34. Symposium Solarthermie und Innovative Wärmesysteme
Industrial Processes
https://doi.org/10.52825/st-symposium.v1i.1342

Published: 26 Nov. 2024

Power Transfer Station for Process Heat

Dirk Krüger[1], Jakob Leicht[2], Sven Fahr[3], Joachim Krüger[4], Stefan Bonleitner[5], Andreas Burger[6], Navina Konz[1], Bärbel Epp[7], and Jana Stengler[1]

[1] German Aerospace Centre, Institute of Solar Research, Germany

[2] AURA GmbH & Co KG, Germany

[3] Fraunhofer Institute for Solar Energy Systems (ISE), Germany

[4] Solarlite CSP Technology GmbH, Germany

[5] Protarget AG, Germany

[6] Industrial Solar GmbH, Germany

[7] Solrico, Germany

*Correspondence: Dirk Krüger, dirk.krueger@dlr.de

Abstract. The challenges of integrating solar heat into industrial processes are discussed using the example of two plants. To this objective, the standardisation concept for a power transfer station developed in the Modulus project is explained using the example of the solar plant in Turnhout, Belgium. Test plans were defined for a standardised qualification during the production and installation of the power transfer station on site. The in-situ test plans were categorised according to characteristics that have a significant influence on the test procedure. In a next step, the developed test plans were transferred to the commissioning of the plant in Belgium. The findings and results of the commissioning are described in detail and possible problems that arose are analysed. Attention is then focussed on the largest solar thermal process heat plant in Seville, Spain and its design and technical features are discussed. To conclude, the results of the 2023 global market analysis for concentrating solar collectors are presented.

Keywords: Solar Thermal Process Heat, Balance of Plant, Parabolic Trough

1. Introduction

Industrial process heat consumers are increasingly looking for low-CO_2 technologies to cover their heat requirements. Solar thermal system technology is increasingly coming into focus. This is also reflected in the German 8th Energy Research Programme for applied energy research, which explicitly mentions "concentrating solar thermal energy" for the heating transition under "Programme objective 2: defossilise heating and cooling supply in industry and commerce and make it more efficient" [1]. Internationally, large solar thermal systems are increasingly being built for operating temperatures above 100 °C, as described using examples. The Modulus project demonstrates the integration of solar heat at high temperatures of up to 380 °C at the Turnhout site. Part of the demonstration is the evaluation of the solar field functionality and performance. For this purpose, testing is required as defined in the next chapter. The definition of the required test sequences is also considered from the point of view of standardisation: Standardisation and modularisation is a key step towards planning, building and commissioning process heating systems in a cost- and time-efficient manner. This is the focus of

the Modulus project funded by the German Federal Ministry for Economic Affairs and Climate Action (grant number 03ETW021).

2. In-situ test plan for commissioning a power transfer station

As part of the Modulus project, in which the standardisation of BoP (balance of plant - power transfer station) is being developed, a test plan was defined for the standard qualification at the production and installation site. Among other things, a P&ID (process and instrumentation diagram) and a monitoring and control concept were developed for this purpose, which have already been explained in more detail in [2] and [3]. In addition, the requirements and tests were also categorised according to various distinguishing features that have a significant influence on the test process to be standardised. These characteristics are:

- Origin of the requirement: Product requirements that result from legal regulations, ordinances or technical guidelines, are based on customer requests or market requirements or relate to quality criteria defined by the manufacturer itself.
- Timing of the test: The timing of a test can be relevant for technical reasons (e.g. the tests can relate to individual components, parts or the entire system), but also has a significant logistical impact. Problems that may occur during the tests are usually easier, faster and cheaper to resolve if the test object is still at the production site.

Tests at the production site include: Testing in accordance with the Pressure Equipment Directive, electrical safety test, Input/output (I/O) check of sensors/actuators. Tests at the installation site include: Electrical safety test in accordance with local regulations, leakage/pressure test of the entire system, I/O check of sensors/actuators, safety chain test, start-up/shutdown procedure, integration into the customer process, temperature control and automatic operation.

3. Experience with the commissioning of a power transfer station

Before commissioning began at the operating site in Turnhout, Belgium, the control technology software for visualising and logging the data and for controlling the solar field and the BoP was set up. The hardware had already been delivered and installed in the control cabinet at the start of production. The measured values were checked for plausibility.

