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Solar Process Steam for a Pharmaceutical Company in Jordan

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Abstract. This paper presents details of the recent installation of a linear Fresnel collector to provide saturated steam for process heat usage through Direct Steam Generation (DSG) for industrial use in the Jordanian pharmaceuticals manufacturing company RAM Pharma, where first solar steam has been provided in March 2015. This commercial DSG project also represents the first solar DSG plant in MENA. During sunshine, the system achieves a solar fraction of 100 %, and the conventional steam boiler is not needed. In the evening the fossil fired backup takes over automatically and replaces the solar collector in operation. Operational experience, details of the control strategy, and measurement data are presented in the paper.

Keywords: Solar thermal, solar-hybrid, linear Fresnel collector, process heat, solar steam, process steam, industrial application

TECHNICAL DESCRIPTION

The Fresnel collector field of 396 m² aperture area provides saturated steam directly to the steam network of RAM, which runs at a pressure of 6 bar gauge and 166°C, and is mainly used for pill drying. The direct steam generation has been realized with the so-called recirculation concept. According to the typical operation procedure the solar field is supplied with a surplus of feed water, so that only a part of the water is evaporated in the absorbers. [1-4]. This secures enough cooling of the absorbers to avoid overheating, which would occur at a dry-out of the absorbers. Behind the collector field the water/steam mixture will be separated. In a steam drum at the upper side steam leaves for the RAM steam network, while the water content is being recirculated into the solar field. The evaporated steam is being replaced by condensate from the RAM condensate network.

The Solar Collector Field

18 modules of the linear concentrating Fresnel collector by Industrial Solar GmbH have been installed on the rooftop of the RAM Pharma company building. The collector modules have been arranged in two parallel strings of 9 modules each, connected to a loop on one side, so that inlet and outlet of the field are on the other side. Each module contains one 4m long absorber pipe, and 11 primary mirror segments underneath. To form a string out of several modules, the absorber pipes are being welded together, while the primary mirrors are connected in the couplings (see FIG. 1).

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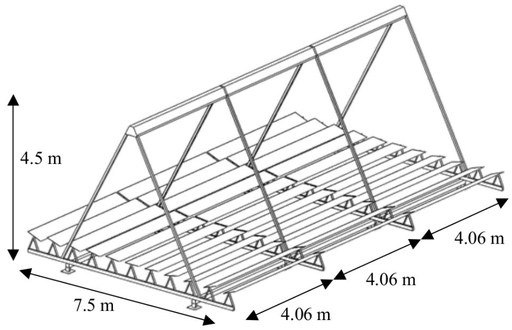

FIGURE 1. Schematic of three modules of Industrial Solar's Linear Fresnel Collector LF-11.

The Steam Drum

The size of the drum is 2000 l, the gliding operation pressure range currently is between 7 bar_g and 14 bar_g. Apart from its function as a separator the steam drum has been enlarged to work as a Ruths' storage, which can be loaded by the solar field with a pressure of up to a maximum of 14 bar_g. During short periods of missing solar power (i.e. due to clouds), the steam drum still supplies steam to the steam network. Then the pressure drops until reaching a lower threshold, when the controlled steam valve shuts off the steam supply from the solar collector system to the steam network. The closing point for the valve currently is 1 bar above the operation pressure in the steam network of the industrial process.

Furthermore the drum buffers changes in water content in the piping due to variation of the solar thermal power input. For example while a cloud passes over the solar field, the absorber pipes fill up with liquid water and the drum level drops. After the cloud clears away, the liquid water is then driven out of the absorber pipes, rapidly rising the fill level of the drum back to the same state as before. The functions of the Steam Drum are described in greater detail in [6].

