

TRNSYS 18: The Continued Evolution of the Software

Timothy P McDowell¹, David E Bradley¹, Marion Hiller², Jochen Lam², Jakob Merk², Werner Keilholz³

¹Thermal Energy System Specialists, LLC, Madison, WI, USA

²Transsolar Energietechnik GmbH, Stuttgart, Germany

³Centre Scientifique et Technique du Batiment, Sophia Antipolis, France

Introduction

Since its creation in the 1970s, the TRNSYS software package has undergone constant changes, improvements and additions. With the release of version 18 in early 2017 this process has continued. All aspects of the software package were reviewed and deficiencies determined. The TRNSYS development team then went about addressing these deficiencies and user requests in creating the newest version of the software. Changes and improvements were made in all aspects of the software: kernel, standard library, building modelling, and user-experience.

Kernel

The basic concepts and underlying principles of TRNSYS have not changed from their original creation. However, many of the ancillary routines and methods have been updated as new techniques are developed. One of the biggest changes in the 40 years that TRNSYS has been around is the increase in computer power available to the user. With this release, a 64-bit version of TRNSYS will be available for the first time. The 32-bit version will also continue to be available.

Over the years, ASHRAE modifies the psychrometric routines in the Handbook of Fundamentals as more accurate measurements are available. A complete review of the psychrometric calculations was undertaken and algorithms were modified so that the TRNSYS psychrometric routines are up-to-date with the latest ASHRAE algorithms.

Calculating solar radiation in building performance software is difficult because the data in standard weather files is a total over an hour and the program needs to know solar radiation values at sub-hourly timesteps. The trick is to determine a shape to the solar radiation that preserves the hourly total and does not return negative values, since a negative value of incident solar radiation is physically impossible. The solar data available in standard weather files is typically the total horizontal, diffuse horizontal and direct normal radiation. This is redundant, as only two of these values are needed to calculate the remaining solar radiation values. In previous versions of TRNSYS, the total horizontal and the direct normal radiation data were used to determine the remaining radiation values. For sub-hourly values, the horizontal radiation was assumed to have the same shape as the extraterrestrial radiation over the same time period and the direct normal was assumed to follow the clear sky radiation. Applying

this shaping technique produced radiation values that did preserve the totals from the weather data files, but also produced a characteristic saw-tooth pattern in the radiation with step changes on the hours as shown in Figure 1. An issue with using total horizontal and direct normal is that once the horizontal beam is calculated from the shaped direct normal and the zenith angle it is possible to have a beam radiation equal to the total horizontal. Since the diffuse horizontal is determined by subtracting the beam horizontal from the total horizontal, if the total and the beam are equal then you would have time period with beam radiation on the horizontal but no diffuse on the horizontal. This is not a realistic solution.

Two changes have been made to the solar radiation routines in this release. The first is that now the diffuse horizontal and direct normal are used to calculate the remaining solar radiation values. This ensures that whenever there is positive diffuse horizontal in the data file there will be diffuse horizontal calculated by TRNSYS. The second is that a new method for determining the sub-hourly radiation has been added. This method eschews physical based shaping of the radiation for a mathematical model. In this method, the ending point for the hourly radiation is estimated from the starting point for that hour (the ending point for the previous hour or 0 at sun-up) and the radiation over the up-coming hour. The ending point is also forced to be zero at sundown. Knowing the starting and ending point for the hour and the total radiation over the timestep from the weather file, the value at the midpoint of the hour can be determined. The radiation is assumed to vary linearly from the start point to the midpoint and from the midpoint to the endpoint. This technique still preserves the hourly total from the weather files, avoids negative values and produces a smoother curve for the radiation values as shown in Figure 1.

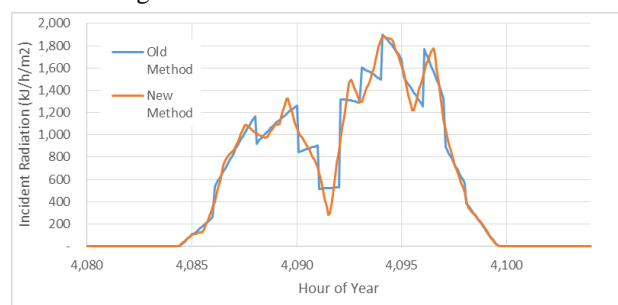


Figure 1: Total Horizontal Radiation for June 20 in Madison, WI for Two Solar Methods

To facilitate an improvement in the daylighting capabilities of TRNSYS, solar illuminance calculations have been added. The calculations are based on the work of Perez (Perez 1990).

TRNSYS has always included routines for calculating the thermophysical properties of fluids and refrigerants, but the list of available fluids was limited. The capability of calling routines from CoolProp (Bell 2016) has been added in this version. This gives the user access to the properties of 122 fluids and refrigerants.

To promote usability, TRNSYS has previously been linked to other programs, like Matlab and Excel, allowing users to create components in environments where they are more comfortable. The ability to link to Python scripts during a simulation has been added in the latest version. As with the other programs, users will be able to pass inputs to and receive outputs from the Python script at each iteration.

Standard Library

TRNSYS has always included a standard library of components. However, these components traditionally came from graduate student research projects and were not created with the beginning user in mind. The standard library has now been supplemented with a large number of basic component models that will allow for beginning users to easier learn how to use the software. A complete list of the new standard library components is shown in Table 1.

