

IMPROVEMENTS ON THE CAPABILITIES OF TRNSYS 15

T. Welfonder¹, M. Hiller¹, S. Holst¹, A. Knirsch¹

¹TRANSSOLAR Energietechnik GmbH, Stuttgart, Germany

tel.: +49 711 / 67976 - 0, fax: +49 711 / 67976-11

welfonder@transsolar.com, <http://www.transsolar.com>

ABSTRACT

This paper is about new features which were added to TRNSYS15 (Beckman, 2000) to improve its capabilities.

For system simulations with TRNSYS15 now 6 new component libraries are available. Those Libraries include more than 160 new TYPES like solar, geothermal and HVAC components

Also building simulations have been improved significantly. Thermally activated elements for heating and cooling are now integrated in the building model. Due to this simulations are now 5 times faster as with old finite element approach and setting up the system is now a matter of minutes instead of hours.

Improvements on the solar radiation distribution within a zone and the possibility to have internal windows make it very easy to simulate double facades and air flow windows. For the detailed window model a new library with special windows based on manufacturing data provided by Pilkington, Saint Gobain, Interpane and Luxguard are now available.

In order to speed up the performance of single zone building simulations significantly, the new interface TRNSYSlite for TRNSYS 15 was developed. Due to a variant manager and predefined control strategies it is possible to simulate several variants in less than half an hour. TRNSYSlite is a very useful tool for both experts and beginners.

INTRODUCTION

In the planning process and evaluation of innovative energy concepts simulation of buildings and systems gets more and more important. With the internationally well known software program TRNSYS 15 those simulations can be accomplished with a very high complexity.

NEW: TESS-LIBRARIES

For system simulations with TRNSYS15 Thermal Energy System Specialists (TESS) of Madison, Wisconsin have developed 6 new component

libraries. The components have been extensively tested. Each of these libraries comes in the IISiBat front-end format for TRNSYS 15 (documentation, on-line help, icon, etc.). The source code is provided for all of these models so that they can be modified if the user wishes to make changes to the model. For each library there is at least one example project that demonstrates the typical uses of the components found in that library. An example project is shown in Figure 1.

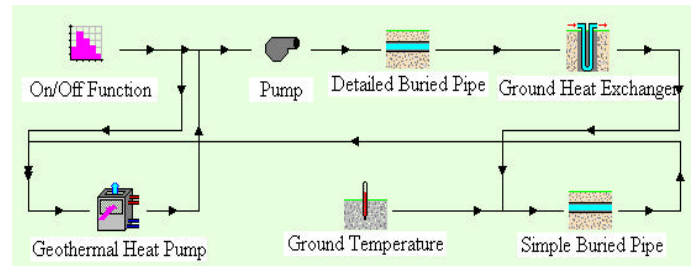


Figure 1 Geothermal Heat Pump

The TESS-Libraries include more than 160 new TYPES like solar, geothermal and HVAC components:

Solar Collectors Component Library:

- Flat Plate Collector with Variable Speed Pump Option and Mass Effects
- Evacuated Tube Collector with Variable Speed Pump Option
- Linear Parabolic Concentrator
- Integral Collector Storage with Immersed Heat Exchanger

Storage Tank Component Library:

- Aquastat Models (Heating and Cooling)
- Vertical Cylindrical Tank with Diverse Heat Exchangers
- Horizontal Cylindrical Tank with diverse Heat Exchangers
- Spherical Tank with Diverse Heat Exchangers

HVAC Component Library

- Residential Cooling Coil
- Heating Coil
- Heating and Ventilating Unit

- Diverse Heat Pumps
- Air and Water-Cooled Chillers
- Diverse Single and Double-Effect, Absorption Chillers
- Diverse Heat Exchangers
- Hydraulics: 100-Port Flow Mixer/Diverter, Pumps

Geothermal Heat Pump Component Library

- Buried Horizontal Pipes (Simple and Detailed)
- Ground Temperature Model
- U-Tube Vertical Ground Heat Exchangers
- Tube-in-Tube Vertical Ground Heat Exchangers
- Water Source Heat Pump

Other libraries are:

- New Utility Component Library
- Application Component Library

NEW: THERMO-ACTIVE BUILDING COMPONENTS

Thermo-active building components (slabs or walls of a building) are used to condition buildings by integrating a fluid system into massive parts of the building itself. Examples are radiant floor heating or cooling systems, radiant ceilings or wall heating or cooling systems.

