building Technologies group at the Federation of American Scientists (FAS). At FAS, Mr. Hagerman conducted research in new building technologies while demonstrating these technologies in the public sector. His efforts helped address environmental and energy injustice in affordable housing.

Mr. Hagerman 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

This session will provide an overview of the BTO portfolio in transactive energy applications in buildings, including enhancement of the VOLTTRON platform.

Over the last three years, BTO has supported research on using transactive energy applications to lower buildings’ energy use, raise building’s efficiency, and provide wider, ancillary benefits to the power system. Transactive energy in buildings will rely on robust control software that enables automatic, market-based intra-building efficiency optimizations. BTO believes that the best way to further the development of such software lies in the formation of a broad community of stakeholders that provides technical expertise, develops applications, and a deployment platform supporting transactive energy for buildings.

In BTO’s paper, [Buildings-to-Grid Technical Opportunities: Introduction and Vision](#), DOE laid out a vision of transaction based controls that first, and foremost, benefit the owners and operators of buildings through the delivery of energy efficiency. Transaction based controls are controls that respond to information as well as energy – this commingling of energy and information informs, possibly triggers, or transacts the control actions. In addition to the energy efficiency savings, transaction based controls can benefit the system efficiency of the electricity grid by delivering traditional grid services such as Demand Response (or ancillary services such as frequency regulation in the future).

In the report, [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); 2) energy market services (e.g. campus or fleet control that take advantage of portfolios of clean energy and load technologies); 3) grid services (e.g. traditional Demand Response and, in the future, other ancillary services or load management), and 4) societal services (e.g. services society have deemed important through policies or regulations).

Transaction based controls require the commingling of energy and information. Because DOE must not “pick a winner” in the selection or award of proprietary solutions and needs to support the larger discipline of transaction based controls, in early 2010 DOE adopted an Office of Electricity and Energy Reliability related control “platform” (VOLTTRON) as the flexible open source solution to accelerate the development of its controls program and simplify the tech transfer process. VOLTTRON was developed

by PNNL using the Laboratory Directed Research and Development funding as part of the Future Power Grid Initiative. In 2010 DOE began the enhancement of the solution to extend the functionality to include buildings specific control strategies and fully released the solution (and future solutions) as open source.

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

1. DOE should invest in comprehensive core RD in the fundamentals of sensors and controls in areas like plug and play, large scale complex control methodologies, agent based control theory, etc. which is bigger than one sole solution or industry entity,
2. DOE should continue development of an open source transaction based controls platform and related tools (e.g., VOTTRON, 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 it), and
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 flesh out the use cases, business case, and market justification with the industry.

In each of these areas, DOE programs (including BTO and other EERE offices) have key roles to play. The ARRA investments worked with municipalities and cities to install and deploy clean energy technologies; however, in many communities those investments simply deployed the technologies – such as EVs, or smart meters, or building located PV. 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 and installations thrive by lessening any perceived or real burdens within the utilities caused in whole or in part by clean energy technologies and more importantly to create opportunities for continued investment in the energy and information sectors.

VOTTRON is a key, open source enabler to that goal and comes with it DOE's past investment and history in the controls space.

Motivation for the Transaction-Based Reference Platform



George Hernandez joined PNNL in 2009 and works in the Advanced Building Controls group. Mr. Hernandez is a Staff Scientist and senior demand side management professional with innovative and detail-oriented knowledge to develop and produce successful programs that deliver products and services to the commercial and industrial energy marketplace. Mr. Hernandez is distinguished by exceptional execution skills that enable efficient concept to product delivery.

