TRNSYS – FEATURES AND FUNCTIONALITITY FOR BUILDING SIMULATION 2009 CONFERENCE

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ABSTRACT

This paper seeks to highlight the recent developments in TRNSYS including the introduction of a three-dimensional geometrical building model and interface, improvements in the TRNSYS simulation engine to facilitate the creation of user-written components, ease-of-use modifications to the graphical interface, and new components including a BESTEST reference standard model that accurately calculates and displays the energy transfer between a building and the surrounding earth.

INTRODUCTION

TRNSYS, a transient systems simulation program that has been commercially available since 1975(Klein et al., 2006), continues to develop by the international collaboration from the United States (Thermal Energy System Specialists and the University of Wisconsin-Solar Energy Laboratory), France (Centre Scientifique et Technique du Bâtiment), and Germany (TRANSSOLAR Energietechnik). TRNSYS remains a flexible energy simulation software package by facilitating the addition of mathematical models, the available add-on components, and the ability to interface with other simulation programs. TRNSYS has been used extensively to simulate solar energy applications, conventional buildings, and even biological processes.

Even though the release of TRNSYS 17 is this year, almost 35 years after the initial release, the philosophy remains the same: simulate the performance of the entire system by breaking it down into individual black box components. Since the inception of TRNSYS, it has had the open modular structure with open source code. The end user is able to create custom components for their dynamic simulation needs, or the end user may choose from the TRNSYS standard library of components such as solar (thermal and photovoltaic), HVAC, hydrogen systems, and many others.

GRAPHICAL INTERFACE MODIFICATIONS

Up until the release of the TRNSYS Simulation Studio graphical interface in the late 1990's, it was not uncommon to manually write and edit TRNSYS inputs files as a text file. Defining the connections and keeping all of the inputs and outputs organized became a frightening task for the more advanced projects. With the graphical interface, 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.
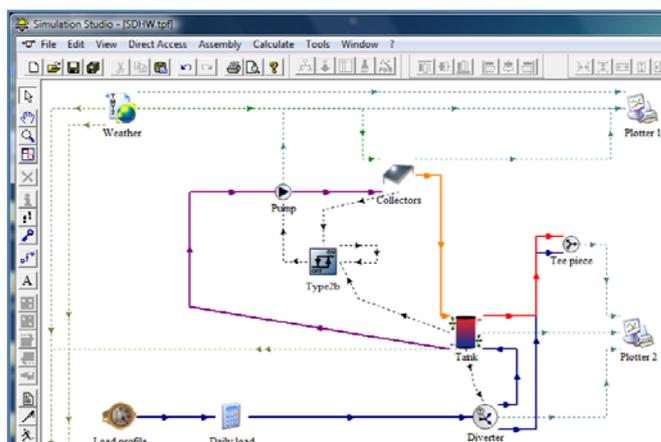
Figure 1 Example Project in Simulation Studio

This feature hides the all of the other components that are not connected to the focussed 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.
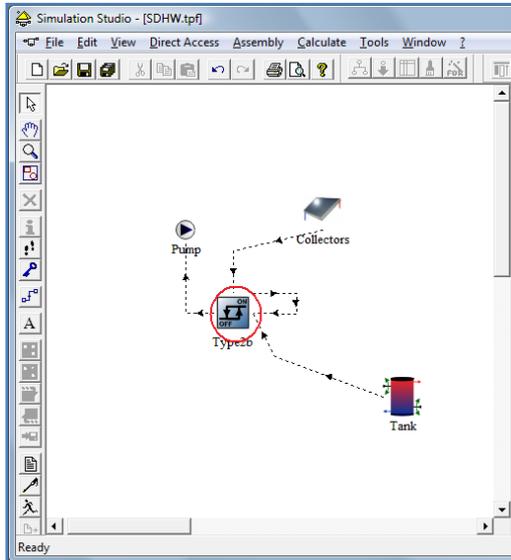

