FAULT ANALYSIS AND OPTIMISATION OF THE SOLAR THERMAL SYSTEM FOR DOMESTIC WATER AT THE UNIVERSITY OF APPLIED SCIENCES TRIER

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Abstract

The reason for analysing the solar heating system located at the University of Applied Sciences in Trier were permanent problems with the operation, the reduced solar income and the continuous error message every morning.

In summary it can be said that the calculated dimensions of the system back in 2005 were correct but the operation was inappropriate. The system pressures did not match the set value and in the freely programmable controller [2] many parameters were improvable and amendable. Due to the specially developed collector-cooling mechanism and other optimisations the system now runs very satisfying; stagnations caused by high solar radiation can successfully be delayed in time or even be avoided. System components and solar fluid are being saved through the shorter or absent steam period.

From December 2008 until February 2009 the solar system produced enough hot water to supply the showers of the sports centre it is placed on. In the past two years this was not even possible in the annual balance sheet.

1. Inventory

The solar circuit works with an external heat exchanger, a special device causes the solar harvest to flow into different heights of the two 750 litre buffers, depending on its temperature. The hot domestic water gets provided by a fresh-water-station with a large external heat exchanger. The additional energy is provided by a 6 kW heating cartridge in summertime and by district heating in the winter.

To monitor the whole system a data logger was connected to the controller. This logger stores all sensor temperatures and the switching status off all pumps. An online-scheme was created in cooperation with Dr. Molter, a member of the universities computing centre. It can be viewed at the following page: http://solvis.fh-trier.de/GRAFIK.htm.

When read out to a PC, a program is able to produce a graphic with the logged data which makes it easy to analyse weak points and failures. The biggest problem is the malfunction during high solar radiation, the solar system overheats very fast and the buffers don't get heated up. In the winter the system works because the radiation isn't high enough to cause overheating but the problem here is the high difference of temperature between the collector and the main line. The reason for this effect could be air in the system or the speed of the primary solar pump is too low.

2. Energy flow

To make a statement about the system performance, the past records were consulted. Since 2006 the counters of the yellow measuring devices (see Fig.1) get read out once a week. The green counters were installed during this examination. To capture the losses of the circulation a flow rate was necessary, it was detected with a ultrasonic device.

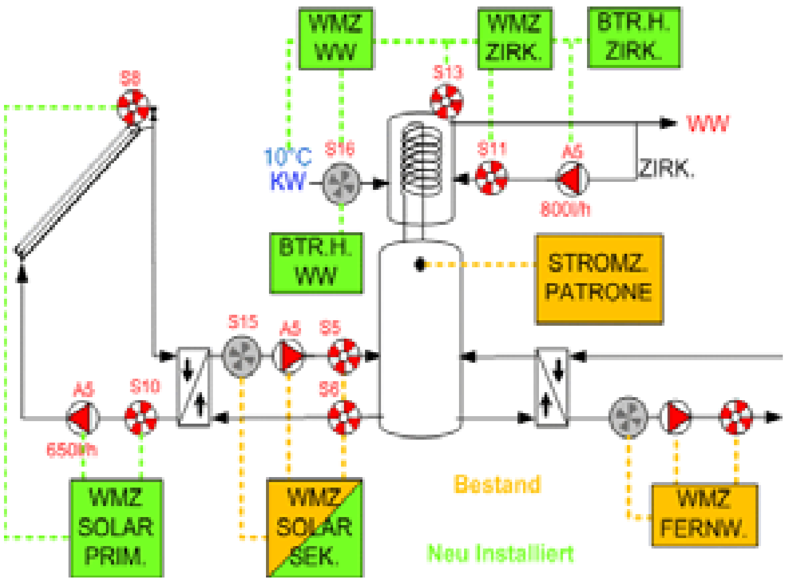

Fig. 1: Simple system scheme with counting devices

In the reference year 2008 the circulation used around 11 % of the provided energy, only 21 % were used for hot domestic water, the thermal losses add up to 68 %. Most of the losses occur on the long local heat supply line and in the central heat storage room. On the producers side the local heat supply line takes the main part with 73 %, the heating cartridge contributes 11 % and the solar collectors provide only 16 % of the whole energy supply in 2008.

