Joining forces to open the market for solar heat in industry

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Abstract

Worldwide, industry is responsible for more than a quarter of the total primary energy consumption and associated CO2 emissions. About two thirds of this energy is in form of thermal energy, while only one third is electrical energy. Thus, the use of solar thermal collectors for industrial applications is an obvious step in the direction of energy and cost savings. The sun does not shine continuously, despite industry's demand for process heat around the clock. Therefore it is necessary to combine the solar collector with a fossil fuel fired technology as a backup to ensure continual process heat supply according to the industrial load profile.

To save planning and engineering effort for the integration of solar and fossil fired process heat technologies the German company Industrial Solar has joined forces with renowned industry partners.

In this paper we describe three groundbreaking cooperations resulting in integrated packaged system solutions meeting the needs of industry and opening the market for solar thermal technologies for industrial applications.

Keywords: Fresnel-collector; solar process heat; direct steam generation; solar cooling; combined heat and power.

1. Introduction

Solar thermal process heat has a higher chance to become successful, when collector manufacturers collaborate with other engineering companies and technology providers in the field of process heat generation. Cooperations are of great advantage in order to provide complex turn-key system solutions for solar thermal process heat.

The market share of solar process heat installations accounts for less than 1 % of worldwide [1]. At the same time market-ready technologies offer the possibility to integrate solar energy at competitive costs and comparably high utilization ratios.

One major obstacle for faster and further market penetration is confidence in the technology. Potential customers with the possibility to finance large scale thermal solar process heat installations, such as Fresnel-collector systems, confide in long-term proven technologies. In order to tackle this chicken and egg situation showcase installations need to be implemented to gain experience, references, and thereby confidence.

In addition, an industrial customer requires a solution for easily integrated heat generation systems, which do not affect the thermal processes or the production line of the company. In order to achieve this solution, the cooperation between collector manufacturers and process heat technology providers is of great benefit.

Collaborations make it possible to

- ➔ provide integrated solutions instead of components.
- ➔ save planning costs due to a recurring system design.
- ➔ to harmonize controls for flawless operation.

In order to push solar thermal process heat installations, integrated system solutions feature advantages as opposed to the provision of single components from different manufacturers.

Industrial Solar GmbH is an experienced supplier of solar process heat systems for industrial applications with a track record dating back to 2005. With eight years of experience implementing its systems, Industrial Solar has the longest track record with this technology worldwide.

This paper describes three path-breaking collaborations between the Fresnel-collector manufacturer Industrial Solar and three technology providers from different fields:

- ➔ Polygeneration of Heat and Power with Dürr
- ➔ Fossil and solar steam generation with Viessmann
- ➔ Solar Heating and cooling with Fischer eco solutions

2. Solar Heat for Combined Heat and Power

Dürr AG is one of the world's leading suppliers for automobile manufacturing technology. As a systems supplier, Dürr plans and builds complete automobile paint shops and final assembly facilities. A first result from the cooperation with Industrial Solar was the Eco+Paintshop, in which a solar process heat system had been integrated to provide heat for the curing of autobody paint at 200°C [2]. The first demonstration system was successfully tested in 2012.

In a next step the development of a micro gas turbine with solar preheating, pursued by Dürr and Industrial Solar, aims at industrial applications in the power range of up to 500 kW of electrical energy in the automotive sector. The sustainable but fossil-fuel-fired micro gas turbine technology can profit from renewable solar thermal energy, and on the other hand, the solar thermal technology is supplemented by a technology that is not dependent on solar irradiation conditions.

Ideally, micro gas turbines are deployed where process heat and decentralized power supply are needed. For example, the waste heat of gas turbines, with their high temperature profiles (275 - 600°C) is suitable for curing paint in the automotive sector, which has a temperature demand of up to 200°C.

