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An integrated Physical and Data-driven model for a Chiller Evaporator

Hongwen Dou[1*], Kun Zhang[1]
[1]Department of Mechanical Engineering, École de technologie supérieure, Montreal, Canada

ABSTRACT

The Heating, Ventilation, and Air Conditioning (HVAC) system is a critical component of building mechanical systems. A number of sensors have to be installed within the HVAC system for control, operating, and monitoring purposes, particularly in chillers, which can account for approximately half of a building's total energy consumption. As such, variables within a chiller evaporator, which represents its operational load and performance, are of paramount importance. For instance, the chilled water temperature leaving the evaporator is usually used as a setpoint of the related control system and serves as the baseline for designing the secondary cooling system. State-of-the-art research on evaporators mainly focuses on the refrigerant side, utilizing detailed physical models such as computational fluid dynamics or data-driven approaches like neural networks. However, these models are typically complex, computationally expensive, and require laboratory-level detailed experiments for validation. Such characteristics make them impractical for direct application in building HVAC systems.

Considering that the water-side information of chillers is often of greater interest for HVAC operation optimization, this paper presents a combined chiller evaporator model under steady-state conditions, integrating both physical and data-driven approaches. The model development starts with an analysis of the evaporator energy balance and heat transfer on both the water and refrigerant sides. It is then simplified into a practical formulation requiring minimal input variables, which are usually available in building automation system. A single coefficient is derived through a straightforward model training process. The proposed model predicts the temperature difference between the entering and leaving water in the evaporator, rather than the chilled water temperature leaving the evaporator, as its target. This is because the direct estimation of the chilled water temperature leaving the evaporator can be challenging as it is typically a setpoint and varies little in HVAC projects. A case study conducted on a real building with datasets at 15-minute intervals validates the high performance of the proposed model, achieving a coefficient of variance of root mean square error of 3.89%. The outcomes of the proposed model can temporarily replace physical sensor readings, ensuring accurate and reliable measurements for HVAC control and operation, while avoiding the costs associated with installing additional sensors and their maintenance. Moreover, the model has potential applications in HVAC operation optimization, fault detection, and diagnosis, ultimately contributing to improved energy efficiency and system reliability.