New features for solar thermal simulation in TRANSOL

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Abstract

This paper seeks to highlight the recent developments in TRANSOL, including new systems, improvements in the TRNSYS simulation projects, new and updated components, extended and new databases, ease-of-use modifications to the graphical user interface and implementation of parametric runs. The result is a new version of the software package with improved performance and nine new schemes. The total number of schemes, i.e. basic configurations for solar thermal systems, is now 34 which allow to simulate up to 163 different configurations. New systems have been included to simulate the performance of solar thermal systems for covering heating demand of industrial processes, cooling of buildings or thermal demand in covered swimming pools. Updated and new systems have been included to design systems for covering domestic hot water (DHW) and heating demand, both in detached houses, multi dwelling buildings or collective buildings, like hotels, sport centres, etc. The changes introduced in how the TRNSYS projects have been built and the modifications in some key components result in a decrease of computation time: up to four or five times compared to the previous version. This gives the possibility to launch parametric comparisons of up to 25 runs within a reasonable computation time.

1. Introduction

TRANSOL, a tool for the design of solar thermal systems, continues to develop through the international collaboration between France (Centre Scientifique et Technique du Bâtiment) and Spain (AIGUASOL). The third version of TRANSOL, which has been released in November 2009, remains a flexible, easy to use and intuitive software package for use by consultants, engineers, installers, architects or energy planners. By using the dynamic simulation engine TRNSYS 16 [1], TRANSOL incorporates a lot of new features and improvements with respect to its predecessor TRANSOL 2 [2], but keeping the philosophy: TRANSOL is a Graphical User Interface (GUI) that performs the following tasks:

- Reads the interface data and generates a TRNSYS input file with the parameters which define the system configuration
- Launches the simulation in the TRNSYS engine, using predefined TRNSYS projects
- Post-processes the results and gives the user the possibility to visualize them in different ways.

A lot of effort has been done both updating and adding new features to the TRNSYS projects and to the GUI. Thanks to the extensive and advanced work of creating new TRNSYS projects, new concepts and ideas, mainly about the use of "macros" in Simulation Studio, have been developed, tested and finally incorporated into TRNSYS 17 [3].

2. New systems

The application calculates a variety of configurations of solar thermal systems for hot water production, space and swimming pool heating. Multi dwelling systems using centralized or decentralized storage have been reviewed and new configurations have been added to the new version. Besides that, TRANSOL incorporates new schemes to simulate:

- Industrial processes allowing to feed up to four different heat processes at different level of temperatures
- Solar cooling systems with thermal driven chillers
- Covered swimming pools
- Space heating systems

In Figure 1, the scheme of the system for industrial processes is depicted. A simplified load profile can be described for the four different processes defining the average water consumption during a day, the number of weekdays (5, 6 or 7) and the hours that the system is working during the day. Additionally, the inlet and return temperature to the process need to be defined, so you can define different temperatures levels for each process.

