TRNSYS 17

a TRaNsient SYstem Simulation program

Updates in Version 17
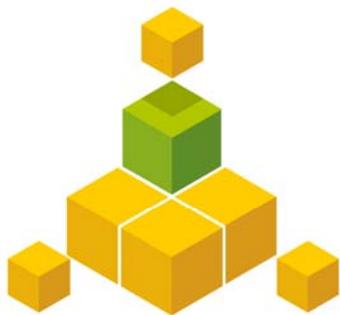
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TRANSSOLAR Energietechnik GmbH
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1. INTRODUCTION

TRNSYS, the transient systems simulation program that has been commercially available since 1975, continues to develop by the international collaboration of the United States, France, and Germany. TRNSYS remains one of the most flexible energy simulation software packages by facilitating the addition of mathematical models, the available add-on components, the capabilities of the multizone building model, and the ability to interface with other simulation programs.

The following document explains the updates for the new TRNSYS version 17. Updates include improvements to the TRNSYS Simulation Studio, the addition of new capabilities to the TRNSYS multizone building model, developments for the TRNSYS engine, and new components to the TRNSYS standard library.

1.1. New Features at a glance

Simulation Studio

- Focus on components

- Rotate and mirror icons

- Input and output information of macros can be specified

- Visualisation of used/unused inputs

- Equations editing in a simple editor

TRNSYS-addon (not included in the package)

- TRNSYS3d, free plugin for Goggle SketchUp^{TM} for creating 3d geometric building input data

TRNbuild - User interface of the multizone building model

- Import /Update of geometric information by an TRNSYS3d file

- Generating shading / insolation matrices

- Generating view factor matrices

- Multi-airnode zones

- multi-comfort definition per airnode

- userdefined emissivity for walls

- rel. or abs. humidity for ventilation, humidification and dehumidification

- new NTYPES (balance entities etc.)

Multizone building model

- Detailed shading of beam and diffuse solar radiation of external windows
- Detailed geometric distribution of primary beam radiation within a zone
- Detailed geometric distribution of diffuse radiation within a zone
- Detailed geometric longwave radiation exchange within a zone
- Detailed comfort model
- four new inputs

TRNSYS Engine

- New access functions instead of the INFO array
- More descriptive syntax
- Type 65 with 10 Plotters and possible split screen

New Components

- Type 46 Printegrator
- Differential equation solver
- Type 49 Multizone slab model
- Scope
- Type 75 Sherman-Grimsrud Infiltration model
- Type 15 weather data reader
- Type 125 TRNSYS3d printer

1.2. TRNSYS Simulation Studio

With the TRNSYS graphical interface, the Simulation Studio, the user could connect the outputs from one component to the inputs of another in a simple, easy-to-follow fashion. Thus became the possibilities to have connection loops in certain line colors and styles to easily distinguish and interpret the system in the simulation.

As the user base and the complexity of the systems continues to become more advanced in TRNSYS, the TRNSYS Simulation Studio graphical interface evolved accordingly for the next release. For the complex projects with numerous connections and components, the TRNSYS Simulation Studio now allows the user to focus exclusively on one component and that component's connections.
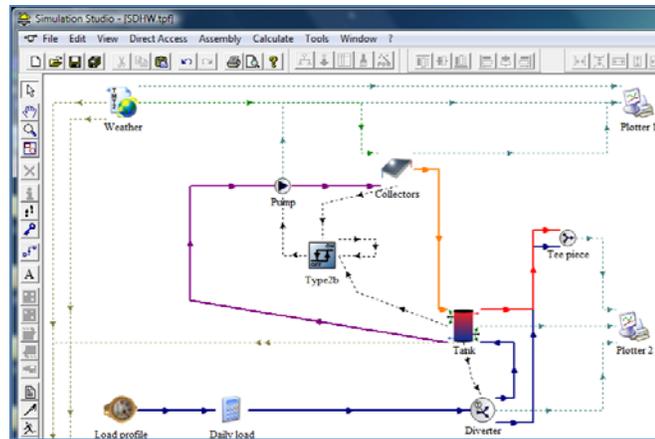
Figure 1 Example Project in Simulation Studio