These simpler component models will also facilitate the use of TRNSYS earlier in the design process when less detailed information is known about the process being modelled. These basic models can then be replaced with detailed models as more information is known. For example, early in the design process the overall cooling load made be known but the cooling coil may not yet be selected. The simple cooling coil model that only requires the capacity of the coil can be used in this early stage and once the cooling coil has been designed, the simple cooling coil model can be replaced with the detailed cooling coil model.

Building Model

For TRNSYS 18 the code of the multi-zone building model (Type 56) has been revised and restructured for implementing new features. In addition the GUI TRNBuild has been improved, especially the defining of gains. New libraries for glazings, gains and schedules have been added. The main new features are presented in the following.

Integrated Light Control and Daylight Modelling

The capability to control artificial lighting by daylight availability is added to the building model. The illuminance on the sensor can be defined in three ways: using a daylight factor, using the integrated DAYSIM Method or passing calculated values from external TYPES (Figure 2).

Most of the weather data sets provide solar irradiance data. As for two of the three options the outdoor

illuminance is needed, a calculation routine of the outdoor illuminance is added to the TRNSYS Kernel and called by TYPE 56. The used algorithm is based on the Perez model (Perez et al, 1990).

The model requires solar radiation, zenith angle, empirical coefficients depending on the Sky Clearness ϵ , as well as the atmospheric precipitable water W and sky brightness Δ . While DAYSIM calculates W with a constant dewpoint, the availability of the outdoor dewpoint in TRNSYS allows the dynamic calculation of W .

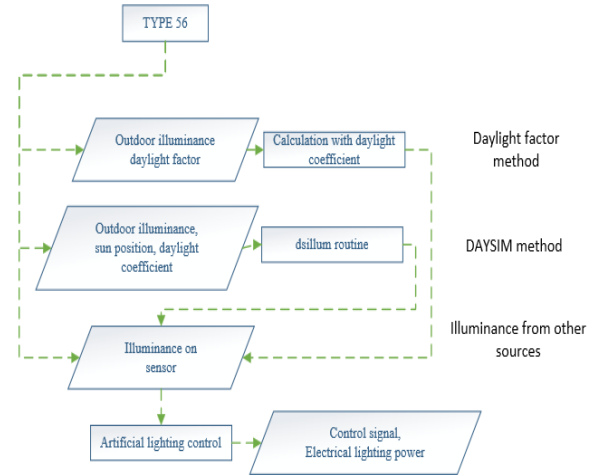


Figure 2: Schematic of artificial lighting control by daylight availability in TRNSYS

1. Input: Daylight factor

The determination of the illuminance by using a daylight factor D is a rough method, but the simplest option. The illuminance on the sensor $E_i(t)$ is calculated, based on the horizontal outdoor illuminance $E_a(t)$ according to equation (1).

$$E_i(t) = D \cdot E_a \quad (1)$$

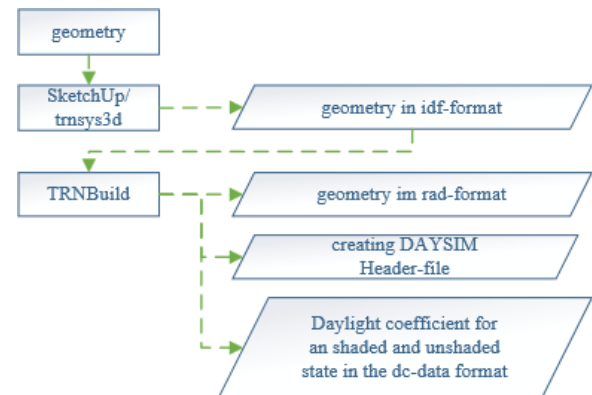


Figure 3: Preprocess for generating daylight coefficients

2. Integrated DAYSIM Method

DAYSIM routines are implemented to allow detailed illuminance $E_i(t)$ simulation in an 3D environment. Original as well as modified DAYSIM routines are called and delivered within the TRNSYS package.

Figure 3 shows the preprocess for generating daylight coefficients. The geometry can be created in SketchUp with the TRNSYS3d PlugIn and imported into a TRNSYS building description file (b18) by TRNBuild. Additionally the position of the sensors have to be defined in TRNBuild.

The integrated converter in the TRNBuild sub-program trnRAD generates radiance files based on the available 3D information.

Opaque walls are defined with the radiance material plastic and a reflectivity derived from the absorption coefficient defined in the wall assembly definition. Transparent surfaces are modeled with a user-defined material. For glazing, the radiance material 'glass' is used with a transmissivity derived from the visual transmittance. The transmittance τ is usually given in glazing specifications. It can be converted to the transmissivity T according to Radiance (Ward 2016) by equation (2).

$$T = (\sqrt{0.8402528435 + 0.072522239 \tau^2} - 0.91665306) / 0.0036261119 \tau \quad (2)$$

A decisive influence on the illuminance results is the modelling of the solar shading device. Modelling strategies were studied and shown in the validation section below. The shading effect can be modelled by a reduced transmissivity of the 'glass' material, another radiance material 'trans' and a combination of both.