Due to the fluid pipes a multi-dimensional heat transfer problem has to be solved for calculating thermo-active construction elements. Usually, a Finite Element Method (FEM) or Finite Difference Method (FD) is applied for such problems e.g. TRNSYS component TYPE 160 (Fort, 1987). Therefore, the building component to be examined needs to be transformed into small three-dimensional grid cells. In order to achieve a sufficiently high level of precision, the grid must be sufficiently dense. In general, this leads to complex calculations and long calculation time. In addition, a certain level of experience is required for creating the geometric input and an effective grid design.

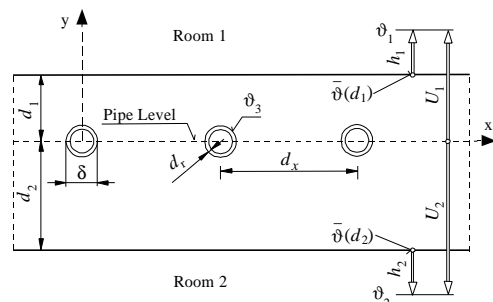


Figure 2: Typical structure of a thermo-active construction element

For this reason, a more powerful alternative method for modeling thermo-active construction element

systems was developed by EMPA (Koschenz, 2000) and integrated in the multi-zone building model TYPE 56 of TRNSYS 15. The integrated model is based on solving the stationary differential equation for heat conduction.

The heat conduction through the element is reduced to a one dimensional form by applying resistance models. Thereby, the existing transfer function method of the building model TYPE 56 for walls can be used for solving the one dimensional heat conduction problem. The developed theory can be applied for dynamic simulation by a smart approximation. Due to the large thermal mass of thermo-active components a dynamic (time-dependent) simulation of its behaviour is important.

Figure 3: Input data for the new model

The model is defined easily within the building description as a “wall” as a so-called active layer. The active layer requires only very simple data to define the geometry (pipe spacing, pipe diameter, pipe wall thickness) and the property for the pipe and the fluid (pipe wall conductivity, specific heat coefficient of fluid). Due to this setting up a system is a matter of minutes instead of hours for to a FEM approach (see figure 3).

A validation of this new model by comparison to detailed FEM calculations and measured data is provided by EMPA (Koschenz 2002)

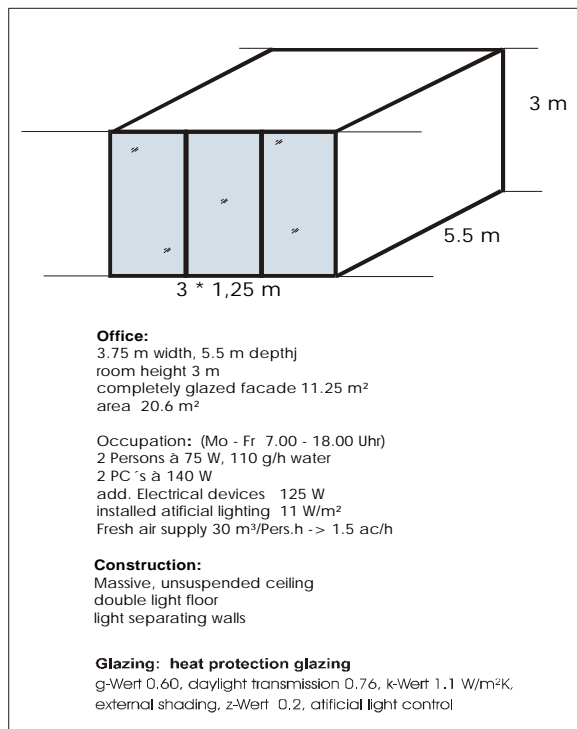


Figure 4: Boundary conditions of the simulation

In the following, a comparison of both models, the new integrated model and the finite difference model TYPE 160, has been performed for a continuously operating concrete core cooling system. The boundary conditions are shown in Figure 4.

The simulation is performed for 8 hot summer days according to VDI 2078 (VDI, 1996). For TYPE 160, the ceiling with the concrete core cooling is modelled by 500 temperature nodes. The ambient temperature, the air temperature, ceiling temperature and supply and return temperature are shown for the last 4 days in figure 5.