Figure 2 Example Project with Focussed Component

The components in the TRNSYS Simulation Studio consist of the proforma, information about the component, and the bitmap icon. A complex simulation may have many components: pumps, fans, plenums, mixing valves etc. 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.
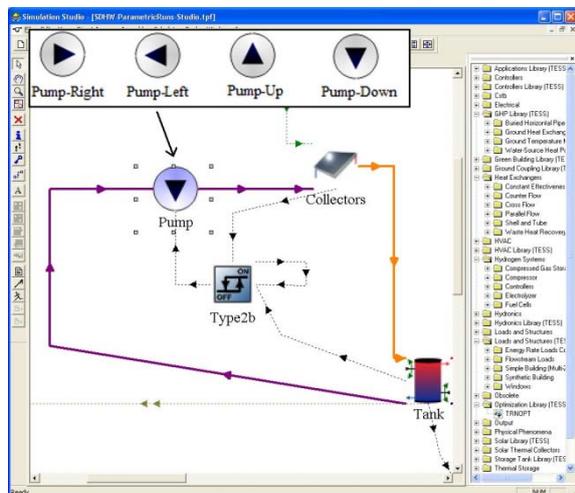

Figure 3 Simulation Studio Rotate Component

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. 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.

The new TRNSYS Simulation Studio has the capability to export a component to MATLAB SIMULINK (Mathworks, 2009). The process creates a SIMULINK project (*.mdl) where the TRNSYS component can be executed. Alternatively, a MATLAB/SIMULINK subsystem could also be transformed into a TRNSYS component. To simplify the process for the MATLAB user, the user selects the TRNSYS target, and the necessary dynamic link library (DLL) is created by the MATLAB Real Time Workshop (RTW). The user simply creates the proforma of the MATLAB subsystem in TRNSYS to create the inputs and outputs of the subsystem. As the subsystems exported from MATLAB use this runtime (i.e. all the MATLAB functionality), there are no constraints imposed on such subsystems.

TRNSYS MULTIZONE BUILDING

The capabilities of the TRNSYS multizone building continue to expand as the improved model focuses on the implementation of many tools, including a Google SketchUp plugin (Google, 2009), to model large atriums and other heavily glazed buildings. Multiple air nodes, improved radiation model, and preprocessing to caluculate view factors and shading factors are the contributions to the model that yield more accuracy when modelling the large, glazed buildings.

The new building model contains geometric information that is required for the new detailed radiation calculations. To easily input the geometric information into the building model, it is planned to utilize OpenStudio plugin for SketchUp (Ellis, 2009). The geometric information is used in a preprocessing step in TRNBuild, the building input description tool of TRNSYS. The preprocessing step calculates view factors, sunlight factors, and distribution factors, necessary entities for the new building model. Flexibility, computing time, and the input effort are various advantages to the preprocessing step.

Stratification to the new building model is improved with the addition of multiple air nodes. The convective heat transfer is not only be exchanged from the inside wall surfaces to the air nodes but also

from the adjacent air nodes as shown in Figure 4. The figure considers a simple zone with a glazed ceiling (denoted by the dashed line) with incoming solar radiation. The radiation heat transfer is only displayed from the bottom surface to the other surfaces for the purposes of the display. The figure contains three air nodes for convective heat transfer exchange.
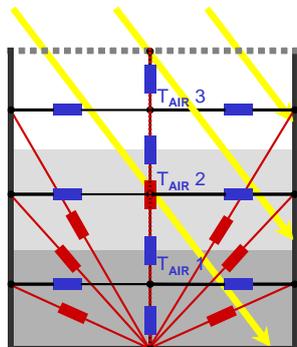

Figure 4 Radiative zone with 3 air nodes

The inputs to the building such as the ventilation with the conditioned air or infiltration are assigned to the specified air node. The longwave radiation exchange and shortwave radiation exchange are applied to the entire zone as Figure 4 also displays.

The available add-on TRNFLOW (Weber 2006) integrated air flow network can also be used with the multiple air nodes in the TRNSYS multizone building.

