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A New Multizone Model for the Simulation of Building Thermal Performance

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A new multizone model which is an improvement on the state space model is presented, which is potentially more efficient in the simulation of large scale buildings than other methods such as finite difference, transfer functions, or finite volume. The modelling philosophy is firstly discussed. Then the principle and algorithm of the new model are described. Finally, a PC based program BTP developed based on state-of-the-art modelling strategy reveals its applicability with fast calculation speed and satisfactory accuracy in the modelling of building energy performance. © 1977 *Elsevier Science Ltd. All rights reserved.*

INTRODUCTION

USING software packages such as ESP, DOE2, SERIRES, HTB2, and others developed world-wide in the building environmental engineering field, simulations of building thermal performance are increasingly being used to address real world problems in the design of energy efficient buildings and healthy buildings. As the user base becomes wider, there is an increasing chance that a program will be used improperly or outside the range of applicability of the program. The reasons for this are, on the one hand, that the real world issues are often complicated, uncertain and nonlinear, and so simplifications, assumptions and approximations have to be introduced in a modelling process (Fig. 1); on the other hand, the documentation of a detailed program [1], i.e. about 50 pages is needed to explain the modelling scenario of ESP, is always not so easy and clear for users to follow. The IEA (International Energy Agency) Annex 21 "Calculation of Energy and Environmental Performance of Buildings" Subtask A "Program Guide" seeks to address some of the obstacles to the use of prediction programs [2].

Modelling is a trade-off between reliability, accuracy and time (Fig. 2). The simplified steady state models benefit in reliability and time, but are poor in accuracy, so they are often applied at the preliminary design stage. Detailed dynamic models benefit in accuracy; they are often applied in the analysis of annual energy consumption and performance of building HVAC systems. Detailed programs require users to prepare much input data (some of them are empirical coefficients) in the specific format, so users act as slaves rather than masters of a computer program. The solution is the using of an integrated building simulation environment [3] with knowledge based systems [4], which will release users from boring tasks.

As the real world issue is complicated, the actual solution is often hard to obtain. Traditional modelling process introduces lots of assumptions, simplifications and approximations, in order to locate the single solution or optimal solution, which often leads the single or optimal solution to be far away from the actual solution. What should be pursued is the rational solution, i.e. the satisfactory solution based on a certain degree of confidence. The rational solution is often not a single value, but a range or set (Fig. 3). This is the main idea of The Principle of Bounded Rationality put forward by H. A. Simon [5], who won the Nobel prize in Economics in 1978.

Modelling of the real world should help us easily find the rational solution. IEA Annex 30 "Bringing Simulation to Application" [6] aims to control and reduce "the quickly growing gap between what the scientists are offering as calculation and simulation tools and what is really used in current practice", which will encourage more and more users to enjoy the computer modelling world.

Two kinds of mathematical methods are used in the simulation of building thermal performance: one is frequency domain method, such as Fourier transformation, which requires the harmonic decomposition of all heat disturbances with FFT (Fast Fourier Transformation) technique; the other is time domain method, such as transfer function [7], thermal response factors (Z-transform function) [8], nodal method (finite volume) [9], state space method [10]. A brief overview of thermal zone models is given in [11]. Besides the stated physical models, black-box methods such as ARMA time series and neural network [12] are also applied to predict the building energy performance. Black-box models need training or parameter identification based on the real measured data; the link between model parameters and physical parameters is difficult to establish without any prior knowledge of the system to identify, hence these methods are

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