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Design, control and first monitoring data of a large scale solar plant at the meat factory Berger, Austria

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Abstract

Within the European FP7 Project InSun, which started in April 2012, three large scale solar plants for industrial processes in three different countries are installed and will be monitored in detail over a period of almost two years. The main idea of InSun is to demonstrate the reliability and quality of large scale solar thermal systems using different types of collectors for the generation of heat employed in different industrial processes.

One of these demonstration plants is located in Austria and it is providing heat up to 90°C for the manufacture of meat products in the factory Berger. Zafh.net, the coordinator of the project, developed a dynamic simulation model of this plant, which should be used to improve the control strategy of the real process. After two months of operation, the first monitoring data are available and will be compared with the simulation results. Based on this comparison, key performance figures (e.g. solar yield) could be predicted for the whole lifetime of the plant. Furthermore economical outputs could be calculated more precisely, which provides essential information for the key stakeholders in the industry.

1. Introduction

The industrial and commercial sector is responsible for 28% of the energy consumption in Europe. Two third of this energy is spent on heating applications. More than 60% of the industry processes uses heat with temperatures below 250°C.

Until 2008 about 90 solar thermal plants for process heat were operating worldwide with a total installed capacity of approximately 25 MWth. About 55 of these plants use flat plate collectors and only about 10 systems were installed with concentrating collectors (CPC and parabolic trough).

Both, concentrating and non-concentrating technologies have a great potential for future projects as soon as the technology is accepted as feasible and commercially viable.

The European FP7 Project InSun aims to demonstrate the reliability and efficiency of three different collector technologies suitable to supply heat for industrial processes in different climatic regions. The selected technologies range from improved flat-plate collectors supplying temperatures of up to 95°C in moderate northern Europe climate to tracked concentrating collectors (linear Fresnel collectors and parabolic trough collectors) supplying temperatures between 160 and 250°C in hot and dry Mediterranean climate in Italy and Spain. Each of the three investigated systems has a maximum heating power of 1 MW. All 3 applications offer a high replication potential.

Missing standards especially for concentrating collectors and the large uncertainty of system integration costs are the main bottlenecks for a fast system deployment in the industrial sector. Therefore, the project aims to give a significant input to the standardization process in terms of construction, integration and dimensioning of this young and innovative technology.

Within the frame of the Project InSun, the simulation of thermal solar systems is planned in order to improve the control strategy and optimize the energy consumption of the processes. One of these systems corresponds to the company Berger, which is located in Sieghartskirchen, Austria. This company is dedicated to the elaboration of meat products.

The present work compares the first monitoring data of the installed solar system in Berger with results of a model built with the program Trnsys 16.1. This model is developed considering technical information of the installed solar system and controlling provided by the company SOLID.

2. Technical details of the solar Plant "Berger"

Fleischwaren Berger GmbH is a company located in Sieghartskirchen, Lower Austria with about 380 employees. The Production is approximately 80-90 tons of meat and sausage products per day.

For the processing of the delivered feed stock / raw material coming from the abattoirs, Berger together with SOLID plan to install solar flat plate collectors with an overall area of ca. 1,067 m², which will be mounted on a green field on the west side of the mechanical room and the factory.

The produced thermal energy shall mainly be used to preheat feed water for steam boiler and the surplus heat shall be used to increase the supply temperature within the heating water system up to 60°C. The feed water of the vapor vessel shall be preheated from approx. 40°C (fresh water is preheated by using waste heat from compression chillers) up to 95°C. The steam is internally required for process heating – specifically for ham cooking. The hot water is required for drying the air conditioning systems – specifically in the climatic chamber and the maturation room for production of long-lasting sausages. The implementations at Berger concentrate on centralized water and steam production facilities that can be found in almost any industrial production site that uses thermal energy. Therefore, the system analyzed at Berger can be easily transferred to other sites and offers a high replication potential.

2.1. Controlling of the thermal solar system

The controlling of the thermal solar system is described according to the simplified schema shown in Fig. 1

2.1.1. Primary and secondary pumps (PU01 and PU02)

- Overheating: the primary and secondary pumps are stopped if the temperature of solar collectors is higher than 125°C or if the temperature of the storage tank is higher than 110°C, otherwise they work according to the normal operation.