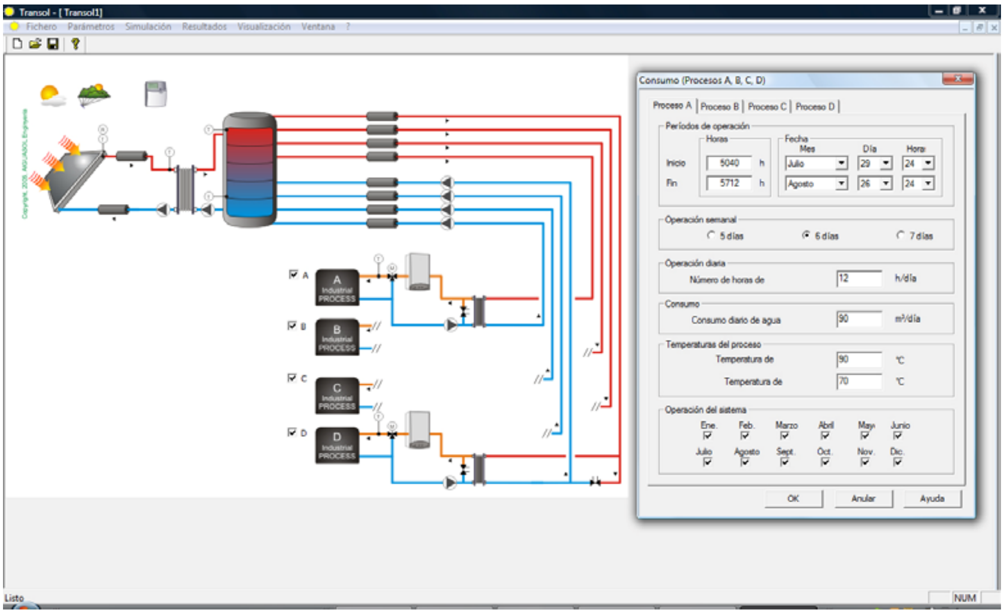


Fig 1. Scheme of TRANSOL model for solar thermal for industrial processes

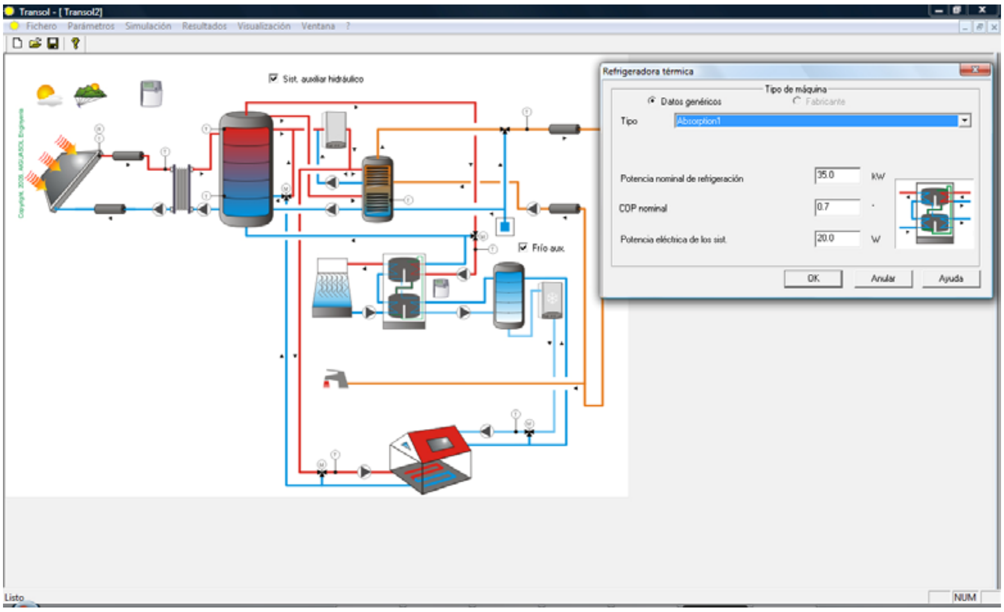


Fig 2. Scheme of TRANSOL model for solar cooling system

One of the big improvements related to the previous version of TRANSOL is that one basic solar cooling configuration has been made available to the users. The system, shown in Figure 2, is a general solar thermal system which can cover the cooling and heating loads of a building and the DHW demand. Several types of thermally driven chillers, absorption and adsorption machines, can be chosen from a generic database included in the GUI. To complete the "cooling" part of the system you should define the basic parameters of the cooling tower, the cold water tank, the cooling control, the cold water distribution system and the back-up chiller, if any.

TRANSOL incorporates a one-zone building model for the precise calculation of heating and cooling loads. In the new version the database of walls and windows has been reviewed and extended, with a wide range of options of covering any world climate.

3. New options for meteorological data

Climate data generated with METEONORM is now available for any location in the world. You can select your location from a list of weather stations or you can generate the Typical Meteorological Year (TMY) defining the latitude, the longitude and the altitude of the place where you plan to locate the solar system. You can also use your own meteorological data if it is in one of the common formats that TRANSOL accepts. These formats are: Typical Meteorological Year version 2 (TMY2), EnergyPlus Weather, International Weather for Energy Calculations (IWEC), Canadian Weather for Energy Calculations (CWEC) and standard Meteonorm format.