TRNSYS SIMULATION ENGINE

Perhaps the most significant reason that TRNSYS has not become stagnant over the last 35 years is the ability for the user to create and implement a component into their simulation. TRNSYS has been able to evolve with the emerging technologies and cutting edge research without exhausting numerous resources. With some computer programming experience and knowledge of the theoretical behavior, a user is able to create the component for their simulation. 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.

The source code for the new version of TRNSYS implements more descriptive syntax to eliminate the confusion with the INFO array. Figure 5 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 SetTLerationMode(1)

    Call SetNumberStoredVariables(N_Values)
```

Figure 5 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.

NEW COMPONENTS IN TRNSYS

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.
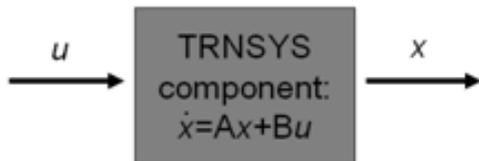

Figure 6 TRNSYS Differential Equation Component

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 following Figure 7 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 Figure 7 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.
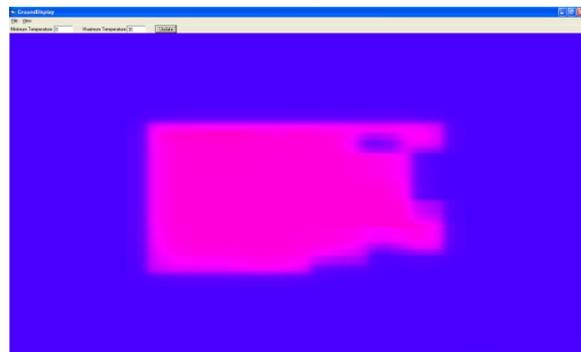

Figure 7 Multizone Slab Temperature Viewer

Add-On Components

In addition to the TRNSYS standard library of components, other components and libraries are available to extend the capabilities and amplify the simplicity in TRNSYS. An available multizone, multilevel basement model increases the potential for modelling unique, underground features of the building or zone. From nominal residential basements to wine caves, the component has the capability to simulate the building to ground heat transfer with a high degree of accuracy. Other ground coupling models that use the same methodologies include buried pipe, buried tank, and ground heat exchanger components. Improvements to many of the other add-on components consist of more complex controllers, normalized heat pumps and other normalized HVAC devices, volumetric flow models (oppose to only mass flow models for pumps and fans), and models that control the flow rate to maintain a specified outlet temperature. The add-on solar collector components feature the ability to include capacitance into the model as well as

outlet temperature control modes in order to supply a specified outlet temperature.

A new cogeneration add-on library is currently available with TRNSYS. The library features many steam system components that are used in power plant and combined heat and power (CHP) applications: steam generator, superheater and desuperheater, heat recovery, chillers, gas turbines, and liquid-cooled internal combustion engine. From modelling large scale power plants to residential combined heat and power applications, the library broadens the capabilities of TRNSYS.

CONCLUSION

The new features and modifications in TRNSYS 17 increase the usability and capability of the dynamic simulation program. The new features of the multizone building model more accurately model large atrium and heavily glazed buildings, or a less detailed modelled may be used to fit the user's need. The graphical interface, TRNSYS Simulation Studio, allows more clarity and ease while mapping the simulation of the system. Creating and deciphering components with the new TRNSYS 17 source code prevents confusion. The new components will add diversity and simplification to the standard libraries and additional add-on libraries.

ACKNOWLEDGEMENT

REFERENCES

Klein, S.A. et al. 2006. TRNSYS 16: A Transient System Simulation Program, SEL, University of Wisconsin, Madison USA.

Mathworks, Inc., MATLAB and SIMULINK are registered trademarks, 2009.

Google, Inc., Google SketchUp is a registered trademark, 2009.

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Weber, A. 2006. TRNFLOW: A module of an air flow network for coupled simulation with the multizone building model of TRNSYS

ANSYS, Inc., Fluent is a registered trademark, 2009.