DR22.01 LBNL Hardware in the Loop Flexible Modeling DOE FOA-0002090

Overview

Lawrence Berkeley National Laboratory (LBNL) submitted a proposal to the Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) Building Technologies Office (BTO) in response to the DOE's Energy Efficiency and Renewable Energy (EERE) funding opportunity exchange DE-FOA 0002090, "BUILDINGS ENERGY EFFICIENCY FRONTIERS & INNOVATION TECHNOLOGIES (BENEFIT) – 2019". The BTO's overall goal is to improve the energy productivity of buildings without sacrificing occupant comfort or product performance. The goal is to use energy more productively and efficiently, not simply to use less energy. Progress towards achieving this goal will make building energy costs more affordable to the benefit of American families and businesses. Achieving BTO's priorities across the building technology landscape requires sustained, multifaceted innovation.

LBNL FLEXLAB Test Site

The LBNL proposal was titled "A framework to characterize the performance of building components in providing flexible loads and building services using a hardware-in-the-loop approach" and was awarded a contract agreement by the DOE for $1.6M to fund the development of a framework to characterize the performance of building components in providing flexible loads and building services using a hardware in-the-loop approach. The overall project objectives are to measure demand flexibility for different grid services and system/building types (commercial) and generate data for researchers/policy makers.

SCE provided a Letter of Commitment (LOC) in support of LBNL's proposal titled "A framework to characterize the performance of building components in providing flexible loads and building services using a hardware-in-the-loop approach" in response to the DOE's BENEFIT FOA 0002090 solicitation, intending to cost share $300,000. This DOE

project will generate high fidelity measurements of building system energy use and their ability and performance to provide grid services and demand flexibility while maintaining acceptable levels of service to building occupants. It will measure demand flexibility for different grid services and system/building types (commercial) and generate data for researchers/policymakers.

Research questions include:

- How much demand can be actually "shifted" by a light commercial building?
- What are the controllable end-uses & equipment types that provide highest impact?
- How do mass and insulation affect the amount of shiftable load?

The project objectives are:

1. Generation of high-resolution data (i.e., 1 min sampling or less) measuring the performance (building and grid service) of at least 3 systems (e.g., HVAC, lighting, plugs) while operating under all four flexibility modes (i.e., efficiency, shed, shift, modulate) in at least 5 different scenarios (e.g., a mix of weather, occupancy, building characteristics)
2. Development of test procedures to measure building flexibility
3. Generation of a component-level and system-level Modelica model of FLEXLAB to be used in future simulation research (e.g., to test advanced controls)
4. Setup of a hardware-in-the-loop infrastructure at FLEXLAB to support new lab experiments

The project was funded under EM&T Market Assessments and Technology Assessments investment categories, as there are elements of both research goals in this study. The Market Assessments category is designed to create a better understanding of emerging innovation and developments of new consumer markets for DR-enabling technologies and an awareness of consumer trends for smart devices. The Technology Assessments category assesses and reviews performance of DR-enabling technologies through lab and field tests and demonstrations designed to verify or enable DR technical capabilities.

Collaboration

The project is supplementary to work funded by DOE's Energy Efficiency and Renewable Energy (EERE) funding opportunity exchange DE-FOA 0002090, "BUILDINGS ENERGY EFFICIENCY FRONTIERS & INNOVATION TECHNOLOGIES (BENEFIT) – 2019". SCE is working with LBNL as a funding partner and active reviewer of the work in progress.

Results/Status

SCE-LBNL conducted check-in meetings Q2 of 2023. SCE was provided with several deliverables:

- Summary of FLEXLAB Modeling activities (Modeling Plan, List of End Uses, building components, FLEXLAB configurations & other modeling variables)

- Existing calibration datasets
- FLEXLAB experimental results

Calibration Summary Findings

- Successes
  - Calibration of parameters and schedules allowed for good agreement between model and tests, most importantly for parameters such as VAV terminals, fan power and cooling load
  - VAV control sequences works well for both model and test (e.g., Dual Maximum VAV Box Control Logic)
  - Calibration allowed 12/14 components to pass ASHRAE G14 tests (most importantly chilled water-cooling load)
- Shortcomings
  - Mismatch between controls in FLEXLAB and idealized case in modeling (economizing sequence, coil valve control, scheduling)
  - Values reporting from test components are not idealized and must be taken into account (damper positions)
  - Limited base case testing period for model calibration

FLEXLAB Test Results

Test 1: Three controls tested (Baseline, Ideal Model Predictive Control-MPC, Hybrid MPC)

- Total building power measurements show MPC's clear benefit in reducing peak demand in peak price window.
  - 30% reduction compared to that of the baseline scenario.
  - Approximately 20% HVAC energy cost
- Achieved by providing higher price differential in peak period
- Hybrid MPC (estimated values for internal gains) performed equally as well, providing promise for more scalable MPC option using less sensing.

Test 2: Two controls tested (Baseline-Heuristic, price responsive control. Blackbox- price responsive MPC)

- MPC successfully shift load by using thermal energy storage (TES).
- Despite Baseline already avoiding the peak time, MPC gets 19% of cost reduction by increasing load shifting.
- There is an 8% HVAC load discrepancy between the two cells.

Next Steps

LBNL and SCE will continue coordination and transfer of key findings and outcomes as the project progresses. Receipt of remaining deliverables, including project check-in/completion meetings and final reporting, is expected in Q3 - Q4 2023.