Generating dc files is done by the DAYSIM sub program gen_dc, which is called by trnRAD. Longitude, latitude and ground reflections as well as radiance parameters have to be entered in the TRNBuild environment by the user for the automatic generation of the DAYSIM Header-Files (*.hea). The algorithm generates daylight coefficient files (*.dc) for an activated and deactivated shading device for each zone.

As the geometry in thermal simulation models is abstract and simplified, the user is free to generate dc files by any other method and model and integrate those files into the process.

In the simulation, a modified version of the DAYSIM routine dsillum is called by TYPE 56 to calculate the illuminance considering the daylight coefficient, sun position and the outdoor illuminance.

3. Passing the illuminance values

The third option is passing illuminance values by reading in values obtained by other programs or measurements or calculated by other TYPES e.g. DLT-type (De Michele, 2014).

Because of the introduction of the complex fenestration model based on BSDF data (Hiller, 2014) in TYPE 56 for thermal simulations, the possibility of using BSDF data in an integrated daylight simulation within TYPE 56 will be explored in future developments.

Artificial lighting control

Three modes of artificial lighting control are implemented in the TRNSYS building model (Figure 4).

1. A hysteresis control, where an upper threshold and a lower threshold are defined by the user. This control provides only control signals of 0 or 1.
2. A linear dimmer, where the artificial lighting contribution ideally compensates insufficient daylight availability to match the set illuminance. A minimum operation ratio has to be provided by the user, the value never drops below this ratio during operation time.
3. A combination of mode 1 and 2. This control allows turning off the artificial lighting during operation time.

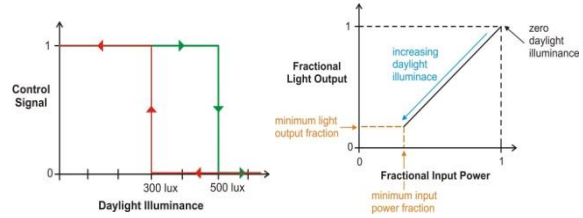


Figure 4: artificial lighting control, hysteresis control (left), dimming control (right)

The signal is used to control the lighting loads defined in the internal loads of the building model. With this implementation, the electrical energy demand and the effect on the thermal model is taken into account in every timestep according to the daylight availability.

Outputs

New outputs have been introduced with the implementation of the integrated daylight simulation: global, direct and diffuse outdoor illuminance, illuminance on sensor, signal of artificial lighting control, electrical lighting power and the daylighting metrics daylight autonomy (DA), continuous daylight autonomy (CDA) and useful daylight illuminance (UDI).

Validation

The implemented model was validated by comparing the simulation results with measured data from the ERS Daylighting Experiment 2 from SHC Task 34 / ECBCS Annex 43 Project C (Loutzenhiser et al., 2007 and (Loutzenhiser et al, 2008). Within this project, measurements were done with different shading devices, orientations, etc. In this paper the comparison between simulated and measured data of a west facing room is shown.

Boundary Conditions

The experiment was done at the Energy Resource Station (ERS), which is located in Des Moines Area Community College Campus in Ankeny, Iowa, USA. The geographical coordinates are 41.71° N and 93.61° W. The testing facilities are orientated exactly to East, South and West. The window to wall ratio of the test boxes are 40 %. The windows are 1.7 m high and located 0.9 m above ground. The light sensor is located in the center of the box. In the experiment a textile shading screen 'Nysan Superweave 1000' was mounted. The specification of the

white textile is a visual transmissivity of 30.5%, a visual reflectivity of 67.3% and an opening of 10%. As inputs to the simulation, the following parameters were used from the measurement:

- Global irradiation on the horizontal
- Normal direct irradiation
- Dry bulb temperature
- Relative humidity

All further details of the testing setup are documented in the test report (Loutzenhiser et al., 2007)

Results

Experiment 2, Outdoor illuminance

The calculation of the outdoor illuminance with the measured solar radiation is done according to Perez and compared with the measured illuminance (Figure 5). The calculated values match well with the measured data. On June 6th and June 7th, the illuminance is slightly overestimated.

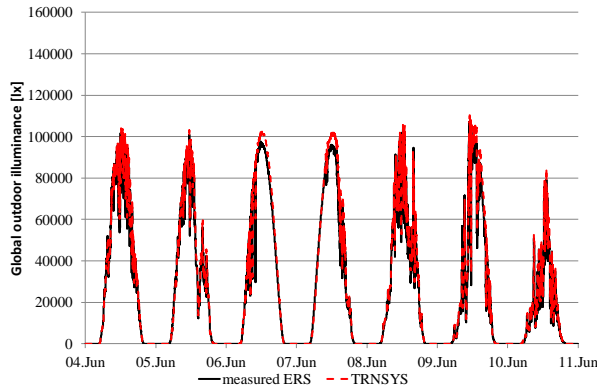


Figure 5: Comparison of measured and simulated global outdoor illuminance

Experiment 2, Test Room West A

As mentioned in the implementation section, the modelling of the solar shading devices is investigated. The radiance material ‘glass’ is used and the transmittance of the glazing is reduced by the transmittance of the shading screen in the variant Gl 0.22 (blue, dotted). In variant Tr.0.22 the ‘glass’ material is replaced by the material ‘trans’ which models diffuse scattered materials, the ratio of direct transmitted light can be defined and is set to 0.1 (green dash-dotted). In the last variant, the setup is modelled as it is: the original transmittance of the glass is used; additional radiance geometry is added with a distance of 0.01 m and assigned with the material “trans” and a transmittance of 0.3 (red dashed).

