Validation Exercise Applied to Some TRNSYS Components in the Context of IEA34/43

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ABSTRACT

An important part of IEA 34/43 is concerning validation of building simulation models. Analytical and comparative validation of multizone building simulation models are the object of Subtask B while empirical validation of models dealing with the shading, day lighting and cooling load interaction is targeted by Subtask C.

For the first approach, the Multizone Building Component of TRNSYS ("Type 56") was tested in a series of exercises ranging from analytical and simplified cases up to more complex situations where special features like presence of site obstructions, internal windows are taken into account. The good capabilities of TRNSYS Type 56 as well as its limitations were pointed out by the exercise and the results are discussed in the paper.

In the second approach, a well-instrumented testing infrastructure (a test-cell) located at EMPA in Zürich, Switzerland was used to check the performance of TRNSYS regarding the solar processing features (calculation of diffuse radiation; repartition of solar radiation on vertical facades) as well as the dynamic behavior of the Multizone Building model in different shading situations: no shading, internal shading, external shading. High quality measurements corresponding to periods of 600h were generated for each of these situations and the simulation model was tailored to represent as much as possible the experimental conditions. In general, the behavior of TRNSYS was demonstrated very good. The influence of some specific features of Type 56, for instance concerning the calculation of the infrared exchanges, is illustrated in the paper.

KEYWORDS

Modeling, building simulation, validation, solar radiation

INTRODUCTION

Energy conservation in buildings represents a major issue of the 21st century. Improvement of both the design and the operation of buildings is promoted by authorities and this process will be accelerated by the application of the European Performance of Buildings Directive. Design as well as operation improvement appears greatly enhanced by the use of modeling and simulation resources. Application of these tools nevertheless relies on a preliminary and critical issue which is the quality insurance of the models. Validation of simulation models, specially in the field of energy and buildings is a continuous process which started in the late eighties and still generates substantial amount of work in the scientific community. A major part of this validation work was organized in the frame of the IEA (Solar Heating and Cooling and Energy Conservation in Buildings and Community Systems

Implementing Agreement): sequentially, Task 12 (in connection with Annex 21), Task 22 and Annex 43 (or Task 34) were and are still devoted this important issue. These projects have been addressing increasingly complex modeling features included in the major programs available on the market.

This paper addresses some of the validation exercises carried out in the on-going Annex 43 (Task 34) project with the particular focus given to the TRNSYS program, more exactly to some of the components (those related to building simulation) of the TRNSYS program: Type 56 (Multizone Building), Type 16 (Solar Processor), Type 109 (Combined data reader and solar processor). These validation exercises follow the general methodology progressively developed in the sequence of the IEA projects and include some analytical, comparative and empirical aspects. For part of them, they were developed using the "BESTEST" procedure which allows specific features of simulation software to be progressively incorporated in the testing protocol.

The work described here was carried out in the frame of the IEA Annex 43 (Task 34) project and more precisely in the Subtasks "B" ("Multizone Building") and "C" ("Shading, daylighting and cooling load interaction") of that project.

TRNSYS SOFTWARE AND TESTED COMPONENTS

TRNSYS is a well known simulation software developed from the seventies by the Solar Energy Laboratory of the University of Wisconsin. It is based upon a modular structure, each component being designated as a "Type" and devoted to the simulation of a particular thermal or energy system. Out of these types, a number are directly in line with the simulation of the thermal and energy behavior of a building. The validation work described below was applied to Type 56 ("Multizone Building") and to Type 16 ("Solar Radiation processor") which appears as two components systematically used when performing a building simulation. The solar radiation algorithms of Type 16 are identically included in Type 109 (Combined Data Reader and Solar Radiation Processor).

Type 56 (Multizone Building)

Type 56 was included for the first time in version 12.2 of TRNSYS (which was released in 1988), following a development work of Braun (1984) and Seem (1987). Afterwards, it followed a continuous evolution, mainly driven by TRANSSOLAR (2004a). A specific interface to enter the numerous data of the model was developed ("PreBid" which became TRNBUILD with release 16 of TRNSYS). The main characteristics of that model are as follows:

- non geometrical model (view factors not considered)
- arbitrary number of zones
- conduction process represented by the "Transfer Function" formalism (input-output model)
- thermal couplings by air flows between zones are considered and can be calculated but this requires an "advanced" version of Type 56: TRNFLOW (a

multizone air flow calculation engine derived from COMIS), developed by TRANSSOLAR (2004b)

In this validation work, only the “basic” version of Type 56 (excluding TRNFLOW) was tested. This model was successively submitted to the following testing procedures.