The cold water temperature, i.e. the temperature of the water from the water supply network that the solar system must heat, is an important parameter which can significantly affect the performance of the solar system. New options have been added with the aim to extend the possibilities for defining the temperature for the net cold water more precisely. These new options are:

• Automatic generation of the data for main water temperature based on one already known algorithm [4] based on the ambient temperature of the location, which gives the expected temperature exiting a system of buried pipes. Note that the correlation is for the USA, so it should be used carefully in case your location is outside the usual latitudes of the USA.

• The second option allows to define a sinus-shaped function based on three parameters: the annual mean value of the temperature (ºC), the amplitude (i.e., the difference between the maximum value and minimum value in ºC) and the day of the year (by default, the day 227) where it is expected to have the maximum value.

• The third option to define the cold water temperature is only valid for sites located in Spain and France and is based in the regulations of these countries. In the case of France, it is based on the standard NF EN 12976-2; the user should define the province (départment) to which the location belongs and if that location is close to the coast (less than 5 km). In the case of Spain, it is based on the standard UNE 94002:2005, the temperature will depend on the location (you should indentify the province) and its altitude.

• The last option allows the user to define the mean monthly values for the main water temperature, for each of the twelve months. This option gives constant values during each whole month.

4. New components and improvements on deck programming

A new TRNSYS type has been used which allows to simulate the performance of several kinds of solar collectors more precisely: flat plate, evacuated and CPC collectors. The new model calculates the solar field performance by a multi node approach for the different flow paths with the Hotter-Bliss equation, considers thermal inertia in the solar field, allows the definition of bi-dimensional IAM for ETC and CPC collectors and considers the appropriate radiation component depending on collector technology. The bi-dimensional IAM can be defined by the user through an ASCII file. New control strategies have been defined for the primary loop, including match-flow.

Type 340 [5] has been used to model solar and auxiliary tanks. The advantage of this model compared to the components used in previous versions is that it allows simulating stratified tanks more precisely. It has been found to be one of the key components in the improvement of the computation time, since it allows for a variable number of nodes depending of the system complexity and tank volume. The available standard components were revised and modified for solving unexpected behaviour in those cases where more than one Type 340 were used in the same TRNSYS project. The thermal losses by the tank are corrected to account for imperfect insulation as described in [6].

New types have been developed to model real boilers and compact heat exchanger units usually used in solar thermal systems. The boiler type has been developed to include the data set available from the EC Boiler Efficiency Directive 92/42/ECC to describe boiler performance. However, if a more complete data set of part load ratio (PLR) and inlet temperature are available to define the efficiency of the boiler, they can be included in the simulation. Parasitic consumption by boilers is simulated as defined in [6]. Both compact heat exchangers and boilers can have different on/off status in a single simulation time step to better reproduce the instantaneous performance of these components if a high time step is defined by the user.

The TRNSYS projects developed for TRANSOL make extensive use of the macro model concept in TRNSYS Simulation Studio: sets of components (types) performing a given task are grouped together to form macro models. These macro models are then stored in libraries and reused repeatedly, both within the same project and within several different projects. The gain in efficiency of this method is obvious; at the same time, it decreases the risks of modelling errors thanks to the reuse of thoroughly tested components.

Thanks to the experience with TRANSOL project templates, improvements to the macro functionality have been proposed and implemented in Trnsys 17; these include:

- The possibility to select which variables should be visible outside the macro
- The possibility to access incoming links inside a macro, without “zooming” back to the context where the macro is used
- The possibility to rename variables in macros, to adapt their semantics to the macro’s context
- The possibility to change and memorize component order inside a macro

One of the most desired improvements that TRANSOL 2 users have been asked in a dedicated survey or through the hotline was to make the simulation to go faster. The efforts of using new components and improving the TRNSYS project programming have a positive and important impact in the computation time. By average, computation speed has been reduced between 40 and 80%, depending on the system.

