WP4-D2.3a and WP4-D2.3c

TEST METHODS FOR VARIABLE FLOW CONTROLLERS AND COMPLETE SYSTEM CONTROLLERS

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CONTENTS

The document describes test methods for controllers for thermal solar systems.
Beside the thermal solar system modern multi-function controllers in parallel often control the entire heating system of a building.
As examples for the test methods the document summarises the procedures to test and evaluate multi-function controllers featuring:

- Control algorithms to archive variable flow by adjusting the power of the circulation pump in accordance to a given temperature or a certain temperature difference.

- Control algorithms managing more than controlling one solar circuit, here in addition to control the return flow of a space heating system for the usage of solar thermal energy.

SUMMARY

Over the past years significant attention regarding thermal solar systems was dedicated to thermal collectors and hot water stores. As will be outlined hereafter, beside these key components there is a significant need to investigate the behaviour of controllers and control equipment and to adapt the test methods for these components to the requirements of modern controllers and accessories. With the presented methods and test facility a powerful tool for testing different kinds of controllers, not only for solar applications is available.
The aim of the test and evaluation procedures described in this document is to characterise the behaviour of electronic controllers, mainly applied within thermal solar systems and the remaining heating system.

The test methods and the set-up of the test facility described in this document enable detailed investigations of nearly all kinds of controllers and control algorithms. As examples the variation of flows on the two sides of an external heat exchanger when charging a heat store and a control algorithm implemented in a controller to remove heat from a combistore for space heating purposes is summarised. Both examples are derived from testing of so-called ‘multi-function’ controllers, which in general manage more than controlling a collector circuit within a thermal solar system. Typically multi-function controllers feature more than one temperature differential algorithm or include other control algorithms than simple differential thermostats.

With respect to multi-function controllers and testing of further control equipment, the introduced methods will be one basis for the upcoming standard EN TS 12977-5, replacing ENV 12977-2, Annex B.

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1 Introduction

Modern multi-function controllers are used to control different heat sources with varying numbers and kinds of heat loads, depending on time and external parameters such as weather conditions and user demands. For quality assurance of the total heating system and performance prediction particularly of a thermal solar system, the knowledge of the *real* controller behaviour is as important as to know the influential collector and store parameters.
One standardised way to determine the performance of thermal solar systems is based on **c**omponent **t**esting and **s**ystem **s**imulation. To apply the CTSS[1] method a detailed determination of all relevant component parameters, e. g. for the collector, the store and the implementation of all relevant algorithms, features and parameters of the control equipment is mandatory. Together with the collector and store parameters, that are determined according to EN 12975-2 and EN 12977-3 respectively, a system description including control parameters based on component testing is much more complete. An entire set of parameters forms an excellent basis for performance prediction and evaluation of thermal solar systems according to the CTSS method, which is standardised in EN TS 12977-2 /ENV05/.
The approach of the CTSS method is to test the solar collector, the store, the controller and other selected components separately and to carry out system simulations for defined boundary conditions using the determined parameters. Until now, due to the lack of component parameters for controllers, control equipment and actuators like pumps and valves from appropriate testing, particularly with respect to these components quite often the parameters delivered by the manufacturer or final suppliers have to be used. Data reported by the manufacturer or final supplier typically intend to represent nominal and therefore *ideal* values of the respective parameters. Investigations made in practise and by testing controllers and control equipment reveal that the real parameters and behaviour frequently deviate from the intended ones. Hence, in order to improve the quality of the performance predictions, in addition to the parameters of the collectors and stores, parameters determined from testing of controllers and favourable all relevant control equipment as actuators and supplementary active components should be used as a basis of the performance predictions. For the CTSS method together with the hydraulic scheme of the system and the control strategies the parameters have to be implemented in a simulation program like TRNSYS[2].

Supplementary to the improvements with regard to performance prediction of thermal solar systems by means of computer simulation, quality assurance and the reliability of the control equipment will be enhanced. Beside the CTSS method the testing of controllers enables detailed investigations of specific control parameters that can be used for the development of controllers and control algorithms. Not at least the detection of malfunctions of control equipment installed in the field is possible.
Testing of controllers and control equipment will be defined in prEN TS 12977-5, ‘Performance test methods for control equipment’ and will presumably be adopted in 2008.
Beside controller testing in prEN TS 12977-5 procedures to test different kinds of sensors and actuators are included.

Before focusing on the new developed test methods and their advantages, the European Standard ENV 12977-2:2001, Annex B and its limits will be summarised. Until prEN TS 12977-5 is officially established, ENV 12977-2:2001, Annex B remains the standard for controller testing.

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[1] **C**omponent **T**esting - **S**ystem **S**imulation
[2] **Tr**ansient **Sy**stem **S**imulation Program

2 Controller testing according to ENV 12977-2, Annex B

For the time being testing the function of controllers and temperature sensors is described in the European Standard ENV 12977-2: 2001, Annex B, 'Testing of solar loop controllers with temperature sensors'. In practice with regard to controllers the test procedures described in this standard are only applicable to simple differential thermostats. Hence, due to the development and market share of so-called *multi-function* controllers for solar combisystems, virtually the standard is out of date.

Nevertheless, in the following ENV 12977-2: 2001, Annex B is summarised. In general the standard is divided into a mandatory test and an optional part:

2.1 Mandatory Test

Testing of the capability of temperature sensors to resist high temperatures. This test is mainly dedicated to sensors installed inside solar collectors, which are frequently exposed to the high stagnation temperatures of the collectors.

