DEVELOPMENT OF A MODULAR AND COMPACT CHARGE AND DISCHARGE UNIT FOR LARGE-SCALE SOLAR THERMAL SYSTEMS

K. Zass[1], C. Wilhelms[1], K. Vajen[1], U. Jordan[1] and W. Kramer[2]

[1]Kassel University, Institute of Thermal Engineering
Kassel, Germany; solar@uni-kassel.de

[2]Wagner & Co. Solartechnik GmbH,
Cölbe, Germany; info@wagner-solar.com

Abstract

In Europe, small domestic hot water (DHW) and combisystems have already been available for some years as prefabricated and standardized systems. In contrast, large systems with collector areas of more than 20 m² are still planned individually and the components are assembled on site. This results in high costs for planning and installation of the large system and a high probability of errors. It hinders a broad market penetration of large-scale solar thermal systems.
Based on this experience, a new concept for a compact charge and discharge unit has been developed that is introduced within this paper. This unit comprises all necessary components and can be prefabricated. Due to its modular design, the field of application is broad: It may be used for combisystems with high fractional energy savings in single-family houses as well as for DHW systems in multi-family houses, independent from storage and auxiliary heating concept. The concept is brought to the market by the partner company Wagner & Co. Solartechnik. In order to test the functionality and reliability of the new developed unit, two field tests are being carried out.

1. HYDRAULIC SET-UP

The hydraulic set-up of the system was chosen such that it may cover a broad range of applications without the need to rearrange the basic design considerably (see Tables 1 and 2). Therefore, external heat exchangers are used to transfer the heat from the collector loop to the store and from the store to the hot water preparation loop. This makes the system independent from the type of storage tank and auxiliary heater installed. Usually, the upper part of the store is used as auxiliary volume. For very large stores the integration of a separate store for the auxiliary volume is also possible (see Table 1, option b). Large-scale DHW systems can be realized by simply omitting the space heating loop in the charge and discharge unit. The store can optionally be operated pressureless by adding two additional heat exchangers that separate the fluid in the store from the fluid in the space heating and auxiliary heating loop. In addition to that, the following components shall ensure the optional use in a broad range of applications:

- **Valve in the forward flow of the auxiliary heating loop**

The switching valve in the forward flow of the auxiliary heater allows the integration of combined heaters for hot water preparation and space heating without the need to access their controll. In case the heater runs in space heating mode, the flow temperature can be lower than the set temperature for the auxiliary volume. The switching valve allows the charging at a lower store level and thus avoids a cooling down of the auxiliary volume (see e.g. Table 1, option c).

- **Valve in the return flow of the auxiliary heating loop**

The switching valve in the return flow of the auxiliary heater makes it possible to connect a second heater with long operation times, e.g. fired with solid fuels. Those heaters require a larger buffer volume than modulating heaters. This can be realized by switching to a lower store outlet level (see e.g. Table 1, option d).

- **Valve in the return flow of the primary loop of the heat exchanger for hot water preparation**

With a circulation line in operation the temperature of the return flow is considerably increased. in order to avoid the mixing of the store, the return flow is fed back into to the store at two different heights by use of a switching valve (Zass, 2008).

Table 1. Range of applications for the new developed charge and discharge unit: combisystems (additional or modified components in green)