The resulting temperatures of both model indicate a good agreement. The simulation time of the integrated model of TYPE 56 is only 1/5 compared to the simulation time of the finite difference model TYPE 160. Therefore, TRNSYS 15 includes now a building model offering an easy-to-use and efficient way of modeling thermo-active building components.

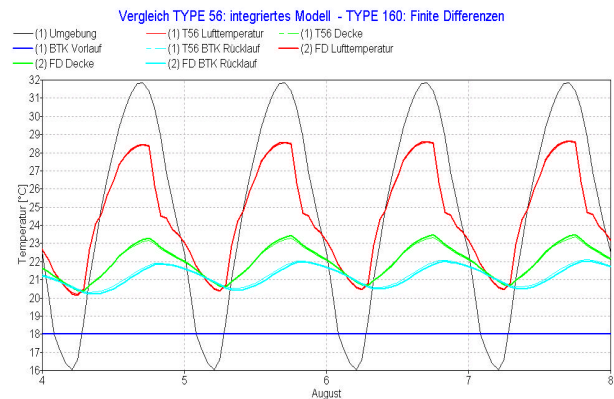


Figure 5: Resulting temperatures of comparison

IMPROVED: SIMULATION OF SOLAR BUFFER ZONES

For the simulation of solar buffer zones the modelling of solar short wave radiation is important. Therefore, significant improvements have been integrated in TRNSYS 15.

a) Incoming solar radiation (external windows)

Since version 14.2, a standard library of typical window and glazing systems is included.

W4 - Lib						
ID	Description	Design	U-Value	G-Value	T-sol	
12008	Pilkington, OPTITHERM S Besch #2#5	4/16/4/16/4	0.7	0.45	0.358	
12009	Pilkington, INFRASTOP Brilliant_6633	6/16/6	1	0.33	0.275	
12010	Pilkington, INFRASTOP Brilliant_5025	6/16/6	1	0.26	0.202	
12011	Pilkington, INFRASTOP Titan_6538	6/16/6	1.1	0.39	0.322	
12012	Pilkington, INFRASTOP Neutral_5137	6/16/6	1.3	0.37	0.296	
12013	Pilkington, INFRASTOP Silber_5030	6/16/6	1.1	0.31	0.252	
12014	Pilk, INFRASTOP Brilliant6633+OPTITHERM.S.#5	6/12/6/12/4	0.7	0.3	0.24	
12015	Pilk, INFRASTOP Brilliant5025+OPTITHERM.S.#5	6/12/6/12/4	0.7	0.22	0.177	
13001	Saint_Gobain, CLIMAPLUS FUTUR, AR, 1.4	4/15/4	1.4	0.61	0.521	
13002	Saint_Gobain, CLIMAPLUS FUTUR, AR, 1.1	4/15/4	1.1	0.61	0.521	
13003	Saint_Gobain, CLIMAPLUS FUTUR, KR, 1.0	4/15/4	1	0.61	0.521	
13004	Saint_Gobain, CLIMATOP FUTUR, KR	4/8/4/8/4	0.6	0.4	0.33	
13005	Saint_Gobain, CLIMATOP FUTUR, AR	4/16/4/16/4	0.7	0.4	0.33	
13006	Saint_Gobain, CLIMATOP SOLAR, KR	4/10/4/10/4	0.7	0.59	0.456	
13007	Saint_Gobain, CLIMATOP SOLAR, AR	4/10/4/10/4	0.7	0.58	0.456	
13008	Saint_Gobain, PLANISOL Neutral_6636	6/16/6	1.2	0.39	0.325	
13009	Saint_Gobain, PLANISOL Bleu_5339	6/16/6	1.3	0.39	0.322	
13010	Saint_Gobain, PLANISOL Neutral_6242	6/16/6	1.2	0.42	0.355	
13011	Saint_Gobain, PLANISOL Neutral_5036	6/16/6	1.4	0.37	0.298	
13012	Saint_Gobain, PLANISOL Silber_4427	6/16/6	1.1	0.29	0.239	
13013	Saint_Gobain, PLANISOL Gruen_4024	6/16/6	1.4	0.27	0.193	

Window ID: 1001
Description: Einfachglas, Gr.0

OK Cancel

Figure 6: Window library based on manufacturing data

A new library with special windows based on manufacturing data provided by Pilkington, Saint Gobain, Interpane and Luxguard are now available. This library contains detailed data like angular dependent transmission, reflection and absorption of single window panes based on WINDOW 4.1. (see Figure 6). This standard library may be extended by the user.