Within the mandatory test the capability of temperature sensors to resist high temperatures as well as possible differences of the sensor's accuracy before and after the exposure should be determined. If the measured values after exposure differ by less than 1 K from the corresponding value before, the sensor may be accepted.

In addition a visual inspection of all sensor parts that had been exposed to the high temperatures is carried out in order to check if they were demanded during the test. Decompositions due to temperature influence may be included in the test report.

2.2 Optional test

Beside the mandatory test, which is dealing with the capability of the sensors to resist to extreme operation condition or temperatures respectively, optional test procedures aim on function testing of controllers and their sensitivity on variations of the nominal mains voltage.

In detail the optional tests are:

- Testing of the functioning of differential thermostats with the objective to investigate starting and stopping of pumps or switching of valves, depending on the temperature differences and temperature levels within the system.
- Comparison of all indications and functions with the guidance delivered by the manufacturer.
- Documentation of the sensitivity of the starting and stopping differentials within a certain range of the nominal mains voltage (230 V –10 % to 230 V +6 %).

According to the specifications in ENV 12977-2, Annex B the optional test of differential thermostats may be carried out by:

- locating the temperature sensors in temperature calibrators or temperature bathes or
- simulating the resistors of the temperature sensors by means of a simulation box, providing adjustable resistance values to the controller.

When testing a differential thermostat according to ENV 12977-2, Annex B, the temperature calibrator or simulation box should be applied for different temperatures, e.g. store temperatures of 20 °C, 50 °C and 90 °C. The optional test of the mains voltage dependency on the behaviour of the controller should be carried out for each differential thermostat function. For both, 207 V (230V –10 %) and 244 V (230V +6 %) at least three different temperatures, or temperature differences respectively should be investigated.

For so-called *multi-function* controllers each operational situation should be tested separately. However, due to increasingly complex control strategies, particularly implemented within multi-function controllers for solar combisystems, the described test method for controllers is hardly to be applied for devices common at present.

2.3 Limits of ENV 12977-2:2001, Annex B

Annex B of the former version of ENV 12977-2, issued in 2001, is dedicated to temperature sensor testing and function testing of simple differential thermostats. As mentioned above, with respect to modern multi-function controllers in practice the procedures given in ENV 12977-2, Annex B are hardly applicable. Since the standard was developed in the middle of the nineties, it mainly focuses on controllers for small-scale domestic hot water systems marketed at that time. In the 90th the temperatures occurring during stagnation of a thermal solar system in most cases did not cause serious problems. Due to the further development of solar combisystems and the introduction of solar collectors with stagnation temperatures around 300 °C, the thermal load on the temperature sensors, particularly in the collectors, raised rapidly.

Besides demanding requirements on the temperature sensors, the integration of the solar and conventional part of a heating system for hot water preparation and space heating, frequently in combination with complex heat distribution systems results in multi-function controllers. Only mentioned in a short note within ENV 12977-2, Annex B, actually the attention has to be turned towards those types of controllers and their specific functions and options.

With respect to increasing working and stagnation temperatures of modern collectors as well as increasing stagnation periods particularly in combisystems, in the new developed part of the EN 12977 series beside an advanced method to test multi-function controllers, the temperature requirements and the time exposing the temperature sensors to high temperatures will be adapted. Testing of controllers and control equipment will be defined in prEN TS 12977-5, ‘Performance test methods for control equipment’ which will presumably be adopted in 2008.

Before describing the test procedures on the basis of examples to evaluate control algorithms for varying the flow within a hydraulic loop or control functions beside the solar loop, a test facility suitable for testing nearly all kind of multi-function controllers will be described.

3 Test facility for multi-function controllers

Due to increasingly complex control strategies, particularly implemented within multi-function controllers for solar combisystems, the hitherto available test method for controllers (ENV 12977-2, Annex B) had to be extended. For this purpose a computer based test facility featuring an input/output-emulator between the controller and a PC has been developed. The emulator generates varying resistance values as input signals for the controller and records the status of the different outputs as its response. The entire test facility will be described hereafter.

3.1 Set-up of the test facility

In order to test multi-function controllers used in common solar hot water or combisystems, an advanced test method and a test facility as shown in Fig. 1 has been developed. The target was to operate (and test) the controllers as close as possible in the way as they are operated in real systems.

The test facility mainly consists of a new developed input/output-emulator, which is connected to the sensor and the output terminals[3] of the controller to be tested. Furthermore 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. Due to this the task of the input/output-emulator is twofold:

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[3] In this context an option (e.g. plug) for connecting electrical inputs and outputs is considered as a terminal.

Depending on the test sequence supplied by the PC, it provides varying resistance values as inputs for the controller. The resistance values are generated by means of pulse-wide-modulation. At present values between approx. 10 Ω and 19 kΩ can be generated. This range enables to cover Pt 100, Pt 500 and Pt 1000 temperature sensors as well as other common PTC and NTC sensors[4].
On the other hand the emulator is connected to the switchable outputs of the controller and recognises all controller responses like switching of pumps, relays and valves. For each single step of a temperature profile that is transferred via the emulator to the controller, the status of all outputs, whether they are active or inactive is detected and transferred back to the PC.
Together with the corresponding temperature profile the response of the controller is stored in a data file. One emulator is able to serve up to four sensor terminals of the controller. In addition it provides four lines to be connected to switchable outputs of the controller. To operate pumps and valves most multi-function controllers serve 230 V alternating current (AC). Therefore the emulator is designed for being directly connected to those outputs. In case the controller features relays without internal power source, an external source might be connected. Using additional serial ports of the PC, a second or third emulator can be connected.