During the filling of the solar field and the BoP with a silicone oil, venting was already carried out at various high points. In the next step, the expansion tank was pressurised with nitrogen so that the heat transfer medium could reach all areas of the system. After filling the pipework, the first step was to further check the signals during operation of the pump, in particular the flow measurements.

The first test runs were carried out at ambient temperatures. As the collectors may only be focussed when a flow is present, it must first be ensured that the flow is stable. During the first start-up of the pump, the pressure on the pump's pressure side initially built up only irregularly. A hissing noise could be heard, which gave the impression that air was still being pumped in. The start was cancelled after the pressure dropped too much to avoid damaging the pump. This process was repeated several times. In each case, the pump ran for about a minute. It is also possible to use an external pump for degassing during start-up so that the more expensive built-in pump is not damaged. After starting the pump several times and increasing the total pressure to 5 bar by further filling with nitrogen, the pump then ran regularly and built up pressure.

The next step was to vent the circuit, vaporise water and remove volatile oils at increasing temperatures up to 250 °C (Figure 1). Typically, the gases in the pipes of the solar field are entrained with the oil if the flow rate is fast enough. Parallel to the expansion vessel, a stabilising tank is flown through, in which the gas bubbles rise and are then directed to the expansion vessel. The stabilising tank is located on the suction side of the pump.

Figure 1. *Blowing off air, water vapour and light gases from the collector circuit (Photo: DLR)*

The gases are directed from the expansion vessel via a valve into the outlet vessel located outside the container, in which entrained liquid components are separated. The outlet vessel has an outlet at the top through which the gases are discharged to the outside.

Firstly, the oil was vented at low temperatures between 30 and 70 °C. To do this, the oil was circulated for a few hours. The gas was then drained from the expansion tank and the pressure was increased again to the required starting pressure using nitrogen. This process was repeated several times.

In order to remove the residual water from the oil circuit, a temperature of over 100 °C or, more precisely, above the vapour pressure is required, which is ultimately reached during blow-off. For example, if blowing off with 1 bar overpressure, the vaporisation temperature corresponds to around 120 °C. The temperature of the oil should always be higher than this. For this reason, the blow-off was carried out several times at approximately 150 °C. For this process, it is necessary to know the temperature in the expansion tank. If no temperature measurement is installed in the tank, the temperatures of the flanges can alternatively be measured with an infrared measurement.

For the removal of volatile substances, the manufacturer of the heat transfer oil specifies the degassing process, in particular the temperature levels at which degassing should take place. The temperatures were increased in the tests with heat from the solar field. The process is therefore only possible when the sun is shining. The gas is blown into a 1 m³ stainless steel tank, where it condenses on the walls. There is an outlet at the top through which the gas can be vented. At high blow-off speeds, a considerable amount of oil is entrained. This was evident when blowing off at 150 °C and 200 °C. Most of the oil was collected in the waste water tank. However, a considerable amount was entrained by the gas through the top outlet of the drain tank, as shown in Figure 1. Therefore, the flow rate should not be too high. In addition, the pressure should not be released too far, as the oil is then more easily entrained. To protect the environment and the operating personnel, it is advisable to use a filter to collect the escaping gases and liquid particles.

Venting was performed via a short circuit so that the heat exchanger was bypassed. If there is no short circuit available, the medium must be pumped simultaneously on the consumer side so that there is an even temperature increase in the heat exchanger. A one-sided temperature increase must be avoided in order to prevent mechanical stress due to high temperature gradients within the heat exchanger.

When starting up the system, it must therefore be ensured that the heat exchanger to the customer is heated evenly on both sides. This requires circulation on the user side in a short circuit. In this way, the long pipe to the user network is also heated.

The solar field is operated at max. 380 °C to feed a concrete storage tank with heat.

