COMPARISON OF TWO DIFFERENT METHODS FOR SOLAR COMBISYSTEMS PERFORMANCE TESTING

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Abstract

This work is part of the Combisol project which aims to encourage and to promote an improved quality of solar combisystems. Laboratory determination of primary energy savings of such systems is one of the fields investigated within this project. One commercial solar combisystems has been tested according to two available test methods: a components test approach and a global test approach. The expected results are a better knowledge of the limit of each method and an improvement of them to establish a test method for solar combisystems that is well accepted by manufacturers, and can be used by CEN TC 312 to complete the existing standards.

1. Introduction

Depending on climatic conditions, today's solar combisystems provide nearly 20 to 50 % of the total heat demand of a modern standard single family house. Until now, assessments of real energy savings achieved by individual solar thermal systems are very scarce, especially for solar combisystems. This is an obstacle for a good global evaluation of the impact of such systems in national or European energy policies. Methodology based on a common European and /or international agreement is still lacking. CombiSol is a project supported by Intelligent Energy Europe program. The aims of this project are to encourage and to promote an improved quality of solar combisystems. Laboratory determination of primary energy savings of such systems is one of the fields investigated within this project.

2. Methods

The objective is to develop methods for the determination of primary energy savings achieved by solar combisystems. In principle the thermal performance can be determined with two approaches presented below.

2.1. The component approach: CTSS method

It consists on a physical test of the main components of the solar combisystems [3]: the heat store is tested according to CEN 12977-3 and the controller according to prEN/TS 12977-5. During the tests, the characteristic parameters for each component are determined, and then a complete model of the system is built including the results of the components test. The application range of the CTSS method is very flexible because of its component-oriented approach. It is possible to apply the method on nearly every system configuration, including solar combisystems. The performance can be determined for different reference conditions (meteorological data, load profiles) by means of annual system simulation. This test method has been validated through real performance tests. The performance indicator is the energy use of the auxiliary heater which implies that the solar combisystem is always tested in combination with the heater. One of the major advantages is the feasibility of changing components during the test phase, but on the other hand it requires a long testing period and there is no opportunity to examine the system control in real, because interconnections between the components are just simulated.

2.2. The global approach : the Short Cycle System Performance Test

The Short Cycle System Performance Test (SCSPT) is based on the CCT method [2; 4; 5; 6]. The complete system is set up in an indoor test facility. The building is simulated on-line so that the heat supply is controlled via the regulation of the solar combisystem and therefore provides the right flow rates and temperatures. This ensures that all system functions may be assessed, which is one major advantage of this kind of test method.

The testing consists of a 32 hours preconditioning phase, a 12 days core phase and an 8 hours discharge of the storage tank (Table 1.).

Table 1. The different phases of the test sequence.

N°	Phase	Duration (Hrs)	Description
1	Initial conditioning	0	Conditioning of the storage to 20°C (without solar and auxiliary energy).
2	Primary conditioning	8	Upper and lower part of the storage has to be brought to reasonnable temperatures. Upper part is heated to the auxiliary set point temperature.
3	Secondary conditioning	24	Final conditioning with the simulation of one winter day. It permits to bring the storage to an energy level which corresponds to the last day of the core phase.
4	Core phase	288	12 test sequence days with climate and charge simulation.
5	Final discharge	8	Discharge of the storage tank.

All days together represent the average weather and load conditions of a whole year. During the elaboration phase of the SCSPT, weather data have been obtained in an iterative optimization process (Fig. 1.), in which the predicted annual values of a reference system, evaluated from a 12 days simulation [1], are compared with the values of an annual system simulation. The predicted results from the 12 days simulation have to correspond to the results of the annual simulation in terms of space heating demand, domestic hot water demand and internal energy of the storage. The annual performance of the system is predicted by extrapolating the 12 days test results to a complete year.