Piping and Instrumentation Diagram

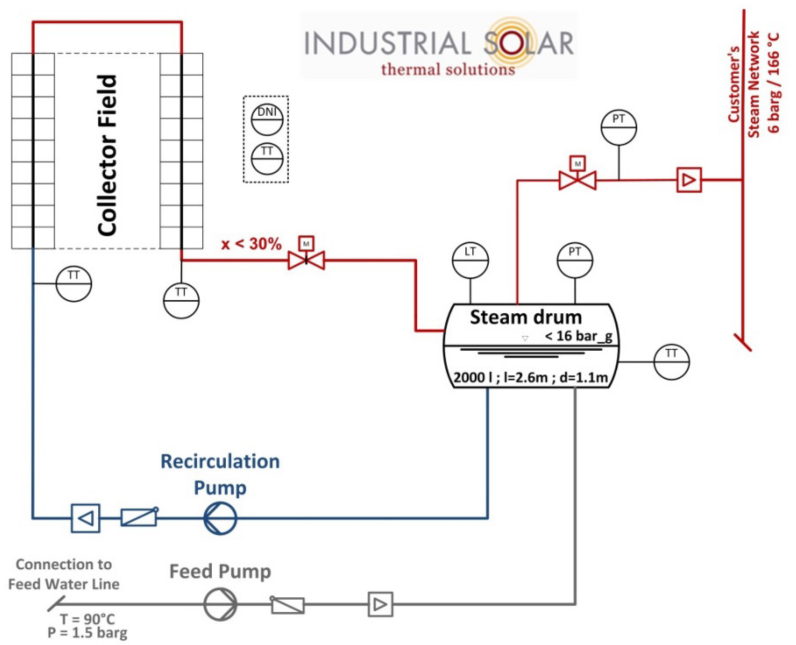

FIGURE 2. Simplified Piping and Instrumentation Diagram (P&ID) of the DSG plant in recirculation design in Jordan.

OPERATIONAL EXPERIENCE

The commissioning of the plant had been completed and first steam has been provided to the factory's steam network on March 17th, 2015 (photo see FIG. 3). Since then, the plant is continuously operational. During sunshine, the system achieves a solar fraction of 100 %, and the conventional steam boiler is not needed. In the evening the fossil fired backup takes over automatically and replaces the solar collector in operation.

FIGURE 3. Image of one of the two collector strings in operation. Picture taken, when first solar generated steam was delivered to RAM Pharmaceuticals on March 17th, 2015.

Control Strategy

Pressure Control

The pressure in the steam network changes, whenever the steam mass flow coming from the collector does not match the amount of steam being consumed. A motor valve is installed in the steam line to maintain the pressure in the steam network by control of the steam mass flow into it coming from the steam drum. Since the diesel fired steam boiler has its own pressure control, the pressure set point for the steam valve of the solar collector system has been set 3.5 bar above the set point of the conventional steam boiler. With this choice of set points, the conventional steam boiler will not start to produce steam as long as the solar collector system delivers enough steam to maintain the pressure. In the late afternoon, once the collector power and hence the produced steam mass flow by the collector drops, the pressure will go down to the point where the conventional boiler starts and takes over. In the morning after start-up of the solar collector system, the pressure will rise and the conventional boiler will shut down again.

However, during a day of solar collector operation the production processes do not run continuously and the steam consumption may fluctuate strongly. When no steam is needed for a longer time, the pressure in the steam drum will reach the upper threshold of operation. As a short-time buffer storage, the steam drum is fully loaded. To prevent critical high pressures, the solar collector control will then modulate the power by turning some mirrors out of focus until the steam drum pressure stabilizes between 12 and 14 bar_g.

Water Mass Balance

Whenever the solar collector systems supplies steam to the steam network, it loses water, which has to be replaced by treated feed water. The feed water is taken from the existing feed water treatment plant which also produces the feed water for the existing steam boiler.

A level meter in the steam drum measures the fill level continuously. The fill level is controlled by the feed water pump, which is currently switched on and off according to the measured fill level. The feed water with a temperature of around 90 °C is directly fed into the steam drum.