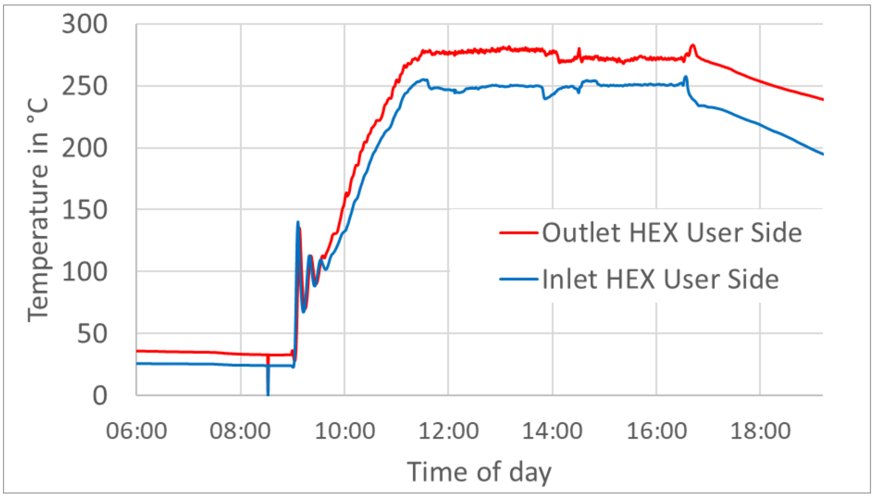

Figure 2. *First heat delivery to the consumer at the Avery Dennison plant (HEX: Heat Exchanger)*

Figure 2 shows the first heat supply in partial load operation, still without operating the storage tank. The target temperature of 275 °C could be controlled within the tolerance range straight away. Some of the temperature fluctuations at the outlet of the heat exchanger towards the consumer were caused due to fluctuations that already occurred at the inlet of the heat exchanger, i.e. from the consumer circuit.

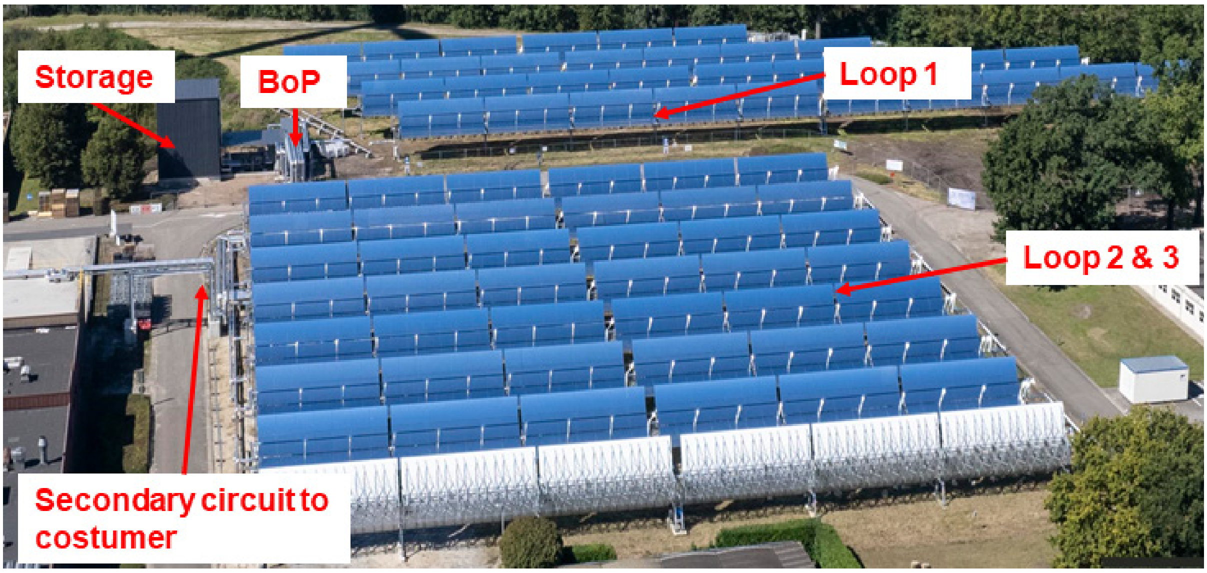

Figure 3. *Solar field (Photo: Avery Dennison)*

Figure 3 shows an overview of the solar field with balance of plant (BoP) and storage in the background, as well as the pipework to the user. Loops 2 and 3 are arranged in parallel and each consist of 4 collector rows of 6 modules. Their feed and discharge lines to the BoP are combined. Loop 1 is also connected in parallel, although it has a larger aperture area. This is compensated for by higher mass flows. All three loops are equipped with a valve for mass flow control at the inlet. The collectors can also be operated with sheep grazing (Figure 4).

