# FLEXLAB®: RESEARCHING FREQUENCY REGULATION FROM BUILDINGS

## EXPERIMENTAL VALIDATION OF COMMERCIAL BUILDING DEMAND RESPONSE PROVIDING FREQUENCY REGULATION

### THE CHALLENGE: Evaluating a Control Approach for HVAC Systems to Provide Frequency Regulation

Balancing electricity supply and demand has become challenging for utilities due to increasing penetrations of uncertain renewable generation and new types of large electric loads. One mitigation approach includes demand response - a strategy for automating demand-side load management when grid conditions require adjustment.

The motivation for exploration in this area is to alleviate rising power system uncertainty with low cost, new demand-side resources for reserves.

With renewables, new load types and distributed generation we see the uncertainty at the transmission level accelerating. Typically, supply-side, central generators handle all balancing operations through frequency regulation reserve services, but advances in computing, control, and communications have opened up opportunities for flexible demand-side resources, such as heating, ventilating and air conditioning (HVAC), to supply these balancing reserves.

With funding from the Department of Energy (DOE), researchers evaluated a control approach for frequency regulation from HVAC air handling units fitted with Variable Frequency Drives (VFDs). Additionally, the team evaluated the potential for energy efficiency losses of this type of demand response for ancillary services.

### THE SOLUTION: FLEXLAB

Under the auspices of DOE's Office of Electricity Delivery and Energy Reliability, Berkeley Lab researchers Jason MacDonald and Emre C. Kara teamed with Evangelos Vrettos of ETH Zurich (a science and technology university in Switzerland), and Principal Investigator Duncan S. Callaway of UC Berkeley, to design an experiment to show:

- A demand control hierarchy that's easily integrated into transmission markets
- Highly accurate frequency regulation reserve service provision
- How to explore the energy efficiency impacts of dynamically-controlled loads for power systems

The team spent five weeks in two of FLEXLAB's test cells, creating a unique and highly effective foundation for experimentation.

> ***"The value of FLEXLAB is that it gives you the ability to do a controlled experiment with an actual, measured baseline for demand response, which usually requires a counter factual. We were able to use the unique properties of FLEXLAB -- having identical twin test cells -- to measure identical physical environments with and without our control, and you can't do that in any other environment."***
>
> **EVANGELOS VRETTOS** | LEAD RESEARCHER
> ETH Zurich
> Swiss University for Science and Technology

## THE BOTTOM LINE

### FLEXLAB was able to implement our hierarchical optimal control of building loads that can provide frequency regulation in a manner consistent with electricity market timelines

**In the experiment, a data-driven optimization-based hierarchical control with a simple physical model of the space was created and tested. It showed it is possible to accurately predict the amount of reserve offered to a market in the day-ahead and manage the temperature set points within a comfortable range, while providing frequency service with an extremely high level of accuracy.**

**Preliminary results showed that actually following the frequency regulation signal has very little energy impact, likely due to its fast time scale relative to temperature dynamics in the space. When compared to other results in the literature, these fast time scale demand response services may offer more efficient operations.**

**EVANGELOS VRETTOS** | LEAD RESEARCHER
ETH Zurich
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## THE EXPERIMENT

- The team of four people set aside a five-week period of time at FLEXLAB.
- Parameters for a simple thermal model of the space were quantified by varying the control input (air flow) and observing the system's dynamic temperature response for nearly two weeks.
- A three level hierarchical control approach was implemented, which incorporated:
  - A day-ahead optimization to determine available regulation reserves from the space.
  - A model predictive controller, run every 15 minutes, to manage a comfortable room temperature.
  - A real-time controller that managed power to an exact set point to follow frequency regulation signals on a four-second basis.
- Multiple scenarios were tested to break apart the impacts on temperature and efficiency of holding reserves versus following the frequency regulation signal.

## THE RESULTS

- FLEXLAB was extremely useful in providing two separate yet equal environments for testing providing a realtime, comparable baseline to the test case.
- The day-ahead reserve provision was clearly accomplished with accuracy upwards of 95%. Preliminary analysis of efficiency results look promising, with low impacts resulting from control.
- Temperature dynamics with and without reserve provision were simulated.
- Temperature within a predefined comfort range was maintained while providing reserves.
- Identical test cells within FLEXLAB were utilized to ascertain efficiency impacts of the control approach.

FLEXLAB is located at Lawrence Berkeley National Lab

BERKELEY LAB

**FOR MORE INFORMATION ABOUT FLEXLAB, VISIT flexlab.lbl.gov**
flexlab.lbl.gov/publication/frequency-regulation-I
flexlab.lbl.gov/publication/frequency-regulation-II