Currently, Mr. Hernandez is on detail at DOE as a Technical Advisor specifically in the area of Sensor and Controls. While at DOE, he has co-authored the High Performance RTU Challenge, the Buildings Performance Database, the Low Cost Wireless Metering Challenge, Energy Information Handbook, the Portable Sensor Suitcase, Open Source Small Building Control System, and the Transactional Network project. Mr. Hernandez 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. Mr. Hernandez 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

A transactional energy platform defines the basic structure of the future energy integrated ecosystem. It will lay out the transition from today's static, one directional, and often times "manual" energy system ("current state") to a new "future state" of energy, characterized by highly automated, two way (or even n-way) exchanges of information, data and energy between entities in the energy system, leading to a flexible, resilient and automatically adjusting system. The future ecosystem will be characterized by a more distributed power system, blurring currently clear lines between producers and users of power. Utilizing distributed generation, responsive loads and automation at the distribution system, the future ecosystem will see an abundance of software and application-based sensors that work autonomously to optimize energy generation and energy use starting at the smallest application all the way towards the largest entity. This is made possible by the addition of smart, intelligent meters and sensors to all stages of the energy system, able to interconnect, exchange information, and act upon it.

The framework enables transactions of products, rights and other services that support various micro and macro energy objectives. On the micro scale, these objectives include more efficient buildings. On the macro level, more efficient buildings will lead to reduced greenhouse gas emissions, increased grid reliability, an increased share of clean energy sources, and the creation of clean energy jobs.

This new model needs to seamlessly integrate new, distributed generation as well as smart assets while adding value to the building owner/customer and other third parties. It needs to be able to control and connect assets and loads, within buildings, between buildings and, at a possible future state, between buildings, the grid and third-party providers, and enable participants to transact in ways that lead to economic and environmental benefits. The idea is to derive benefits for the customer (e.g., better managing their bills) for participating in new markets and interacting with the grid and third-party providers.

Where We've Been and Where We are Going – VOLTTRON™ 1.0 to 3.0



Jereme Haack is a Senior Research Scientist at PNNL. For the past 4 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 the Digital Ants project which has been covered in Scientific American and NPR 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.

Mr. Haack holds a B.S. Computer Science and in Mathematics from Doane College, Crete, Nebraska, and a Graduate Level Certificate in Intelligence Studies from Mercyhurst College.

Abstract

With support from BTO, the VOLTTRON™ platform's capabilities and security features continue to be enhanced to provide a stronger base for the development of transactional energy and other building efficiency applications. This session will give an overview of the platform from its beginnings as an internally funded PNNL research project to an open source platform with a user base spanning national labs, universities, and commercial companies. The goal of this session is to explain the capabilities of the different versions of the platform and present potential plans for the next release.

VOLTTRON™ Technical Overview and Features



Brandon Carpenter is a researcher with the Secure Cyber Systems group at PNNL. He specializes in the development of new and innovative software tools to assist and train cyber security professionals and to augment their effectiveness in defending against and preventing cyber-attacks. His current work focuses on GNU/ Linux and how existing Linux features can be used in novel ways, and possibly combined with new tools, to assist in the defense of our nation's most critical networks.

Mr. Carpenter is the author of the open source Hone sensor for Linux, which provides accurate and performant packet-to-process correlation. He also regularly contributes to many other open source tools.

Mr. Carpenter holds a B.S. in Computer Science from Washington State

University.

Abstract

With the 3.0 release, VOLTTRON™ has many new features to improve security, scalability, reliability, and extensibility, all enabled by the new VOLTTRON™ Interconnect Protocol (VIP). Built on ZeroMQ, VIP provides a single protocol on which many new VOLTTRON™ subsystems are built and will be the primary focus of this session. Topics will include the improved publish/subscribe subsystem, the new Remote Procedure Call (RPC) subsystem, generic historians, updated driver framework, and the new web-based management console.

VOLTTRON™ Scalability Testing



Teja Kuruganti is a senior R&D staff member in the Computational Sciences and Engineering Division at ORNL since 2003. His research interests include wireless sensor networks, propagation modeling, novel sensors and communication systems, and control systems, hybrid systems, additive manufacturing of wireless sensors, and thin film sensor development. He won an R&D 100 award in 2012 for co-developing electromagnetic wave propagation simulation engine for harsh environments. He earned M.S. and Ph.D. 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 IEEE and ISA. He is currently the director of ISA Test and Measurement Division.