Figure 4. *Collector HYT6000/SL5770, type EuroTrough (photo DLR)*

4. Integration of heat in Europe's largest process heat field

Between June and October 2023, a solar field in Seville with an aperture area of 43,414 m² was put into operation to generate process heat for the Heineken brewery [4]. ENGIE Spain is selling the heat to Heineken for a contract period of 20 years, organised in a heat transfer agreement. After that, ownership is transferred to Heineken. The plant with solar field, storage and BoP was planned by Solarlite CSP Technology GmbH, Rostock on behalf of its Belgian parent company Azteq. AURA GmbH & Co. KG, Germersheim, was responsible for the 3D planning in the boiler house, modelled and designed the storage tanks and their interconnection, and provided support in the selection of components for the BoP. Process flow diagrams for the pipework and fittings were created by Tiede & Niemann, Hamburg. The solar field was constructed by Solarlite Spain, Bilbao, and the storage tanks by ENGIE Spain. ENGIE Spain commissioned the plant and is responsible for its operation.

Figure 5. *Western part of the solar field at Heineken Sevilla (Source: ENGIE [4])*

Figure 5 shows the western part of the solar field. For processes on the consumer side, there is a pressurised water line at 110 °C/145 °C. On the solar field side, pressurised water is also used as a heat transfer medium, which is heated up to 210 °C in order to store heat in 8 pressurised water tanks of 100 m³ each with temperature stratification (Figure 6). Two tanks are always connected in parallel, recognisable by the distributors. According to Heineken, 4 to 5 hours of operation from the storage tanks are possible, although this information is still from the commissioning phase. The restriction to 210 °C is necessary in order to remain within the PN40 pressure rating. Above this pressure level, fittings become considerably more expensive.

Figure 6. *Pressurised water storage facility in Seville (Source: ENGIE)*

The solar field is arranged in 3 fields with a total of 18 loops, whereby the loop lengths are partly irregular in order to adapt to the contours of the plot. The axes of the collectors are arranged in an east-west direction for better seasonal distribution of the heat supply. According to verbal information from Heineken, 70% annual solar coverage is planned, according to the website of Solarlite CSP Technology GmbH up to 53% [5].

In the brewery, demand fluctuates between 10 MW and 20 MW due to batch processes. No brewing takes place on Saturdays and Sundays, which means that consumption is considerably lower during the weekend.

5. Results of the 2023 global market survey on concentrating collectors

The annual survey by Solrico [6] shows a significant increase in solar thermal system installations in 2023 compared to the two previous years (Table 1). In terms of the aperture area, almost 50% of the new plants were installed in Spain.

Table 1. *Market development of solar thermal process heat in 2023 (SHIP: Solar Heat in Industrial Processes)*

	2017	2018	2019	2020	2021	2022	2023
Number of SHIP systems put into operation	107	99	86	85	73	116	116
Newly installed aperture area / m²	219,280	55,583	358,641	132,316	51,866	43,664	134,990
Newly installed thermal capacity / MW	153	39	251	93	36	31	94

Please note the conversion of aperture area to output ("newly installed thermal capacity") with a factor of 0.7 kW/m², which is agreed for statistics. Manufacturers' output figures for systems are generally lower; often it is not the nominal output that is stated, but a value that is achieved more often per year.