5. New multivariate parametric analysis

The new version helps the process of finding the optimal configuration with the multivariate analysis. It can compare the behaviour of the system with different solar collectors, different inclinations and azimuth orientation of the solar field, and number of collectors in series. The volume of the storage can be changed, too. Up to 25 runs can be defined that the GUI manages and launches. Two of the proposed variables can be chosen at the same time and up to 5 discrete values of each variable can be defined (see Figure 3). Finally, the results are presented graphically (see Figure 4) and individual reports can be opened easily from the graph. In the following example, the system is simulated for 3, 5, 8, 10 collectors and for different solar tank volumes (400, 500, 800 l). TRANSOL will then run 4*3=12 simulations.

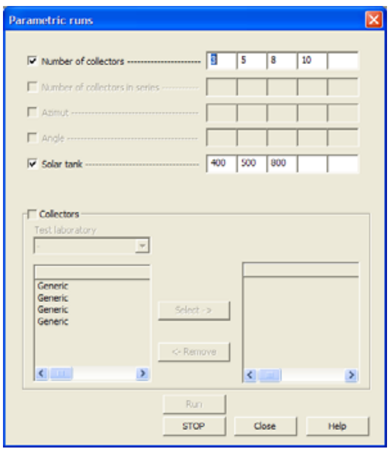


Fig 3. Parametric run values

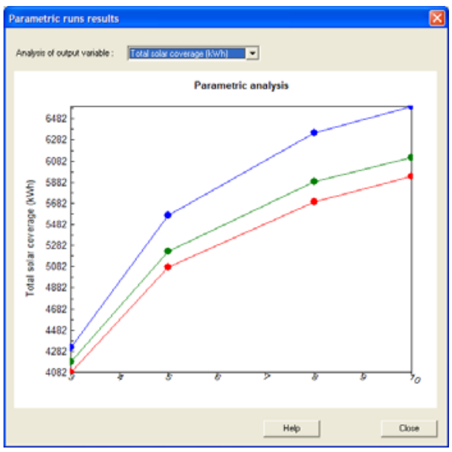


Fig 4. Parametric run results

Once all simulations are finished, a dialog allows to select the best configuration depending on a specific main result: Total solar coverage, Auxiliary production, Domestic Hot Water demand, DHW Solar fraction, Saved CO_2 emission, Solar field production.

One of the problems with this kind of analysis is that an inconsistent parameterization may arise when one variable is studied; this is one (but not the only) of the reasons why all the parameters in a system are correlated as a function of other parameters. This is better explained through an example.

Assume that a system performance is evaluated for different numbers of collectors in the solar field; to have comparable results, the primary loop flow rate should be adapted to the new collector number, and, if primary pump flow rate is different, also pipe diameter should be resized. In this case, TRANSOL will re-evaluate for each simulation these parameters as following:

Primary loop pump flowrate:

$$\dot{Q}_{pump} = \dot{Q}_{test} \cdot N_{col} \cdot A_{col} / N_{serie} \quad (1)$$

where

$\dot{Q}_{test}$ = collector test flowrate

N_{col} = Number of collectors

A_{col} = collector area

N_{serie} = Number of collectors in serie

and then, the pipe internal diameter:

$$PiDi = MAX\left(0{,}0162 \cdot \sqrt{\frac{\dot{Q}_{pump}}{\rho}}; 0{,}012\right) \quad (2)$$

where, ρ is the primary loop fluid density

Similar considerations can be done for heat exchanger UA or pump parasitic power, for example. This set of correlations is not active for those parameters edited by hand by the user, and they allow also to have a consistent simulation in the case that the user wants to make a fast pre evaluation of a system, defining only, for example, the load, location and collector field size.

6. New output options

One of the most powerful tools that TRANSOL incorporates is the so-called “temperature watcher”, which allows the user to analyze the behaviour of one or more variables of the system in detail over a period of time. Depending on the simulated system, a small bitmap of the system is displayed and a huge number of variables can be chosen for each system, mainly temperatures and flow or energy rates. These values can also be exported to be analyzed in separate tools like Excel.