- Normal operation: The primary pump (PU01) is turned on if the temperature at the solar collectors is higher than the storage tank. The secondary pump is switched on if the fluid coming from the collectors is higher than the temperature at the bottom of the tank.
- Antifreezing: Additionally the secondary pump is turned on when the temperature at TC26 or TC8 are lower than 5°C in order to keep the temperature of the fluid above 8°C in the secondary loop.

2.1.2. Charging and discharging of the storage tank

- The charging of the tank depends on the temperature of water coming from the heat exchanger HE1 (TC11) and the temperature at different levels of the tank. Since there are two inlets, only one of them can be opened. The tank is recharged through the highest inlet if the temperature TC11 is higher than TC12 otherwise the second inlet is used. Similarly, if the middle tank temperature TC14 is lower than 45°C, then the upper outlet is used otherwise the water flows through the outlet at the bottom of the tank.
- The discharging depends on the temperatures at the middle (TC13), the temperature at the top of the tank (TC12) and the temperature of water to be heated and supplied through heat exchangers HE2 (TC18) and HE3(TC22). The heat exchanger HE2 receives water from the top of the tank, while three way valve UV select the outlet to supply water to heat exchanger HE3 according to middle tank temperature (TC13), if this temperature is higher than 75°C, water come from the middle of the tank, otherwise water come from the top. The temperature of water to be supplied by the heat exchangers HE2 and HE3 is adjusted by varying the mass flow of pump PU04 and with the mixing valve CV correspondingly.

   The flow rates at the cold side of heat exchanger HE2 and HE3 are given by the consumption profiles of feed water preheating for the steam boiler and hot water preheating for drying air conditioning systems correspondingly. The inlet temperature at the cold side of both heat exchangers is considered constant and equal 27°C for heat exchanger HE2 and 40°C for heat exchanger HE3.
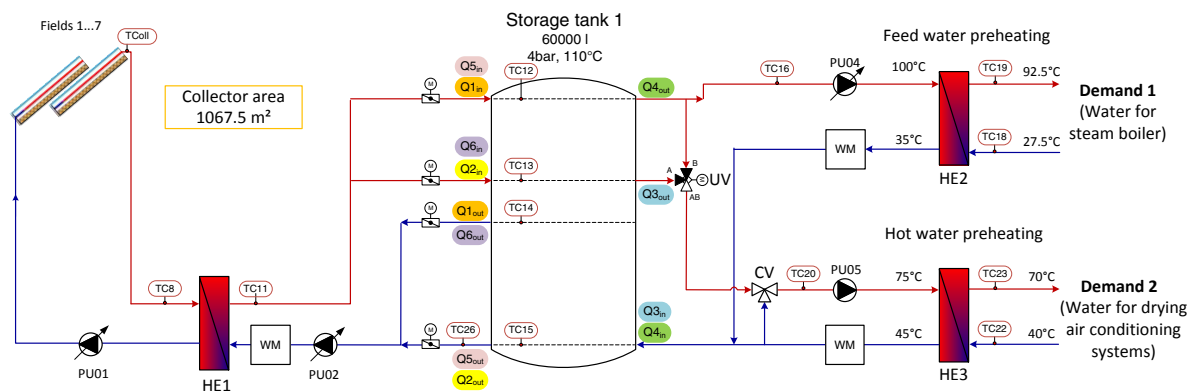

Fig. 1 Simplified hydraulic scheme of the solar system integration at the company Berger

3. Dynamic simulation model of the solar system of Berger developed by ZAFH

The model for the simulation of the solar system of Berger is developed using Trnsys 16.1 according to the controlling provided by SOLID. The solar collector field is simulated using a dynamic collector model [1]. The hot water storage tank of 60m³ has three inlets and four outlets and is modeled with a multiport storage model [2]. The combinations of inputs and outputs give four possibilities (Q1, Q2, Q5 and Q6) to charge the tank and two possibilities (Q4 and Q3) to discharge the tank as shown in Fig. 1

The charging of the tank depends on the temperature of water coming from the heat exchanger HE1 in the secondary loop and the temperature at different levels of the tank. The discharging depends on the temperatures at the middle and top of the tank and the temperature of water to be heated and supplied to the steam boiler and for drying air conditioning systems through two heat exchangers HE2 and HE3.

