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Automatic calibration model of a building energy simulation using optimization algorithm

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Abstract

A lot of studies have been made to enhance the similarity between the target facility and building energy simulation (BES) model for an analysis of exact energy savings. Towards this end, ASHRAE guideline 14 presented the Coefficient of Variation of the Root Mean Square Error (CV(RMSE)) as criteria by which the similarity between the target facility and BES model can be measured. However, since the criteria of the CV(RSME) were met through manual and iterative performances in previous studies, this posed a disadvantage in that a lot of time and effort were consumed. In this regard, this study proposed an automatic calibration model for approaching the minimum CV(RMSE) using the BES model and optimization algorithm. The framework was conducted in five steps as follow: (i) collecting the target facility information; (ii) establishment of the BES model; (iii) calibration of the BES model in accordance with the CV(RMSE); (iv) setting the design variables and objective functions; (v) development of the automatic calibration model using optimization algorithm. As a result, the CV(RMSE) was automatically reduced from 18.10% to 12.62%. The proposed model improved calibration between actual energy data and simulation energy data while reducing time consuming.

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Keywords: Calibration; CV(RMSE); optimization; building energy simulation; genetic algorithm

1. Introduction

Climate change has now become an crucial issue as one of the most complex and challenging problems [1]. The total energy demand in 2035 is expected to increase by 48.3% compared to 2010 with an increase in population and economic growth in developing countries [2].

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Energy consumption accounts for the largest proportion in the building sector. In this regard, a building energy simulation (BES) plays a significant role in predicting energy consumption as well as energy savings of buildings after the application of retrofit strategies [3]. The BES calculates energy consumption through the use of appropriate input and operation parameters and displays appropriate output. It also plays an important role in analysing energy savings through the retrofit strategies [3-5]. BES has several advantages [6], however, there are often cases where the result values of the BES model are different from those of the actual building [7]. Thus, the reliability of the BES model depends on how similar it presents the result values are to those of the target facility. Because accurate building energy analysis is difficult, there is a need for mathematical and physical calculations by considering the HVAC system and weather conditions of the building. In a related move, ASHRAE 14, including International Performance Measurement and Verification Protocol(IPMVP) and Federal Energy Management Program(FEMP), presents criteria to determine the similarity between the BES model and target facility [8]. Each of the criteria utilizes the Coefficient of Variation of the Root Mean Square Error (CV(RMSE)), which is one of statistical indices, as a method for determining the similarity of the structure [8]. Meanwhile, in the previous research, several calibration methods were developed: (i) Manual and iterative calibration is performed until the criteria are met based on trial-and-error through the user's experience and proper input parameters [6,8]; (ii) Graphical and statistical methods present statistical display and graphical representations with respect to the results of the calibration procedures [3-6]. (iii) Automated and calibrated methods present specific tests and measurements through the analytical procedures based on the calibration [9]. In order to solve the limitation of previous researches, this study aims to develop an automatic calibration model of a building energy simulation using optimization algorithm. This study was conducted in 5 steps: (i) collecting the target facility information; (ii) establishment of the BES model; (iii) calibration of the BES model in accordance with the CV(RMSE); (iv) setting the design variables and objective functions; (v) development of the automatic calibration model using optimization algorithm. As shown in Figure 1, this study presented a research framework in a total of 5 steps to minimize the CV(RMSE).

As the target facility of this study, the target facility located in Seoul was selected. For energy simulation, EnergyPlus was selected, and GA was utilized as an algorithm for optimization. In this case, the design variables and objective function were set, and then the minimum CV(RMSE) was finally presented by automatically repeating the optimization.

For this study, EnergyPlus, developed by the Department Of Energy(DOE), was selected as the BES model [9], and the genetic algorithm(GA) was utilized to perform the optimization. The accuracy was improved by selecting the CV(RMSE) as the objective function.

2. Material and Methods

2.1. Step 1&2: collecting target facility information and establishment of the BES model

For analysis of energy savings through the prediction of building energy consumption and retrofit application, the BES model is needed. Prior to this, the target facility to be analysed should be selected. At this time, it is necessary to choose an operation strategy and for the design variables of the building to be adjusted to meet the minimum CV(RMSE): (i) weather conditions for predicting the energy consumption of the building; (ii) passive energy saving technologies; (iii) active energy saving technologies. In this study, the target facility located in Seoul was selected. Kim et al. presented the basic conditions of the target facility [10]. The target facility is a three-story building located in Seoul, South Korea, and its total building area is 4,265m^2. The operation schedule of the school complies with the Korea school schedule. As a system for conditioning, an electric heating pump (EHP) has been used.