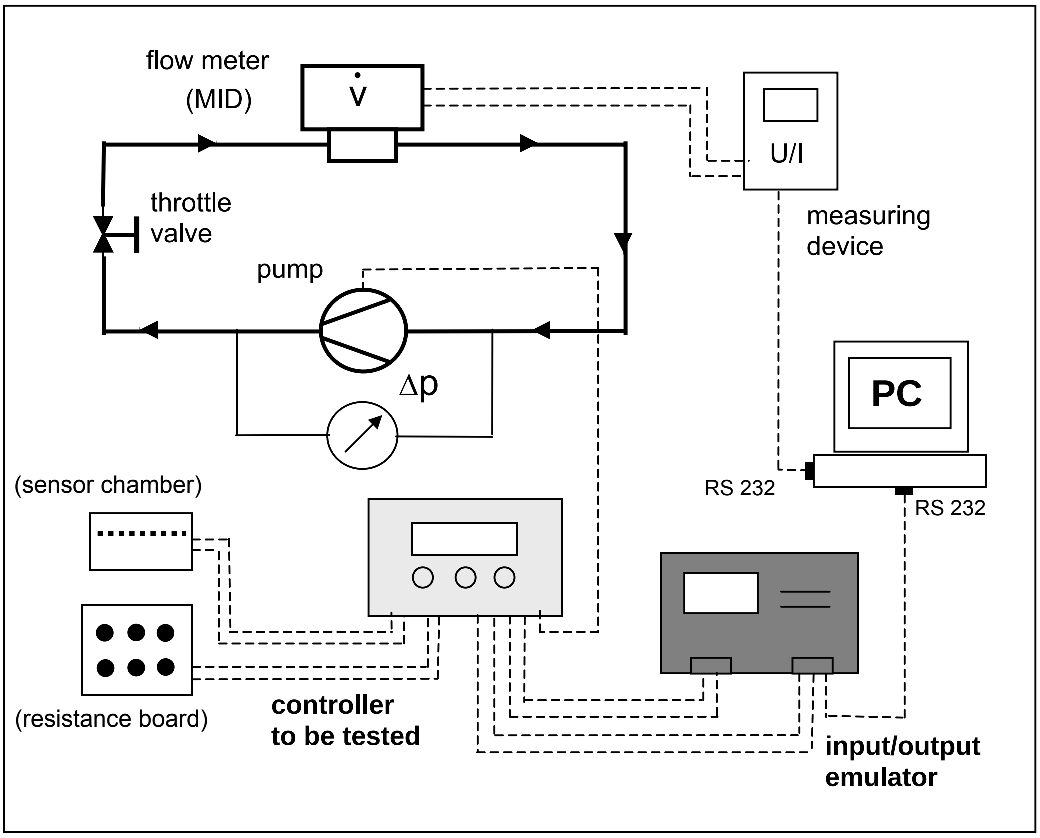

Figure 1: General layout of the test facility for multi-function controllers, options in parenthesis

In the case of controllers featuring variable mass flows, as will be discussed later, a pump installed in a hydraulic circuit is connected to the particular output of the controller, see Fig. 1. To adjust the pressure drop of the hydraulic circuit in accordance to the pressure drop of a collector loop or to flush the device, the circuit is equipped with several valves. In Fig. 1 only the main valve required for adjusting the pressure drop is shown.

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[4] PTC/NTC sensors are temperature sensors with positive, respectively negative temperature coefficient.

In addition manometers and an electromagnetic flow meter (MID) are mounted. Usually the circuit is operated with water, but also other fluids are possible. After conditioning of the signals of the flow meter by means of a measuring device, the data are transferred to the PC.
Together with the temperature profiles and the status of all controller outputs, the actual flow is recorded in a data file. In order to investigate the influence of e.g. the control algorithm of a speed controlled pump on the energy consumption, supplementary the power consumption of the pump is recorded.

4 The test procedure in general

In the following section a general description of the test procedure of a multi-function controller of a solar combisystem is given. Apart from the test procedures, represented by different temperature profiles provided by the PC via the input/output emulator to the controller, the preparation of the test facility before performing a test is always the same, see Fig. 2.