In the following example, the “outlet temperature from collector”, “solar tank top temperature” and “domestic cold water temperature” are selected and displayed on the graph. A zoom feature allows analysing specific hours of the simulation in detail.

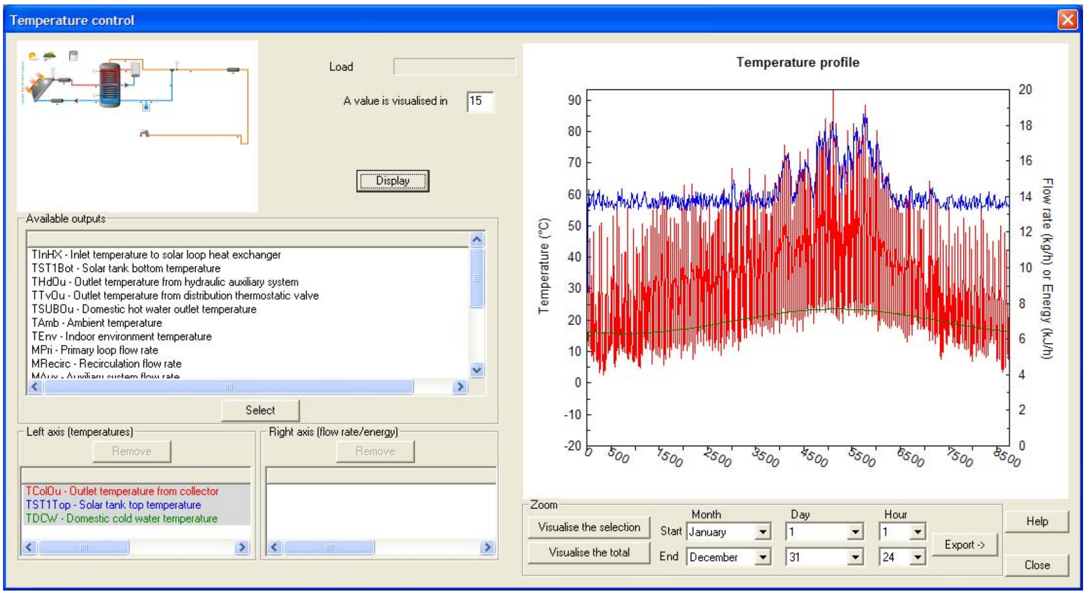
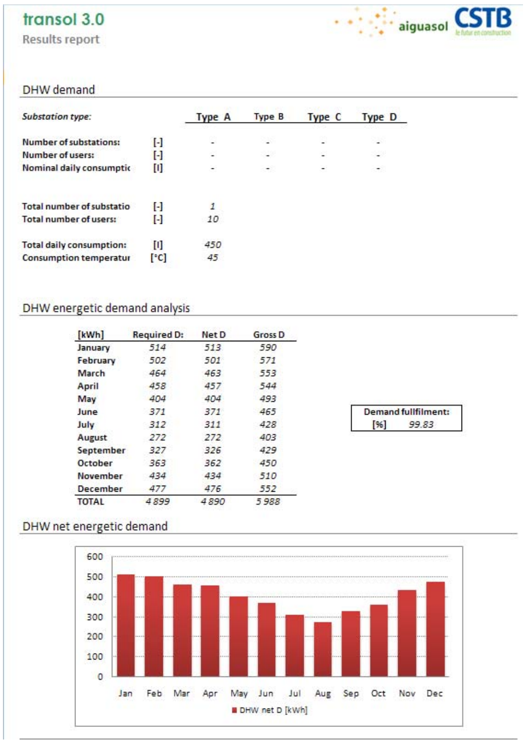


Fig 5. Example of the “temperature watcher” capabilities to analyze results of the simulation

Finally, the results of each simulation are presented in an EXCEL report that includes 7 tabs : General system information, Performance, Efficiency data, Energy balance of the system, Analysis of the looses, Economical analysis and Electrical parasitic consumption. Fig. 6&7 show the demand and the balance of the system simulated as example: Examples of some of the tabs of the report are depicted.