Abstract

VOLTTRON™ Scalability Testing: ORNL in collaboration with PNNL is working on understanding scalability of VOLTTRON™ platform from the perspectives of 1) applications and the concomitant scalability of VOLTTRON™ when realizing these applications and 2) system-level requirements for transactional networks that will support next generation building to grid applications. The goal of the work is to quantify what load of messages and services, a VOLTTRON™ platform can sustain and still operate efficiently. We will establish a performance envelope for VOLTTRON™ platforms operating on hardware with varying capabilities from small form factor boards to desktop machines. The goal is to stress the platform on each of these hardware solutions so reasonable deployment recommendations can be made and define minimum acceptable requirements for hardware and network capability. Initial results and plans for this work going forward will be discussed during this presentation

VOLTTRON™ Platform Security and Hardening

Brandon Carpenter, PNNL (see previous bio)



Bora Akyol holds M.Sc. and Ph.D. degrees from Stanford University in Electrical Engineering in the area of Wireless Networking. Before joining PNNL, he was a technical leader at Cisco Systems in San Jose. His work at Cisco includes service blades for the Catalyst 6500 series switches, 1250 and 1140 series 802.11n access points, IKE and IPSEC protocols as well as the next generation identity-based networking products. Bora has published two IETF RFCs, holds 15 patents in the areas of wireless and Ethernet networks, network security, congestion control and software engineering, and has been active in both IETF and IEEE. He is a veteran of three start-ups in SF Bay Area.

At PNNL, Bora is performing research and development in the areas of network security, information sharing protocols and smart grid. He is the cyber security lead for the Pacific Northwest Smart Grid Demonstration project and the principal architect for VOLTTRON™ and OpenEIS projects funded by DOE. Bora is an experienced technical leader, an architect of real-world scalable systems and a secure development evangelist.

Mr. Akyol holds a Ph.D. and M.Sc. in Electrical Engineering from Stanford University, Stanford, CA, and a B.Sc. in Electrical Engineering, Bilkent University, Ankara, Turkey.

Abstract

VOLTTRON™ is designed with security in mind, but how do we define security? In this session we will discuss how we assess VOLTTRON™ using threat modeling to determine possible threats and mitigations and how the review of version 2 informed the changes in version 3. It will also cover best practices for hardening the underlying Linux operating system.

BEMOSS Open Source Controls for Small Buildings



Professor Saifur Rahman is the founding director of the Advanced Research Institute (www.ari.vt.edu) at Virginia Tech where he is the Joseph R. Loring professor of electrical and computer engineering. He also directs the Center for Energy and the Global Environment (www.ceage.vt.edu). He is a Fellow of the IEEE and an IEEE Millennium Medal winner. He is the founding editor-in-chief of the IEEE Electrification Magazine. He was the founding editor-in-chief of IEEE Transactions on Sustainable Energy. He has served as a vice president of the IEEE Power and Energy Society from 2009 to 2013 and currently serving as a member-at-large of the IEEE-USA Energy Policy Committee. In 2006 he served on the IEEE Board of Directors as the vice president for publications. He has served as the chair of the U.S. National Science Foundation Advisory Committee for International Science and Engineering from 2010 to 2013. He has conducted several energy efficiency related projects for Duke Energy, Tokyo Electric Power Company, the U.S. Department of Defense (ESTCP Program), the State of Virginia and the U.S. DOE.

Abstract

In the United States, buildings consume over 40% of the country's total energy consumption, and 90% of these buildings are either small-sized (<5,000 sq. ft.) or medium-sized (5,000-50,000 sq. ft. Specifically, Heating, Ventilation, and Air-Conditioning (HVAC), lighting and plug loads account for almost 90% of all consumption in buildings. But these small and medium-sized buildings do not have building automation or energy efficiency applications. Under a contract from the U.S. DOE, Virginia Tech is developing a web-based Building Energy Management Open Source Software (BEMOSS) platform for optimizing electricity usage and implementing demand response (DR) in small- and medium-sized buildings. This can help accelerate development of market-ready products like embedded Building Energy Management systems and device controllers for HVAC, lighting and plug loads. This presentation discusses the core concept of the BEMOSS platform, and shows how single board computers like the Raspberry Pi are being used to implement the software being developed.