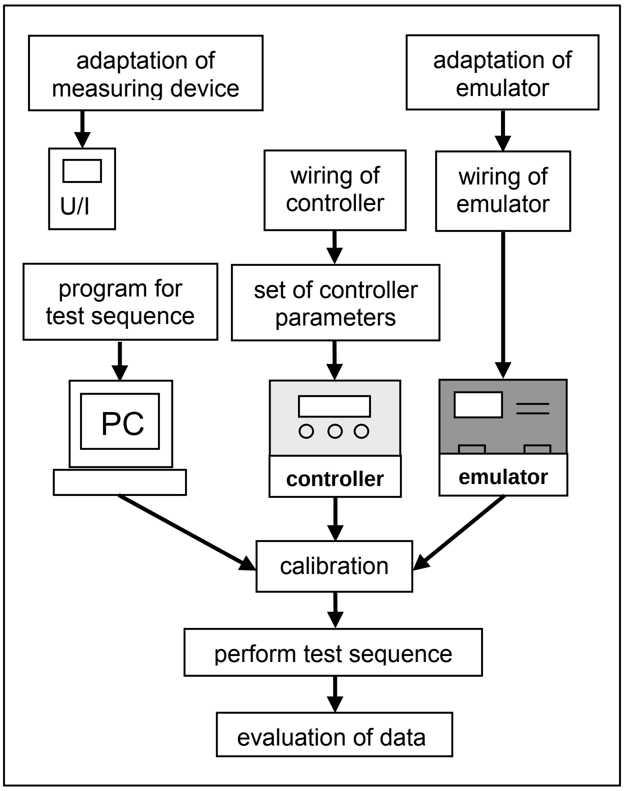

Figure 2: Preparation of the test facility and performing a test

4.1 Adaptation of the emulator and measuring devices

According to the specific needs of each controller to be investigated, the set-up of the test facility has to be adapted. Regarding the resistance values that would be provided by the original sensors within a specified temperature range, at first a suitable set of variable resistors has to be connected to the emulator. In general sensors with resistance values up to approx. 19 kΩ can be simulated while resistance values in a range of 0.1 up to 5 kΩ are most common. As mentioned before, this range covers all Pt 100, Pt 500, Pt 1000 and most other PTC as well as common NTC sensors. If necessary, additional variable resistors above 19 kΩ can be connected.
In most cases for input and output purposes of a multi-function controller the number and the functions of terminals provided by one emulator (4 inputs and 4 outputs) meets the needs.

4.2 Wiring of controller, emulator and PC

After the emulator is equipped with suitable variable resistors and all relevant outputs of the controller have been defined, the emulator and optional measuring devices are connected to the PC using RS 232 ports. In the following the 'sensor resistors' of the emulator are connected to the terminals for the temperature sensors of the controller - the switchable outputs of the controller are connected to the corresponding terminals of the emulator or additional devices like the pump in the hydraulic circuit respectively.

Requirements concerning the wiring and specifications for cables in the manufacturers guidelines should not be disregarded. All sensor terminals have to be used in accordance to the installation in the field and should be supplied with realistic values. If not occupied by a 'sensor resistor' of the emulator, additional resistors with fixed or variable values have to be connected. Alternatively real sensors might be used. When connecting real sensors it has to be considered, that the signals of the sensors might change with the surrounding conditions of the test facility and that this might influence the test results. A convenient option to the usage of real sensors is to use fixed or variable resistors connected to terminals not occupied by the emulator. Variable resistors enable an adjustment of additional temperatures, e.g. the 'ambient temperature'. Finally the emulator, additional devices and the controller are connected to the power supply.

To ensure stable and steady state conditions during the test sequences, the controller and the entire test facility should be started up at least 6 h before performing a test and should remain switched on during standstill and between different test sequences.

If the mains voltage supply is unstable and significant fluctuations (e. g. ± 2 V) of the nominal value might occur, the power supply has to be monitored and recorded.

4.3 Setting of controller parameters

All parameters and settings of the controller have to be checked carefully and, if necessary, have to be adjusted. For common controller tests the parameter settings specified within the documentation or otherwise defined by the manufacturer or final supplier are used. If parameters are not specified, default values are retained. For special investigations the settings might be adapted according to particular specifications. Each set of parameters has to be documented and in addition stored in the corresponding software and data files for the test sequence.

4.4 Calibration of the input/output-emulator

Before performing a test sequence, the variable resistors of the emulator have to be calibrated:

First of all the resistance range of each sensor is adjusted by operating two potentiometers. Depending on the sensor, weather a positive (PTC) or negative (NTC) temperature coefficient has to be emulated, one potentiometer determines the absolute level and the other the operation range of each particular sensor. Within the defined ranges the electronic equipment enables the emulation of nearly any resistance value. For each single step, respectively temperature value, the PC provides the corresponding resistance value to the emulator. To calibrate the controlling signals from the PC for each particular resistor and to the controller to be tested, the emulator is driven through the complete temperature range of each respective sensor in manual operation. The corresponding temperatures displayed by the controller are monitored. Together with the settings of the emulator, they are recorded and stored in a data file. Dividing the temperature range into discrete steps of each 10 % is sufficient. To minimise the influence of hysteresis effects the calibration routine is performed twice, with increasing and with decreasing values. Usually by accomplishing a third order polynomial regression the constants needed to describe the sensors resistor characteristics by the PC are determined. The constants are adopted within the corresponding control and measuring software.

4.5 Defining of test sequences

After adjusting and calibration of the hardware the specific procedure to test a particular feature of a controller has to be selected from the software. At ITW, University of Stuttgart the software package LabVIEW® distributed by National Instruments is used.

Depending on the time constants of the sensors and the time span the controller measures and processes the resistance values to update the status of its outputs, the time steps of the temperature profiles and the amount of changing the resistors have to be defined. Usually the time steps for changing the temperatures (resistance values) are in a range of 5 to 10 s. The response of the controller is measured permanently.

Even though depending on particular investigations, the changes of the resistors for each single step typically corresponds to temperature differences between 0.1 and 1.0 K.

4.6 Evaluation of measured data

During a test sequence, all important data like control signals, temperatures, the response of the controller to be tested and optional a volume flow rate are stored in a data file using ASCII format. In parallel during the test all relevant values are displayed on a PC screen.

After performing a test sequence, the data can be evaluated using spreadsheet programs (e.g. Microcal Origin®, Microsoft Excel®). The data contain information about the response of the controller and its behaviour caused by defined temperature profiles, comparable to investigations carried out in real systems. All kinds of thermostat functions can be inspected. By calculating the temperature differences from appropriate sensors out of the measured data and plotting the results together with the corresponding response of the controller, the real behaviour as well as extraordinary effects of the control equipment becomes visible. An example of a line graph showing the variable flow within the collector circuit on the primary side of an external heat exchanger and the variation of the flow on the secondary side of the heat exchanger is presented in Figure 3, chapter 6.

