US India Joint Center for Building Energy Research and Development (CBERD)

Integrated Sensors & Controls

2016 Building Technologies Office Peer Review

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

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Project Summary

Timeline:

Start date: October 2012

Planned end date: September 2017

Key Milestones

1. >70% accuracy in identifying plugged-in device type for >5 common device types, using networked plug-strips with plug-load control algorithms attained and verified. March 2016
2. Demonstrate transaction-based controls for constrained-resource buildings in Indian and US testbeds; Sumer 2017

Budget:

Total Project $ to Date:

- DOE: $615K
- Cost Share: $25K

Total Project $:

- DOE: $950K Cost Share: $50K

Key Partners:

International Institute of Information Technology, Hyderabad	Lighting Research Center - Rensselaer Polytechnic Institute
Indian Institute of Management Ahmedabad	Honeywell
Philips Research US/India	

Project Outcome:

Developed an integrated workstation control system (lighting, plug loads and HVAC), demonstrated in Indian and US test-beds, based on open source transaction based controls.

Purpose and Objectives

Problem Statement:

- Increased focus on **occupant** controls for **comfort** and **energy** savings. Lack of **coordination** among building systems (e.g., lighting system might turn off when space is unoccupied, but HVAC system unaware).
- Loads in buildings do not adjust to **constrained** energy resources.

Solving this problem requires:

- **Communications** and integration across end-uses,
- New control paradigms for buildings using software-driven tools and services like the **Transactive Energy** frameworks.

Target Market and Audience:

- Commercial building owners and system innovators.
- Small/medium buildings with inadequate controls consume ~3 Quads source energy annually in US; ~0.5 Quad savings potential.

Impact of Project: This project will:

- Demonstrate an integrated workstation control system (lighting, plug loads, HVAC) in an Indian and US test-bed
- Release open-source software tools enabling unified, transaction-based control

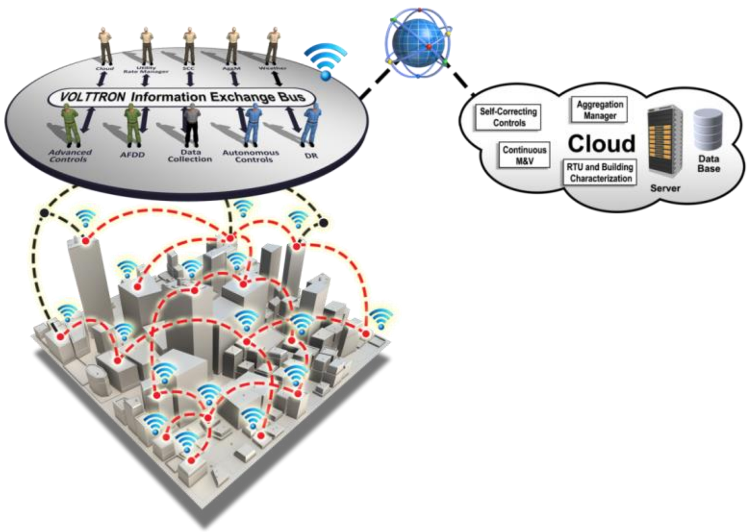
Transactive Energy

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.

Gridwise Architectural Council

VOLTTRON

A open source distributed **control** and sensing **software** platform supporting Transactive Energy, developed by Pacific Northwest National Laboratory (PNNL).



Approach

Approach:
Integrate commercial control systems using open-source tools

- Utilize open-architecture control platform for buildings with transaction-based controls (VOLTTRON)
- Demonstrate advanced plug-load management capabilities as part of platform
- Field-test VOLTTRON with a far less reliable grid (India) and with generators
- Aggregate from workstation to zone and building
- Address lighting, HVAC and plug loads

Key Issues:

- Can we integrate control of several end-uses into one, easy-to-use platform?
- Can transactional-energy principles be applied to individual workstation?

