Building and Environment 46 (2011) 409–420

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

A rapid calibration procedure and case study for simplified simulation models of commonly used HVAC systems

Guopeng Liu [a,*], Mingsheng Liu [b]

[a] Pacific Northwest National Laboratory, P.O. Box 999, MSIN K5-16, Richland, WA 99352, USA
[b] University of Nebraska-Lincoln, Omaha, NE 68182, USA

ARTICLE INFO

Article history:
Received 3 June 2010
Received in revised form
3 August 2010
Accepted 5 August 2010

Keywords:
Calibration
Building simulation
Models
HVAC

ABSTRACT

A rapid procedure for calibrating simplified building energy simulation models of commonly used HVAC systems has been developed. The procedure developed will allow building professionals to project annual cooling and heating energy consumption of buildings with multiple HVAC systems from short-term field measurement data. This paper describes the general calibration procedure developed, and demonstrates the use of the calibration procedure by applying it to an office building. The calibration methodology requires as little as two weeks of measured hourly heating and cooling consumption data. In the example presented, the simulation model was calibrated using only two weeks of measured heating and cooling data. After calibrating the simulation using this procedure, the RMSE is reduced significantly. The simulation calibrated to two weeks of measured data is then used to simulate the hourly consumption of the building for the year 2004. Comparison of the results of this simulation with the measured data gave monthly CV(RMSE) values of 10.3% and 3.7% for cooling and heating, respectively, which are both well below the 15% values considered acceptable in ASHRAE Guideline 14 [1]. It also shows monthly NMBE values of 2.2% and 1.4% for cooling and heating respectively.

1. Introduction

Energy analysis plays an important role in developing an optimal HVAC and architectural design for new buildings and in determining optimal retrofit and commissioning measures for existing buildings. In most cases, computer simulations are required to develop an optimal design due to the complex nature of building energy systems, although manual hand calculations may be more suitable for some simple cases.

Before the 1960s, building energy calculations and system sizing were conducted using manual methods such as degree day, equivalent full load cooling, and bin heating/cooling methods if done at all. Automated calculation methods evolved over the next two decades, with first generation automated methods developed between 1965 and 1975, and with the second generation of automated methods developed between 1975 and 1983.

The second generation of automated methods includes both detailed simulation methods and simplified methods. Programs representative of detailed simulation methods are BLAST [9] and DOE 2.0 [16]. These programs are capable of considering a building's dynamic behavior using hourly simulations. However, detailed input information is required to produce correct output [15].

The ASHRAE simplified energy analysis procedure (called the modified bin method in this paper) is representative of the simplified methods. The modified bin method uses steady state analysis to determine the envelope heat transfer and internal gains and uses a simplified temperature dependent representation of solar heat gains. This enables the use of envelope inputs that are much simpler than those used in detailed simulation methods [14]. Significant effort and research have been conducted to compare the detailed and simplified methods over the last thirty years [4,15].

Calibrating computer models to actual metered data is not a new practice. As early as 1970, recommendations were made to calibrate models based on measured data [2]. Some researchers and engineers have attempted to compile "how to" manuals and methods in order to simplify this task [3,6–8,10–12,20,21,25]. Further, in almost all cases the end result falls short of a useful toolkit of procedures. Most of these calibrations rely on comprehensive simulation packages that model building energy flows and HVAC system performance in a more detailed manner than does the simplified systems approach. If the building has multiple HVAC units, models for each unit need to be formulated. This procedure is

* Corresponding author.
E-mail addresses: guopeng.liu@pnl.gov (G. Liu), mliu2@unl.edu (M. Liu).

0360-1323/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.buildenv.2010.08.002