5 Test sequences for multi function controllers

Most of the control strategies and options implemented in multi-function controllers are based on temperature measurements and calculation of temperature differences. Simple solar loop controllers only use the difference between the collector and the store temperature. Beside those simple solar loop controllers, additional functions, e. g. enabling and disabling an auxiliary heater as well as complex algorithms calculating the set temperatures of a space heating system depending on the outdoor temperature and characteristics of the building can be implemented in a controller. In most cases the calculation of temperature differences are based on measured values or the comparison of a fixed value, like a set or threshold temperature with a measured one. Temperature differences constitute the predominant information for most controller responses. Even though the principles to control heating systems in general are quite simple, experience shows, that testing and validating of control algorithms and controller behaviour is necessary. In order to investigate all kinds of different control strategies and options of multi-function controllers, a large number of adapted test sequences might be defined. Table 1 shows examples of common algorithms and corresponding test sequences for multi-function controllers. In the framework of this document the focus is directed to controllers enabling variable flow(s) by adjusting the pump(s), e. g. to match a certain temperature or temperature difference. On the other hand controllers managing more than the thermal solar system, for instance in addition driving a valve to pass or to bypass a solar heated store in accordance to the desired flow and the actual return temperature of a space heating loop as well as the actual temperature in the solar store is observed. In Table 1 the two examples discussed in the following are printed in bolt letters.

Algorithm to be tested	**Temperature profiles to be supplied to the controller and aspect(s) to be investigated**
Changing of the status of a solar loop pump in dependence on the temperature differences between collector and store.	For different store temperatures, e. g. every 10 °C, the value of the collector temperature is increased until starting and decreased until stopping of the pump.
Adjusting of flow rates by means of controlling of pumps, e.g. according to system temperatures.	**According to the specifications of the influencing parameters the variation of the pump speeds and volume flows have to be monitored. In the case of temperature dependency of the pump speed, the temperature should be varied, e. g. every 0.1 °C within the specified range. The volume flow and the corresponding power and energy consumption are monitored permanently.**
Switching of valves	Varying of the corresponding temperatures with increasing and decreasing values until switching of valves is observed.
Adjustment of flow mixers and flow diverters.	For the testing of flow mixers the temperatures and, if relevant, the ratios of the incoming flow streams have to be varied, e. g. every 5-10 °C and every 5-10 % respectively. The temperature of the resulting (mixed flow) has to be monitored. For flow diverters the volume flows of the different streams have to be monitored in accordance to the values allowed by the controller.
Thermostat function for auxiliary heaters.	For different set-temperatures, increasing and decreasing of the temperature value of the corresponding (store) sensor until starting and stopping of the auxiliary heater.
Controlling of the auxiliary heater based on variable temperatures of the store and space heating loop and depending on the outdoor temperature.	Varying of the corresponding sensors (e.g. store, flow, return temperature) with increasing and decreasing temperature values until enabling and disabling of the auxiliary heater. The behaviour shall be monitored for different outdoor temperatures, e.g. in steps of 5 K.
Controlling of a three-way valve directing the return flow of a space heating loop through or bypassing a solar heated store	**For different store temperatures, e. g. every 10 °C, the value of the return temperature of the space heating loop is varied by increased and decreased values until switching of the corresponding three-way valve is observed.**
Hot water circulation according the desired temperature and time	Varying of the corresponding temperature with increasing and decreasing values depending on the set-temperature and considering of the time functions until switching of the pump.

Table. 1: Examples of common control algorithms and corresponding test sequences for multi-function controllers. Note that only brief descriptions without details are given. Controller functions based on similar algorithms might be tested accordingly.

If others than temperature sensors are used, e.g. irradiance or pressure sensors or whenever dependencies to arbitrary components or parameters should cause a response of an other component, adequate test methods have to be applied.

6 Examples of testing multi-function controllers

In the following results from controller testing are presented. In order to underline the necessity and the relevance of the introduced controller test method, examples showing objectionable behaviour of controllers are chosen. It should be noted, that the function of numerous controllers was tested without any serious failure in the behaviour or within the electronic parts of the controller. Nevertheless at least for some systems the control equipment seems to be the weak point.

6.1 Adjustment of flow rate(s) by the controller

The first example shows the adjustment of the flow rates on the primary and the secondary side of a heat exchanger installed within a solar loop to charge a store of a combisystem by heat delivered from the thermal solar collector, see Fig.3. To modify the flow rates, pulsing of both pumps is provided. For the collector loop this results in flow rates between 150 and 250 l/h, for the store loop between 120 and 200 l/h respectively. While the controller settings enable a variability of the fractional operation time of the pumps between 30 and 100 % by modulation of the pulse-width, the range of the real flow rates in both cases is about 60 to 100 %. Such observations have been made for several other combinations of controllers and pumps.

