

ASHRAE Research Project 1051- RP

Procedures for Reconciling Computer-Calculated Results With Measured Energy Data

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Calibrated simulation is the process of using an existing building simulation computer program and “tuning” or calibrating the various inputs to the program so that predictions match closely with observed energy use. Historically, the calibration process has been an art form that inevitably relies on user knowledge, past experience, statistical expertise, engineering judgment, and an abundance of trial and error. Despite widespread interest in the professional community, unfortunately, no consensus guidelines have been published on how to perform a calibration using detailed simulation programs. This research project was initiated with the intention to cull the best tools, techniques, approaches, procedures from the existing body of research and develop a coherent and systematic calibration methodology that includes both “parameter estimation” and determination of the uncertainty in the calibrated simulation. A general methodology of calibrating detailed simulation programs to performance data is proposed which we deem to be methodical, rational, robust and computationally efficient, while being flexible enough to satisfy different users with different personal preferences and biases. The methodology involves various concepts and approaches borrowed from allied scientific disciplines which are also reviewed in this report. The methodology essentially consists of four aspects: (i) heuristically define a set of influential input parameter and schedules along with their best-guess estimates and their range of variation depending on the building type; (ii) perform a coarse grid search (involving thousands of simulations) wherein the heuristically defined influential parameters are subject to a Monte Carlo simulation in order to identify a sub-set of the most sensitive parameters, define narrower bounds of variability of such parameters, and identify a small set of feasible parameter vector solutions; (iii) perform a guided grid search to further refine the feasible parameter vector solutions and (iv) use this solution set to make predictions and determine the prediction uncertainty of the entire calibration process. The methodology has been illustrated with three case study buildings that include two synthetic cases, and one actual building.

This report also provides a pertinent and detailed literature review of calibrated simulation techniques, describing their strengths, weaknesses and applicability. Literature reviews of several

concepts, issues and procedures are also assembled which though related to the building design process were deemed pertinent enough to the calibration process that they would be of interest to calibration professionals. Though the methodology is applicable to any building energy simulation program, the scope of this research project is delimited to the public domain DOE-2 program and to the widely prevalent case where year-long utility bill data is the only performance data available for calibration. The application of this methodology to the case study buildings supported the original intention of being able to automate the entire process and also to apply it to cases where additional monitored performance data (short-term monitoring or interval data) is available. Further, several aspects of this research can be immediately adopted by those performing calibrated simulations, while commercial adoption would require some additional research into certain aspects which have also been identified in this research. This research is also meant to benefit software developers in that it would specify additional capabilities to existing building energy simulation programs which would allow calibration to be performed by practitioners with relative ease and with higher consistency.

Publications:

1. Reddy, T.A., I. Maor and C. Ponjapornpon, 2006, "Calibrating Detailed Building Energy Simulation Programs with Measured Data- Part II: Application to Three Case Study Office Buildings", HVAC&R Research Journal, accepted, March
2. Reddy, T.A., I. Maor and C. Ponjapornpon, 2006, "Calibrating Detailed Building Energy Simulation Programs with Measured Data- Part I: General Methodology", HVAC&R Research Journal, accepted, March.
3. Sun, J. and Reddy, T.A., "Calibration of Building Energy Simulation Programs using the Analytic Optimization Approach", HVAC&R Research Journal, vol.12, no.1, pp.177-196, January
4. Reddy, T.A., 2006. "Literature Review on Calibration of Building Energy Simulation Programs: Uses, Problems, Procedures, Uncertainty and Tools", ASHRAE Transactions, vol 112(1), January.