Figure 6 and Figure 7 show illuminance and electrical lighting power in graphical comparison while Table 2 gives the statistical deviation between measured data from ERS and simulated results by TRNSYS according to the DAYSIM methodology.

The results show a good match during the morning hours, when mainly diffuse light is present on the west façade. In the afternoon, the sensor is hit by direct light. This leads to high deviations in the variant Gl 0.22, as it does not

consider diffuse scattering from the shading screen. However, the large deviation affects the electrical lighting power just slightly in most of the times. The largest differences between measured and simulated data occur during the peaks, where illuminance is sufficient and no additional artificial lighting is necessary. But on days with low daylight availability (e.g. June 10th), the deviation is noticeable in the illuminance as well as in the electrical lighting power results. The results of the other modelling methods of the shading device Tr 0.22 und Gl. 0.74 Tr 0.33 are almost identical and indicate good matching between measured and simulated data.

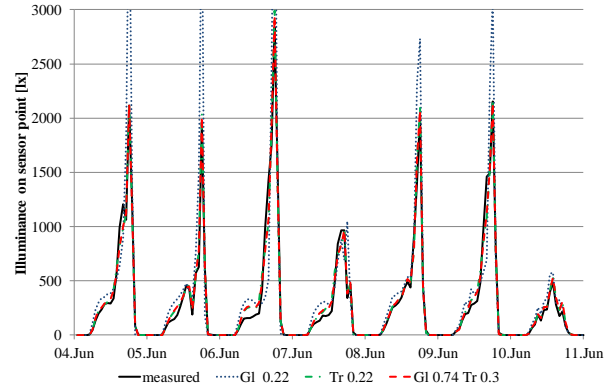


Figure 6: Illuminance on sensor measured and simulated

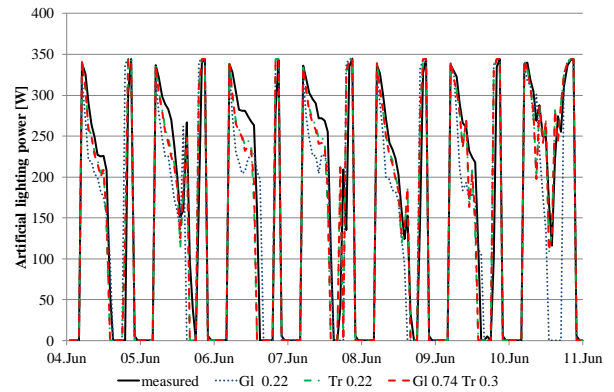


Figure 7: Electrical lighting power measured and simulated

Table 2: Statistical Analysis of the deviation between simulated and measured results

	Gl 0.22		Tr 0.22		Gl.074 Tr.0.3	
	E_t [lx]	P_t [W]	E_t [lx]	P_t [W]	E_t [lx]	P_t [W]
\bar{D}	-139.4	33.8	-14.4	11.1	-15.5	11.4
$ \bar{D} $	244.3	55.9	58.7	34.6	56.3	34.8
$ \bar{D} _{max}$	2205.0	274.0	390.8	231.2	355.0	231.2
$ \bar{D} _{95}$	917.6	207.1	179.1	137.7	193.6	136.1

Complex fenestration systems (CFS)

A new glazing model was developed by Schöttl in 2013 to enable a reliable and detailed CFS simulation with relatively little input by the user. (Schöttl, 2013) This

model has been restructured and integrated into the multi-zone building model (Type 56) for TRNSYS 18.

The aim of the new model is to represent the bidirectional scattering of radiation which occurs in slat systems or honeycomb structures and the interaction with the other layers. Furthermore, the opening areas of individual layers influencing convection and long-wave radiation exchange is taken into account.

A key aspect when creating the model was flexibility to allow the user to portray any combination of shading/glazing in detail, while also to easily generate the inputs from the manufacturer information.

The optical modeling approach is based on so-called “Bidirectional Scattering Distribution Function” (BSDF). This term was used by Heckbert in 1991 to express the scattering distribution of a light ray on a complex surface as shown in Figure 8 (Veach, 1997).

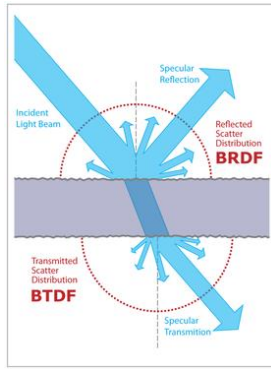


Figure 8: Scattering distribution on a complex surface (Wikipedia, 2014)

This function describes the ratio of incident light, reflection and transmission for exactly two 3D angle pairs that define the direction of the incident and reflected or transmitted radiation. The transmission, for example, can be written in polar coordinates:

$$\tau = \frac{I_{out}(\theta_{out}, \gamma_{out})}{I_{in}(\theta_{in}, \gamma_{in})} = f(\theta_{in}, \gamma_{in}, \theta_{out}, \gamma_{out}) \quad (3)$$