The solar process heat generated by a Fresnel-collector field is used to preheat the compressed combustion air of the micro gas turbine via a heat exchanger. For this system, thermal oil is heated to a maximum temperature of 340 °C and then circulated through a heat exchanger where compressed air of the micro gas turbine is preheated from 180 °C to 320 °C.

The working principle of the Eco+Energy CPS Suntec, which combines micro gas turbine technology with a linear Fresnel-collector, is to solar preheat compressed air injected with water before it enters the combustion chamber. Air leaving the compressor of the micro gas turbine at a pressure of 4 bar and a temperature of 220 °C is injected with water, resulting in a mixture temperature of 180°C. This injection of water in combination with solar preheating is a new concept that comes with three advantages:

- ➔ The share of solar thermal energy can be increased
- ➔ The turbine power is increased with the water injection
- ➔ The NO_x emissions are decreased

In a second step, the air is preheated inside the solar driven thermal oil heat exchanger to 320 °C, before it is lead into the recuperator, where it is heated up to 600 °C by the heat of the flue gas. Next, the hot gas is injected into the combustion chamber, where fuel is added, and due to the combustion the temperature increases to 950 °C. The hot flue gas is then expanded in a turbine, which drives the generator and compressor. Finally, the heat of the flue gas is lead - after passing through the recuperator - to the waste heat recovery (i.e. paint dryer).