MZ-200: 2-zone steady state analytical verification base case

This is a basic verification which consists in testing the ability of TRNSYS type 56 to model steady-state interzonal conduction for two zones. An analytical solution exists for such a problem which yields the heating required in two zones “A” and “B” to maintain prescribed temperature setpoints. Solution as calculated by TRNSYS Type 56 yields exactly the same values. Comparison of the TRNSYS Type 56 solution with results from other programs is shown by fig. 1.

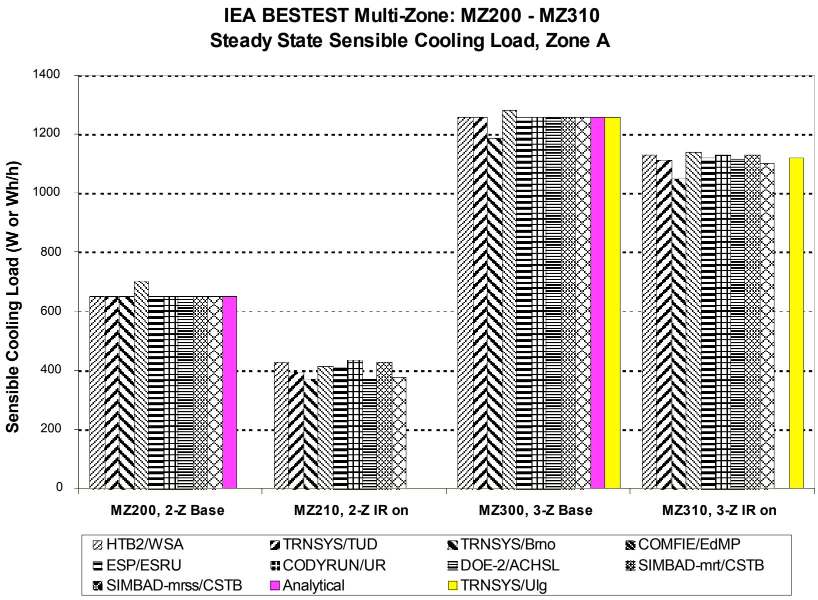

Figure 1: MZ-200 case: comparison of TRNSYS Type 56 with other programs

MZ-210: 2-zone steady state conduction with infrared radiation exchange

This case is identical to the previous one with the only difference being the fact that infrared radiation exchanges are not cancelled: en interior emittance of 0.9 is set for all interior surfaces. This is not that easy to reproduce in TRNSYS Type 56 where all interior surfaces are supposed as “black” for all radiation exchanges. The model considers the usual “linearizing” approximation of the radiation exchanges with (T_1^4-T_2^4) approximated as (T_1-T_2)*T_{mean}^3. In order to simulate the 0.9 emittance, the best solution seems to be the reduction of T_{mean} down to a value which is equivalent to the situation where a comparable radiation level is obtained, but with an emittance of 1. This temperature is calculated as:

$$T_{meanNEW} = \frac{293.15}{\sqrt[3]{\frac{2}{\varepsilon_{NEW}} - 1}}$$

where $T_{meanNEW}$ and ε_{NEW} are the fictitious surface temperature and the emittance which are equivalent to the association of T_{mean} and ε (real).

No analytical solution does exist for that case but the good performance of TRNSYS Type 56 compared to other models is shown by fig. 1

MZ-300: 3-zone steady state analytical verification base case

The purpose of this exercise is to test the ability of whole-building simulation software to model steady-state interzonal conduction for three zones with: internal gains in all zones, temperature controlled in zone A and zone B and temperature floating in zone C.

An analytical solution also exists for such a case and is correctly retrieved by TRNSYS Type 56 (fig. 1).

MZ-310: 3-zone steady state conduction with interior infrared radiation exchange

This is an equivalent problem to MZ-210 but with 3 zones. To solve it in TRNSYS Type 56, an equivalence has to be found between the original "delta" network (fig. 2) and the corresponding star network as derived from the application of the Seem approach (with definition of the star network). This equivalent scheme is shown by fig 3.