Energy Efficiency and Grid Services for Small and Medium-Sized Commercial Buildings



Justin Sipe is the Senior VP of Technology for Transformative Wave Technologies. He is a co-inventor of the CATALYST Efficiency Enhancing Solution, and he holds five patents around rooftop unit efficiency. Justin has been involved in the controls industry for 18 years. During his time in the industry he has designed, serviced, installed, and trained on control systems for commercial buildings and industrial process control. In addition he leads the development efforts at Transformative Wave that are focused on finding innovative solutions to reduce HVAC energy use. He has certifications in Tridium, Honeywell, Johnson Controls, Distech, Magnetrol, Belimo, and Fireye. He is also a Tridium Certified Developer and a Honeywell Authorized Trainer.

Abstract

Over 90% of the building stock is less than 50,000 square feet in size, and less than 10% of those buildings have a building automation system. An unmonitored building leads to unnecessary energy use. This sector is looked at as the crown jewel by many in the HVAC industry, but success has been hard to come by. Most control systems on the market aren't designed with small buildings in mind. Some of the systems targeted at small buildings lack the sophistication to properly control the space. There are economic challenges specific to this building size and market group that currently prevent deep market penetration. VOLTTRON™ provides the means to overcome some of these issues. By leveraging a smart connected system small buildings can participate in utility programs. Utility funding can help offset the initial capital cost for a smart building infrastructure. The ongoing energy savings provide a return on investment that may not be present with traditional control systems. The open source framework allows developers to create a full featured but simple system that can meet the needs of operators. We'll focus on these challenges that face the market, our view of how VOLTTRON™ meets those goals, and our practical experience of using VOLTTRON™.

VOLTTRON™ Transactional Node



Linda Rankin was the technical lead for QualityLogic; an industry partner that participated in the Pacific NW Smart Grid Demonstration Project. In this role, she led the development of web-based test harness, contributed to project data analysis and visualization tools, demonstrated how to adopt emerging smart grid standards to transactive control, and led the definition and development of a transactive node using the VOLTTRON™ platform.

A former Principal Engineer at Intel Corporation she has more than 20 years of experience as a computer and system architect working in applied research and advanced product development. Linda has authored papers for technical journals, is a senior member of IEEE, and holds more than 40 patents, some of which are international.

Abstract

As part of the Pacific Northwest Smart Grid Demonstration project (www.pnwsmartgrid.org) a unique distributed communication, control and incentive system was defined and implemented comprising a “transactive control node” along with a pair of signals used for communicating between nodes. The node is intended to be used at all levels of the power distribution hierarchy for managing and controlling assets. The signals, one for incentive (predicted cost) and one for feedback (predicted load), are generated by and distributed between nodes. Using distributed control is a departure from the centralized paradigm in use today, but is considered an important step to addressing electric power grid reliability issues as well as enabling widespread adoption of greener energy sources.

This talk will cover the development of a transactive control node that is intended to be used by researchers to explore and refine transactive control concepts. First, the reasons why VOLTTRON™ was selected as the development platform will be presented, followed by how the node was architected to take advantage of VOLTTRON™ services. The choice of a modular architecture for the node and using VOLTTRON™ as the platform were two key factors that enabled us to meet a tight schedule; building a four-node demonstration system from the ground up in four months. The talk will highlight key functions that were developed to support the architecture, how they relate to VOLTTRON™, and will close with feedback on current and future VOLTTRON™ services.

Unified HVAC and Refrigeration Control for Small Footprint Supermarkets

Teja Kuruganti, ORNL (See previous bio)

Abstract

Unified HVAC and Refrigeration Control for Small footprint Supermarkets: Small footprint supermarkets and convenience are one of the energy intensive operations. Refrigeration systems in these stores consume around 50% of the total store energy use. ORNL in partnership with Emerson climate technologies is working on developing control retrofit for coordinating the operation of multiple RTUs and refrigeration systems for the purposes of (1) reducing peak demand, (2) reducing energy consumption, and (3) enabling transactive energy services to the electric grid. VOLTTRON™ platform is used for deploying the control technology. In this presentation the integration approach and relevant VOLTTRON-based applications will be discussed along with future deployment strategy.