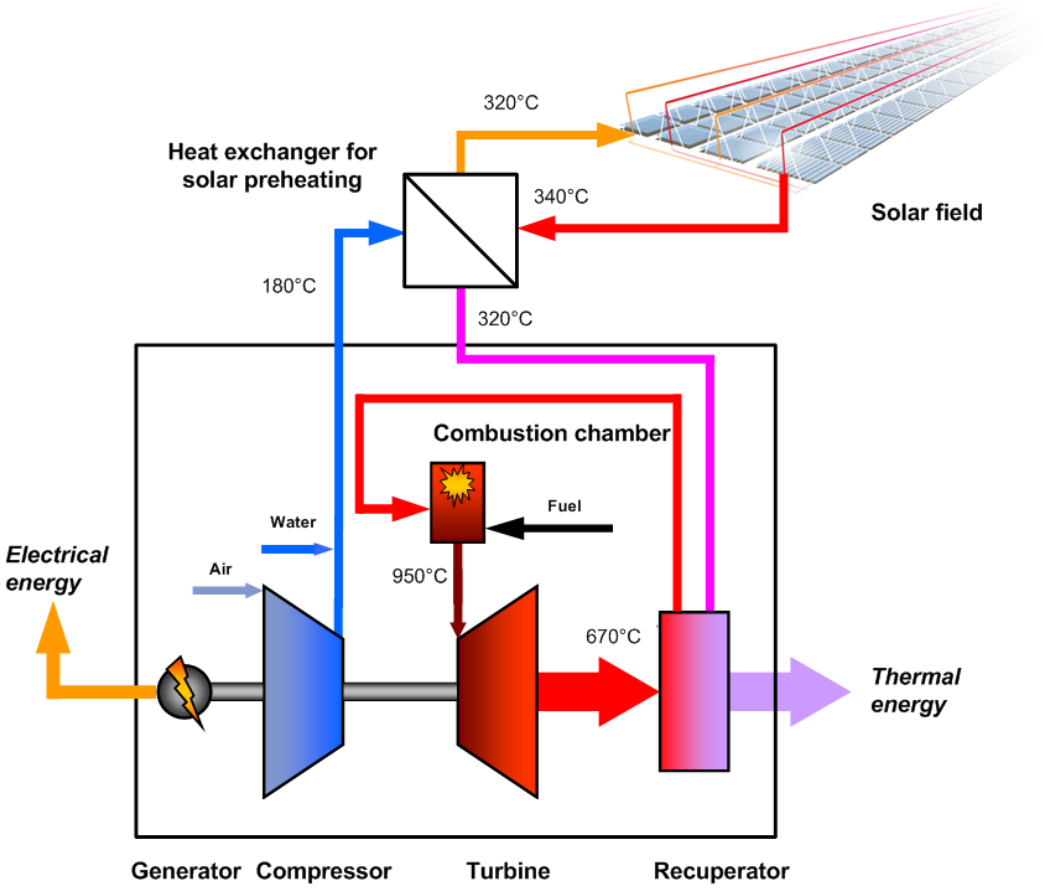

Figure 1: Schematic diagram of an Eco+Energy CPS Suntec system

One advantage of this production process is that the temperature level of the turbine flue gas (up to 645 °C) remains well above the maximum temperature inside the solar thermal circuit. Furthermore, the efficiency of power generation from solar thermal energy by the CPS (30 %) within the design power range of 100 kW - 500 kW is up to 10 percentage points above the current state of the art.

The development of the Eco+Energy CPS Suntec introduces a new and cost competitive approach of solar-fossil fuel hybrid power generation. By combining two technically and economically compatible systems, Eco+Energy CPS Suntec promotes two competing technologies in a single product – combined heat and power (CHP) and concentrating solar heat production via Fresnel-collectors for industrial applications. The sustainable but fossil fuel-fired micro gas turbine technology can benefit from utilizing renewable solar thermal energy, and on the other hand, solar thermal technology is supported by a technology that is not dependent on irradiation conditions. Hence the 24/7 supply of process heat and electric power can be assured, independent of daylight and weather.

By feeding in solar process heat, the consumption of fossil fuels can be reduced by up to 35% at nominal power. The overall efficiency, including the usage of the hot exhaust gas of the turbine (i.e. for an industrial application) can reach values beyond 90%. The integration of a micro gas turbine and a solar process heat system also improves the economic viability of the solar thermal system, promoting the dissemination of solar thermal technologies for industrial applications.

The next step will be to perform micro gas turbine tests to research more closely the injection of water in combination with solar preheating of the compressed air.

3. Hybrid Solar and Fossil Process Steam Generation

The Viessmann Group is one of the world's leading manufacturers of heating and renewable energy systems. Viessmann employs over 9,400 employees worldwide and has an annual turnover of approximately 1.7 billion Euros. As a market leader in industrial steam boilers, and with their strong commitment to make steam generation more sustainable, Viessmann is an ideal partner for this project.

Viessmann and Industrial Solar have paired up to offer a cost-effective and environmentally friendly standard solution package. With the scientific support of DLR Institute for Solar Research and with funding from the German Ministry for the Environment, the aim is to create a "solar-fossil fuel" fired hybrid system that will be a cost effective and environmentally friendly solution to providing steam for industrial customers.

Industrial process steam as a market segment has been opened up poorly by renewable energies so far. Concentrating solar collectors can efficiently utilize solar energy at the high temperature levels required for such applications. Of great advantage with respect to investment cost and operation behavior, is the direct steam generation (DSG) inside the solar collector system. The ideal combination of a solar steam generator with a fossil fuel fired back-up ensures a safe and steady supply of steam for any production process, independent of weather conditions or daylight hours.

A main obstacle for the dissemination of solar process steam systems is the disproportionally high cost of demanding engineering services, permits for compliance with industrial regulations, and system certification, when each system is individually tailored to suit a specific industrial process. This problem is addressed by developing an integrated, modular system.

The ongoing joint research project SolSteam aims to answer the basic technical questions of combining a direct steam generating solar collector with a fossil fuel fired steam generator, thereby laying the foundation for the development of a solar-fossil fuel hybrid system. The commercial availability of such a system is the precondition for swift entry of renewable energy into the industrial process heat market. This solution combines cost-efficiency with security of steam supply.

The results of this project will lead directly to the development of a marketable system. Additionally, new insights into further optimization of the technology are expected, in addition to the identification of new scientific questions. Simulation tools will be optimized so that manufacturers will be able to plan cost effective and accurate process heat systems with the integration of direct steam generating solar collectors.