Distinctive Characteristics: Shifting from whole building management to individual workspace control to develop Grid Responsive Buildings

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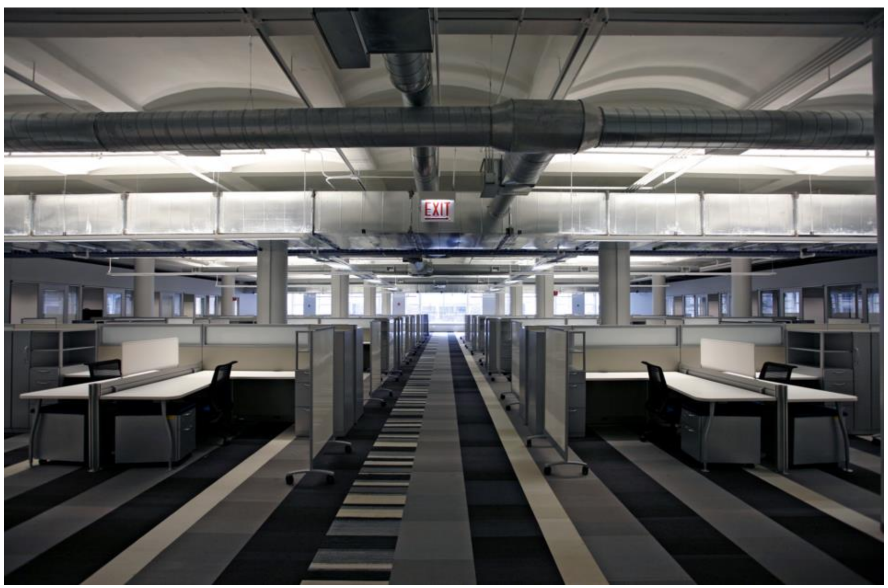
Scale

- Managing energy consumption on an individual workspace level instead of whole building level (bottom-up). But aggregating from workstation to zone to building.

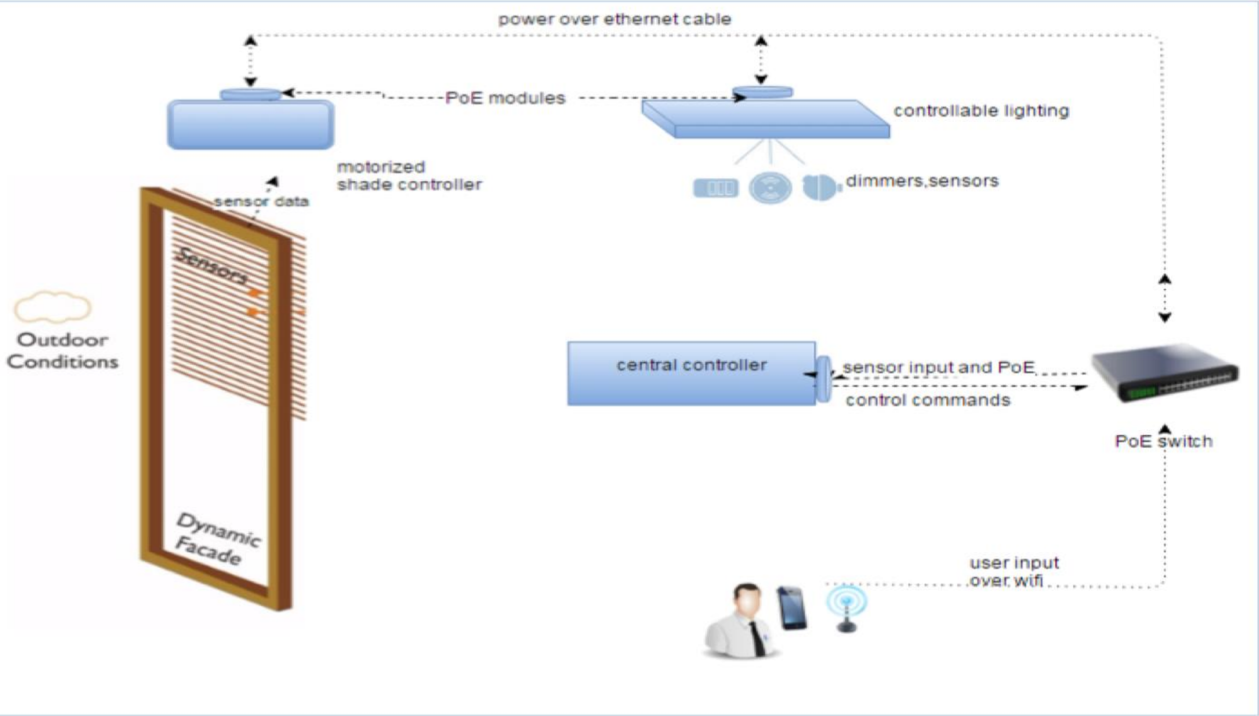
From this → To this



DEMO

Accomplishments

- Radiant cooling desk and personal workstation control IIIT-H
- Integrated window and shade control IIIT-H
- Literature review in progress state of the art in personalized controls (Honeywell)