Automatic Fault Detection and Diagnostics for Air-Handling Units



Dr. Jin Wen is an Associate Professor in the Department of Civil, Architectural, and Environmental Engineering at Drexel University. She is actively involved with teaching and research in the building energy efficiency and indoor air quality areas. She has served as the principle investigator on various building energy efficiency and indoor air quality research and/or educational projects funded by the U.S. DOE, the National Institute of Standard Technology, the National Science Foundation, the Department of Homeland Security, and the American Society of Heating, Refrigerating, Air-Conditioning Engineers (ASHRAE), and Philadelphia Housing Authority. She has also worked as a control engineer for the Johnson Control Inc. before she joined Drexel University. Dr. Wen currently serves as the Research Chair for the ASHRAE Smart Building Systems Technical Committee.

Abstract

Faults exist in building mechanical systems could cause significant energy waste, degraded indoor environment, and shortened mechanical component life. However, automated fault detection and diagnosis (AFDD) is not widely adopted in buildings. This presentation examines the needs and challenges of applying AFDD for air-handling unit, a widely used building subsystem. Open source platform could reduce implementation cost, which is a significant market barrier, for AFDD tools. In this presentation, the experiences and lessons learned from developing our AHU AFDD tools to be VOLTTRON™ compatible is presented.

Day 2

Key Meeting Takeaways from 2014 Meeting at Case Western and Changes made to VOLTTRON™ in Response



Srinivas Katipamula is a Staff Scientist at PNNL. He joined PNNL in 1994. Dr. Katipamula has extensive technical experience in the evaluation of advanced design concepts for heating, ventilation and air-conditioning systems, demand response techniques for commercial and residential buildings, development of automated fault detection and diagnostic techniques, building and energy system simulations, analysis and evaluation of new energy efficient technologies, and development and use of analytical modeling techniques. Dr. Katipamula recently led a team of PNNL staff that demonstrated transactive (price-based) controls in commercial and industrial sites. He is active in both ASHRAE and AMSE technical committees and is an associate editor of the ASME Journal of Energy Resources Technology. He is a Fellow of ASHRAE. He holds a Ph.D. and M.S. in Mechanical Engineering from Texas A&M University and B.E. in Mechanical Engineering, Osmania University, India, 1983.

Abstract

Feedback from the community of current and potential VOLTTRON™ users is essential to ensuring platform development is focused on the highest impact capabilities. Feedback collected at the previous workshop, during VOLTTRON™ office hours, and through the mailing list has been incorporated into VOLTTRON™ planning and much of it has been addressed in 3.0. This presentation will review community priorities to discuss what has already been addressed, what will be addressed, and prompt for additional comments.

VOLTTRON™ Development Primer: How to Use the New Features in Version 3.0

Jereme Haack and Brandon Carpenter, PNNL (see previous bios)

Abstract

Intended as the next step beyond the overview presentations, this session will go into the technical details of the VOLTTRON™ platform. For those new to VOLTTRON™, there will be an overview of building the platform and how to develop and deploy agents onto it. For those familiar with previous versions, there will be discussion of the additions to 3.0, how to utilize those new capabilities, and how the compatibility layer works to simplify moving agents from 2.0 to 3.0.

VOLTTRON™ Enabling Vehicle-to-Building Integration



Rick Pratt, lead of PNNL Vehicle Systems team, has developed and deployed distributed control systems that control electric vehicle charging systems and other devices, develops and tests Society of Automotive Engineers standards for electric vehicle communications, and is jointly developing and deploying distributed building control systems using the VOLTTRON™ system.

Abstract

Vehicle Systems has implemented the VOLTTRON™ (transactional platform) to demonstrate how controlled electric vehicle charging can provide a rapid response to dynamic residential loads while following the requirements contained in the SAE J1772 communication standard. The demonstrated method monitored and controlled home total power consumption by varying the PEV charging rate showing that home peak power could be reduced by 20-30% without implementing any other home load device control. These test results showed that VOLTTRON™ is technically capable of enabling this managed PEV charging use case.