In addition, external and internal shading devices can be defined. In TRNSYS 15, the modelling of internal devices is detailed including multiple reflection between the window pane and the shading device.

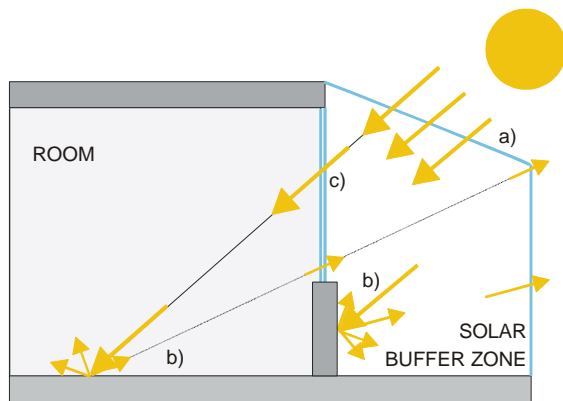


Figure 7: Modeling of solar shortwave radiation

b) Solar distribution with a room

The new distribution model enables a separate treatment of beam and diffuse radiation within a room. The diffuse radiation is distributed by area absorptance weighted ratios to all surfaces of a room. For beam radiation distribution factors are introduced. The distribution factor of a surface represents the percentage of incoming beam radiation that strikes this surface. The movement of the sunlit parts within a room, from an east oriented wall in the morning, over the floor at noon to the west oriented wall in the evening hours can be modeled by time-dependent distribution factors.

c) Forwarding solar radiation (internal windows)

In general, solar buffer zones are placed in front of the “real” rooms whereas the separating wall is mainly transparent. Therefore, a large amount of the incoming solar radiation is forwarded from the buffer zone to the room behind it. In TRNSYS 15, the user simply defines an adjacent window between the buffer zone and the room. The same detailed window model is applied as for external windows taking into account the angular dependencies. In addition, shading devices can be defined.

The introduction of internal windows together with explicit distribution factors for beam radiation reduces the effort of the simulation of solar buffer zones drastically. Thereby, the accuracy is increased and the error-proneness is reduced.

INTEGRATED: COMFORT EVALUATION

For consulting work the evaluation of thermal comfort in buildings is a common task. Temperatures only are insufficient as an indicator of thermal comfort. The degree of activity, the clothing and the possible heat exchange by radiation and evaporation influences the judgement. In addition, thermal comfort depends on corporeality, body mass, age and sex. Therefore, a certain situation is always judged different from various persons: an ideal climate with

100 % satisfied persons does not exist. (Lechner 1997)

Due to these facts a comfort evaluation according to EN ISO 7730 (EN ISO 1995) is integrated in the multi-zone building model TYPE 56 of TRNSYS 15. The method presented in EN ISO 7730 is based on a statistical description proposed by P.O.Fanger:

PMV (Predicted Mean Vote)

PMV represents the comfort of the majority of test persons in an environment. A PMV equals 0 means that most people feel comfortable with the boundary conditions, but some are still dissatisfied. Therefore, the percentage of dissatisfied is never smaller than 5 %.

PPD (Predicted Percentage of Dissatisfied)

The evaluation of “warm” or “slightly cold” given by the PMV value is transformed into a percentage of dissatisfied persons. Thereby, a quantitative comparison of various situations and measures can be performed.

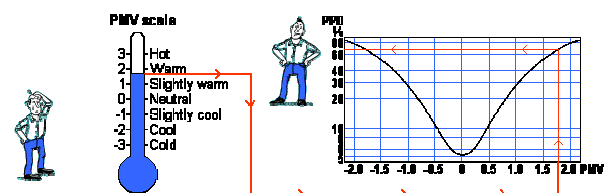


Figure 8: Comfort evaluation with PMV and PPD

NEW INTERFACE: TRNSYSLITE

What is TRNSYSLite for?