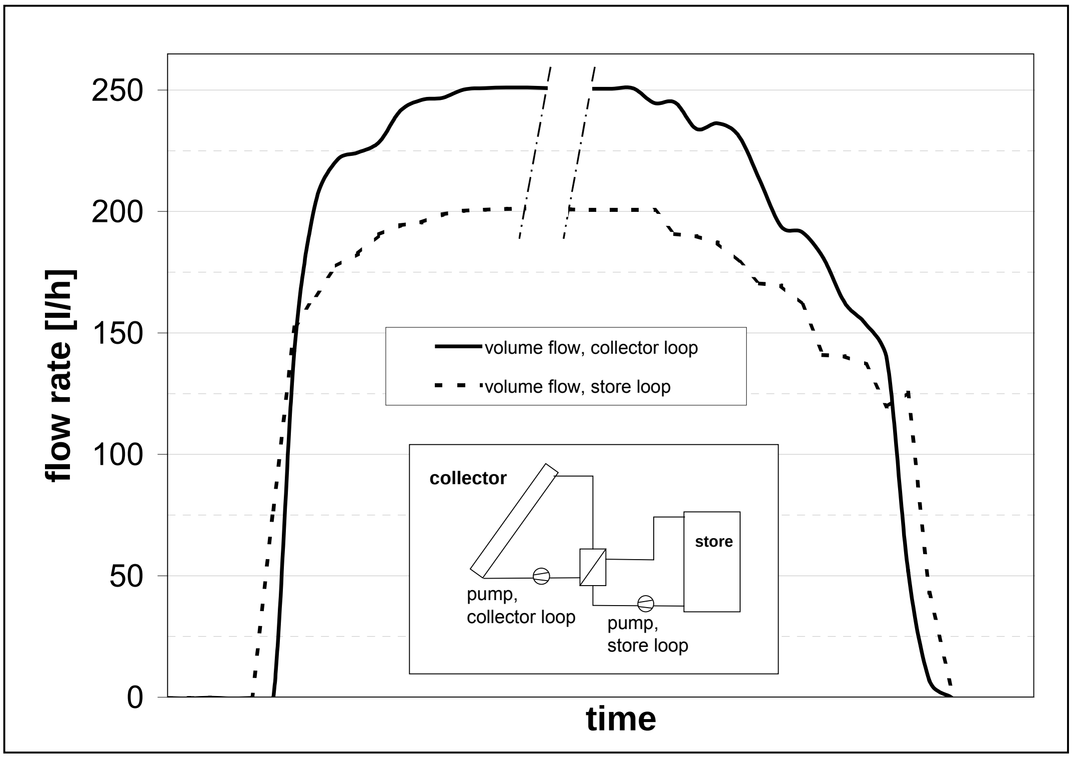

Figure 3: Variation of the flow rates in the collector loop and the store loop of a combisystem with external heat exchanger with increasing and decreasing power of the pumps. Identical for both loops, the variation of the power of the pump was in the range of 30 to 100 %.

As can be seen from Fig. 3, the power of the pumps is controlled in such a way, that the flow rates in the collector and the store loop show the same pattern. Depending of the pressure drop of the respective circuit the absolute value of the flow rates differ significantly. In the case of Fig. 3 the flow rate through the collector is up to 25 % higher compared to that through the store. Because the flow rate is depended of the pressure drop of the respective circuit, which is in turn in the square dependent on the velocity of the fluid within the tubes, the differences increases with increasing flow rates.

The investigations presented here were made with a test facility as shown in Fig. 1. In order to determine the flow rates and pattern of the two loops, the test was carried out two times, one time for the collector loop and one time for the store loop.

The pressure drop for each loop was adjusted by means of a throttle-valve to such a value, that it was similar to a typical pressure drop of a collector loop or a store loop respectively, the controller and the pumps are intended to be used for. Therefore, in real systems the behaviour of the controller influencing the fractional operation time of the pumps and hence the flow rates will be comparable.

6.2 Heating the return of the space heating loop by solar energy

In addition to the control of the thermal solar system, multi-function controllers in parallel are often responsible for controlling the auxiliary heater and the heat distribution system.

Fig. 4 shows the response of a controller on the return temperature of a space heating loop and the store temperature controlling a three-way valve, which is installed in the return line of the space heating loop. The return should enter the store, when the temperature in the middle of the store plus a defined temperature difference is higher than the temperature of the return line. The bypass is provided to avoid heating the store by the return flow with energy actually dedicated to the space heating when the store temperature is below the return temperature.