For modeling the short-wave radiation of the whole glazing system including shading layers the window hemisphere was divided into 145 patches according to Klems (Mitchell et al, 2006). This results in two 145 x 145 matrixes each (front and back) for transmission and reflection. For the absorption, the matrix degenerates into one row vector per layer. The vector only depends on the incident angle pair. When multiplying an irradiation vector \vec{I}_{in} with the Klems-Matrix K the distribution vector \vec{I}_{out} can be obtained:

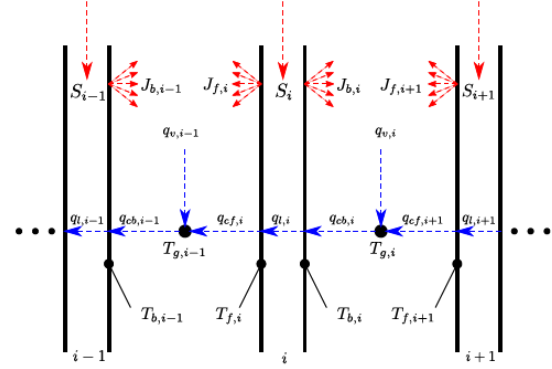
$$\vec{I}_{out} = K \vec{I}_{in} \quad (4)$$

The thermal model representing the glazing system and shading elements is essentially based on a comparatively complex model of the ISO 15099, 2003.

The model is based on the heat flow balances of each layer. The layers are merely differentiated by air-

impermeable (e.g. glazing) and permeable (e.g. shading elements) layers. Adjacent gaps or a gap and the external/internal air are aerodynamically connected due to the opening areas of shading elements

Figure 9 shows the heat flow for each layer i of the glazing system. If the direction of the heat flow is a priori unknown, it is depicted from right to left.



Red short and long wave radiation

Blue convection and conduction

Figure 9: Thermal exchanges in the glazing system (Schöttl, 2013)

The used variables are described as:

The **radiation flow** S_i is caused by the solar radiation absorption of each particular layer. It is assumed that the radiation flow is absorbed evenly over the pane thickness t_i .

The **radiosities** $J_{f,i}$ and $J_{b,i}$ include the fraction emitted by the boundary surface as well as those transmitted and reflected.

By means of **heat conduction** a heat flow emerges and flows through the solid layer with the thickness t_i and thermal conductivity λ_i .

The **convective heat transfer** h_{cv} causes the flows $\dot{q}_{cf,i}$ and $\dot{q}_{cb,i}$. They flow from the solid layer to gas and vice versa.

When the gas gap is ventilated, a **heat flow** \dot{q}_{ven} , which influences the gas temperature, exists. The ventilation can be thermally or mechanically induced.

The new model is implemented in addition to the standard window model of Type 56. As in the existing window model in TRNSYS, the calculation of optical properties of the CFS occurs in the external program *Window 7* (LBNL, 2016). *Window 7* is developed by the Lawrence Berkeley National Laboratory (LBNL) and is available for no charge. This program not only includes a large product database, but also algorithms to calculate different shading systems like horizontal or vertical slat systems, perforated screens or woven layer, etc. Additionally, any shading system data can be imported as an xml-file.

For every glazing/shading configuration, the BSDF matrixes (transmission front/back, reflection front/back

and absorption per layer) must be generated beforehand for the whole system in the solar and visual band. The BSDF matrixes as well as the glazing construction of the different shading configurations are combined into one external file that is imported by Type 56 during the initializing step.

During the simulation, the configuration can be changed in every timestep, for example, depending on the irradiation. For the current position of the sun in a timestep, the optical system properties are determined by a bilinear interpolation of the Klems-matrix values.

The calculation of the thermal system of equations proceeds separately from the optical calculations. Given the comparatively small size and diagonal structure of the matrix, it can be solved by a direct LU factorization according to Crout. The solution process is performed iteratively, due to the temperature dependency of the heat transfer coefficients.

Validation results of a beta version of the implemented glazing model have been published previously (Hiller et al, 2014). The validation was carried out in two steps:

- Steady state comparison with the program *Window*. The glazing systems consists of a double uncoated glazing with different venetian blind position (external, in gap, internal) as well as the slat angle (0° , 30° , 60° , 90°) varied. Besides the important U-value and SHGC, the temperatures of each layer were compared. The validation cases were rerun with the TRNSYS 18 package. The absolute differences of all calculated systems were in the same range (u-value ≤ 0.004 , SHGC ≤ 0.001 , layer temperature $\leq 0.08^\circ\text{C}$). These deviations are negligible small.