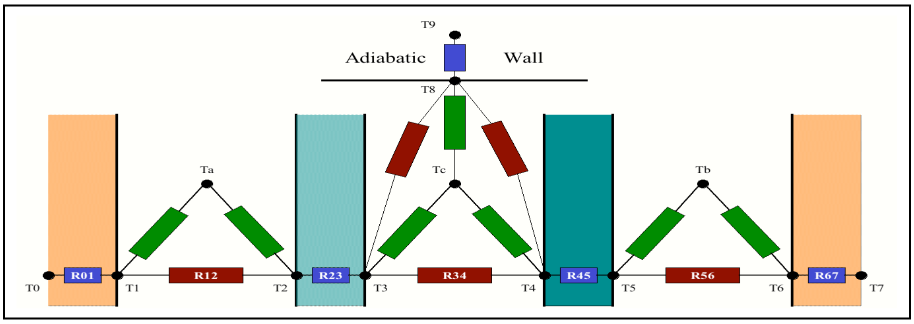

Figure 2: Original delta network for the three-zone simulation

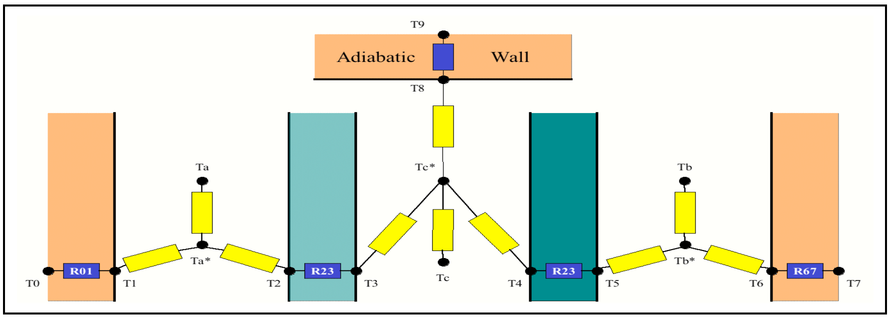

Figure 3: 3-zone problem as formulated in the star network of Seem

Fig. 1 shows the results of TRNSYS are in the range of the tested softwares.

Type 16 and Type 109 (Solar Radiation processor)

Type 16 is one of the oldest components of TRNSYS. This is due to the fact that the original application of TRNSYS was the simulation of solar systems. Therefore, a relatively detailed calculation of the solar radiation distribution of walls, facades, solar collectors,… is required. This is the task performed by Type 16: distribution of solar radiation in direct, diffuse and reflected components; spatial distribution of the diffuse radiation. Different methods are available in Type 16 to perform both tasks:

Distribution into solar radiation components: Type 16 has five methods to obtain beam and diffuse radiation on a horizontal surface from total radiation on a horizontal surface. Modes 1 and 2 are based upon the relationships developed by Reindl (Mode 1 is a reduced form of the full correlation given in Mode 2). In Mode 3, beam and diffuse radiation on a horizontal surface are input directly while in mode 4, total horizontal and direct normal radiation are inputs and Mode 5 has inputs of total and diffuse radiation on a horizontal surface.

Spatial distribution of diffuse radiation: Type 16 provides four modes for estimating the total radiation on a tilted surface. Each model requires knowledge of total and diffuse (or beam) radiaition on a horizontal surface as well as the sun's position. The models differ in the estimation of diffuse radiation on a tilted surface (isotropic model, Hay and Davies model, Reindl model, Perez model).

The performance of this model could be tested thanks a preliminary exercise proposed by IEA 34/43 subtasks C: an experiment was conducted on the EMPA outdoor test facility located in Duebendorf, Switzerland for a period of 3 weeks (between October 2 and October 26, 2004). The purpose of the exercise was to take two of three radiation measurements (beam, diffuse, global) along with the measured ground reflectance and predict the the total irradiance on a vertical (south-facing, 29°W) surface. A high-level measurement station was used which delivered high quality measurements.

What comes out of these results is that the different options of the solar processor (regarding distribution into solar radiation components) are relatively equivalent: a good fit between measurements and calculations is obtained (fig. 4).

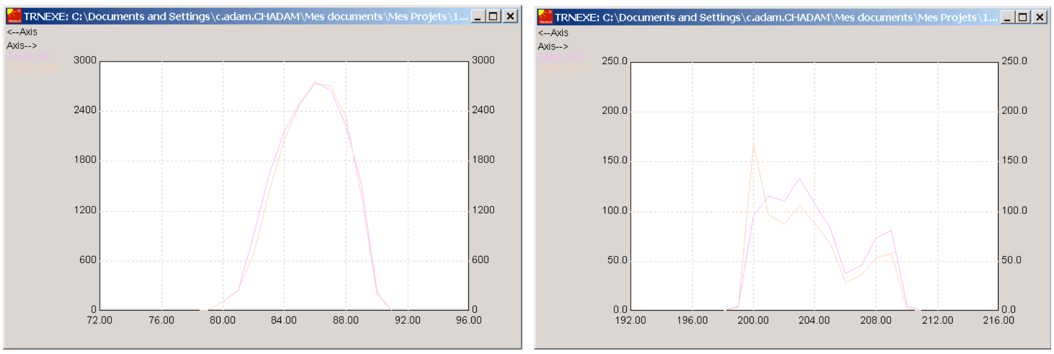

Figure 4: measured and calculated radiations on the vertical surface (Mode 1)