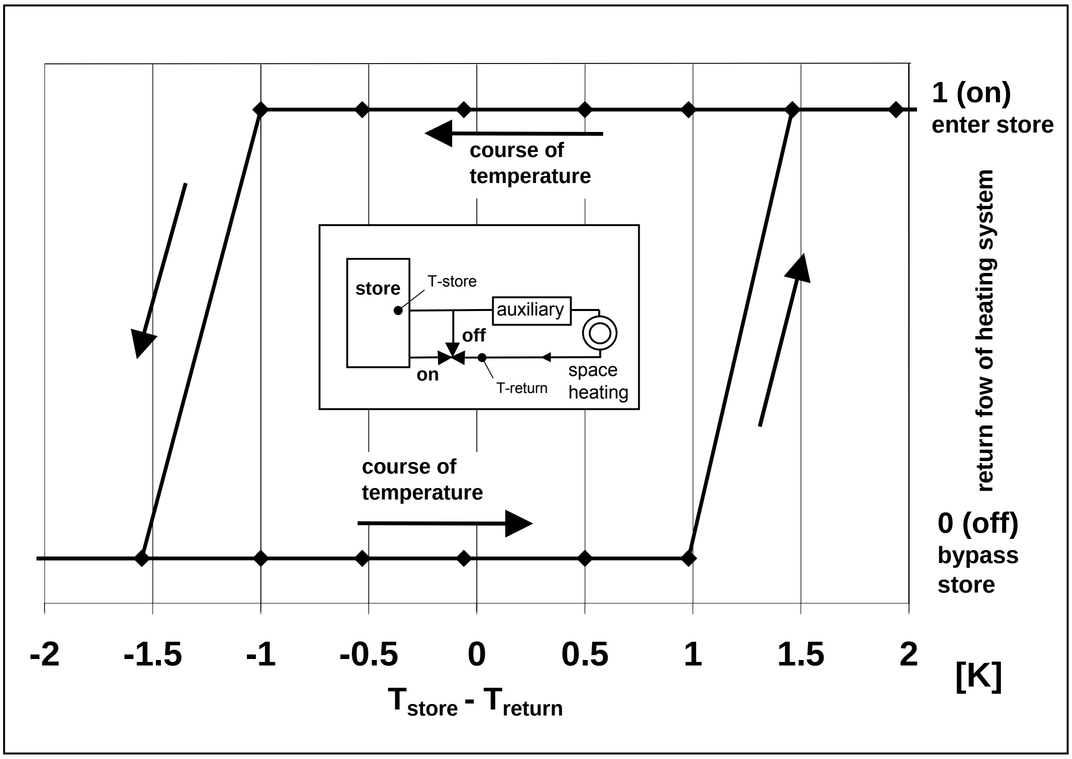

Figure 4: Temperature differences and hysteresis between the store and the return temperature of a space heating loop.

Whenever the temperature in the store is below the return temperature of the space heating loop, the store should be bypassed. As evident in Fig. 4, due to objectionable behaviour of the controller, the opposite can be the case. The store will be heated up by the return flow of the space heating loop.

7 Conclusions

For a detailed investigation of a controller, testing the starting and stopping of a pump in a solar loop in most cases is not sufficient. Controllers for solar combisystems often drive several pumps and valves to control different flow streams. Beside the collector loop, enabling or disabling of an auxiliary heater, setting of the demanded flow temperature of the space heating circuit depending on the outdoor temperature, hot water circulation and several other tasks might be implemented in a multi-function controller.

After detailed evaluation of numerous controllers and confirmed by experience in practice it has to be remarked, that for several heating systems the control equipment seems to be the weak point. In some cases, for example, the stability of the control algorithms or settings were not sufficient. Particular controllers with a large number of features and options frequently show interactions between functions that are not specified in the documentation and that are not meaningful for the system. To minimise the risk of insufficient behaviour, in general the control equipment should be as simple as possible and not more complex as necessary.

Due to inaccuracy of measurements, e. g. caused by temperature sensors and/or the transfer or conditioning of signals to and within the controller, some response observed during the tests was faulty. In practise the proper mounting of sensors and all other control equipment is an additional, very crucial item.

In the framework of a comparison between 16 solar domestic hot water systems and 11 solar combisystems carried out for the German consumer magazine ‘test’ in 2000 and 2001, the introduced method was successfully applied to determine controller parameters for system simulations and performance predictions using TRNSYS.

The method presented in this paper is one basis of the new standard for custom build thermal solar systems within the European Standard series ENV 12977, ‘Thermal solar systems and components – Custom build systems’. Together with the revised parts 1, 2 and 3 the new added part 5, titled prEN TS 12977-5, ‘Performance test methods for control equipment’ will presumably be officially established during the year 2008[5]. With the European standard prEN TS 12977-5 for the first time a test and evaluation procedure for a comprehensive examination of controllers and control equipment for thermal solar systems is available. The new test methods afford a reliable determination of control parameters that will serve as an excellent basis for testing advanced solar domestic hot water systems and combisystems based on the CTSS-method.

In principle the method can be extended to nearly every kind of controller, sensor and various controller outputs. Test sequences can be adapted to any specific control algorithms, particular options or details to be investigated. As the entire test procedure all algorithms can be examined with a high degree of accuracy and reproducibility. The consistent application of the procedures will increase the quality and reliability of the control equipment and thus of the total solar heating system. Not at least the detailed test procedures can be used for development and optimisation of controllers, control equipment and control algorithms as well as durability and reliability tests of sensors. At least malfunctions of control equipment installed in the field can be detected.

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[5] During summer 2007 part 1,2,3 and 5 of the 12977 series will be submitted to CEN Technical Comity TC 312 for CEN enquiry, a procedure within the European standardization process, taking place before the formal vote on the drafts of the standards. After the formal vote the complete standard can be officially established (CEN, **C**omité **E**uropéen de **N**ormalisation)

References

/Bac04/	Bachmann, S., Peter, M., Drück, H., Heidemann, W., Müller-Steinhagen, H., Prüfung von Reglern für thermische Solaranlagen, Proceedings of „vierzehntes Symposium Thermische Solarenergie“, Otti-Technologie-Kolleg, Pages 193 – 197, Regensburg, April 2004,ISBN 3-934681-33-6
/ENV01/	European Pre-Standard ENV 12977-2:2001, Thermal solar systems and components – Custom built systems -, Part 2: Test methods. Annex B: Testing of solar loop controllers with temperature sensors.
/ENV05/	European pre-Standard prENV 12977-2:2005, Thermal solar system and components - Custom build systems – Part 2: Test methods for solar water heaters and combisystems
/Kle96/	Klein S. A. et al. (07/1996), TRNSYS 14.2, User Manual University of Wisconsin, Solar Energy Laboratory
/Pet03/	Peter, M., Drück, H., Testing of controllers for thermal solar systems, Proceedings ISES Solar World Congress, June 14th to June 19 2003, Gothenburg, Sweden, ISBN 91-631-4740-8
/Pet03a/	Peter, M., Anlagen- und Regelkonzepte für solarthermische Kombianlagen, 7. Fachtagung “Solares Heizen“, Intersolar 2003, Freiburg im Breisgau
/Pet07/	Peter, M., Drück, H., Testing of controllers for thermal solar systems, accepted for publication in Solar Energy 2007/2008, under press
/Pet07a/	Peter, M., Drück, H., Testing of control equipment for thermal solar systems according, ISES Solar World Congress 2007 – September 18-21, 2007 - Beijing, China
/prE06/	European Standard prEN TS 12977-5, Thermal solar systems and components – Custom built systems -, Part 5: Performance test methods for control equipment. (3rd DRAFT, Jan. 2006, editing by CEN/TC 312 WG3)
/Str00/	Stryi-Hipp, G., Kerskes, H., Drück, H., Bachmann, S. Kombianlagen. Abschlussbericht des Projektes ’Testverfahren für Solaranlagen zur kombinierten Brauchwassererwärmung und Raumheizung (Kombianlagen), Deutscher Fachverband Solarenergie, DFS