Fluctuations in the fill level of the steam drum are caused by changing steam content in the absorber pipes. When steam generation in the solar collector starts i.e. in the morning, the developing steam in the absorber pipes displaces liquid water from there, which is driven out towards the steam drum, causing a flush of up to 260 l volume. When, on the other hand, steam generation is interrupted i.e. by a cloud, the absorber pipes will be filled up with liquid water by the recirculation pump, thereby drawing up to 260 l out of the steam drum. By measuring the direct solar irradiation, clouds are detected and the set point for the fill level is therefore adapted according to the current solar steam generation.

The ion concentration is regulated by simple manual blow-down, which is handled manually on schedule. The interval for blow-down is calculated based on the amount of delivered steam. In the beginning, a blow-down ratio of 1:100 has been assumed to be sufficient. After the first year of operation, the ratio can be adapted according to the results of a visual inspection.

First Measurement Results

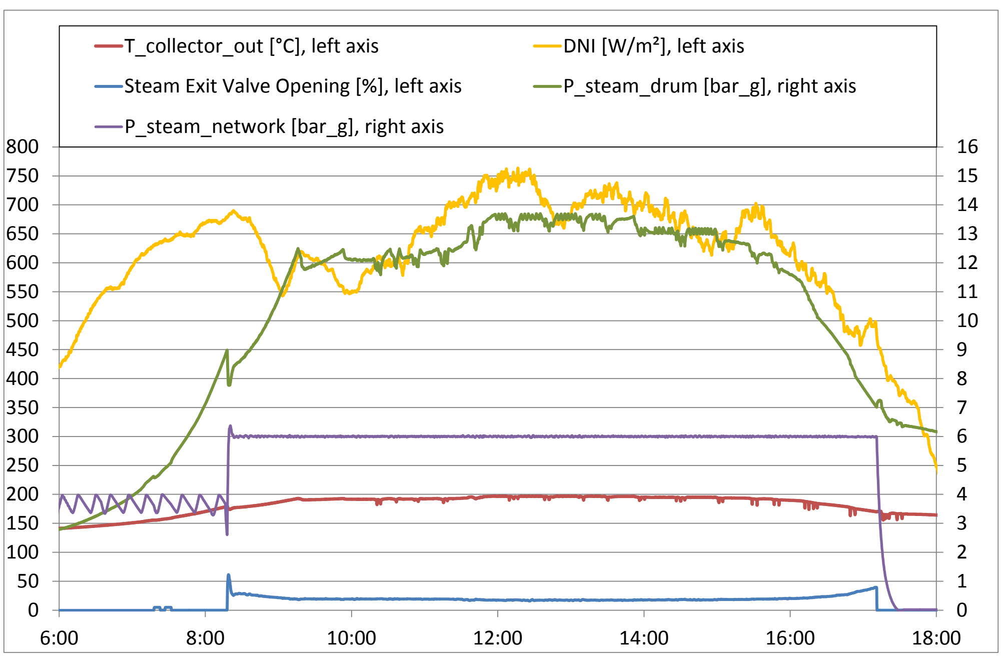

FIGURE 4. Measurement Data from June 19th, 2015. A day with several high clouds and thus fluctuations in DNI.

Since the commissioning, the solar collector system is operational and pressure control during sunshine works with satisfying stability. FIGURE 4 shows measurements from June 19th, 2015. In the early morning, before start-up of solar steam generation, there is already some steam demand by the production. The steam is produced by the Diesel fired steam boiler, which runs at a lower pressure set point. The pressure is maintained between 3.5 bar_g and 4 bar_g.

After start-up of the solar collector around 08:15 a.m., as can be seen from the two pressure curves, the pressure in the steam drum is rising and falling between 7 bar_g and 13.5 bar_g according to the amount of energy stored. The pressure in the customer's steam network can be maintained accurately by the pressure control from the solar system within a range from 5.95 bar_g to 6.05 bar_g, five times more precise compared to the conventional boiler. This control is mainly achieved by the position of the steam exit motor valve, which is also shown in the same diagram.