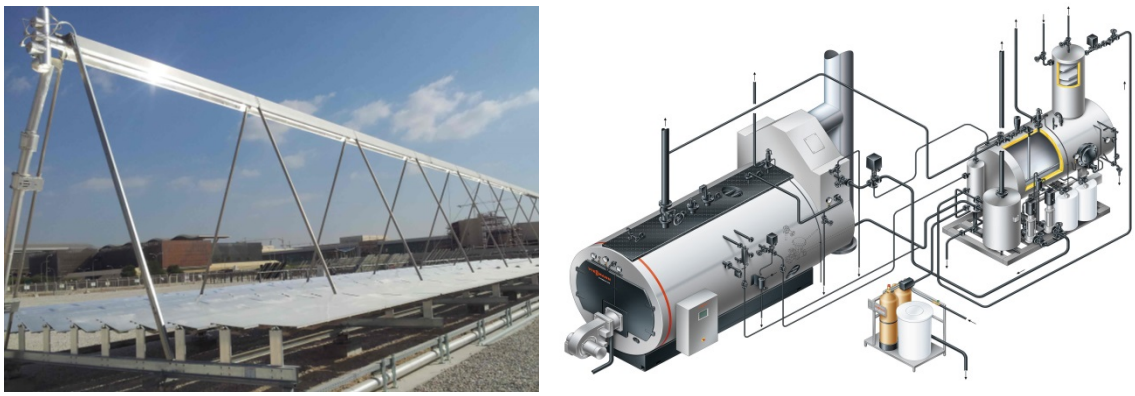

Figure 2: (a) Industrial Solar Fresnel-collector; (b) Viessmann steam boiler with peripheral components.

The cooperation of Viessmann, Industrial Solar, and DLR is developing a standardized packaged solar-fossil fuel steam generation system for industrial applications that is paving the way for a more sustainable production in sectors such as food, textile, pharmaceutical and many others. This system consists of two main

components: a Fresnel-collector field and a shell boiler. Within the SolSteam project, integration of saturated steam supply for process heat consumers in a reliable, energy efficient and cost effective way is investigated. A variety of detailed integration options will be considered. In the second phase, a solar/fossil fuel plant will be erected, implementing the design of choice into a European plant to demonstrate the product.

4. Solar Driven Absorption Chillers

fischer Rohrtechnik as a leading supplier for stainless steel tubes and its sister company fischer eco solutions as a manufacturer of absorption cooling machines have installed a solar cooling and heating system in their newly built office building in Achern. The working fluids are Lithium bromide as the absorbent and deionized water as the refrigerant. The machine is 100% built of highly corrosion resistant stainless steel by using latest laser cutting and welding technology.

Figure 3: fischer eco solutions absorption chiller with 100 kW cooling capacity.

Running at its design point the unit delivers 100 kW cooling capacity with a COP > 0,7. The temperatures are 6°C / 12°C in the chilled water loop and min. 90°C hot water in the generator. The product line ranges from 20 kW to 1000 kW cooling capacity.