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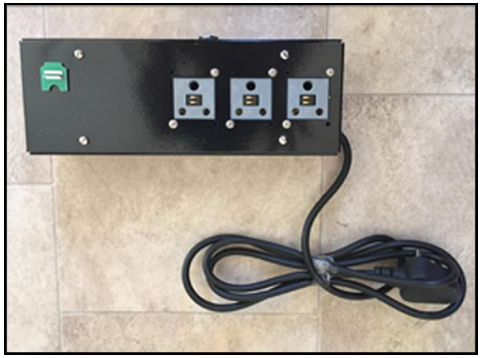
Smart Plug strip

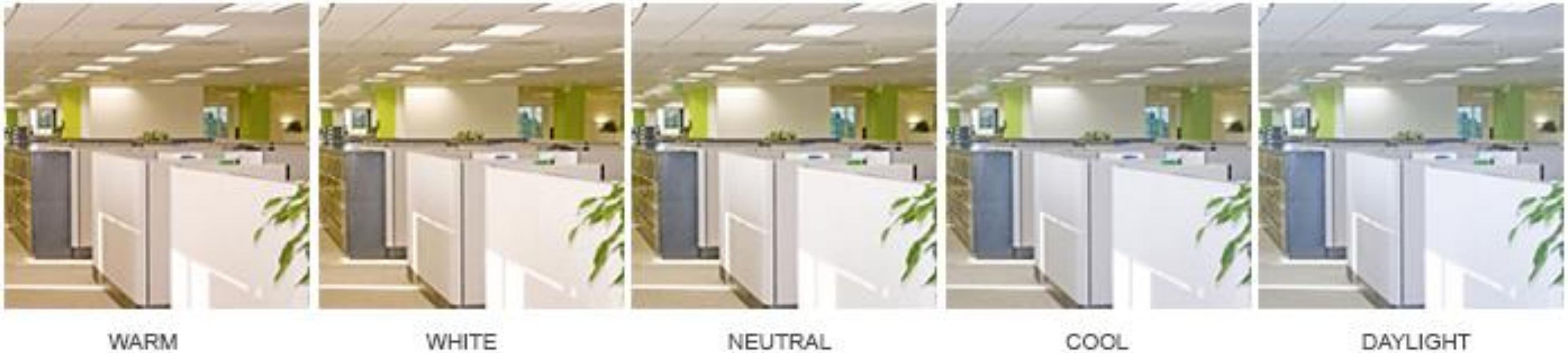


- A plug strip that can identify its loads by looking at the power characteristics. The plug strip can also control outlets.
- **Low resolution** data was collected with a sampling rate of one reading taken every 2 seconds for a duration of 2 minutes. It was observed that this data was sufficient to identify the device type, device, and its state or operating mode with a **very high accuracy** (>98%).
- Classification by using only features such as RMS voltage, RMS current, Power Factor, Phase Angle, Active Power, Reactive Power, Apparent Power, Peak voltage, and Peak Current
- The dataset is publicly available for download at https://github.com/Raghuna/plugload-data.

Paper: Plug load identification in educational buildings using machine learning algorithms. Raghunath Shivram Reddy, Niranjan Keesara, Vikram Pudi and Vishal Garg. Centre for IT in Building Science, IIIT-H, Hyderabad, India

Accomplishment – LRC-LED color adjustments

- Goal: Optimize the **spectral distribution** of LEDs to reduce electric power demand (by 30% or more) without compromising users' satisfaction with the lighting.
- **Human factors** evaluations were conducted to test the detectability and acceptability of each condition and the results were correlated to the potential input power savings.
- The results of the evaluations showed that **dimming**, without any spectral change, can result in a **larger power reduction** for the same acceptability criterion.
- Input for VOLTTRON algorithm on lighting control



Progress and Accomplishments

Accomplishments:

- Lighting color and dimming study.
- Integration of radiant cooled desk, with fans and lights.
- Integration of window shades and lights.
- Smart plug-strip with load detection.

Market Impact: Indian team (IIIT-H) is starting to use VOLTTRON for their integrated control. Potential for new contributions to VOLTTRON open source software.

Lessons Learned: International collaborative research projects require a lot of coordination.