(Left: clear day; right: cloudy day)

A greater difference occurs between the different tilted surface radiation modes (fig. 5). Best agreement in this situation occurs with tilted surface radiation mode 1 (isotropic model).

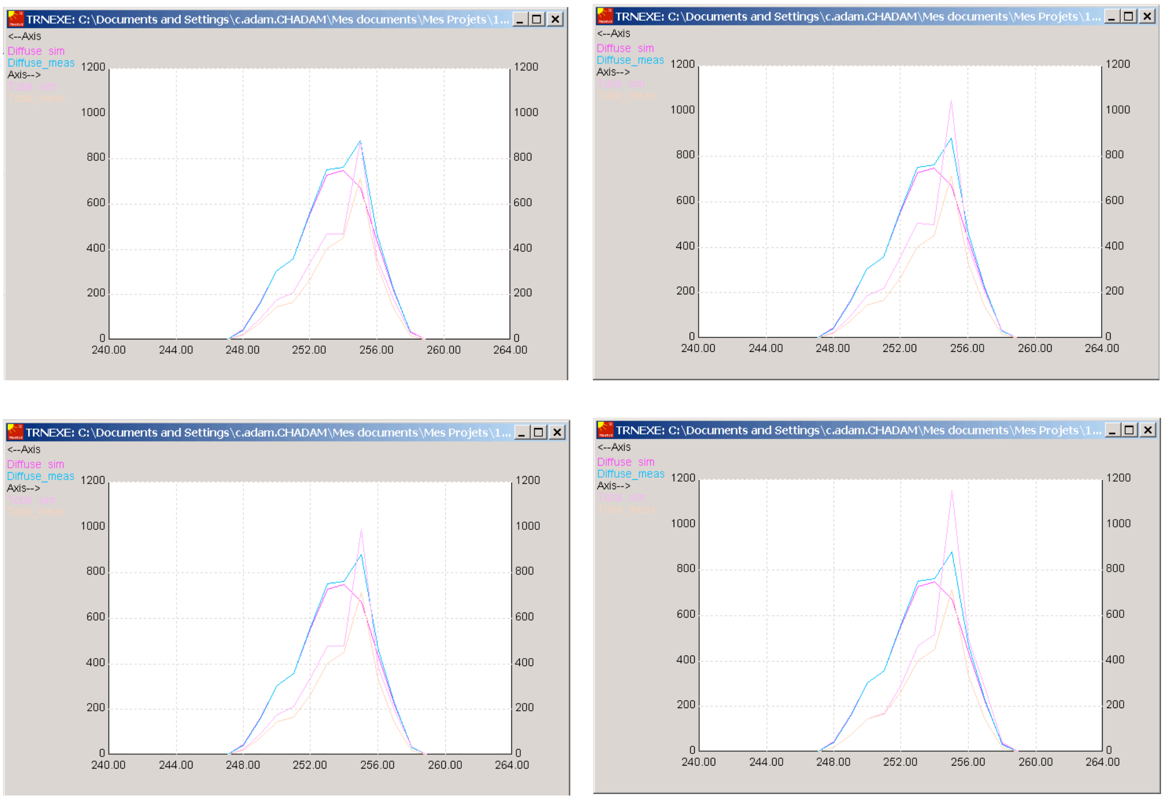

Figure 5: comparison between measured and calculated total radiation on vertical façade for 4 tilted surface radiation modes (upper left: isotropic; upper right: Hay and Davies; lower left: Reindl; lower right: Perez)

CONCLUSIONS

This paper has presented some of the results obtained when submitting TRNSYS Types 16 and 56 to the validation exercises as proposed by IEA Annex 43/Task 34 project. Analytical and comparative tests demonstrate the generally good behavior of TRNSYS Type 56 for a number of basic situations. Type 16 was on the other hand compared to experimental results obtained on the EMPA test cell and this comparison was also generally convincing.

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