Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 133 (2017) 53–67

Energy Procedia

www.elsevier.com/locate/procedia

Climamed 2017 – Mediterranean Conference of HVAC; Historical buildings retrofit in the Mediterranean area, 12-13 May 2017, Matera, Italy

Integration time step issue in Mediterranean Historic Building energy simulation

Livio Mazzarella[a]*, Marina Pasini[a]

Department of Energy, Politecnico di Milano, Milano 20156, Italy

Abstract

The European target towards Zero Energy buildings is focusing on the energy retrofit of existing buildings. Often, in Mediterranean countries, existing buildings have historical relevancies, involving constraints, when dealing with their energy renovation, due to conservation reasons. To analyze possible energy retrofit actions, building energy performance simulation tools (BEPSt) are valuable. However, old buildings are often made of large stone walls whose resolution through conduction transfer function (CTF) used for sub-hourly time step simulation might be critical. This paper analyses how EnergyPlus and TRNSYS address such problem, explaining the differences between them and the reasons for low quality results.

Keywords: Historic Buildings, Performance simulation, Transient Heat Transfer;

1. INTRODUCTION

Today the European target towards Zero Energy buildings is focusing on the energy retrofit of existing buildings, which represent the majority of the building stock. In Mediterranean countries, like Italy, most of the existing building stock is very ancient and very often those buildings are historic buildings. When dealing with their energy renovation, many constraints have to be taken into consideration due to conservation reasons. To be able to analyze and optimize any potential energy saving option foreseen for a constrained problem like energy saving in ancient or historic

* Livio Mazzarella. Tel.: +39-02.2399.3869; fax: +39-02.2399.3838.
E-mail address: livio.mazzarella@polimi.it

10.1016/j.egypro.2017.09.371

building, where local specific cultural heritage considerations are dominant, energy performance simulation tools (BEPSt) represent powerful and essential tools.

Old and historic Mediterranean building are often made of large stone walls from 30, 50 cm up to 1.9 m. These thick walls, combined with a small simulation time step, may produce low quality results if conduction transfer functions (CTFs) are used when solving transient heat conduction in such walls. The requirement of using small simulation time step (less than one hour) is often due to the desire of analyzing the impact of complex control systems on the building energy performance, mainly in connection with the exploitation of renewable energy sources. In such case, but also when one-hour time step is used with very large walls, problems could arise that depends on the quality of the method used to calculate the CTF coefficients and on the minimum acceptable CTF time base compared to the imposed simulation time step. The CTF time base is the time step chosen to build its coefficients and represents its time resolution. When a fix or upper bounded number or coefficients are chosen, the CTF time base is lower bounded, i.e. it is possible that a reliable CTF does not exist for such chosen time base and number of coefficients and that a larger time base or an increasing number of coefficients has to be used to find a high quality solution. The simulation time step is instead the time resolution the user has decided to use in solving the overall energy simulation problem.

Today, two of the most diffused BPSts, EnergyPlus (EnergyPlus [1]) and TRNSYS (TRNSYS [2]), make primarily use of conduction transfer functions for heat conduction resolution, even if also finite difference schemes are implemented in EnergyPlus. The CTF coefficients can be calculated following different approaches, and, as a matter of fact, EnergyPlus implements the State-Space method (SS) (Seem [3]), while TRNSYS implements the Direct Root Finding method (DRF) (Mitalas and Arseneault [4]), even if a custom SS method was tested in a TRNSYS 17 development version (Delcroix [5]). To test the quality of those methods, when dealing with heavy, thick walls like that usually found in historic buildings, reference boundary conditions have been chosen that allows comparing CTF solutions with analytical solutions, even if numerically computed. Thus, periodic steady state boundary conditions (BCs) are applied with a period of 24 h and the results in terms of superficial temperatures and fluxes are compared with analytical exact solutions obtained using the harmonic admittance matrix approach (CEN-ISO [6]). The periodic steady state heat conduction is solved for five different walls in 1D domain with different simulation time steps. The effect on the accuracy of the solution of different CTF time bases, compared to the simulation time step, is investigated too.

Nomenclature

x_i	Discrete i-time calculated generic quantity
$\hat{x}_i$	Analytically calculated generic quantity at time t_i
y_i	CTF transfer function calculated setting the Laplace parameter as harmonic at frequency ω_i, i.e. $s = e^{i\omega i\Delta t}$
$\hat{y}_i$	Module or phase of the superficial or cross coefficient of the admittance matrix evaluated at frequency ω_i

2. Test Methodology

The tested transient heat conduction solvers belong to the Conduction Transfer Function (CTF) method and their coefficients are computed using:

- State-Space method (SS), as implemented in EnergyPlus 8.6;
- Direct Root Finding method (DRF), as implemented in TRNSYS 17.

To analyze not only the impact of each method, SS or DRF, on the quality of the solution, but also the impact of any implemented algorithm, which takes care of possible mismatch between the CTF time base and the simulation time step, an entire thermal zone simulation (instead of a single wall test) has been performed. Thus, the scenario taken into consideration is that described in the "Test TC3: Transient Conduction – Sinusoidal Driving Temperature and Multi-layer Wall" of the ASHRAE 1052-RP (Spitler [7]). The ASHRAE report gives the analytically derived solution of such problem for just one wall. To be able to produce those reference analytical results for any kind of wall obtaining the "exact" values of superficial internal and external temperatures, this analytical solution has been