With TRNSYS 15 dynamic building and system simulations can be accomplished with very high complexity. However due to the modular structure and the high flexibility of TRNSYS 15 simple building simulations with only one zone, like e.g. in the competition consultation or in the concept design phase of buildings, were so far relatively complex.

In order to speed up the performance of such simple building simulations significantly, the new TRNSYSLite for TRNSYS 15 was developed. Due to a variant manager and predefined control strategies it is possible to simulate several variants in less than half an hour. That makes TRNSYSLite a very useful tool for both experts and beginners. The main characteristics of TRNSYSLite are:

- All data needed for the simulation (inclusive control strategies) are defined with only one single interface.

- Simulation of a single thermal zone with as many walls and windows-as desired.
- Consideration of a thermal activated constructions like e.g. slab cooling and heating
- Fast data input due to a construction catalogue with most common walls and glazings
- Variant administration, as well as simple variant production (copy paste)
- Clear input documentation
- Automatic creation of output files and diagrams for temperatures and heat flows
- Meteorological data library according to the German directive VDI 2078-
- yearly simulation can be done with own meteorological data
- resuming more complex simulations with TRNSYS 15 are easily possible.

Input of a building simulation with TRNSYSlite

With TRNSYSlite a user friendly input interface is available, which gives assistance by appropriate references, default values and value ranges. Depending upon type of use of the object (living or office building) default value schedules for the internal heat loads are suggested automatically. Those schedules of course can be changed if the user has more exact information about heat loads. For the building management data can be defined for heating, ventilation, cooling and shading (see figure 9). The variable sun protection device can be controlled by the ambient temperature or the radiation on the facade.



Figure 9 - Main input mask of TRNSYSlite

A integrated building construction catalog of approximately sixty selected wall constructions makes it easy to define a new building. The complex input of a wall with different layers is reduced to the selection of a suitable type of construction and the input of the desired insulation thickness. The construction catalog is documented in detail in the

manual. Beside normal constructions also a so-called Thermal Active Building element (short TAB (Koschenz, 2000) can be selected in TRNSYSlite (see figure 10 a +b).

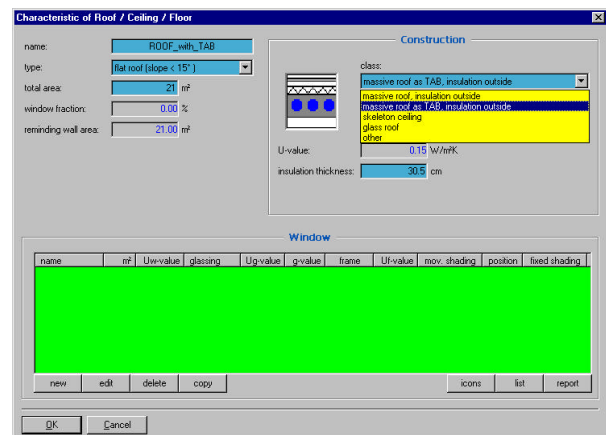


Figure 10a - Input of an thermal active building element in TRNSYSlite

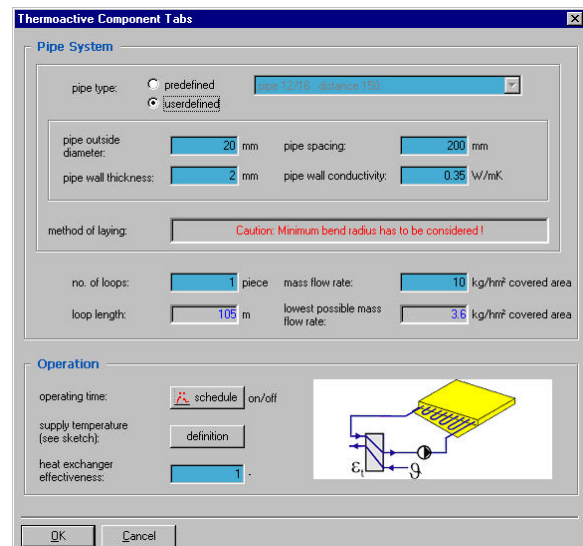


Figure 10b - Input of an thermal active building element in TRNSYSlite

For calculating the behaviour of a building during a hot summer period, simulations according to the VDI 2078 can be done. Other simulations can be accomplished with any meteorological data. Therefore a special header has to be added to the meteorological data file. A description of the data format of the header is given in the manual.