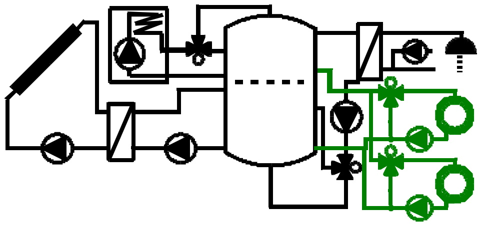
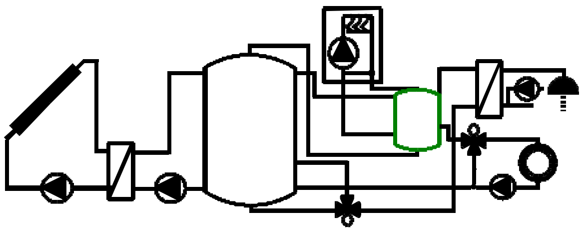
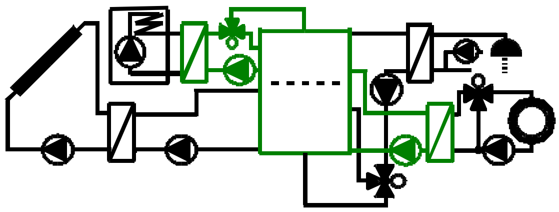
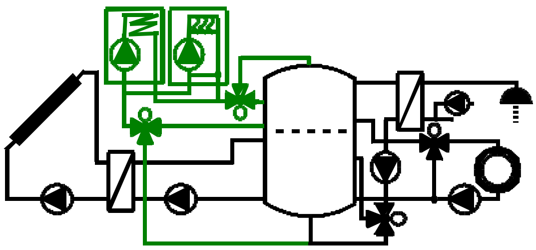
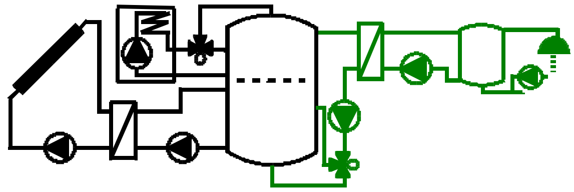
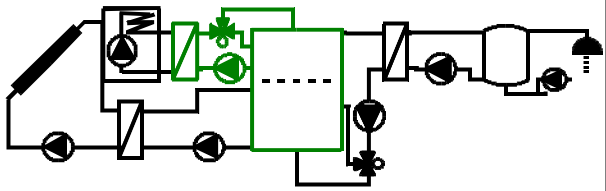
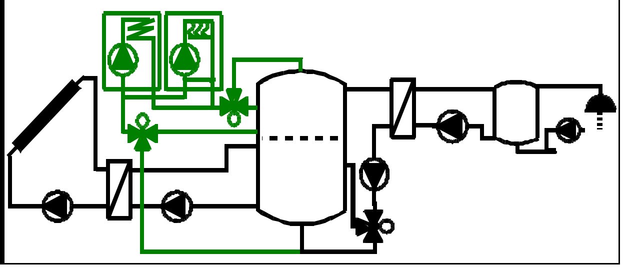
Combisystems for SFH with high solar fraction; combisystems for MFH	
a) 1 or 2 room heating loops	
b) separate auxiliary store: no additional components are required	
c) integration of non-pressurized stores additional heat exchanger and pump units in auxiliary and room heating loop	
d) auxiliary heating (with long operation times) an additional switching valve allows the increase of the buffer volume for the optional integration of a heater with long operation times	

Table 2. Range of applications for the new developed charge and discharge unit: DHW systems (additional or modified components in green)

DHW-systems for MFH & commercial buildings	
a) separate fresh water store the fresh water preparation unit is used as transfer station, an additional pump unit is necessary	
b) integration of non-pressurized stores additional heat exchangers and pump units in auxiliary and space heating loop	
c) auxiliary heating (modulating or with long operation times) an additional switching valve allows the increase of the buffer volume for the optional integration of a heater with long operation times	

2. CONSTRUCTION AND DESIGN

All components of the compact charge and discharge unit are arranged in one single housing. In order to fulfil still the required modularity the components in the housing are grouped together according to their function (see Figure 1). Four functional units are defined: solar loop, connection to auxiliary heater, fresh water preparation unit and space heating loop. Each of these units is placed on its own mounting plates. Conventions for the dimensions of the mounting plates, pipe connections etc. allow an individual composition as well as a simple exchange and extension of the unit. The metal mounting plates can be transported separately and fixed to the housing frame on-site. The external heat exchangers are located on the back of each mounting plate.

By varying the number of plates of the heat exchangers, the heat transfer capacity can be varied. Also, the installation of different pumps is possible. The dimensioning of the pipes, pumps and heat exchangers of the unit as shown in Figure 1 can be used for a collector area of up to 30 m², an auxiliary power of up to 20 kW, a space heating load of up to 20 kW and the preparation of hot water for up to 9 norm apartments. A further upscaling is possible by simply increasing the size of the mounting plates.
An additional simplification is achieved by insulating only the complete housing instead of insulating each pipe and fitting separately (see Figure 2).