This feature hides the all of the other components that are not connected to the focused component as displayed in Figure 2. This solar domestic hot water example in the TRNSYS Simulation focuses on the connections of the differential controller component to solely view the inputs and outputs and does not display any of the other components that are not connected to it. This new feature allows more insight when users have to go through their models with a great detail. It helps prevent more user induced errors, and this feature benefits the building simulations in TRNSYS as viewing the inputs and outputs to the building component is especially straightforward.
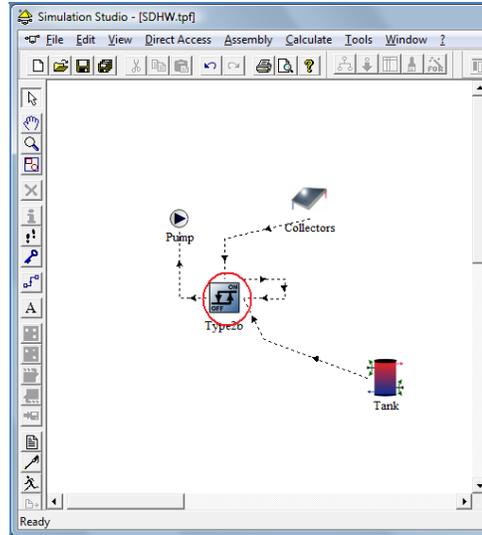
Figure 2 Example Project with Focused Component

A complex simulation may have many hydronic components: pumps, fans, plenums, mixing valves etc. that are connected in a particular direction. The Simulation Studio now accommodates for the direction of the component icon by allowing the user to rotate or flip the component icon. Therefore, all of the components in the user's system loop can easily face the direction of that in a flow or mechanical diagrams.
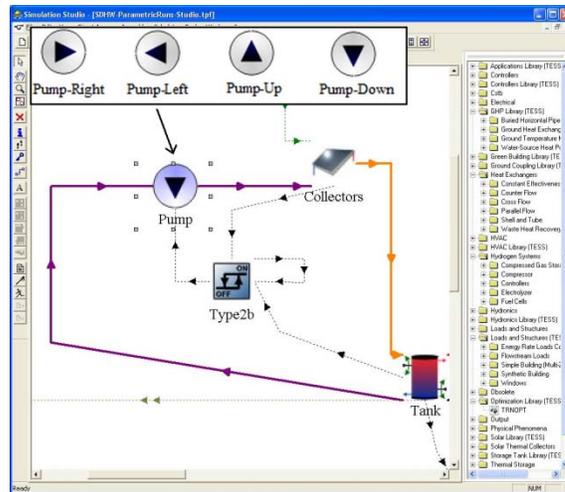
Figure 3 Simulation Studio Rotate Component

Other graphical interface modifications include improvements to the condensed sub-systems or "macros" as they are referred to in the TRNSYS Simulation Studio. The users are able to specify what inputs and outputs to display for their appropriate macro connections.

Figure 4: Inside the Macro in the Simulation Studio

Another graphical interface improvement is the display of the connected or not connected inputs. For the inputs that are not connected, the specified input value is treated as a constant, initial value for that component during the simulation. Allowing the user to have the initial value displayed in a separate color or style again simplifies the simulation and reduces user induced error.

Equations in the TRNSYS Simulation Studio may not only be written as they were in the previous version, but they may also be written as lines of code. Equations can now be written in a simple editor window as text as shown in the following figure. This saves much time for the users who implement many equations into their simulation.

Figure 5: The "Edit All Equations" Window

1.2.1. TRNSYS 16 to TRNSYS 17

The new version of TRNSYS is capable of opening and simulating version 16 Simulation Studio project files (*.tpf). However, once the file is saved as a TRNSYS 17 project, it may not be re-opened in TRNSYS 16.