In a first step, the monitoring data of the first two months of operation (July and August) are shown. Then, the results of the simulation are given for the all year and the achieved primary energy and cost savings are calculated. Additionally simulated and measured data are compared for the two summer months.

4. Results and discussion

4.1. Measurements

At the moment, first measurements were obtained from the heat supplied by the thermal solar plant between the months of July and August. These measurements corresponds to the heat supplied by heat exchangers HE2 and HE3 (see Fig. 1), which is directly used for the stem boiler and air conditioning systems.

The specific energy output is calculated with these data (useful heat) divided by the total area of the collector field considered as 1068m². The maximum specific energy output is 3.34kWh/m²d and the average value is 2.17kWh/m²d.
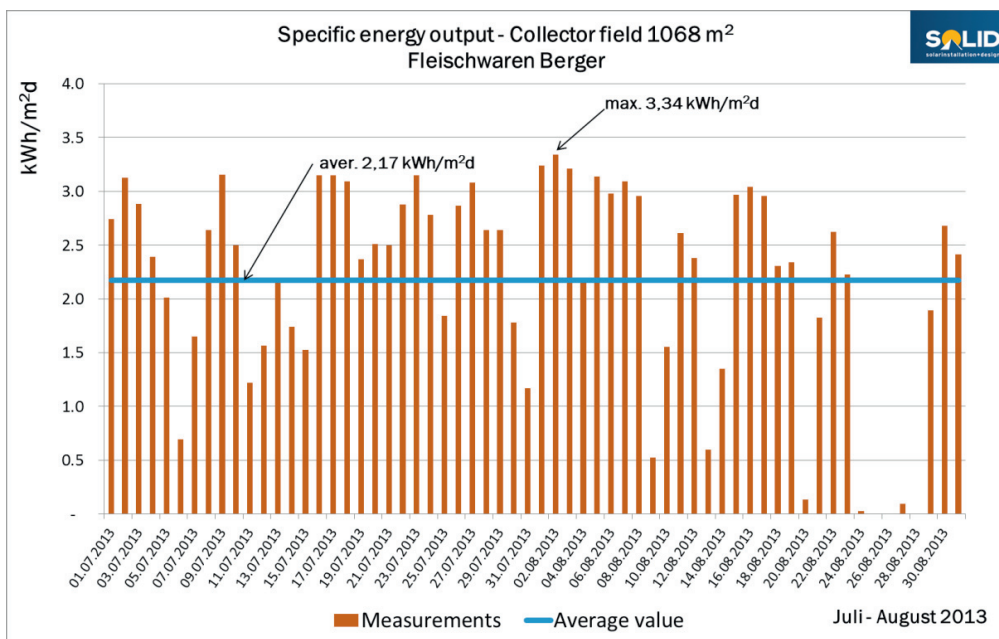

Fig. 2 Specific energy output corresponding to the first measurements of the thermal solar plant at the company Berger

Unfortunately, no data of solar radiation are available at the moment so that it is not possible to have information on the solar system efficiency. Nevertheless, it has to be mentioned that the solar irradiance during the month of July was high compared to other years. At the end of August, almost no solar heat was delivered to the industrial process during 4 days. This is due to almost no sunshine because of cloudy and rainy weather.

4.2. Simulations

The solar system has been simulated with the above described control strategy. The Fig. 3 shows the monthly results of the simulations. The net collector efficiency is calculated by the division of the total heat supplied per year (hot water preheating and feed water preheating) between the total radiation on collector. The net collector efficiency reaches 43% in August, while it decreases until 25% in colder months like December.