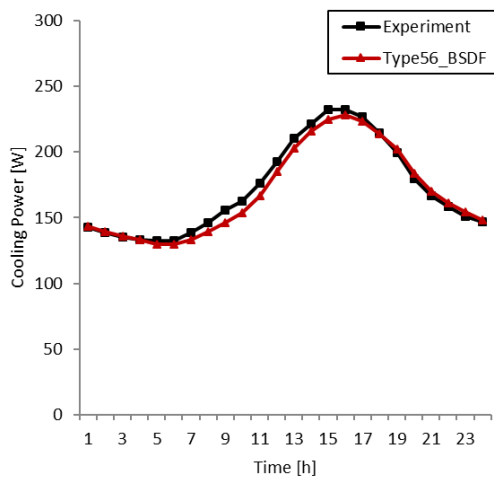


Figure 10: Comparison measurements and simulation, slat angle= 0° (average of the same hour of every day)

- Simulating a non-steady state of a test cell and comparing the results with measurement results. The measured data of Exercise 6 in the SHC Task 34 / ECBCS Annex 43 Project C (Loutzenhiser et al. 2007) was used. The data sets are available online (EMPA, 2014) free of charge. Additionally, there is

more detailed documentation available (Loutzenhiser et al, 2008). In Exercise 6 the test cell is equipped with glazing including an external slat blind. A few days of settling time were followed by a validation period of 20 days. After half the time of the experiment, the slat angle was changed from 0° to 45° . The validation cases were rerun with the TRNSYS 18 package. Figure 10 and Figure 11 present the simulation and measurement results for slat angles of 0° . The absolute differences were in the same range. The results agree well with the measurement results.

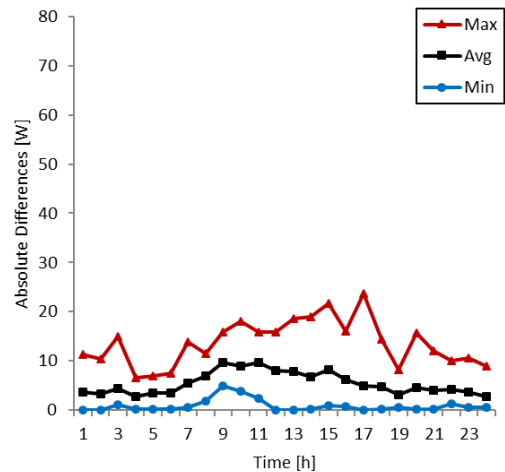


Figure 11: Comparison measurements and simulation differences, slat angle = 0

Improved comfort calculations

The available comfort index Predicted Mean Vote (PMV) described by ISO 7730 (ISO 7730, 2005) is well suited for mid-latitude climate regions. For the evaluation of comfort concepts with tempered air and elevated air speed in warmer zones such as tropical climates, adaptive comfort models are required. In TRNSYS 18 the procedure for evaluating the cooling effect of elevated air speed using the Standard Effective Temperature (SET) described by ASHRAE Standard 55-2013, Appendix G is implemented to meet these requirements.

The SET can be calculated for a wide range of six environmental and personal parameters: air temperature (T_{air}), mean radiant temperature (MRT), relative humidity (RH), average elevated air speed (v), clothing factor (clo) and metabolic rate (met). To evaluate the cooling effect of elevated air speed first the SET is calculated for the parameters and the given air speed. In a second step, the air speed is replaced by still air (0.15 m/s) and adjusted averaged air and mean radiant temperatures are calculated to achieve the same SET as in the previous step (ANSI/ASHRAE, 2015). With the adjusted averaged temperatures, the air speed of still air and the remaining parameters the Predicted Mean Vote for elevated air speeds (PMVeas) is calculated.

A comparative study between the CBE Thermal Comfort Tool (Hoyt et. al 2013) and the TRNSYS calculation were conducted to verify the implementation.

To be useful for the evaluation and design of climate concepts the method is implemented to simulate an occupant-controlled fan. The user can specify up to 4 air speed levels and the code automatically selects the lowest airspeed level required to achieve a PMV_{eas} of ± 0.5 which is equivalent to a satisfaction of 90% of the occupants with the environmental conditions.

A comfort survey at the School of Arts (SOTA) in Singapore shows that the implemented design parameters *SET* and *PMV_{eas}* are useful for comfort evaluation in the tropics (Franke et al., 2014).

User-Experience

TypeStudio

The ability to add content to TRNSYS in the form of user-written components (or Types) has always been a feature of the software. However, doing so required the use of a third-party compiler. With the inclusion of the new TypeStudio, users will now have an integrated environment for writing and adding components into TRNSYS without the need to purchase a compiler. Combining an integrated compiler with further development of the access function meta language introduced with TRNSYS 17 means that users wishing to add new content can do so without having a great deal of familiarity with FORTRAN, the language in which Types have historically been written.

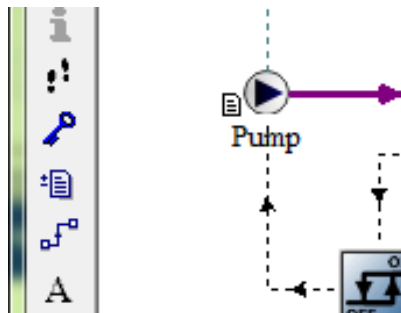


Figure 12: Activating reports for components

Automated output reports

One historic shortcoming of TRNSYS is a lack of automated output reports. The software is used in a wide variety of energy modelling applications from buildings to CHP plants to wastewater treatment digesters. Given the range of systems being simulated, it has been difficult to conceive of what an automatic output file might include. At the component level, however, it is more evident what a user might want to see summarized. With TRNSYS 18, a simple, yet efficient method to produce useful default reports has been introduced: every component defines a standard set of data potentially interesting to the user. For instance, when a solar collector (Type 1) is used in a project, the user might be interested in a summary of the component configuration (Collector Array Area, Number of Collectors in Series, etc.) as well as average values, extremes and integrals over the

simulated period (Total Energy Gain, Maximum Value of Outlet Temperature, etc.). The user can now include this data in a standard simulation report by simply selecting the corresponding model in the project and activating the 'report' icon for it as shown in Figure 12.