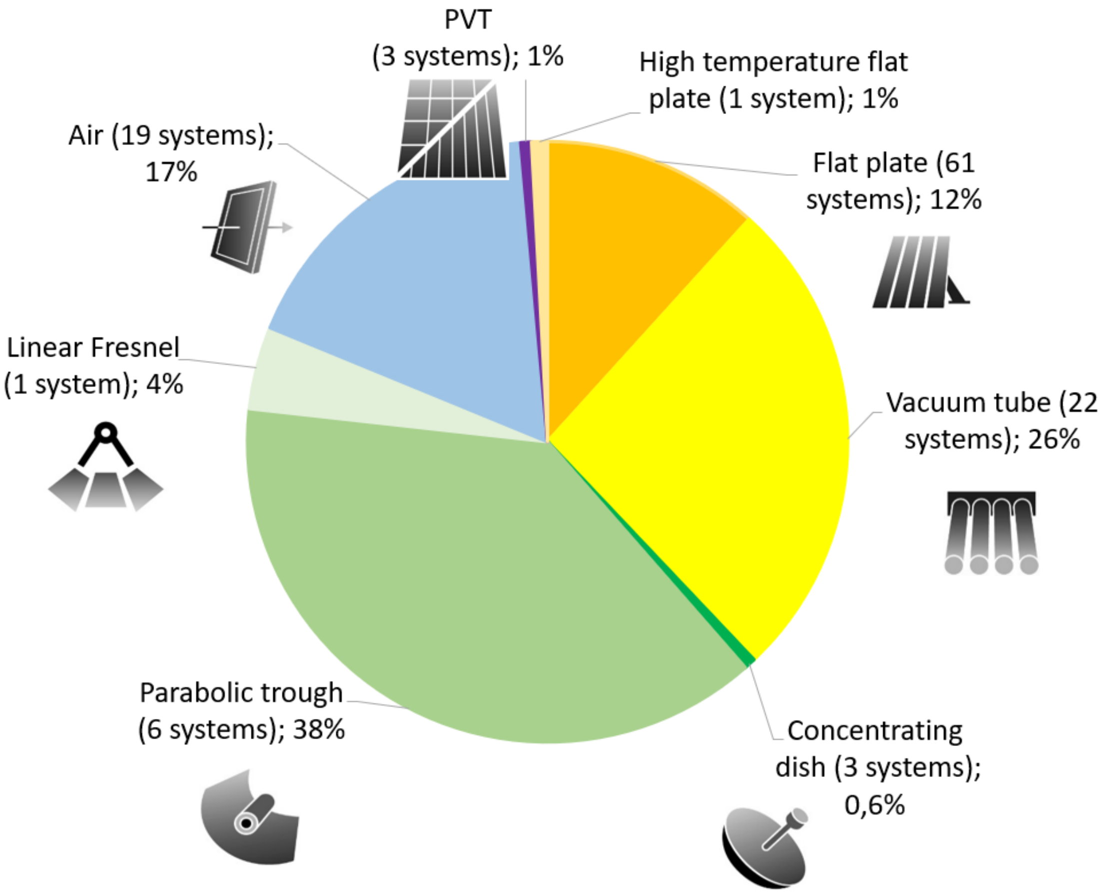

Figure 7. *Distribution of collector type area in the SHIP world market 2023 (Total: 134,990 m²) [6]*

The proportion of concentrating systems has risen sharply and will account for 43 % of the installed collector area in 2023 (Figure 7) compared to 16 % in 2022. At 38 %, parabolic trough collectors were the most widespread technology in process heat in 2023.

Another trend in solar process heat is the increasing number of heat purchase agreements (HPAs). Six large-scale projects with a total capacity of 52 MW were realized in 2023 with heat supply contracts. The remaining plants were realized on the basis of turnkey delivery contracts. The share of solar thermal capacity realised as an energy service company model was therefore 55 %.

Data availability statement

Data are available from the authors.

Author contributions

D. Krüger contributed to the chapters 3 and 4. S. Fahr wrote the chapter 2 “In-situ test plan for commissioning a power transfer station”. J. Leicht and J. Krüger contributed to chapter 3. A. Burger contributed to chapter 2 and reviewed. S. Bonleitner had writing contribution to section "Examples for BoP engineering " and reviewed, too. B. Epp contributed to chapter 5. N. Konz contributed to chapter 3 and reviewed the full paper. J. Stengler was reviewing and editing.

Competing interests

The authors declare that they have no competing interests.

Funding

The authors acknowledge the financial support by the German Federal Ministry for Economic Affairs and Climate Action under contract no. 03ETW021. The sole responsibility for the contents lies with the authors.

References

[1] 8. Energieforschungsprogramm zur angewandten Energieforschung, https://www.bmwk.de/Redaktion/DE/Publikationen/Energie/8-energieforschungsprogramm-zur-angewandten-energieforschung.html (accessed on 9 July 2024)

[2] Dirk Krüger et al., "Standardized Balance of Plant Engineering for Solar Process Heat", 28th SolarPACES Conference, 2022, Conference Proceedings, https://doi.org/10.52825/solarpaces.v1i.690

[3] N. Konz et al., „Integration of Solar Thermal Process Heat", ISEC 2024 –3rd International Sustainable Energy Conference, https://doi.org/10.52825/isec.v1i.1147

[4] ENGIE, "Heineken España y ENGIE España inauguran la planta termosolar de uso industrial más grande de Europa", https://www.engie.es/heineken-espana-y-engie-espana-inauguran-la-planta-termosolar-de-uso-industrial-mas-grandede-europa (accessed on 9 April 2024)

[5] Solarlite CSP Technology GmbH, Heineken Brewery Seville, Spain, Solar heat supply https://www.solarlite.de/en/project_heinekensevilla.cfm (accessed on 16th of July)

[6] B. Epp, "Results from the market survey for 2023 on solar process heat", Solarthermalworld.org, https://solarthermalworld.org/news/the-netherlands-and-spain-drive-ship-market-2023/ (accessed on 9 April 2024)