Dynamic Optimal Control of Building Energy Adapting to External Factors Predictions

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Population growth, increased comfort levels, and the increase of indoor activities are placing more demands on the energy use from buildings across the globe. This contributes to the concerns about the exhaustion of resources and the related negative impacts on the environment. Therefore, energy efficiency in buildings is of critical interest. Since the largest contribution for a building's energy use is Heating, Ventilation, and Air Conditioning (HVAC), efforts that result in even small energy savings will be highly significant. Small to medium commercial buildings such as restaurants, stores, offices, gymnasiums, etc., use multiple Roof Top Units (RTUs) to condition their open spaces. Interaction between these RTUs is generally difficult to simulate using a lumped indoor-air model, and needs to be addressed using Computational Fluid Dynamics (CFD) approaches. In this work, a thermal flow analysis is performed for a gymnasium to optimize its HVAC energy consumption. The distributed dynamic responses of temperature and moisture that correspond to perturbations of input variables are generated using a CFD analysis. The CFD model is validated with experimental data from the RTU return temperatures. To avoid the high computational cost, and provide a reliable on-line model for an optimal controller, a Reduced Order Model (ROM) is developed by approximating the responses to these perturbations using a linear time-invariant model. The resulting indoor-air model is coupled to a dynamic envelope model with longer time scales.

The LTI model developed above, coupled to the dynamic envelope model, is used to compute the cost function and the comfort constraints. The coupled model is represented by a single State Space system. For an optimal operation of the facility, the RTU supply temperatures are controlled. For every other input, the nominal values of the weather parameters, supply water vapor fractions, supply mass flow rates, and occupancy loads are applied. Some outputs are needed for the cost function while some others are needed to formulate the constraints. The objective function consists of the total power required to run the cooling system. The optimal control formulation needs to take into account the uncertainties due to the dynamics of the model, loads, weather, etc. For this work, the focus will be addressing the weather prediction effects on the optimal controller. Optimal control is set using BLOM (Berkley Library for Optimization Modeling). For instance, to launch an optimization at a certain point in time, the weather predictions are updated for the entire time horizon. Naturally, the weather data at a point of time is subject to more error as the prediction horizon increases. So in order to reduce the prediction error, the optimal controller is run through the entire time span, only the first step is applied, then the controller is again run for the rest of the time, after the predictions have been updated. Using this methodology, considerable gains in the cost have been observed.