For multizone building projects TRNBuild updates the BUI file automatically. However, due to the four new inputs of the building model the user has to connect the forth input TSGRD to the ambient temperature within the Simulation Studio. The other new inputs aren't used by the old standard radiation modes and thus doesn't have to be connected.
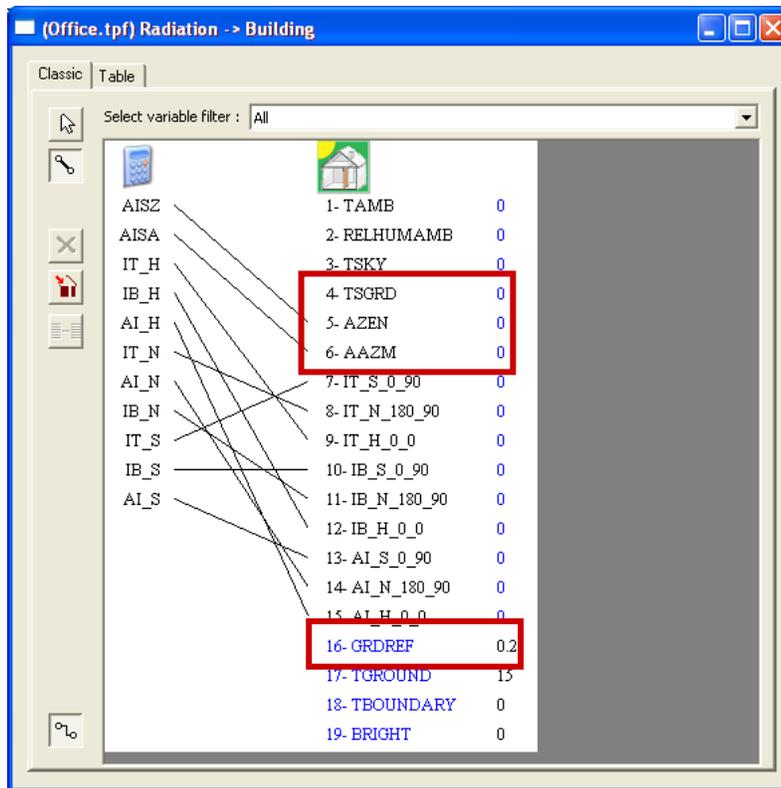
Figure 6: New Inputs of the multizone building model

1.3.   The TRNSYS Multizone Building

For TRNSYS 17, one main focus is the improvement of the simulation of highly glazed large spaces such as multi-story atriums with respect to accuracy, user effort and error-proneness. Therefore, the existing multizone building model has been extended to a detailed modelling of 3-dimensional energy transport by radiation and thermal stratification. Figure provides an overview of the newly integrated features. These new features are optional such that the user can adapt the level of detail according to the needs of the project.
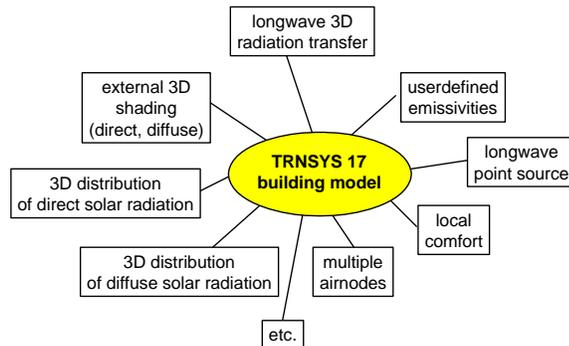
Figure 7: *New features of the multizone building model*

1.3.1.   3D Data

The new building model contains 3D geometric surface information that is required for the new detailed radiation calculations. To easily input the geometric information into the building model, a plugin called TRNSYS3d for Goggle SketchUp[TM] has been developed. TRNSYS3d is based on the open source program OpenStudio[TM] (http://sourceforge.net/projects/openstudio). Therefore, it can't be included into the TRNSYS package but is available for free download under GNU-GPL: http://www.trnsys.de/docs/userservice/userservice_updates_en.htm.
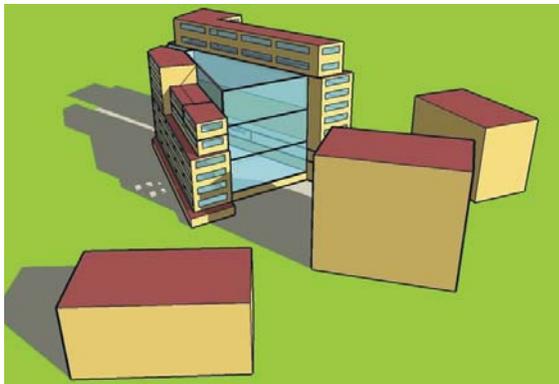
Figure 8: 3D building model