In addition, the monthly values of useful heat calculated from measurements are also shown in Fig. 3. Since the radiation in July of this year 2013 was higher in comparison with the radiation in the last years, the useful heat obtained from measurements (80MWh) is higher in comparison with the values obtained with simulations (70MWh). While the useful heat obtained in August is 65MWh and it is similar with the value obtained from simulations.
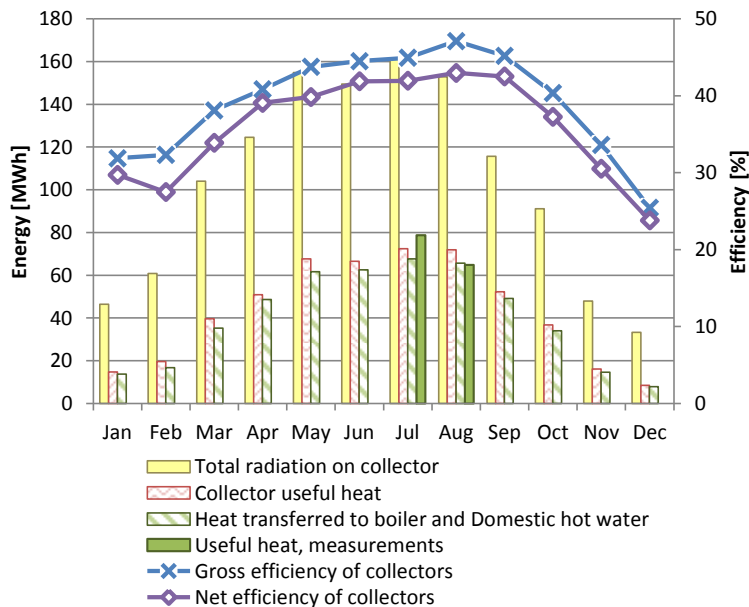

Fig. 3 Monthly results

The specific daily energy output calculated with the TRNSYS simulation model (and Meteonorm weather data) is shown in Fig. 2. Although these results cannot directly be compared with measurement since the weather data are not the same, the daily output calculated with TRNSYS are in the same range of the measurement. The maximum and average values are similar than those obtained from measurements (see Fig. 4).
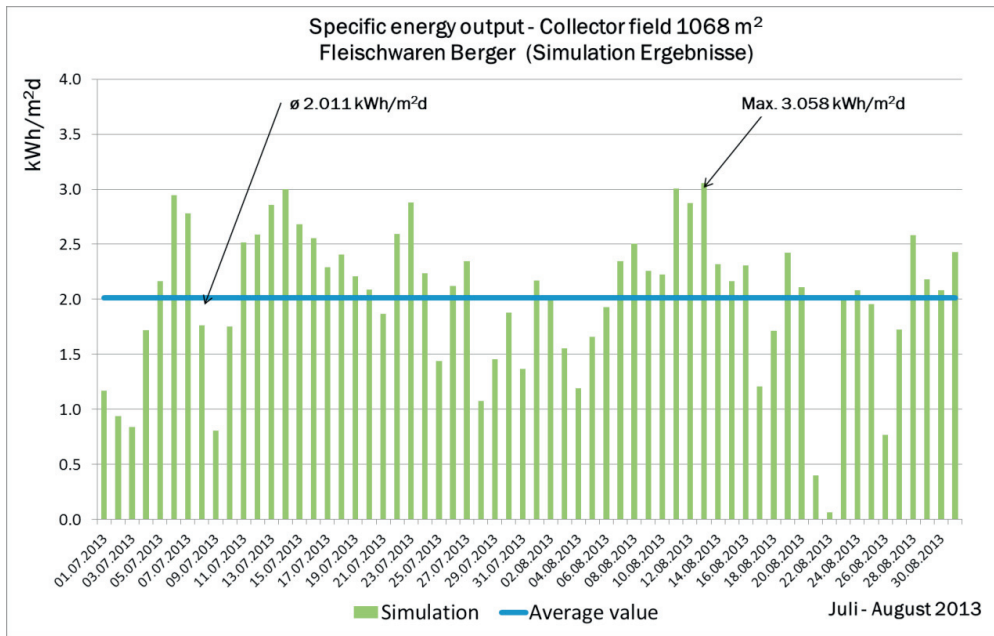
Fig. 4 Specific energy output obtained with useful heat from simulations