New Generation of Solar Thermal Systems

WP 4.3: ACTIVITIES ON ADVANCED CONTROLLERS AT DTU and ITW

April 2007

CONTENTS

SUMMARY

Test methods for evaluation of the energy consumption of pumps and controllers proposed by the Department of Civil Engineering, Technical University of Denmark and ITW, Stuttgart University are described.

Test methods for evaluation of the energy consumption of pumps and controllers

It is suggested to measure the electric power consumption of pumps for solar heating systems in a test facility schematically shown in figure 1. Water is used as the heat transfer fluid. The temperature of the water is about 20°C. The electric power consumption is measured for different flow rates and pressure drops by adjusting the valve.

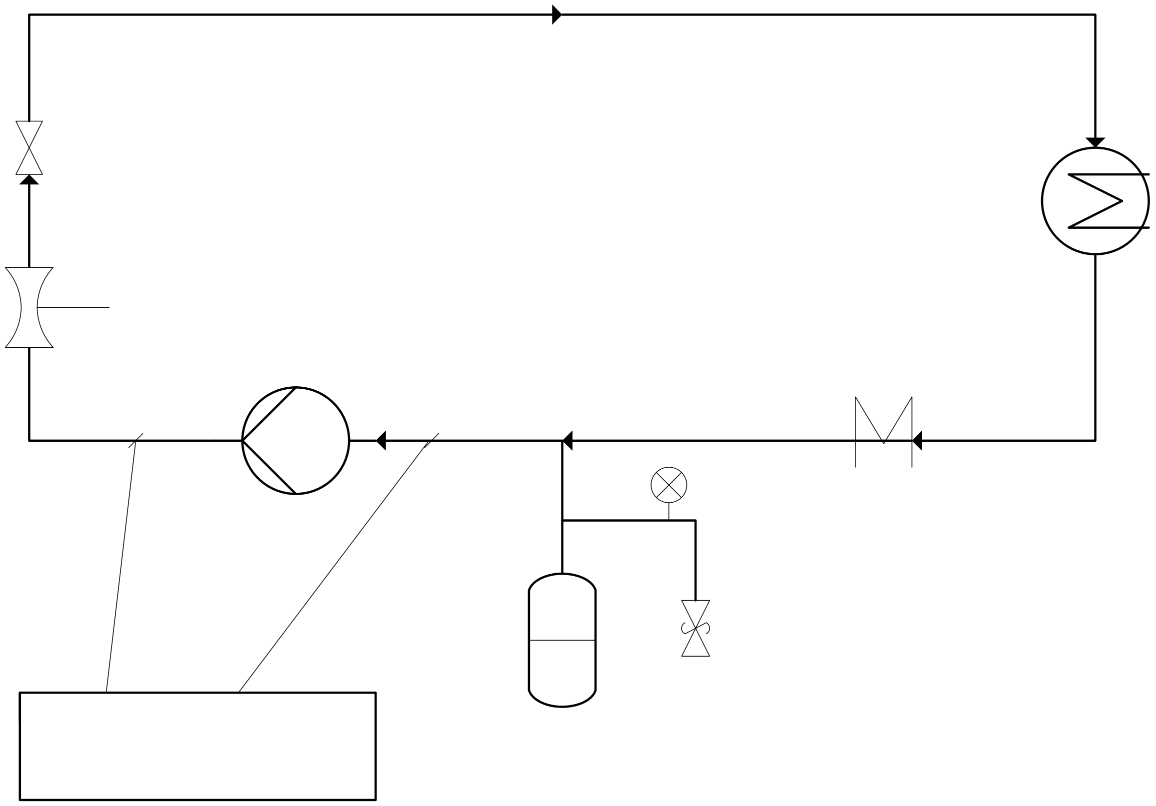

Figure 1. Schematical sketch of test facility for pumps.

If the volume flow rate(s) and the average pressure drop(s) of the loops in which the pump(s) is/are installed and the operation times of the pump(s) is/are known it is possible, based on the measured power consumptions, to determine the yearly energy consumption of the pump(s) with a reasonable accuracy.

Further, it is proposed to measure the power consumption of controllers in a stand by period and in periods with different ports active. If the operation times of the output ports are known, the yearly energy consumption of the controller can be estimated based on these measurements.

It is recommended that test institutes carry out measurements as suggested above. In this way experience on the test methods will be gained and it can be determined if improvements or detailed descriptions of the methods are needed.

Valve

Flow meter