Parametric studies

Parametric studies are an important tool for users of simulation programs targeting optimization. A basic mechanism for creating parametric tables exists since early versions of the TRNSYS package. Using it, however, requires working with the text-based simulation input file (the deck) directly, using *CONSTANTS* to define the variables that are to be varied. The input file is modified using the *TRNEDIT* application, where parametric tables can be created and executed. Although fully operational, the process was somewhat cumbersome. In TRNSYS 18, parametric studies can be directly defined from within the graphical user interface, Simulation Studio: the user simply selects the desired parameters, equations or unconnected inputs to be varied and adds them to a table with the click of a button. Additional runs can be defined by simply adding columns to the table as shown in Figure 13. Parametric tables can be saved to and loaded from simple, comma separated text files (CSV). The user can decide how many CPUs the computer should use for the simulation runs; this allows either speeding up the computation or keeping the computer available and responsive for interactive use while the simulations are running.

More sophisticated tools for optimization are also available as add-ons to the standard package, allowing for a variety of optimization algorithms.

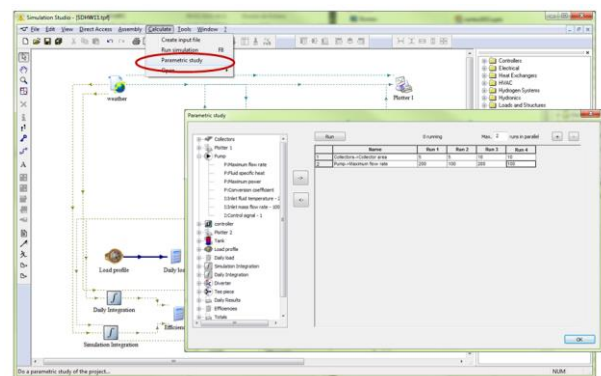


Figure 13: Parametric studies

Easier connection control

The connection window, which defines information flow among component models, has been improved: it now allows sorting variables by name, creating connections right-to-left as well as left-to-right and provides additional keyboard shortcuts.

Improved interoperability

In its on-going mission to open TRNSYS to third-party software packages and allow for interaction with an ever-increasing range of applications, the TRNSYS group has proposed an alternative to the proprietary TMF data format used to describe TRNSYS components in the

graphical interface. The new XMLTMF data format allows exporting and importing Proforma descriptions of TYPES in XML. This format can also be used in the component library, so that it is possible to directly display XML files describing TRNSYS models in the Simulation Studio's direct access tool. FORTRAN code generated from newly created components now use the FORTRAN 90 standard. More style information (waypoints, link colour and style, etc.) is now added to the deck file, so that re-importing deck files produces better-looking projects.

TRNLizard

TRNLizard was developed with the idea of approaching TRNSYS 18 from a different perspective, mainly to facilitate parametric studies of buildings including thermal and daylight simulation. A cluster of components, based in Rhinoceros and Grasshopper as the user interface, generates the system files needed to run a conventional TRNSYS simulation. Each component of the interface is programmed using python and is open-source. The whole package of components can be downloaded and used along with TRNSYS 18.

TRNLizard provides templates: this means that a building is given as starting point (including the Type56 definition and corresponding TRNSYS input file). It is designed in a user-friendly structure and workflow in order to easily set up the desired model by connecting only the required components. It also offers the possibility of post-processing and visualizing the results directly via Grasshopper.

The use of Rhinoceros and Grasshopper as an interface makes parametric studies very efficient and convenient: the thermal and daylight implications of different orientations, geometries and regimes can be evaluated by taking advantage of the dynamicity of Grasshopper and, at the same time, keeping TRNSYS 18 as the engine for thermal and daylight simulations.

Conclusion

With the release of version 18 of the TRNSYS software package, the development team has continued the process of extending and improving the software around the framework established by the original developers.