7. Conclusions

Some of the key improvements in the software for the design of solar thermal systems, TRANSOL, version 3, have been presented and analyzed in the paper. New developements most visible on the level where one user interacts, i.e. the Graphical User Interface, with more systems, new and improved data bases, more design options and the possibility to launch parametric runs. At the same time, developers have made a remarkable effort to improve the TRNSYS projects used by TRANSOL, looking for and programming new and more precise components, as well as exploring and using the “macros” capabilities in Simulation Studio to its limits. This has helped to improve TRNSYS 17, too. TRANSOL is now a powerful and flexible tool that can be used all over the world to design solar thermal systems for a wide range of applications and configurations, including industrial heating processes and solar cooling systems.



transsol 3.0

Results report

DHW demand

Substation type:		Type A	Type B	Type C	Type D
Number of substations:	[-]	-	-	-	-
Number of users:	[-]	-	-	-	-
Nominal daily consumptic	[l]	-	-	-	-
Total number of substatio	[-]	1			
Total number of users:	[-]	10			
Total daily consumption:	[l]	450			
Consumption temperatur	[°C]	45			

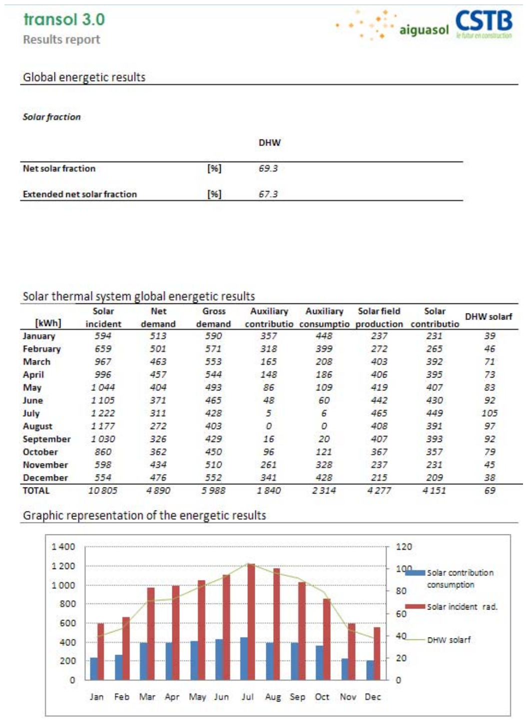
DHW energetic demand analysis

[kWh]	Required D:	Net D	Gross D
January	514	513	590
February	502	501	571
March	464	463	553
April	458	457	544
May	404	404	493
June	371	371	465
July	312	311	428
August	272	272	403
September	327	326	429
October	363	362	450
November	434	434	510
December	477	476	552
TOTAL	4 899	4 890	5 988

Demand fullfilment:
[%] 99.83

DHW net energetic demand

Fig 6. Report, Demand of the system



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Results report

Global energetic results

Solar fraction

		DHW
Net solar fraction	[%]	69.3
Extended net solar fraction	[%]	67.3

Solar thermal system global energetic results

[kWh]	Solar incident	Net demand	Gross demand	Auxiliary contributio	Auxiliary consumptio	Solar field production	Solar contributio	DHW solarf
January	594	513	590	357	448	237	231	39
February	659	501	571	318	399	272	265	46
March	967	463	553	165	208	403	392	71
April	996	457	544	148	186	406	395	73
May	1 044	404	493	86	109	419	407	83
June	1 105	371	465	48	60	442	430	92
July	1 222	311	428	5	6	465	449	105
August	1 177	272	403	0	0	408	391	97
September	1 030	326	429	16	20	407	393	92
October	860	362	450	96	121	367	357	79
November	598	434	510	261	328	237	231	45
December	554	476	552	341	428	215	209	38
TOTAL	10 805	4 890	5 988	1 840	2 314	4 277	4 151	69

Graphic representation of the energetic results

Fig 7. Report, Balance of the system

References

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