1.3.2.   TRNBuild - Multizone building interface

The resulting input file of TRNSYS3d can be imported by TRNBuild, the multizone building GUI, to define the non-geometric building objects ventilation, gains, heating, etc. In addition, the user can select between different level of radiation modes for each zone . TRNBuild will generate view factor (*.vfm), sunlight factor (*.shm), and distribution factor matrices (*.ISM) required by the detailed modes if necessary. Flexibility, computing time, and the input effort are various advantages to the preprocessing step.
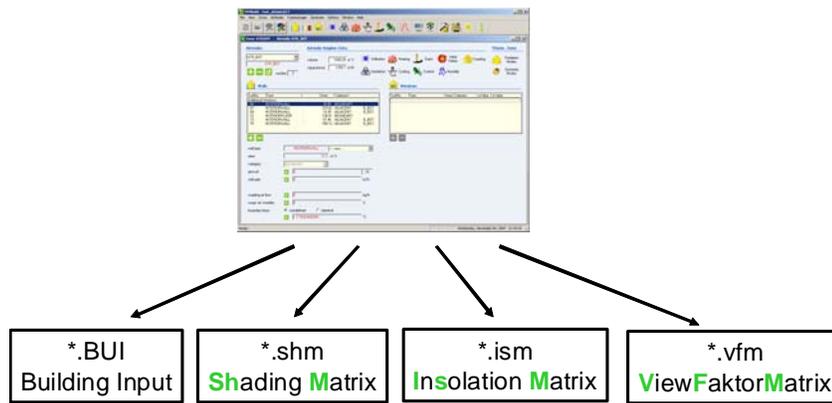
Figure 9: New matrix files for detailed radiation modelling

Due to the integration of the new detailed model a thermal zone may consist of more than one airnode . Thereby, the convective modelling of stratification is improved significantly. Building surfaces and regime data (heating, cooling, infiltration, ventilation, etc.) are assigned to an airnode. The heat exchange between building surfaces and the airnode is based on convection only whereas the shortwave radiation distribution and the longwave radiation exchange is performed over the whole thermal zone. Airnodes of one thermal zone may have a convective coupling to two other airnodes of the same zone. For creating radiative zones a new function "move airnode" is implemented in TRNbuild.
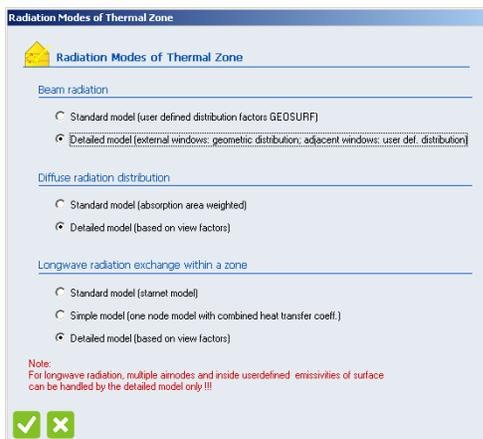
Figure 10: radiation modes of a thermal zone
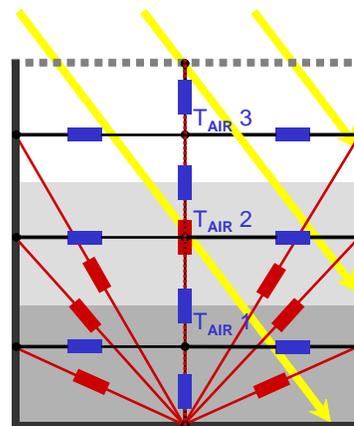
Figure 11: thermal zone with 3 airnodes

In version 16, only one comfort definition was allowed per zone. Now, the user may specify more than one comfort definition and can select between different modes on how to calculate the mean radiation temperature, a key figure for comfort evaluation.
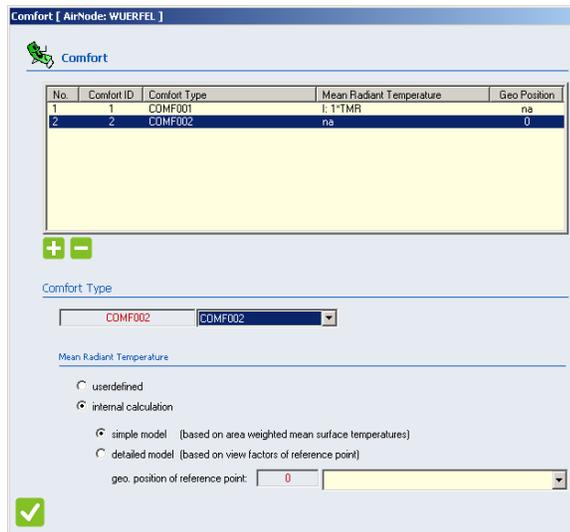
Figure 12: Comfort definition window

In addition, the output list of the building model has been extended. Due to the multi-comfort definition a new category outputs is available, the so called comfort outputs. Balance output entities are now available as ordinary surface / airnode outputs so called NTYPEs.

