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Integrated energy performance modeling for a retail store building

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Research Article

Abstract

This paper presents an integrated energy performance modeling approach that considers heat and mass transfer through building envelope, HVAC (heating, ventilation, and air conditioning) and refrigeration systems of a retail store building with limited measured data. The internal heat gains/losses were estimated based on an Extended Kalman Filter. The simulation coupling strategy among room top units (RTUs), refrigeration display cases and zones is based on the ping-pong coupling strategy. The integrated model was validated against measured data from June to August, 2011. The results show that temperature prediction is within the ± 1.5°C error band and the RTU electricity energy use prediction is within the ±10% error band. The difference between measured and simulated annual electricity consumption from the refrigeration system is 3%. Based on further analysis and diagnostics, deviations of model predictions from measured data were found to be partially due to the faults in the RTUs. Such deviation accounts for a 4% saving of the total building electrical energy consumption.

Keywords

reduced order model,
retail store,
heat and mass transfer,
model calibration and validation

Article History

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1 Introduction

1.1 Background

The total energy use for US commercial buildings was 17.43 quads (CBECS database (2003)), approximately 18% of the total US energy use. The US Department of Energy (DOE), the International Energy Agency (IEA), Intergovernmental Panel on Climate Change (IPCC) and other agencies have declared a need for commercial buildings to become 70%–80% more energy efficient. Buildings with commercial refrigeration systems are among the most energy intensive and have been observed to have large inefficiencies. For example, supermarket annual energy use is documented to range from 2600 to 4300 kWh/m after being normalized by the total meter of refrigeration cabinet (Sienel 2007). Although energy-efficient building technologies are emerging, a key challenge is how to effectively maintain building energy performance over the evolving lifecycle of the building. It is well known that most buildings lose most of their desired and designed energy efficiency shortly after they are commissioned and re-commissioned. Achieving persistent low-energy performance is critical for realizing the energy, environmental, and economic goals. Before any advanced control and fault detection and diagnostics (FDD) technologies can be applied to achieve energy efficiency, a validated baseline energy performance model is often needed to help understand building operation.

There are two major energy simulation software tools which can model supermarket refrigeration systems: EnergyPlus (Crawley et al. 1999) and eQuest refrigeration (eQuest 2010). In both softwares, the total energy use of a supermarket is the summation of energy use of the different subsystems such as refrigeration, HVAC (heating, ventilation, and air conditioning), lighting and plug load. In EnergyPlus, the building heating and cooling loads are calculated based on the heat balance method, while in eQuest the transfer function method with custom weighting factors is applied, which is an approximation of the heat balance method. Particularly, the radiation heat exchange is explicitly modeled between surfaces in EnergyPlus, while in eQuest, radiant heat exchange is only modeled through combined radiation/

Building Systems and Components

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