

A MATLAB-BASED SIMULATION TOOL FOR BUILDING THERMAL PERFORMANCE ANALYSIS

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ABSTRACT

This paper presents the development of a simulation tool based on the Matlab computational environment for building temperature performance analysis with automatic control. The simulation tool contains mathematical models for buildings, HVAC (Heating, Ventilation and Air Conditioning) systems, sensors, weather data and control algorithms. The building mathematical model is described in terms of state-space variables, with a lumped approach for the room air governing equations – energy and mass balances. In this context, the simulation tool structure and components are explained. Five control strategies applied to HVAC systems, integrated to building zones, are discussed as well. A simulation example illustrates the use of the software presented.

INTRODUCTION

The mathematical description of thermal behavior of building systems is complex since it involves the modeling of several interconnect subsystems, each one containing long-time constants, non-linearities and uncertainties such as convection coefficients, material properties etc. Moreover, external unpredicted perturbations, i.e., external weather (temperature, humidity), soil temperature, radiation effects and other sources of energy, such as people, illuminations and equipments, should also be taken into account.

Some points related with building modeling include the analysis of thermal comfort and energy consumption. Several software environments for building simulation are available all over the world, for instance, DOE-2, BLAST, EnergyPlus, Genopt, SPARK, Energy-10. However, computer processing power has been considerably improved in the last decade so that the use of mathematical packages such as Matlab/Simulink can be considered also as a good option for performing simulation-based building thermal analysis. In addition, the use of Simulink features has provided a user-friendly environment for fast configuration of inputs and outputs of the different subsystems included in the building and

equipments, such as HVAC (Heating, Ventilation and Air Conditioning).

In this way, a mathematical model for building simulation by using Matlab/Simulink environment is presented in Hudson and Underwood (1999). In this approach, the building is represented by an RC electric circuit and the model is considered adequate for high mass buildings since they are predominantly capacitive. In Mendes et al. (2001), a lumped approach is used to model the room air temperature and a multi-layer model for the building envelope. The building model allows studying the transient analysis of room air temperature when it is submitted to sinusoidal variation of external air temperature. In Mendes et al. (2002), the model is extended in order to incorporate hygrothermal dynamics of the building and external humidity data. Both works use Matlab/Simulink environment. Another quite interesting example of Matlab/Simulink used in thermal system modeling is the SIMBAD Building and HVAC Toolbox (Riederer et al., 2001). This toolbox provides a large number of ready-to-use HVAC models and related utilities to perform dynamic simulation of HVAC plants. For simulation involving control, this toolbox must be connected to other existing toolboxes.

Another important aspect is the analysis of thermal comfort and energy consumption and its relation with HVAC system control. By using an adequate mathematical model of the building, it is possible to use techniques of automatic control in the regulation of thermal zone temperature and humidity. Some examples of this approach are Dion et al. (1991), Huang and Lam (1997), Ghemari et al. (2001), Oliveira et al. (2003).

The present work describes the development of a toolbox based on the Matlab/Simulink software for hygrothermal building simulation and performance analysis of HVAC automatic control systems. The proposed software version is modularity written, allowing easy expansion and interchangeability of building, HVAC and control systems. The simulation tool contains models for buildings, HVAC systems, sensors and controllers, and actual or typical weather

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