1.3.3.   TYPE 56 – Multi-zone building model

Due to the new detailed radiation modes TYPE 56 requires 4 new inputs:

- TSGRD
  surface temperature of the ground or other surfaces for lonwave radiation exchange with other surfaces for longwave radiation exchange. For running TRNSYS 16 dck's this input has to be connect to ambient temperature. In TRNSYS 16, the ambient temperature was used.

- AZEN
  zenith angle for calculating the actual sun's position for the new detailed direct and diffuse radiation mode

- AZEN
  azimuth angle for calculating the actual sun's position for the new detailed direct and diffuse radiation mode

- GRDREF
  ground reflection for calculating the sky diffuse radiation from the total diffuse radiation for the new detailed radiation shading mode

In addition, to the BUI file TYPE 56 needs the new matrix files as inputs for the new detailed radiation model. These files are connected automatically by their names, no logical unit has to be defined.
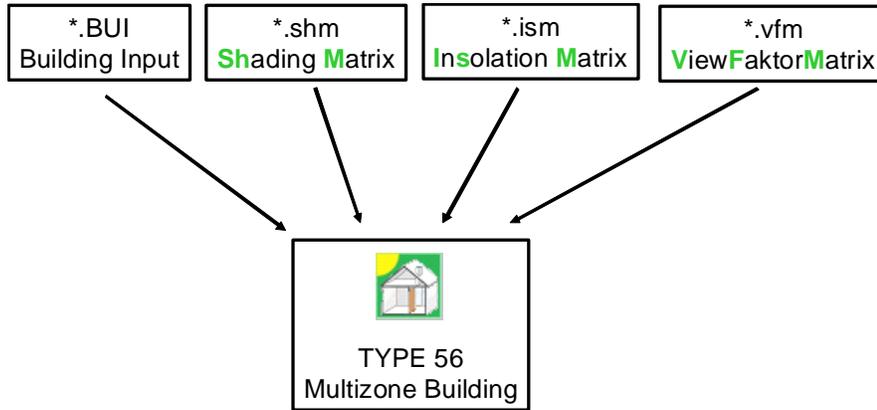
Figure 13: New additional input files of Type 56

The standard output files of Type 56 available in Version 16 defined by optional parameter 4-6 are obsolete for TRNSYS 17. Users are encouraged to use the Balance outputs instead.

1.4.   TRNSYS Engine

The process of creating components, especially more complex algorithms, becomes even easier with the TRNSYS 17 source code. When a component was created in the previous version of TRNSYS, its source code contained an array with up to 15 places with various information about the component, the INFO array. The number of parameters, inputs, outputs, information about the time step and convergence of a solution, and information about what version of TRNSYS was used to created the component were all encompassed in this array. Unless the programmer could memorize all of the places in the INFO array or if they had the programming manual with at their side, this task created much confusion and apprehension.
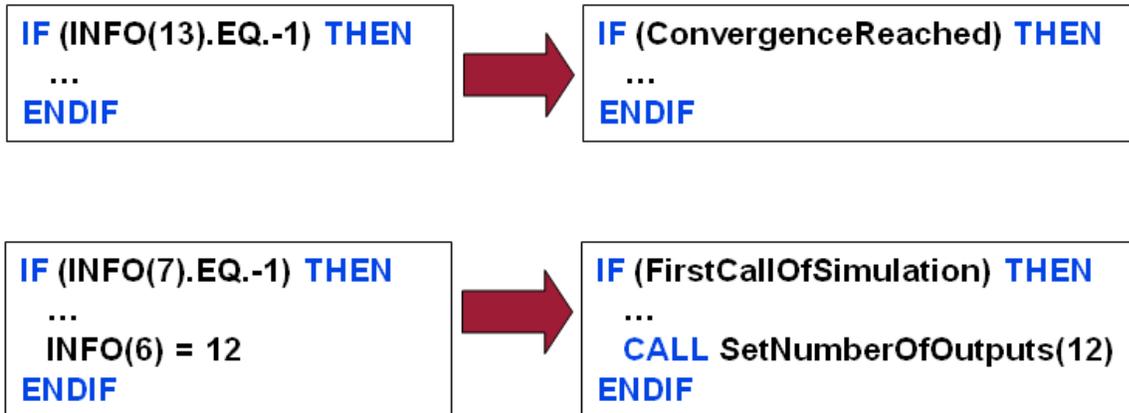
Figure 14: Access Functions for the INFO Array