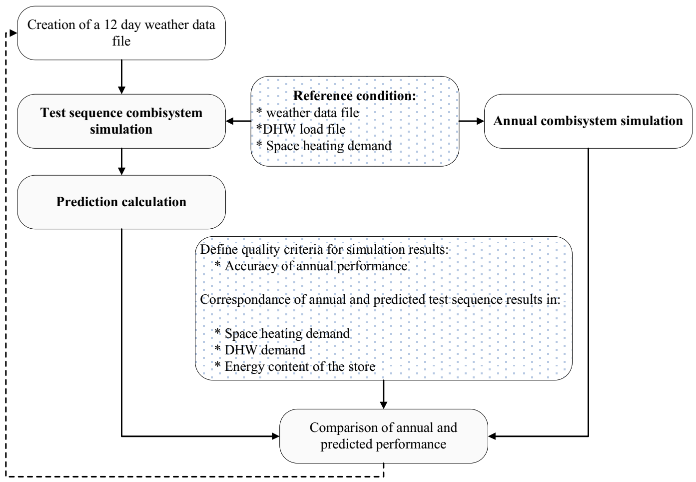

Fig. 1. Iterative process used

3. The test benchs

3.1 Description of the semi virtual test bench from INES

The semi-virtual test bench (Fig. 2.) consists mainly in:

- a central heating room able to supply hot (54 kW at 180°C) and cold (150 kW at -10°C) water on two distribution loops,
- two test modules of 25 kW and one 50 kW able to reproduce the desired dynamical thermal loads within these range of temperature.

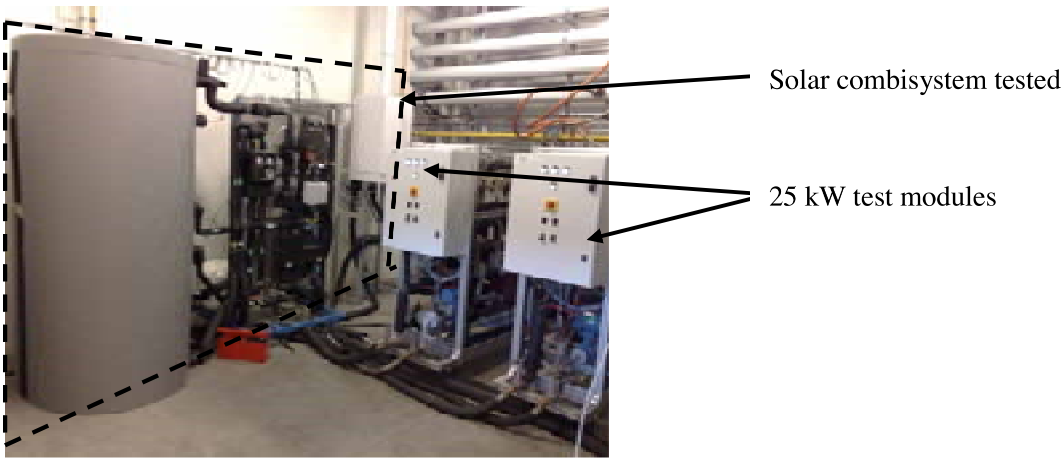

Fig.2. INES semi virtual test Bench

This test bench allows the test of various heating or cooling systems for different applications: single family house, small industry, small tertiary or small collective housing by creating a semi-virtual environment around the tested system. The operating conditions of each module are controlled by a TRNSYS 16 [8] numerical model.

In this study, the climatic conditions, the collectors, the domestic hot water demand and the building are emulated.

3.2 Description of the controller test bench from ITW

In order to perform the test sequences according to prEN/TS 12977-5, the test facility consists of a new developed input/output-emulator which is connected to the controller. For communication, the emulator is connected to a PC via a serial port. The PC is equipped with specific software, providing temperature profiles through the emulator to the relevant sensor terminals of the controller. At the same time the emulator transfers the response of the controller to the PC.

For each single step of a temperature profile that is transferred to the controller by means of the emulator, the status of all outputs, whether active or inactive is detected and transferred back to the PC. In parallel to the temperature profile the corresponding response of the controller is stored in a data file. In case of controllers featuring variable mass flows, e. g. by pulsing the circulation pump, a pump installed in a hydraulic circuit is connected to the particular output. To adjust the pressure drop of the hydraulic circuit according to the real pressure drop of the collector loop and to flush the device the circuit is equipped with several valves. In addition, manometers and a magnetic-inductive flow meter are mounted.

3.3 Description of the store test bench from ITW

In order to perform the test sequences, according to CEN 12977-3, the test facility consists of four modules. Two modules of 22kW are used for charging and two modules of 15kW are used for discharging the store. The charge modules can be used for charging with constant temperature or constant thermal power. The discharge modules are supplied with cold water from a 750 litres buffer store.