IMPROVED MONITORING AND TESTING OF ALTERNATIVE CONTROL STRATEGIES

Apart from gaining more experience with solar process heat facilities it is a major aim to get investment costs down. Therefore various designs to integrate solar steam with a boiler and the steam network have been investigated in the R&D project "SolSteam" [5] executed by the partners Industrial Solar, Viessmann and the German Aerospace Center (DLR). Within SolSteam, the installation in Jordan shall be modified to test a novel design for direct steam generation. Monitored as a pilot system for further optimization, it will then eventually be used as a basis for a standard package hybrid system. For the modifications and the monitoring in the R&D project, Industrial Solar GmbH is being supported by DLR, which has more than 20 years of research experience with concentrating solar thermal technologies and direct steam generation.

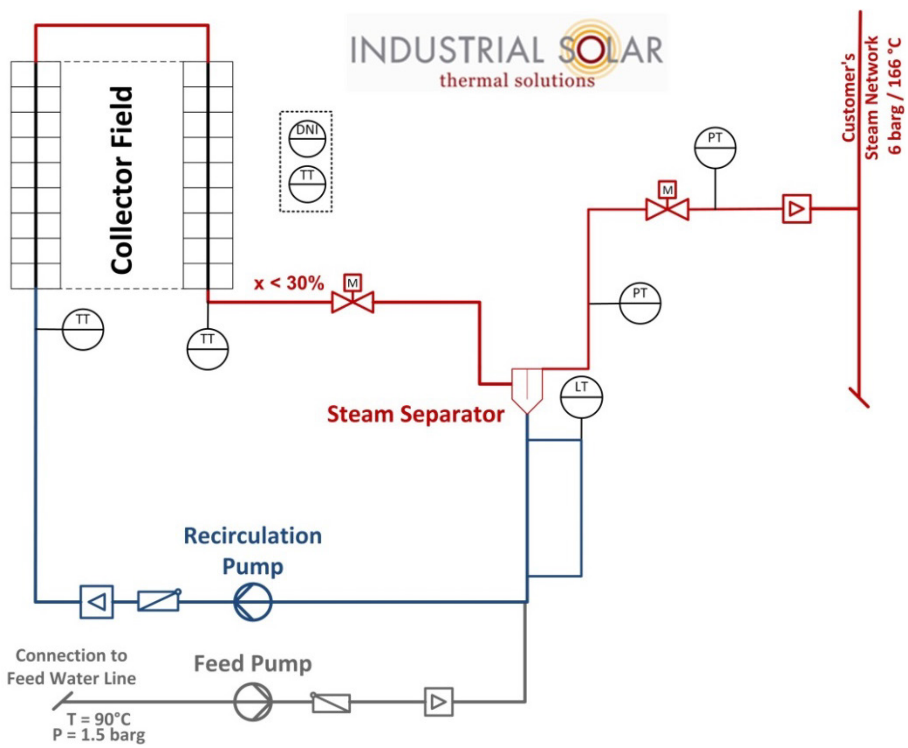

FIGURE 5. Simplified P&ID of the alternative monitoring setup with a separator and level meter instead of a steam drum.

The 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 project officially started in August 2013 and will continue till mid of 2017. After identifying market requirements, a wide screening of different concepts for a standard hybrid system had been made and the three most promising integration concepts have been chosen [5]. One of these three concepts will be introduced end of 2015 to the existing plant in Jordan, which therefore shall then be monitored within the project.

Following commissioning of the adjustments of the facility, test measurements will begin. DLR will carry out an evaluation of the collector field optical and thermal performance to provide reliable and precise input data for the detailed modelling of the operation. Steady-state operation and robust start-up and shut-down strategies will be tested. With load changes, the dynamic behavior of the collector field and boiler will be examined so that operation and control strategies can be optimized.

The system behavior under various conditions will be tested. This includes extreme temperatures, power failure, and failure of individual components, such as the tracking system or pump. After demonstration of safe operation of the new separator under all relevant conditions, further process variations will be tested.

The process optimization will also take into account the influence of different demand profiles induced by the steam consumer. On completion of the testing phase, the improved routine operation will be monitored to verify the anticipated fuel savings.

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