The source code for the new version of TRNSYS implements more descriptive syntax to eliminate the confusion with the INFO array. Figure 9 contains a few examples of the source code that replaces the calls to the notorious INFO array.

```
! Tell the TRNSYS Engine How This Type Works

      Call SetNumberofParameters(1+2*N_Values)

      Call SetNumberofInputs(3*N_Values)

      Call SetNumberofDerivatives(0)

      Call SetNumberofOutputs(N_Values)

      Call SetIterationMode(1)

      Call SetNumberStoredVariables(N_Values)
```

Figure 15 New TRNSYS 17 Syntax

The past version of TRNSYS used a component type calling routine to check for parameters or inputs that were out of bounds, TYPECK. TYPECK would generate a fatal error and stop the simulation with little and sometimes very vague. Similar to the calls to the INFO array, TYPECK is notorious for not being user-friendly. The programmer would also need to constantly reference the manual to implement this in the source code as well. To alleviate this issue for the next release of TRNSYS, easily recognizable calls are used such as "*CALL FoundBadParameter*" and "*CALL FoundBadInput*". The user then is able to write the descriptive error text directly in the source code. For example, if a component uses efficiency as a parameter, the descriptive error text could read, "This error was generated because the efficiency of the component was greater than one or less than zero." In contrast the earlier version with TYPECK would only elaborate what parameter or input *might* be the problem.

The new source code for TRNSYS 17 was designed to make the user even more comfortable with creating components and running simulations. If writing a new component for TRNSYS is not desired, the user may choose from the many components in the TRNSYS standard library or the additional add-on component libraries.

For simulations with multiple variables of interest, the ability to use two screens on the Type65 Online Plotter device will allow to dynamically display more outputs in an easy to follow fashion.
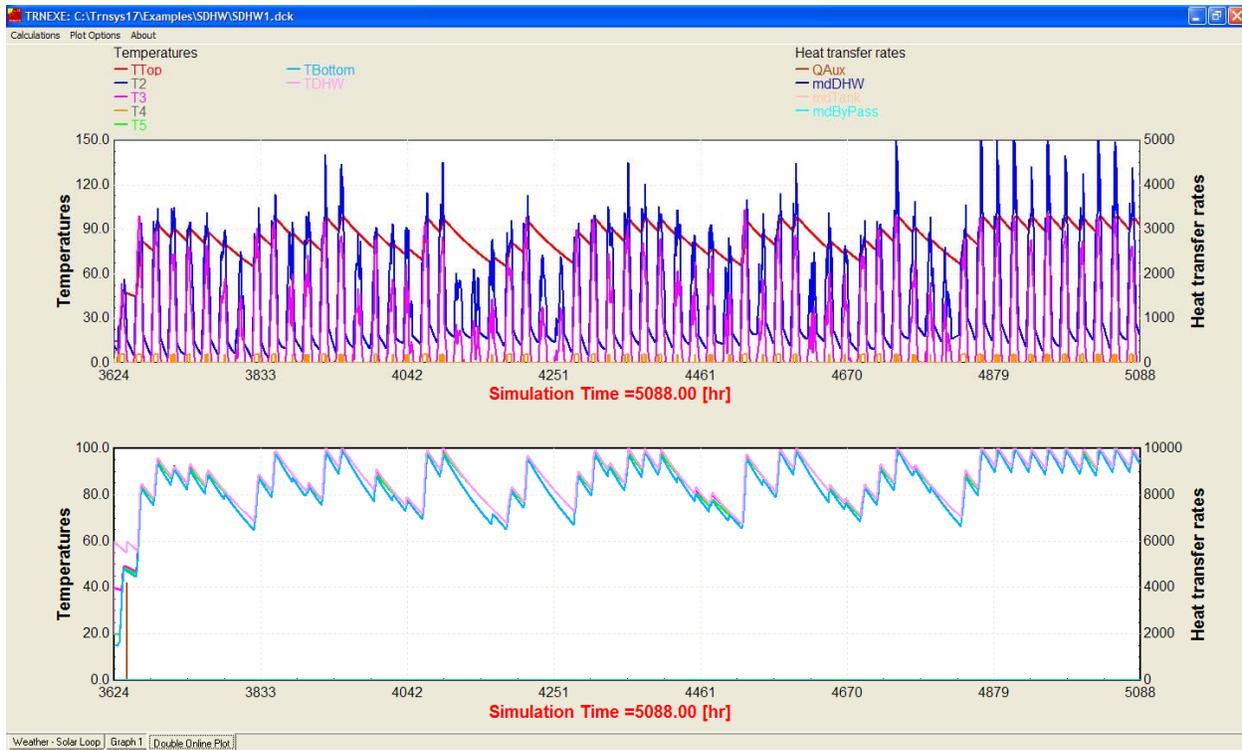
Figure 16: Online Plotter with Two Screens