4. System tested

One commercial solar combisystem has been tested according to these two approaches. In accordance with the Combisol project, the generic hydraulic system [7] concept of the solar combisystem tested is shown in Fig. 3. Charging the heat storage by solar energy is possible and in principle is independent on the remaining hydraulic system. Solar collector loop typically is switched on/off based on temperature difference between collector temperature and temperature at the bottom of the heat storage. The immersed DHW heat exchanger cross the whole storage tank from the bottom (solar volume) to the top (auxiliary volume) The auxiliary volume at the top of the heat storage, needs to be kept at a sufficient high temperature by the auxiliary heater, if the input of solar energy is not sufficient. Space heating loop, heat storage and auxiliary heater are arranged in one line. Depending on the space heating return temperature and heat storage temperature the heat storage is bypassed or space heating flow is preheated by solar heated water in the heat storage and finally heated to the set temperature by the auxiliary heater. Therefore the auxiliary heater is operating within the full range of power: between almost zero and maximum power.

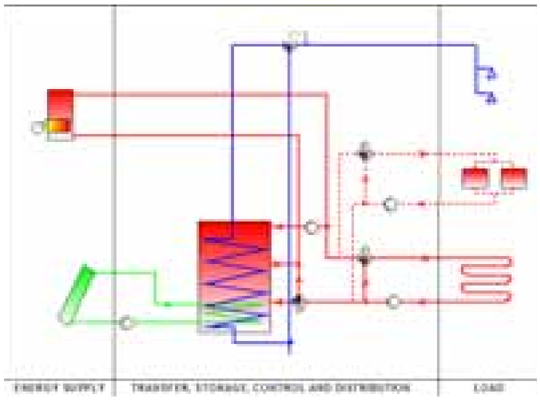

Fig. 3. Hydraulic scheme of the solar combisystem tested

5. Comparison process

In order to be able to compare results from these two experiments, the boundaries conditions used for the global approach were applied for the simulations of the component approach (Fig. 4.).

These conditions are: the weather data file, the heating loads, the collector type, the collector area and the Domestic Hot Water loads.

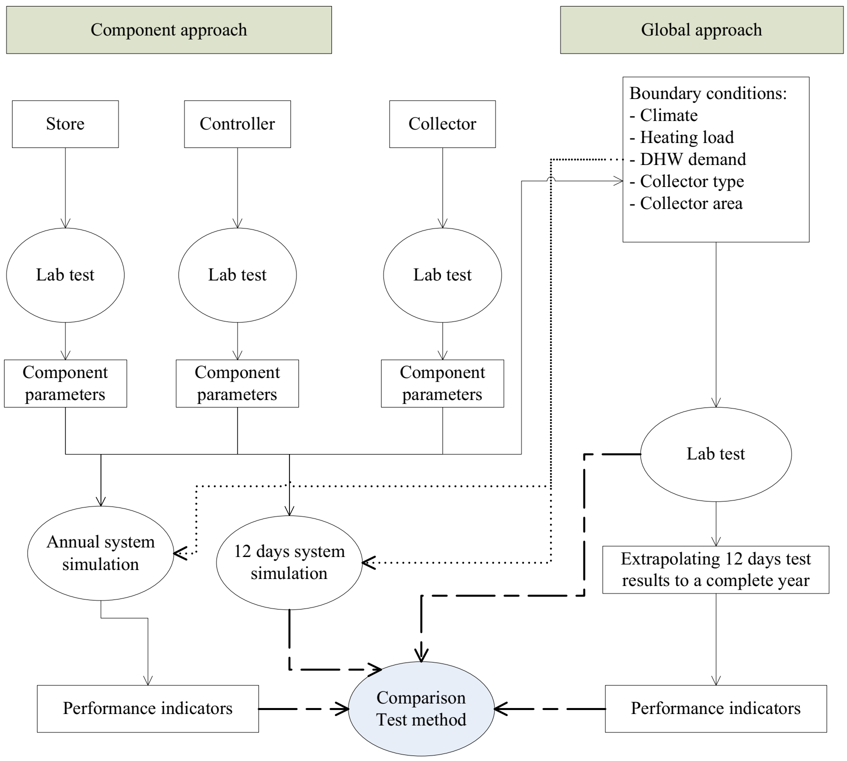

Fig. 4. Procedure for determination of quality criteria with these two methods

Based on this, the comparisons between the two methods were done for 12 days test sequence and annual simulations.

