BRIEF

Demonstrated Energy Savings through Supervisory Control for Building 14

Supervisory control for energy-efficient buildings

In commercial buildings, significant amounts of energy are consumed by the HVAC system. Constrained optimization-based control for building HVAC systems has recently received significant attention for its potential to reduce energy consumption. The most popular and practical optimization-based control strategy is model-predictive control (MPC). MPC utilizes a dynamic system model and an optimization algorithm to predict the future behavior of a plant (e.g., building and systems) and make decisions on control inputs (e.g., set-points) that minimize a certain cost function (e.g., energy).

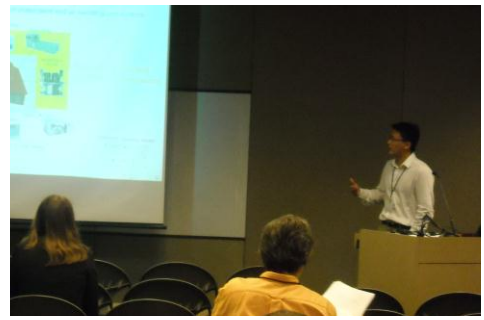

Figure 1: Presentation at the 2nd Purdue High Performance Building Conference

A computationally efficient MPC algorithm developed to optimize the energy use of the heating, ventilation, and air-conditioning (HVAC) system in Building 14 at The Navy Yard in Philadelphia was demonstrated through simulation. The results of the algorithm showing an average energy saving of 15 percent for the cooling season were presented at the 2nd International High Performance Buildings Conference at Purdue University in July of 2012.

Building 14 Case Study

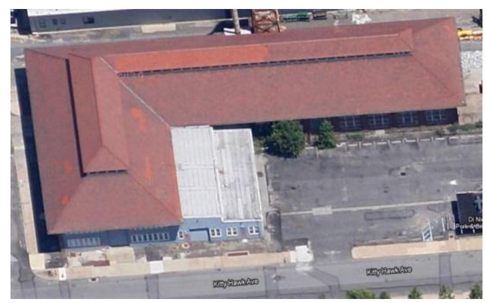

Figure 2: Building 14 at the Navy Yard

A detailed whole-building simulation model of Building 14, as shown in Figure 2, was adopted as the building virtual test bed. The building was functionally divided into five office spaces. Thermal comfort in these areas is maintained by five dedicated Air Handling Units (AHUs) with variable-speed fans. Each AHU has a heating coil and a cooling coil controlled to meet the supply air temperature set point. A water-cooled central chiller plant provides chilled-water to all AHUs for cooling, and gas boilers supply hot water to all AHUs for heating.

- ***Control-oriented dynamic model developed based on system identification***

For each thermal zone, a model obtained from system identification provided sufficient accuracy for predictive control design. The HVAC system models were obtained based on a data-driven method as well.

- ***Efficient tool chain enables controller verification with high-fidelity model***

An open-source optimization solver (e.g., IPOPT) was used to solve the optimization problem at each time step based on predictive system performance. The tool chain, as shown in Figure 3, applied in this study worked smoothly, and was computationally efficient. Computational delay can be straightforwardly accounted for by adding the actuation time delays in the dynamic model used for prediction. Therefore, the proposed control algorithm is very efficient for real-time implementation.

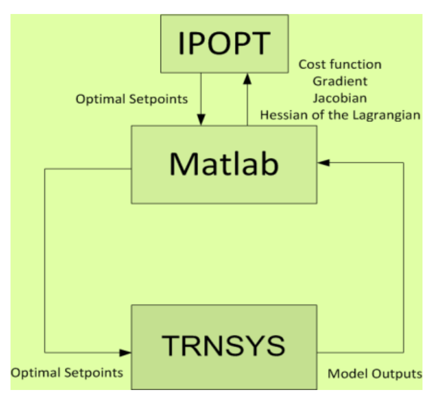

Figure 3: MPC Tool Chain

- ***Promising energy savings achieved with slightly improved comfort***

In this simulation study, both the effectiveness of the MPC controller and the energy savings it accomplished compared to the baseline control strategy were evaluated. The analysis was done for five typical days in July (July 10 to July 15, 2012) in Philadelphia, PA. Weather data was generated from the Typical Meteorological Year 3 (TMY3) data set for the Philadelphia airport. The target of the MPC controller was to maintain the zonal air temperature of each zone within the comfort bound by adjusting the flow rate and the supply air temperature for each zone. Meanwhile, the water temperature set points for the chiller plant were adjusted to maximize the chiller efficiency in terms of Coefficient of Performance (COP).

As can be observed in Figure 4, the MPC was trying to regulate the temperature around the upper bound of the thermal comfort regions (green blocks) while exploiting the trade-offs of supply air temperature and fan flow rate to minimize the energy-based cost function.

In summary, from the thermal comfort perspective, the MPC controller introduced very little oscillation and yielded improved performance compared to the baseline. From the energy use perspective, a promising energy saving of nearly 15 percent, as shown in Figure 5, was observed.

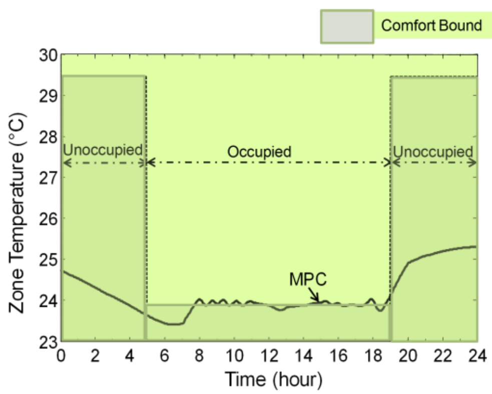

Figure 4: MPC-controlled Zone Temperature Profile

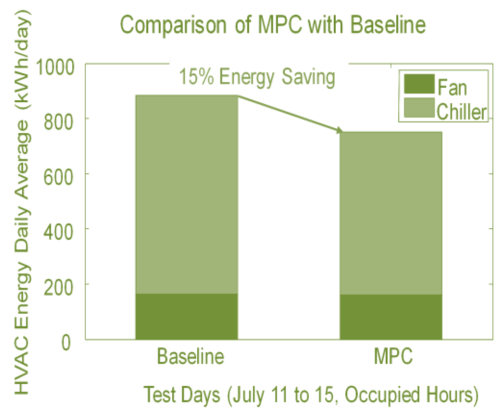

Figure 5: Energy Savings from MPC