1.5. New Components

The TRNSYS standard component library offers over 80 components for many different applications: HVAC, solar, hydrogen systems, etc. The new components focus on ease-of-use and ground to earth heat transfer with the TRNSYS multizone building model.

Since TRNSYS simulates dynamically, the outputs of many of the components are an energy rate or power. Thus, it is necessary to integrate the energy rate outputs over the respective time period to convey, for example, the annual energy consumption of an auxiliary heating device. TRNSYS does have a component to integrate these values; however, after connecting the outputs to the integrator component, the user would again have to connect the outputs of the integrator (the integrated values) to another component to create the output file. With many components and with many zones in a building that also output an energy rate, this becomes a time consuming task. The new component for the next release of TRNSYS conducts both of the tasks. This one component, cleverly titled the *Printegrator*, has the capability to integrate and create the output file with the integrated values.

TRNSYS does have a utility routine that analytically solves first-order differential equations, yet implementing these mechanisms involves programming a new component. A new TRNSYS component has been developed to define models based on one of the most commonly used

differential equations without any programming. The component uses sets of matrices, *A* and *B*, to solve the differential equation.
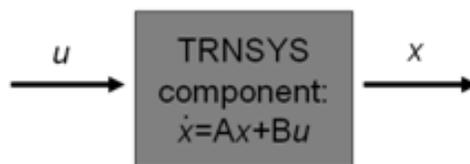
Figure 17 TRNSYS Differential Equation Component

As building envelopes in design and practice become more sufficient, the energy exchange between the building and ground becomes increasingly significant. Simulating the heat transfer between the building and the ground has long been ambiguous and troubled with errors. The IEA Task34/43 conducted work to increase the accuracy of the ground-coupled heat transfer. TRNSYS was not only used for the IEA task, but it was also the only whole building energy simulation program that was deemed as a BESTEST reference standard (along with Fluent(ANSYS, 2009) and MATLAB).

The new TRNSYS 17 multizone slab model is based on the work from the IEA task and also has been refined from other projects. The model implicitly solves the three dimensional finite difference soil field. Nodes in the soil field are determined from an automatic noding algorithm. The model uses an energy surface output from the TRNSYS multizone building model, and then passes the temperature of the soil (calculated from the slab model) back into the multizone building. For users to easily create and define geometrical and node information about the slab and the soil, a Google SketchUp plugin has been created that calculates the vertices of the multizone slab and the meshing based on the drawing of the slab.

The output of the new multizone slab model is a text file with the temperatures for the specified planar surface(s) in each of the three dimensions under the slab. A graphical viewer is also available to display the results of the multizone slab model. The lower right of the following figure displays the ground temperatures approximately 2 meters below the surface of the slab in the plane that is parallel to the slab. The multizone building that was used in the in the project for that temperature display was a very large department and food store. The zone in the upper right corner of the diagram was kept very cool for food storage.
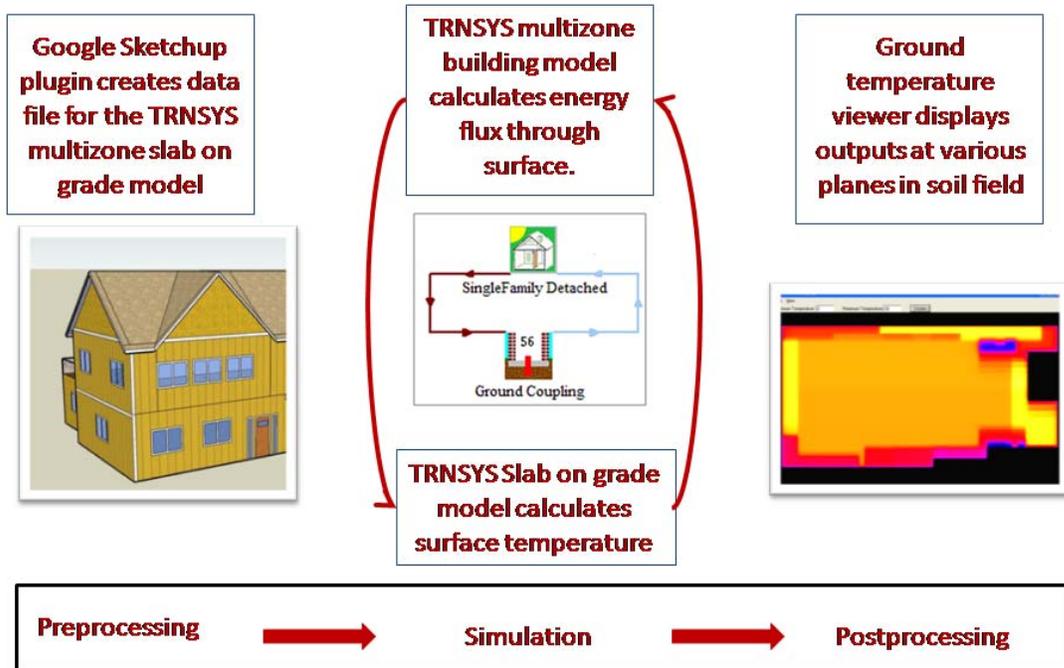
Figure 18: TRNSYS Multizone Slab Model

