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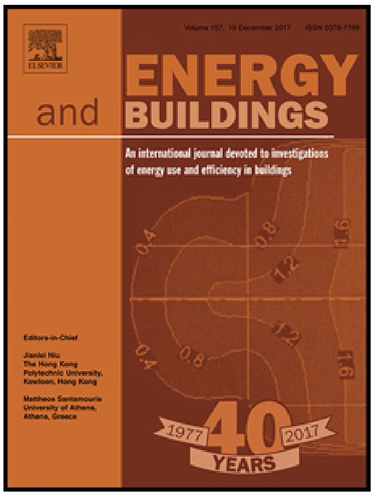

Hidden factors and handling strategy for accuracy of virtual in-situ sensor calibration in building energy systems: Sensitivity effect and reviving calibration

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Hidden factors and handling strategy for accuracy of virtual in-situ sensor calibration in building energy systems: Sensitivity effect and reviving calibration

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Keywords: Virtual in-situ sensor calibration, Building sensors, Sensitivity effect, Bayesian MCMC, Global sensitivity analysis, LiBr-H_2O refrigeration.

Abstract:

Virtual in-situ calibration (VIC) can be conducted on a large scale, in-situ, to calibrate multiple working sensors in an operational building's energy system based on Bayesian inference. As well as random errors, the VIC can handle various systematic errors that are not covered by a conventional calibration, and it does not require removing working sensors or adding reference sensors as is done in a conventional calibration. For successful calibration under the various working conditions of a system, it is important to figure out hidden factors and their negative impacts on the accuracy of VIC. Through case studies for a LiBr-H_2O refrigeration system, this study reveals two different sensitivity effects and how they affect the accuracy of VIC. Moreover, to handle the sensitivity issues, a new calibration strategy (named *reviving calibration*) is suggested and then evaluated in this work. This paper (1) shows the VIC problem formulation process, (2) explains how the two sensitivity effects influence the calibration accuracy, and (3) proves how and how much the suggested handling strategy solves the negative effects problem. The two case studies demonstrate the reviving calibration results in average 53% and 4% improvements, respectively, for temperature and mass flow rate sensors compared to the existing VIC method.

1. Introduction

Building energy monitoring and control systems are used to enhance system performance and indoor environmental quality and to reduce a large portion of the total energy consumed in buildings [1, 2]. Moreover, advanced building systems, which include automated optimization [3, 4], big data technologies [5, 6], and automated fault detection and diagnosis (AFDD) [7-11], have been applied to analyze the potential for improvements and energy savings. The current system technologies are required to use the information available from building sensor networks. If some sensors in the networks are erroneous, they will be ineffective no matter what the technologies used. Even AFDD methods [10, 11] for sensors require the reliable sensors in their training stage. In virtual sensor methods [12-16] in building systems, where challenging measurements can be estimated using existing sensors and building system models without new sensors, the existing physical sensors are very important due to the dependency added from the virtual sensors. That is, sensors are increasingly significant in realizing the high performance and low-energy buildings.

The impacts of sensor errors on building energy consumption have been investigated in previous studies [17-20]. In a typical small-size office building across five representative U.S. climate zones, outdoor air temperature sensor errors and thermostat errors increased the cooling energy consumption by 0.8–13.6% and the cooling and heating energy consumption by 19.07–34.24%, respectively [17]. Thirteen faults including sensor errors in commercial buildings increased the total energy consumption by 4–18% for heating, cooling, ventilation, lighting, and refrigeration [18]. Air-handling sensor errors caused the increase of 30–50% in the annual building energy consumption of an office building [19]. The impacts of