References

- ANSI/ASHRAE. 2013. Standard 55 Thermal Environmental Conditions for Human Occupancy, Atlanta, ASHRAE Inc.
- ANSI/ASHRAE. 2015. Standard 55 Thermal Environmental Conditions for Human Occupancy Addendum d, Atlanta, ASHRAE Inc.
- Bell, I. H. (2016). www.CoolProp.org.
- De Michele, G. 2014, Coupling Energy and Daylight Simulations for Complex Fenestration Systems, Trient,
- EMPA. 2014. Testing and validation of building energy simulation tools
- <<http://www.empa.ch/plugin/template/empa/956/32528/>>
- Franke, L., Kessling, W., Engelhardt, M 2013.: Evaluation of Comfort with Temperated Air and Elevated Air Speed in Tropical Climate, 30th International PLEA Conference, 16-18 December, CEPT University, Ahmedabad
- Hiller, M. Schöttl, P 2014.: Modellierung komplexer Verglasungssysteme in Trnsys, *BauSim*, 22. - 24. September, Aachen
- Hoyt, T., Schiavon, S., Piccioli, A., Moon, D., and Steinfeld, K., 2013, CBE Thermal Comfort Tool. Center for the Built Environment, University of California Berkeley, <http://cbe.berkeley.edu/comfortool/>
- International Organization for Standardization. 2005. ISO 7730 Ergonomics of the thermal environment- Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria
- International Organization for Standardization. 2003. ISO 15099 – Thermal performance of windows, doors and shading devices – Detailed calculations
- LBNL 2016. Software tool for analysing window thermal and optical performance, Window Version 7.4.8.0
<<http://windows.lbl.gov/software/window/window.html>>
- Loutzenhiser P., Manz H. 2007. Empirical Validations of Shading/Daylighting/Load Interactions in Building Energy Simulation Tools, SHC Task 34
- Loutzenhiser, P., Manz, H., Carl, S., Simmler, H. Maxwell, G. 2008. Empirical validations of solar gain models for a glazing unit with exterior and interior blind assemblies, *Energy and Buildings* 40, pp. 330-340.
- Mitchell, R., Kohler, C., Klems, J., Rubin, M., and Arasteh, D. 2006: WINDOW 6.1 / THERM 6.1 Research Version User Manual - For Analyzing Window, Thermal Performance. Lawrence Berkeley National Laboratory (LBNL),
- Perez, R., Ineichen, P., Seals, R., Michalsky, J., Stewart, 1990. Modeling daylight availability and irradiance components from direct and global irradiance, *Solar Energy*, vol. 44, no. 5, p. 271-289.
- Schöttl, P. 2013. Integration komplexer Verglasungssysteme mit Bidirectional Scattering Distribution Functions in TRNSYS, Diplomarbeit, Technische Universität München
- Veach, E. 1997. Robust Monte Carlo Methods for light transport simulation, PhD thesis, Stanford University
- Ward, G. 2016. Radiance. <http://www.radiance-online.org>
- Wikipedia, 2014
<http://en.wikipedia.org/wiki/Bidirectional_scattering_distribution_function>

Table 1: Standard Library Components

Library	Component
Controllers	Differential
	Iterative Feedback
	PID
	Microprocessor
	Thermostat
	Humidistat
	Dehumidistat
	Aquastat (heating and cooling)
	5-Stage Thermostat
	Tempering Valve (heating and cooling)
Electrical	Delayed Inputs
	Simple Differential
	Lead Acid Battery
	PV Charge Controller/Inverter
	Wind Turbine
	DEGS Controller
	Four Parameter PV
	Minigrid Controller
	Diesel Generator
	Power Conditioning
HVAC	Lead Acid Battery with Gassing
	Busbar (Minigrid Energy Balance)
	Five Parameter PV
	Generic Equipment
	Generic PLR Curve
	Cooling Tower
	Detailed Cooling Coil
	Absorption Chiller
	Air Heater (Electric and Gas)
	Air Cooled Chiller
	Air-to-Air Heat Pump
	Boiler
	Simple Chilled Water Coil
	Simple Cooling Tower
	Direct Expansion Coil
	Fan Coil
	Liquid Heater (Electric and Gas)
	Furnace
	Simple Hot Water Coil
	Water Cooled Chiller
Hydrogen	Water-to-Air Heat Pump
	Split System AC
	PTAC
	VAV Air Handler
	VAV with PFP Boxes
	Electrolyzer Controls
	Alkaline Electrolyzer
	Compressed Gas Storage
	Gas Compressor
	Fuel Cell (PEM and Alkaline)
Hydronics	Liquid-to-Liquid HX
	Flow Splitter
	Flow Mixer
	Pipe
	Pump (Constant and Variable Speed)
	Duct
	Fan (Constant and Variable Speed)
	Air Diverter
	Return Plenum

Library	Component
Ground Coupling	Slab on Grade
Load & Structures	Detailed Single Zone
	Overhang and Wingwall Shading
	Glazed Trombe Wall
	Multizone Building
	Infiltration
	Single Zone Lumped Capacitance
Output	Printer
	Simulation Summary
	Printegrator
	Online Plotter
	Scope
	SketchUp Viewer
	Economics
Physical Phenomenon	Radiation Processor
	Collector Array Shading
	Thermodynamic Properties
	Weather Data Generator
	Lumped Capacitance
	Horizon Mask
	Shading Mask
	Sky Temperature
	Ground Temperature
	Convection Coefficient
Solar	Glazed Flat Plate Solar Liquid Heater
	Concentrating Parabollic Trough
	Evacuated Tube Liquid Heater
	Performance Map Collector
	Theoretical Flat Plate
	PV/T
	Thermosiphon with Integral Storage
Thermal Storage	Constant Volume Liquid
	Gravel Bed Thermal
	Simple Electric Heated Liquid
	Simple Gas Heated Liquid
	Plug Flow Vertially Cylindrical
	Variable Volume Liquid
Utility	Data Readers
	Forcing Functions
	Time Values
	Integrator
	Forcing Function Sequencer
	Statistics
	Unit Conversion
	Calling Excel
	Calling EES
	Calling W-Editor
	Interpolation
	Differentiation
	Moving Average
	Holiday Calculator
	Calling CONTAM
Weather	Calling Matlab
	Calling Python
	Standard Format
	User Format