New components have been created to dynamically display some of the variables in the Simulation Studio while running the simulation. Variables such as temperature and the hour of the year may be displayed with your simulation in TRNSYS as shown in the following figure.
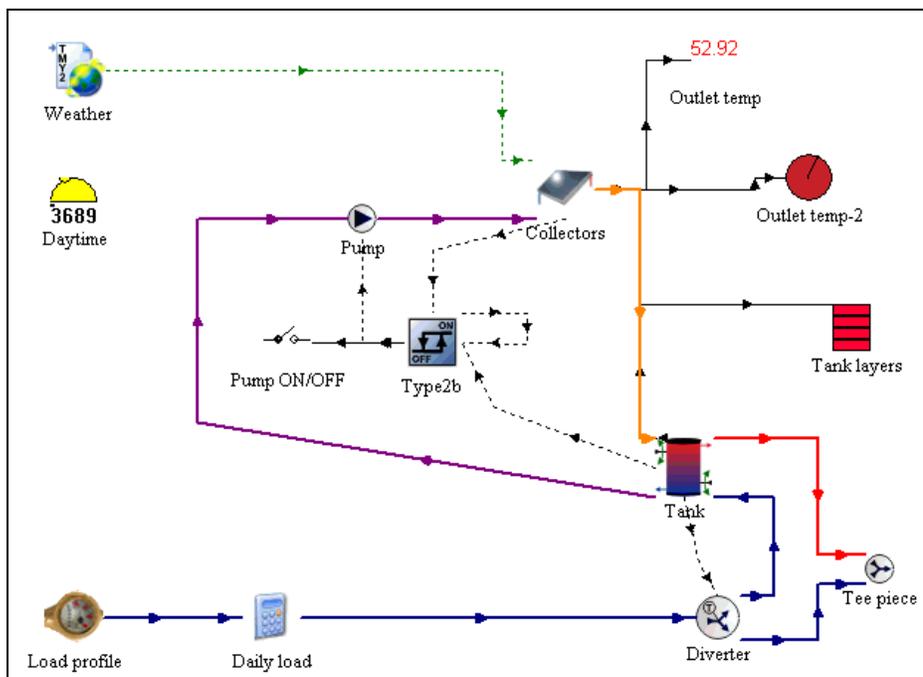
Figure 19: Dynamic Display of Scope Components in the Simulation Studio

In the simulation in the previous figure, the scope component labeled "Daytime" is displaying the hour of the year with indication of day or night. The "Outlet temp" scope component is numerically displaying the current value of the collector outlet temperature during the simulation while the "Outlet-temp2" scope acts as a gauge to dynamically display the outlet temperature. The last scope component in the simulation, "Tank layers", is displaying the tank temperature.

Another new component is the Type75 Sherman-Grimsrud Infiltration model. This component may be used in conjunction with a building model to more accurately calculate the infiltration into and out of the building.

Many components included improvements including the Type15 weather reader and radiation processor. The new Type15 is now capable of processing the TMY-3 weather files that are publically available from the National Solar Radiation Data Base.

Figure 20: The Type15-TMY3 Proforma Icon