Transaction-Based Operation of Resource Constrained Systems



Richard Brown is a Research Scientist in the Building Technologies and Urban Systems Division at LBNL. He has a B.S. in Engineering from Princeton University and an M.S. in Energy and Resources from Berkeley. The underlying theme of his research is understanding, and ultimately reducing, the energy use of network-connected equipment in buildings. He is involved in numerous projects ranging from sensors and controls to communications protocols for advanced buildings.

Abstract

The objective of this project is to provide new sensing and control systems to enable buildings to improve measurement and control of the quality and timing of energy-consuming systems. The goal is to simultaneously maintain building services and ensure energy transactions are coordinated with electric grid and distributed energy systems. LBNL is developing a VOLTTRON™ testbed to assist the DOD TROPEC program (Transformational Reductions in Operational Energy Consumption). This system will demonstrate microgrid operation using this Transactional Network to: publish a power price that varies according to energy resource availability (e.g., fuel supply, battery state) and supply/demand balance and adjust end-use device consumption according to power price & value of services each device provides.

Energy Efficiency and Grid Services for C-Stores and Supermarkets



John Wallace is Director of Innovation, Retail Solutions at Emerson Climate Technologies. He has been active in the design and development of electronic control systems for more than 20 years. Wallace graduated from the University of Kentucky with a bachelor's degree in Electrical Engineering and the University of Missouri with a master's degree in Electrical Engineering. He is a registered Professional Engineer and holds several patents related to HVAC/R control systems. He has served on many industry committees' including the Lonmark Refrigeration committee, DOE's Better Building Alliance and he currently chairs the NAFEM (North American Food Equipment Manufacturers) Data Protocol standardization committee.

Abstract

PNNL's VOLTTRON™ platform provides a platform that can be used to create and test various software applications. The platform provides a consistent interface for development and allows the applications to be ported to different environments based on the end use. Emerson Climate Technologies Retail Solutions provides advanced energy management systems in the retail space. These systems help retail operators save energy and lower operating costs. In this talk, you will learn how Emerson is using the applications developed using VOLTTRON™ to bring value to our customers and advance the DOE's goals.

Innovation Challenge using VOLTTRON™



Galen Nelson is the Director of Market Development at the Massachusetts Clean Energy Center (MassCEC). Galen is charged with identifying emerging cleantech markets and technologies, while helping to shape the MassCEC's approach to supporting company growth, and technology development and deployment in these promising markets. Galen's approach to his work is anchored by a strong belief that targeted, strategic, and timely investments delivered through innovative and industry responsive programs can accelerate market adoption and ultimately job creation and economic growth. Galen directs a clean energy commercialization acceleration program called InnovateMass and leads the MassCEC's microgrid initiatives.

Prior to joining the MassCEC, Galen served under Boston Mayor Thomas M. Menino as the City's Green Tech Business Manager at the Boston Redevelopment Authority where he developed and managed a wide range of program initiatives all tied to strengthening the cleantech industry in Boston. Galen also worked at the Green Roundtable, a green building consulting and advocacy firm, where he managed the construction of the NEXUS Green Building Resource Center. Galen previously served as a consultant to the City of Boston from 2007-2008, overseeing with two other consultants the development of the City's green affordable housing program. Mr. Nelson holds a Bachelor of Arts from Colby College, Waterville, ME.

Abstract

Building on the success of PNNL's Olympic Peninsula Project, and concepts embedded in Massachusetts based US DOE SHINES (Sustainable and Holistic Integration of Energy Storage and Solar PV) residential and commercial proposals, the Mass Clean Energy Center seeks input on a Building 2 Grid challenge. We see several opportunities to contribute to industry understanding of the potential of transactive energy markets, leveraging the VOLTTRON™ platform while addressing some of the New England region's energy challenges. Ideally, the challenge would complement existing transactive energy pilot efforts, address energy challenges unique to our region, create opportunities for Massachusetts based companies, and leverage existing or planned clean energy incentive funding administered by state energy offices.