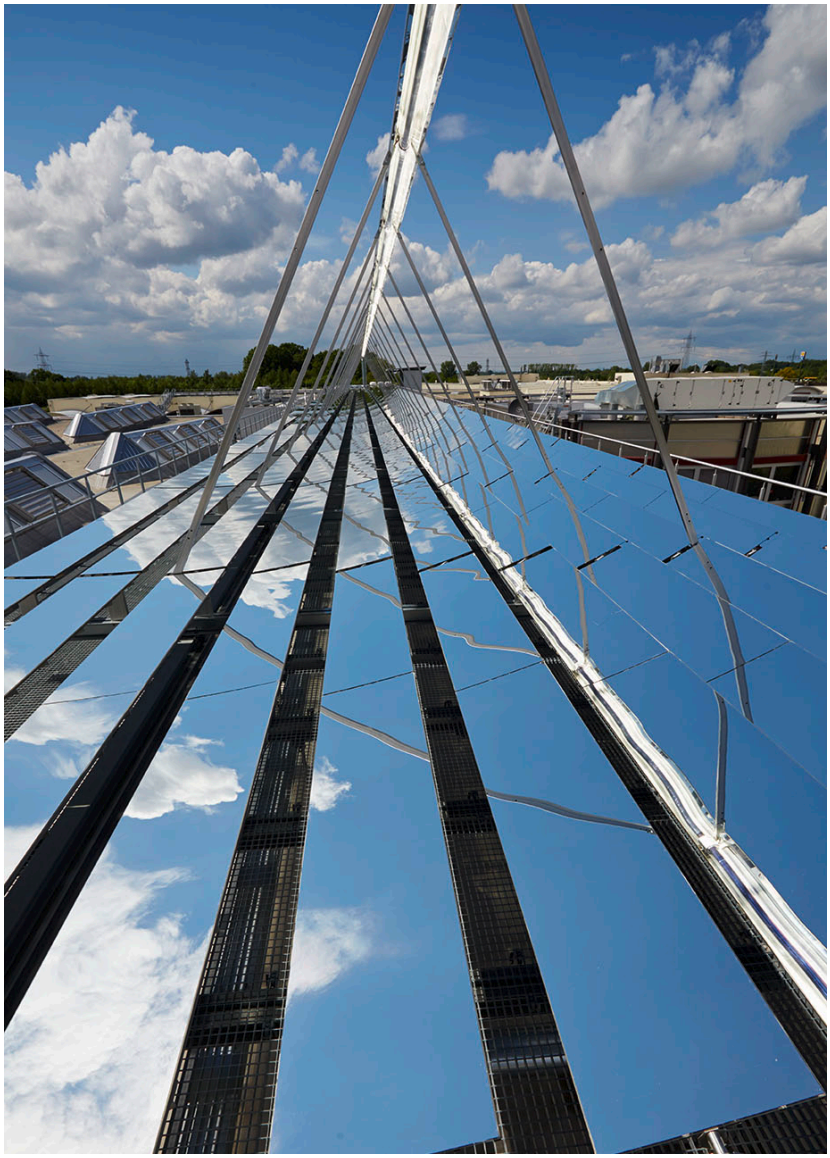

Figure 4: Industrial Solar Fresnel-collector string with a total length of 90 m and 484 m² aperture area at Fischer eco solutions in Achern / Germany.

The heat source for the system is a Fresnel-collector manufactured and installed by the company Industrial Solar in Freiburg. The collector string consists of 22 modules with a total length of 90 m and an aperture area of 484 m², which corresponds to thermal peak power of about 270 kW. The heat transfer fluid is pressurized water with an operating pressure of 9 bar. In summer the process heat at a temperature of 130°C is used to power the absorption chiller with a cooling capacity of 100 kW, whereas in winter the heating system of the office building is supported by the solar heat.

Higher temperatures that can be provided by the Fresnel-collector will allow to investigate new working fluids (Ionic Liquids). First test rows and design customizations are already in progress.

After extensive testing of this solar cooling and heating system at the headquarter of fischer eco solutions the partners will offer this system to customers worldwide. An optional combination with a thermal desalination system, a so-called multi effect distillation with thermal vapor compression (MED-TVC) will make this product line even more attractive.

5. Conclusion

Above, three examples are given for fruitful collaborations between the collector manufacturer Industrial Solar and other technology providers. Within these collaborations the core necessity for further market penetration is achieved: demonstration plants are being implemented together with the partners in order to prove the concepts.

The combined know-how and competence of both parties made each of these new system developments possible. Furthermore, for the companies involved the collaboration can mean path breaking mutual stimulation in the field of know-how exchange and great synergy effects in marketing strategies.

To conclude, cooperation of collector manufacturers and technology providers from different fields is an important strategy for further deployment of solar thermal process heat.

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