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Leveraging the analysis of parametric uncertainty for building energy model calibration

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Abstract

Calibrated energy models are used for measurement and verification of building retrofit projects, predictions of savings from energy conservation measures, and commissioning building systems (both prior to occupancy and during real-time model based performance monitoring, controls and diagnostics). This paper presents a systematic and automated way to calibrate a building energy model. Efficient parameter sampling is used to analyze more than two thousand model parameters and identify which of these are critical (most important) for model tuning. The parameters that most affect the building's energy end-use are selected and automatically refined to calibrate the model by applying an analytic meta-model based optimization. Real-time data from an office building, including weather and energy meter data in 2010, was used for the model calibration, while 2011 data was used for the model verification. The modeling process, calibration and verification results, as well as implementation issues encountered throughout the model calibration process from a user's perspective are discussed. The total facility and plug electricity consumption predictions from the calibrated model match the actual measured monthly data within ±5%. The calibrated model gives 2.80% of Coefficient of Variation of Root Mean Squared Error (CV (RMSE)) and –2.31% of Normalized Mean Bias Error (NMBE) for the whole building monthly electricity use, which is acceptable based on the ASHRAE Guideline 14-2002. In this work we use EnergyPlus as a modeling tool, while the method can be used with other modeling tools equally as well.

Keywords

EnergyPlus,
calibration,
sensitivity analysis,
meta-model based optimization

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1 Introduction

In 2011, buildings consume 40% of the energy and represent 40% of the carbon emissions in the United States. This is more than any other sector of the U.S. economy, including transportation and industry (DOE 2012). Enhancing building efficiency represents one of the easiest, most immediate and most cost effective ways to reduce carbon emissions. Building energy modeling recently has received increased attention as a tool to help reduce building energy consumption as a way to access efficient design and operation strategies without exhaustive field testing. Energy models provide hourly calculations of building energy consumption, HVAC (heating, ventilation and air-conditioning), and lighting systems performance, taking into account the dynamic interactions among the building envelope, airflow, weather, internal loads, building usage, equipment, and controls. Energy models can be used for (1) code compliance such as LEED certification (USGBC 2010) and ASHRAE 90.1 (ASHRAE 2010); (2) evaluations of different concepts during the building design stage; and (3) reference points for building real-time performance monitoring and energy diagnostics during the operation stage. If the model is accurately calibrated to the real building, the data generated by the energy model, which represents "design intent" or ideal performance, can be compared with real-time measured data from the building to identify sub-optimal operation or faults.

In this paper, an EnergyPlus model for an office building was calibrated and validated with real-time measured data

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