Context

While Massachusetts has led the nation in building energy efficiency and solar PV deployment, the state, and the New England region face persistent energy challenges. The region is increasingly reliant on natural gas, driven in part by low commodity prices that have led to an increase in oil to gas home heating conversions, supply pipeline constraints, and the retirement of regional coal power plants. More than ever, the region's grid depends on natural gas for its electricity generation needs. At the same time, while absolute energy consumption has dropped slightly in recent years, largely due to the state's energy efficiency efforts, peak demand has grown modestly. In fact, the region faces both winter and summer electric grid peak challenges; roughly 30% of the region's generating capacity is used to meet peak loads 10% of the year. While energy cost reduction would anchor any MassCEC B2G challenge, shaving peak demand and flattening load curves, at the building and feeder/substation scales, would be important goals. Added to these energy market dynamics, the state's public utility commission is in the midst of a comprehensive "Grid Modernization" proceeding – utilities are expected to submit grid modernization plans to Commission in early August 2015 - and the state's energy office has announced a \$10 million energy storage initiative. The Mass Clean Energy Center, charged with growing the clean energy

economy in the state, and with a strong track record of supporting technology innovation and market development, is uniquely positioned to administer a Building 2 Grid challenge within the MassCEC's existing "InnovateMass" program that leverages momentum in the state with regard to distributed energy resource integration, clean community microgrids, electric vehicle adoption, "cleanweb" product and service development, energy storage, existing energy efficiency incentives, and the state's long track record in supporting high performance buildings.

The MassCEC seeks feedback on core elements of the challenge and sees opportunity to explore new ground with regard to building technology emphasis, customer/building occupant engagement, and private sector investment and business model innovation. Additionally, we seek guidance with regard to project scale: can we establish meaningful performance results with a relatively small scale effort by modeling broader impacts – and development of relevant performance metrics. The MassCEC anticipates a two phase challenge including a concept proposal/design phase followed by a project build out phase. Some possible challenge emphases (not mutually exclusive) include:

- Thermal storage – given the state's natural gas constraints and the region's dependence on natural gas for both heating and electricity production, there may be an opportunity to integrate small scale residential thermal storage, or district scale commercial thermal storage into a transactive energy market demonstration project. This emphasis would leverage the state's anticipated \$10 million investment in energy storage demonstration projects and conceivably address the region's winter peak demand.
- Existing buildings - while new load will continue to be added to the grid, perhaps the state and region's toughest challenges lie in retrofitting existing residential and small to medium-sized commercial building stock. To date, these efforts have largely focused on building envelope and mechanicals upgrades, but identifying targeted, cost effective, "plug and play" B2G technology upgrades could help building owners achieve meaningful energy and demand charge reductions, while activating stranded demand reduction assets and new storage assets that could be controlled by utilities, aggregators or both. The innovation here would lie in the market's ability to develop low barrier, cost effective solutions for existing small to medium-sized commercial buildings that leveraged legacy, but dispatchable equipment loads, coupled with new business models that aggregate those resources on behalf of utilities.
- Price and carbon reduction – building owner energy cost reduction has been a key performance goal in B2G pilots to date. But Massachusetts has aggressive GHG reduction goals and participates in the region's carbon cap and trade market, known as the Regional Greenhouse Gas Initiative (RGGI). Depending on diurnal and annual energy demand, the region's grid carbon intensity can vary dramatically. A carbon sensitive B2G pilot could consider carbon alongside energy pricing, providing building owners and potentially their commercial and residential tenants with additional feedback, perhaps delivered through unconventional channels. Shedding more light on the temporal nature of the grid's carbon content could complement existing state and national building energy labeling efforts.
- V2G – beyond a handful of small pilots, vehicle to grid efforts appear to be moving slowly as they depend on scaled controllable backflow onto the grid, but focusing exclusively on demand reduction – "grid controlled vehicles" – might accelerate the entrance of vehicle batteries into the B2G realm.
- Strictly behind the meter load management – while larger scale multiple building pilots and ultimately grid scale commercial deployment of B2G technology may capture the greatest market share, a sharp focus on strictly behind the meter load flattening on some feeders, within certain building typologies, and in the context of community microgrids, might provide significant benefits to building owners, utilities and microgrid operators.

Given the MassCEC's interest in driving clean energy innovation, technology development company growth, and in tapping the state's considerable information technology and clean energy talent base, we are eager to explore B2G challenge pilot structures that can accelerate progress in this sector.