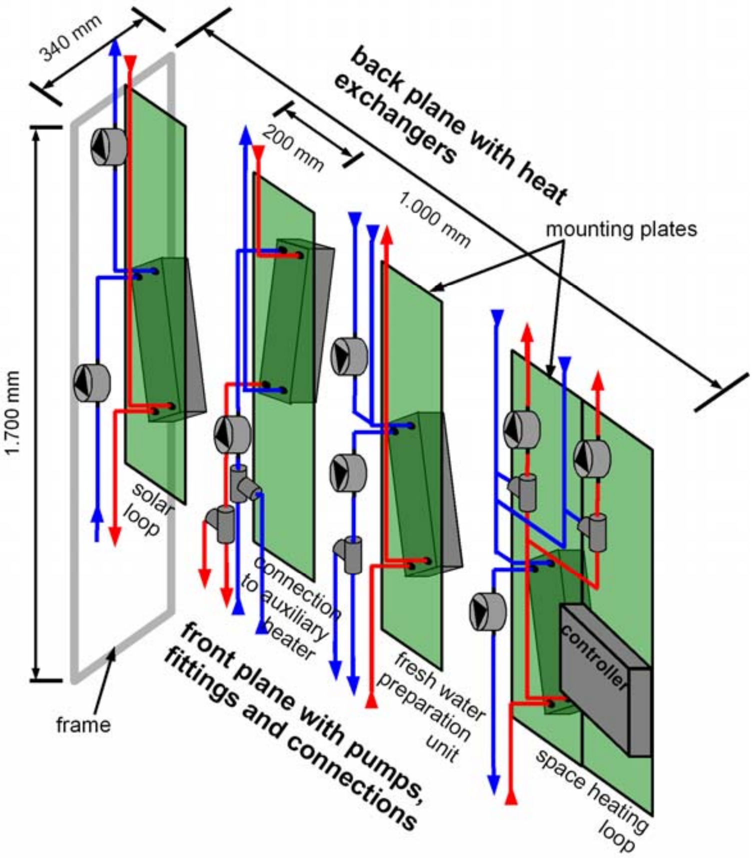


Figure 1. Design of the charge and discharge unit in its largest expansion (i.e. with a heat exchanger in each loop for the integration of a non-pressurized store)

Figure 2. Exhibition model of the charge and discharge unit (without front cover)

3. DESCRIPTION OF FIELD TESTS

In order to proof the functionality and reliability of the new developed unit two field tests are currently under investigation. They are both located near Kassel in Germany.
The first field test is carried out in a new-built low-energy house for a single family. It has an area of 200 m² and is heated via radiators as well as by a floor heating system. The building has a total heat demand of about 15.000 kWh/a. The heat is delivered by a pellet boiler of 10 kW supported by a solar collector area of 16.8 m². The collectors are integrated in the southern façade of the building (see Figure 3, left) and the heat is stored in a standard 1 m³ pressurized store. A prototype of the new developed charge and discharge unit is placed in front of the store (see Figure 3, right) in the basement.

Figure 3. The single-family house with 16.8 m² of façade-integrated collectors (left) and the prototype of the charge and discharge unit in the basement (right) during installation.

The second field test is conducted in the new-built and energy self-sufficient production hall of the partner company Wagner & Co. Solartechnik (see Figure 4, left). The space heating demand for 5.000 m² of production area and an adjacent office building is covered by a woodchip boiler of 350 kW rated power. There is an additional hot water demand of up to 1.000 l/day due to several showers and washstands. The space heating demand for the office building of about 15 kW as well as the hot water demand is partly covered by the solar thermal system. The collector has an aperture area of 30 m². Other than at the first field test, a non-pressurized store is installed. This is a prototype of the store concept that is developed within the frame of another research project (Wilhelms, 2009). The store has a volume of 5 m³ and is connected to a protoype of the charge and discharge unit in its largest expansion (i.e. with a heat exchanger in each loop for the integration of the non-pressurized store and two heating loops, see Figure 4, right).

Both field tests are equipped with a measurement system that logs all relevant temperatures and volume flows in a 1-minute interval. The data is transferred automatically and on a daily basis via GSM connection and email protocoll. The general functionality of the unit could already be proven. A detailed analysis of the results will follow as soon as more data is available.

Figure 4. The production hall with a large PV-collector field as well as 30 m² of solar thermal collectors (left) and the prototype of the charge and discharge unit in the boiler room (right)

4. CONTROLLER

The compact charge and discharge unit is equipped with a new developed universal controller that is able to synchronize the control of all loops (see Figure 5). This leads to an improved performance of the whole system, e.g. thanks to an automatic depression of the auxiliary heater or the intelligent charging of multiple storage arrays.

Due to the complexity of the control processes, special attention has been paid to the development of a simple and self-explaining user interface. This is achieved by the use of a touchscreen, a structured menu navigation and a plain text display. A control unit with a graphics capable display can be installed in the living space. The modular approach is also considered for the controller: depending on the complexity of the system it is possible to connect up to 3 hardware units for the connection of sensors and actors. The model in Figure 2 is equipped with 2 units.

Figure 5. The new developed universal controller, consisting of the hardware unit (top) and the control unit with touchscreen (bottom)

5. SUMMARY AND OUTLOOK

A new concept for a modular and compact charge and discharge unit for large-scale solar thermal systems was successfully realized. The modularity is achieved by the use of four independent mounting plates that each comprises a functional group (solar loop, connection to auxiliary heater, hot water preparation unit and space heating loop) and thus allows to configure the unit to fit to a large range of applications without any effort. The installation costs are further reduced by insulating the complete housing instead of each pipe.

The basic functionality and reliability of the unit was proven in the frame of two field tests. A detailed analysis of the measurement data will follow soon.

A small-sized version of the unit for combisystems in single-family houses (application range from Table 1) is currently being introduced into the market by the partner company Wagner & Co. Solartechnik. It was first presented at the trade fair “Intersolar” in May 2009 in Munich, Germany.

6. REFERENCES

Wilhelms, C., Vajen, K., Zass, K., Heinzen, R., and Jordan, U. (2009) “Pufferspeicher in Modulbauweise mit bis zu 50 m³ Speichervolumen” (English: Buffer store in a Modular Design for a Storage Volume of up to 50 m³) *Proceedings of the 19th OTTI Symposium Thermische Solarenergie*, 238-243.

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