The following schema shows the yearly energy flows of the solar system. The total radiation on collectors (Qrad), the heat gained by the solar collectors (Qcol), the heat losses of pipes and tank, and the heat flowing through the combinations for charging the tank (Q1, Q2, Q5 and Q6) and discharging the tank (Q3 and Q4).
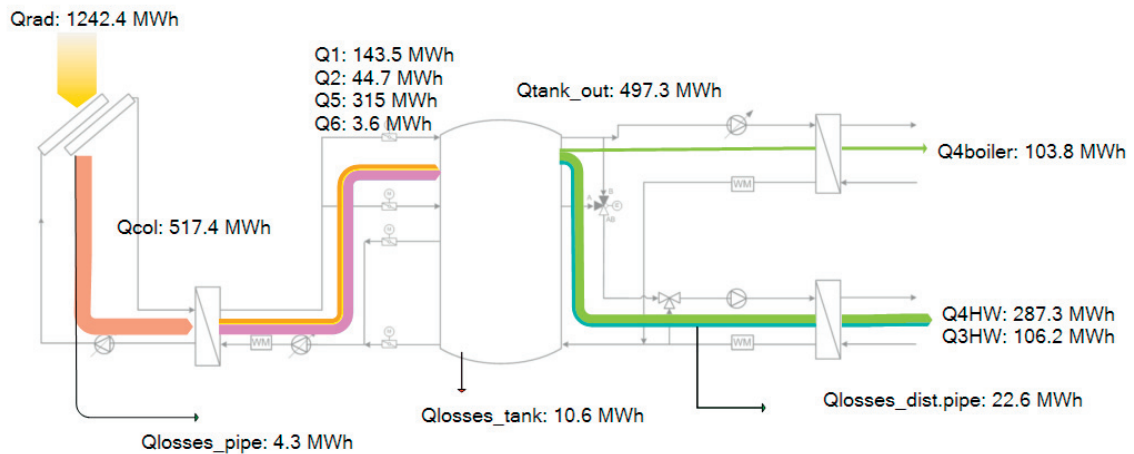

Fig. 5 Heat flow schema of the solar system

The obtained results allow the calculation of both yearly primary energy and cost savings. In order to calculate the oil savings of the system, a boiler with an efficiency of 0.88 and a conversion factor of 10.7kWh/L_{oil} is considered. The price of oil is taken as 0.934€/kWh.

The total oil consumption needed by the boiler to cover the annual demand of hot water preheating and feed water preheating for steam boiler corresponds to the total annual oil demand. The oil savings are calculated dividing the total amount of heat generated by the solar system between the boiler efficiency and the conversion factor 10.7 kWh/L_{oil}. The annual results are shown in Table 1.

According to these considerations 50.7m³ of oil can be saved per year, which corresponds to 26.9 % of the total oil required and approximately 507093€.

From these savings, 78% of the solar heat generated is used for hot water preheating and 21% is used for feed water preheating for steam boiler.

Table 1. Annual summary results

Description	Value	Unit
Total annual oil demand	2022	MWh/a
Solar heat used for hot water preheating	393.5	MWh/a
Solar heat used for feed water preheating	103.8	MWh/a
Solar collector yield	465.8	kWh/(m²a)
Boiler efficiency	88	%
Oil savings	542.9	MWh/a
Oil savings	26.9	%

5. Conclusions

The first monitoring data of a large solar thermal system that provide heat to a meat factory are showed.

A dynamic model of the system has been implemented in TRNSYS. Although a complete validation of the model is not possible at this stage, the simulated results are in agreement with the measurement data.

The maximum and average values of specific energy output from measurements are similar to the values obtained from simulations for the months of July and August. The maximum value is 3.34kWh/m²d for measurements and 3.058kWh/m²d for simulations. While the average values are 2.17kWh/m²d and 2.011kWh/m²d for measurements and simulations correspondingly.

According to the simulations the maximum collector efficiency is obtained in August and it is equal 43%, while it decreases until 25% in colder months like December.

The total heat provided yearly by the solar system corresponds approximately to 475MWh. Assuming a boiler efficiency of 0.88, a conversion factor of 10.7kWh/L_{oil} and an oil price of 0.934€/kWh, it can be saved 50.7m³ of oil per year, which corresponds to 26.9 % of the total oil required and cost savings of approximately 507093€.

From these savings, 21% can be employed for drying air conditioning systems while 78% of the solar heat generated can be used for feed water preheating for steam boiler.

6. Acknowledgments

7. References

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