6. Results

6.1 12-days test sequence

Once the store and the controller tests were done at ITW, a TRNSYS 16 model of the solar combisystem has been built according to the one that has been tested at INES for the global approach. The different insulated pipes between the components of the system have been modelled (Fig. 2.). Moreover the testing room temperature, the set up temperatures for the building and the domestic hot water of the TRNSYS 16 model have been adjusted to the experimental measurements realized on the INES test bench.

Table 2. presents for both approaches the energies production and emission on the different loops of the system. For the SCSPT the results are experimental results, for the CTSS the results are TRNSYS 16 simulation results.

Table 2. Energies on the different loops for the 12-days test sequence

12 days test results				
	Heating loop	**DHW loop**	**Solar loop**	**Back-up consumption (water side)**
	[kWh]	[kWh]	[kWh]	[kWh]
SCSPT method	295.9	102	158.6	314.4
CTSS method	288.9	108	152.5	296
Difference (%)	2.4%	-5.9%	3.8%	5.9%

Some differences exist between the results of these two approaches. The absolute deviations are in the range of 2.4% to 5.9%. The lower deviation is for the heating loop with 2.4% and the maximum for the back-up consumption and the DHW loop with 5.9%. Except for the DHW, the results from the global approach are higher than those from the component approach.

The deviations can be explained by disparities between the experiment and the simulation:

- The heating law used within the component approach came from measurement obtained on the INES test bench but the heating law simulated depends only on the ambient temperature. In the global approach the heating law is calculated by the boiler controller and is based on ambient and room temperatures.
- On the real system, a hydraulic decoupling bottle is installed but it is not modelled within TRNSYS. This increases heat losses of the system and hence the auxiliary energy demand (esp. in combination with the boiler pump running at most times).
- Concerning the DHW loop, the measurement realized at INES show that the domestic hot water temperature is within a range of 44°C to 52°C with a mean value of 48°C. Moreover due to cold water stagnation between two demands, for low flow rate (lower than 100 kg/hr) the cold water temperature can be higher than the one expected.

Otherwise a boiler, delivered by the manufacturer, is part of the system in the SCSP test. For the CTSS method an ideal boiler of 100% efficiency is used.

Once the TRNSYS model has been adjusted for 12-days test sequence, annual simulation has been done.

6.2 Annual results

For the global approach the annual results are extrapolated from the 12 days test sequence. The relation used to extrapolate the results is:

$$E_{annual}^{loop} = \frac{E_{12\ days}^{loop}}{12} .365 \tag{1}$$

For the component approach annual TRNSYS 16 simulation are done using the same deck as before with annual climatic conditions and domestic hot water demand.

Table 3. presents for both approaches the energies production and emission on the different loops of the system and the Fsav.

Table 3. Annual energies on the different loops

Annual results					
	Heating loop	**DHW loop**	**Solar loop**	**Back-up consumption (water side)**	**Fsav**
	[kWh]	[kWh]	[kWh]	[kWh]	[%]
SCSPT method	9000.3	3103.7	4824.1	9563	21.4%
CTSS method	9034.2	3287.9	4392.3	9488.8	22.0%
Difference (%)	-0.4%	-5.9%	9.0%	0.8%	-2.9%

Lower deviations are noted between the global and the component approaches for the heating loop and the back-up consumption. Higher deviation is noted for the solar loop. For the domestic hot water loop the deviation is in the same range of error.

The solar fraction, Fsav, is calculated using:

- a boiler with an efficiency of 85%
- the reference energy used in IEA Solar Heating & Cooling programme Task 32 [4].

$$E_{ref} = 14313\ kWh \tag{2}$$

Even the deviation increase for the solar loop the comparison of these two approaches on a real solar combisystem gives good agreement.

7. Conclusion

This work, part of the Combisol project, concerns the laboratory determination of primary energy savings of solar combisystems. A comparison of the component and global approaches has been made on one solar combisystem. The results of this comparison are promising. Some deviation between the two methods exist but can be explain by the differences between the TRNSYS model realized and the real system installed on the INES test bench.

At the moment, the CTSS method is more suitable:

- to cover a complete system range

• to extrapolate results to other climate, heating load or collectors

On the other way, the SCSPT method is well adapted to:

• test prefabricated systems

• take into account the thermal losses of the system

• take into account the global control command of the system

To increase the capabilities of the SCSPT method, one study is underway to be able to extrapolate results from one experimental test.

In order to have a better knowledge of the limit of each method and to propose an improvement of them, a new solar combisystem with another hydraulic scheme will be tested according to the same methodology.

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Acknowledgements

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