The construction of the solar thermal system was based on the measurements of hot water consumed in 1999 and the resultant calculations of 1,500 liters per day [1]. Somehow the amount of used hot water since 2005 only adds up to around 180 liters per day, such a change of showering behavior was not predictable. Due to over dimensioning of the collectors, the whole system has a non-economic system effectiveness and a high standby time. Due to the reduced consumption the solar thermal system should cover a much higher part of the energy provision, this is why different optimisations were carried out.

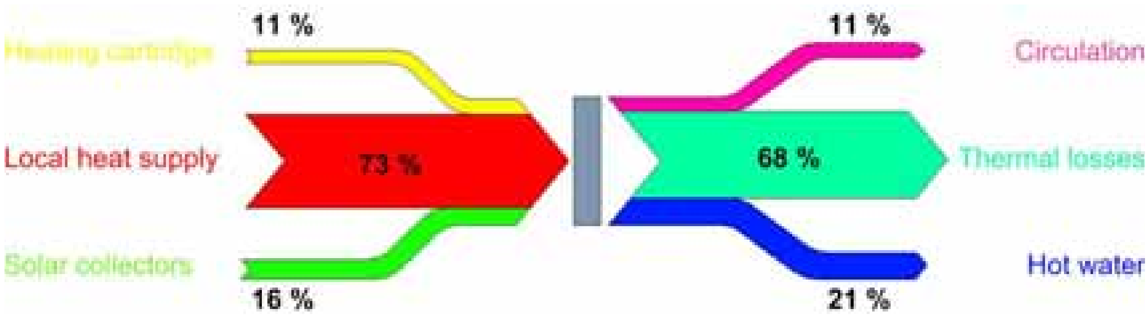

Fig.2: Proportion ratio of producers and consumers 2008

3. Optimisations

So far all improvements were realized without further investments, instead the mode of operation of the existing system was modified.

3.1. Operating pressures

First of all the complete solar circuit was rinsed and all air was exhausted, the calculated system pressures for an optimal operation (system: 2.62 bar and expansion vessel: 2.5 bar) were set. After this measure a clear improvement was determined, the difference in temperature between collector and the main line is now only around 4 K (before it was up to 60 K). The collector now does not overheat so fast because the produced heat gets transported away.

3.2. Controller

Since there is no radiation sensor installed, a “start-function” was programmed. This module uses the collector sensor to “feel” the sunshine and decides whether it is useful to start running the system or not.

To delay the stagnation due to overheating collectors an especially developed collector-cooling mechanism was programmed. At a certain temperature level in the collector, all necessary pumps are activated to transport the heat from the collector to the buffer and then to the 70 m circulation ring line until the whole domestic water system heats up to 75°C. The positive side effect is that all water lines get disinfected from legionella with heat produced from the sun.

Large temperature fluctuation in the collector and as a result in the main line could effectively be avoided by modifying the PID-parameters (rotation speed control) of the primary solar pump.

Sensitising the activating parameters of the circulation pump and programming an additional delay element of ten minutes at the error module caused the absence of the daily error message.

3.3. Insulation

To reduce the thermal losses (at the moment approximately 68%) the ventilation grille in the buffer room was closed. Further action is needed to insulate the central heating room, the largest losses occur in here. All pumps, heating lines and ball valves must be insulated, single glass windows should be replaced with double glazing.

Fig.3: Technical room

Fig.4: Thermographical recording of the technical room

4. Conclusion

At this point the solar system can not be run economically because the hot water consuption is to low. Though it is possible the showering behaviour could change, for example after a refurbishment of the shower rooms.
The University now has a research system where various conditions und improvements can be tested. The total costs for the system back in 2005 reached the total of 58.500 €, the amortisation time for this amount ist 26 years. Using the provided solar heat more intensively and lowering the thermal losses will shorten the amortisation time.
Due to the different improvements and the low hot water consumption of only 180 liters per day, a solar coverage of 100 % can be reached during the summer months. As a result the electrical energy for the heating cartridge can be saved.

$$K = 1910 \ kWh / a \cdot 0{,}22 \ ct / kWh = 420{,}20 \ € / a$$

The saved amount of money adds up to around 420 € each year. The smaller addition of district heating caused by higher solar harvest in winter months was not accounted here. The total amount of additional energy can be added up with the help of the heat meters at the end of the year.

References

[1] R. Hund/ P. Hornberger, (1999). Diploma thesis: "Energieanalyse der Brauchwassererwärmung der Turnhalle an der Fachhochschule Trier (Standort Schneidershof) und Planung einer Solaranlage mit Angliederung eines Versuchsstandes".

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