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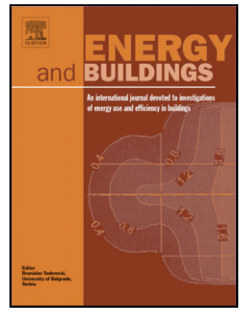

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A Mixed-Integer Linear Programming Model for Real-Time Cost Optimization of Building Heating, Ventilation, and Air Conditioning Equipment

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Abstract

In this paper, we present a framework for the formulation and solution of mixed-integer linear programming (MILP) models for operational planning of HVAC systems in commercial buildings. We introduce the general concepts of generators (e.g., chillers, boilers, cooling towers) and resources (e.g., electricity, chilled water), which allow us to model a wide range of central plants. By using discrete variables for on/off states of central plant equipment and continuous variables for equipment load, storage tank usage, and building temperature trajectory, all critical-to-cost decisions are taken into account. In addition, we consider both time-varying use charges and peak demand charges as well as building models of varying complexity. Because equipment models are often nonlinear, piecewise-linear approximations are used, which can be made arbitrarily accurate and enable real-time solution to the resulting optimization problems. We also employ a symmetry-free formulation to enhance the solution of the MILP model. Such features lead to improved performance compared to approaches employing heuristics or optimization without discrete variables. We demonstrate optimization for a small-scale cooling system and show favorable scaling of solution time with respect to number of units and temperature zones. In addition, we show simultaneous optimization of heating and cooling loops when a forecast of resource demand is available. Finally, we demonstrate closed-loop operation of our proposed optimization scheme. In all cases examined, a solution with an optimality gap below 1% can be obtained within 5 minutes, and thus the proposed optimization can be solved in real time, allowing for rapid response to changing weather, price, or demand forecasts.

Keywords: online optimization; central plants; cost reduction; thermal energy storage; scheduling

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