Variants with TRNSYSlite

Building simulation mostly is used to optimise thermal comfort and energy demand of a building. Therefore variants have to be computed, whose pro and cons in all aspects must be taken into account. In TRNSYSlite a variant administration is contained, which makes it very easy to examine several variants within a project. Variant can be made very fast and simply by copying existing variants. For all entered

data a clear printable input documentation is available.

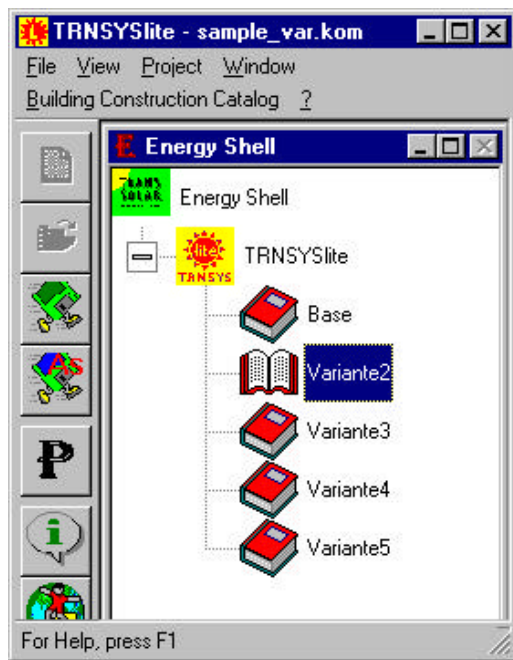


Figure 11 - Variant administration in TRNSYSlite

Results in TRNSYSlite

During the simulation all outputs can be looked at in an online window. Additionally the results are printed into an ASCII-file.

An additional graphic program called TRNGRAPH is included in the TRNSYSlite package. This program is very useful for visualisation of the results and for the comparison of variants.

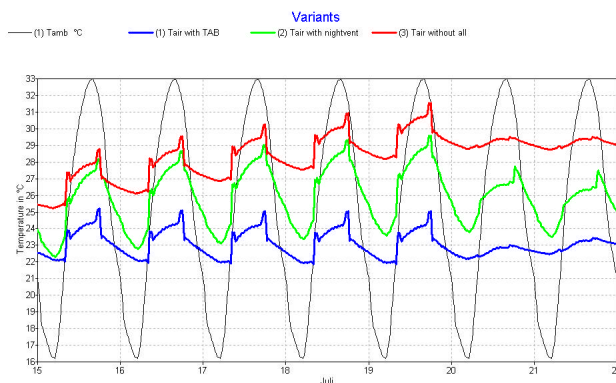


Figure 12 - Comparison of variants with TRNGRAF

The following results are automatically created:

- Outside temperature
- air temperature of the room
- Operative room temperature
- Inlet temperature of TAB
- Return temperature of TAB
- Core temperature of TAB
- Surface temperature of TAB
- Losses due to ventilation
- Heating energy demand
- Convective cooling power (latent/sensible)
- Energy demand TAB system
- Internal convective gains
- Internal radiative gains
- Transmitted solar radiation by all windows

Link between TRNSYSlite and TRNSYS 15

TRNSYSlite generates the project files Bui and DCK needed for TRNSYS simulations. Therefore it is easily possible to make a simple simulation with TRNSYSlite and then continue with TRNSYS as things get more complex.

CONCLUSIONS

Responding to a growing commercial application new developments of both user-friendly interfaces and mathematical models have been implemented into TRNSYS 15.

On the system side a large number of new additional components like solar, geothermal and HVAC components are now available for TRNSYS users with the TESS-Libraries

For the building simulation, the main novelties concern the simulation of thermo-activated building components and solar buffer zones. These new models provide not only a higher accuracy but allow a simple user-friendly input and therewith reduce the error-prone significantly.

Also, interfaces like TRNSYSlite for TRNSYS add to the reduction of input errors.

Due to these new features TRNSYS is an even more powerful tool for the thermal simulation of buildings and energy systems that satisfies new demands of innovative and forward-looking energy concepts.

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