Project Integration and Collaboration

Project Integration:

- Bi-weekly calls with Indian and US research partners
- Visiting student and professor from India planned for Summer 2016

Partners, Subcontractors, and Collaborators:

- Lighting Research Center at Rensselaer Polytechnic Institute
- International Institute of Information Technology, Hyderabad, India
- Indian Institute of Management Ahmedabad
- Philips Research

Communications:

- CBERD Stakeholder meeting, Delhi, December 2015
- 2 Papers on smart powerstrip

Next Steps and Future Plans

Next Steps and Future Plans:

- Extend VOLTTRON transaction-based control system
- Builds on work that uses VOLTTRON to manage military microgrids.
- Integrate Philips battery backed LED luminaire in VOLTTRON
- Demonstration of integration in India and US in a testbed setting.
- Create robust version of control algorithms for deployment outside of testbeds.

REFERENCE SLIDES

Project Budget

Project Budget:

~FY 13-14: $125K for overall coordination and activity on transactional controls, $50K on activity on lighting

~FY 15-17: $150K for overall coordination and activity on transactional controls, $50K on activity on lighting

Variances:

Budget above includes additional 25K provided for FY 15-17 for overall coordination after three original sub-tasks combined in FY15

-Cost to Date: Total funds till date: 615K, cost to date: $518K

Additional Funding: NA

Budget History					
Oct 2012– FY 2015 (past)		FY 2016 (current)		FY 2017 – Sept 2017 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
550 K	-	200K*	25K	200K*	25K

* Total expected funding

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Project Plan and Schedule

Project Schedule		
Project Start: 10/1/12		Completed Work
Projected End: 9/30/17		Active Task (in progress work)
	◆	Milestone/Deliverable (Originally Planned)
	◆	Milestone/Deliverable (Actual)

	FY2013				FY2014				FY2015				FY2016				FY2017			
Task 3: Integrated Sensors and Controls	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Current/Future Work (2015-2017)																				
FY2016 Q2 Milestone, Subtask 3.1: Network standby for computers evaluated for >50% power reduction in idle-mode LBNL]														◆						
FY2016 Q2 Milestone, Subtask 3.1: Capstone demonstration plan for lighting and plug load monitoring and control technology in a laboratory testbed setting finalized [joint]														◆						
FY2016 Q2 Milestone, Subtask 3.1: Peer-review conference paper on review of personal environmental control technologies submitted [IIIT+LBNL]														◆						
FY2016 Q2 **SMART** Milestone, Subtask 3.1: >70% accuracy in identifying plugged-in device type for >5 common device types, using networked plug-strips with plug-load control algorithms attained and verified [LBNL + IIIT]														◆						
FY2016 Q3 Milestone, Subtask 3.1: Proof of concept for extension of LED lighting control to low-voltage DC-powered lighting with communications demonstrated [IIIT+LBNL]															◆					
FY2016 Q3 Milestone, Subtask 3.1: **Proof of concept: Sensors and control systems integrated for radiant cooling table, occupancy, lighting and variable porosity fabric window shade [IIIT]															◆					
FY2016 Q3 Milestone, Subtask 3.3: Grid Responsive Buildings model prototype developed with research paper on commercial buildings [IIMA]															◆					
FY2016 Q3 Milestone, Subtask 3.1: Low energy cooling and natural ventilated systems integrated that are responsive to small zone realtime occupancy patterns, shading requirements and local weather. Response will be within 5 minutes of an environmental change that requires a mode change. [IIIT]															◆					
FY2016 Q3 Milestone, Subtask 3.2: Optimal load-shedding algorithms for task-ambient lighting systems developed [RPI]															◆					
FY2016 Q4 Milestone, Subtask 3.1: VOLTTRON Transactional Network controller developed for workstation energy management; coordinated control of HVAC, lighting, and plug load components demonstrated through full range of operating modes[LBNL]																◆				
FY2016 Q4 Milestone, Subtask 3.1: Sensors and controls embedded in office furniture systems [IIT]																◆				
FY2016 Q4 Milestone, Subtask 3.3: GRB model including CBERD technology data tested [IIMA]																◆				
FY2016 Q4 Milestone, Subtask 3.1: On screen GUI for occupant controls developed [IIIT]																◆				
FY2017 Q1 Milestone, Subtask 3.2: Methods to trade-off light-source color properties and input power developed [RPI]																	◆			
FY2017 Q2 Milestone, Subtask 3.1: Initial lab-based proof-of-concept of integrated control of lighting, plug loads, and thermal zone-level comfort conditioning. verifying that switching building to backup power leads to >10% decrease in zone+workstation power use [LBNL & IIIT]																		◆		