Inside a Field Validation Study of Energy Efficiency and Grid Services in Commercial Buildings

Researchers deploy IoT-based applications in two buildings

The Department of Energy's Commercial Buildings Integration Program funded Pacific Northwest National Laboratory (PNNL) to conduct a field study that launched in fiscal year 2020.

The project sought to show that energy efficiency (EE) and grid services (GS) software solutions deployed and delivered through an Internet of Things (IoT) platform can identify energy-savings opportunities and manage peak electricity load (beyond traditional demand response) in commercial buildings. A secondary goal was to demonstrate that an IoT-based software solution is a more cost-effective deployment approach compared to a manual process—an important consideration as cities increasingly mandate re-tuning and retro-commissioning in commercial buildings.

PNNL partnered with Intellimation, which provides energy services to the District of Columbia (DC) municipal government. Two DC-owned buildings were selected for the project, with testing focused on heating, ventilation, and air-conditioning (HVAC) systems, particularly air-handling units (AHUs) and associated variable air-volume boxes (VAVs).

Building	Building Data/HVAC Systems
 Anacostia High School (AHS)	**200,000 square feet** - Two 250-ton magnetic bearing centrifugal chillers - Three 1,400 MBtu natural gas-fired boilers - Four AHUs serving most of the building, with approximately 170 VAVs
 One Judiciary Square (OJS) office building and parking garage	**875,000 square feet, 14 floors** - Electric resistance heating - Direct expansion cooling coils - Four water-cooled direct expansion AHUs per floor, with each AHU serving 20-30 VAVs, totaling 600 building-wide

PROJECT TECHNOLOGIES

Software Platform for Application Deployment	Description
Eclipse VOLTTRON™	PNNL-developed, IoT-based distributed sensing and control software platform. Eclipse VOLTTRON™ provides an environment for application execution and readily interfaces with building automation systems (BASs), devices, external resources, grid signals, and platform services such as data archival and retrieval.
PNNL-developed EE/GS Applications	**Description**
Automated Fault Detection and Diagnostics (AFDD) algorithms (EE)	Deployed into BASs, the algorithms detect operational faults and provide actionable information to building owners/managers.
Automated Identification of Re-tuning/Retro-Commissioning - AIRCx (EE)	AIRCx incorporates a decision-tree structure to detect, diagnose, and provide actionable information for correcting building operational system issues. In some cases, AIRCx can automatically correct issues.
Intelligent Load Control - ILC (GS)	ILC coordinates with building systems to rapidly and automatically reduce electricity use (with minimal impact to occupant comfort) in response to grid requests. ILC employs the analytical hierarchy process to prioritize the electricity loads that can be curtailed.

DEPLOYMENT AND CHALLENGES

In summer 2021, at each site, continuously running AFDD and AIRCx software applications were successfully integrated with BASs via Eclipse VOLTTRON™. Similarly, the ILC application was deployed to manage controllable electricity loads.

Building infrastructure issues at AHS and OJS presented obstacles, particularly for ILC technology integration. Because these obstacles are likely present in many buildings, identifying and addressing them will also help inform the solutions needed for future broader adoption of the applications. Issues included:

- BAS naming conventions, control sequences, and some settings hindered application deployment.
- Lack of whole-building power measurement hampered ILC capabilities. Virtual power meters were successfully established, but the extra work added time and cost.
- The high school building had rooftop solar resources but no net meter, which impeded ILC peak-load management.
- At OJS, communication and data collection failures pointed to a need for more computational power.

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RESULTS

The project demonstrated that Eclipse VOLTTRON™ and the three applications can be deployed and scaled to meet the needs of various building sizes and types that possess BASs.

- AIRCx identified three measures—**supply-air temperature reset, supply-air static pressure reset, and air-handling unit schedules**—that, if adjusted, would result in estimated whole-building energy savings of 17 percent for OJS and 20 percent for AHS.
  - These numbers could translate to national building stock savings of 1,000 to 1,500 trillion Btus per year, along with reductions of 400,000 to 600,000 metric tons of carbon dioxide.
- ILC was successfully implemented in the two buildings, but the amount of peak-load reduction could not be discerned due to a lack of whole-building meters.
- The knowledge gained from this field validation will help researchers optimize the design and application of the solutions.

PNNL continues to partner with Intellimation, AHS, and OJS to monitor and improve the buildings' operational performance.

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