KANCHANABURI SOLAR THERMAL POWER PLANT WITH DIRECT STEAM GENERATION - LAYOUT

Dirk Krüger[1], Joachim Krüger[2], Yuvaraj Pandian[3], Jan Fabian Feldhoff[4], Markus Eck[5], Martin Eickhoff[6] and Klaus Hennecke[7]

[1] Dipl.-Ing., Researcher, German Aerospace Center (DLR), Institute of Technical Thermodynamics, Linder Höhe, 51147 Köln, Germany, Phone:+49 2203 601-2661, e-mail: dirk.krueger@dlr.de

[2] Director, Solarlite GmbH, Duckwitz, Germany

[3] M.S. Energy Systems, Solarlite GmbH, Duckwitz, Germany

[4] Dipl.-Ing., Researcher, [5] Dr.-Ing. Researcher, DLR, Institute of Technical Thermodynamics, Stuttgart, Germany

[6] Dipl.-Ing., Researcher, DLR, Institute of Technical Thermodynamics, Almería, Spain

[7] Dipl.-Ing., Researcher, DLR, Institute of Technical Thermodynamics, Köln, Germany

Abstract

A solar thermal power plant with parabolic trough collectors is being erected in Kanchanaburi, Thailand. It will supply electricity to the public grid for which a feed-in tariff is foreseen. For the first time direct steam generation will be applied in a commercial plant consisting of an evaporator and a superheater field. It combines the recirculation concept and injection cooling. Also the solar collectors are constructed with an innovative approach. They are made out of fibre glass/resin enclosing foam and are reinforced with a space frame taking torsion forces. The paper focuses on the layout of the solar thermal power plant.

Keywords: solar thermal power plant, direct steam generation, recirculation, parabolic trough

1. Introduction

In Kanchanaburi, Thailand a solar thermal power plant called “KTSE-9100” with parabolic trough collectors using direct steam generation is being erected. The actual power plant size is 9 MWel which will be executed in 2 phases: First phase being the 5 MWe plant discribed in this paper and next phase being another 4 MWe plant. The first plant will generate a nominal power of 5 MWe that will be fed into the public grid for a unit price of up to 11.6 THB per kWhe. Solarlite GmbH, Germany acts as EPC contractor for the solar field and delivers the parabolic trough collector field. MAN Turbo will deliver the steam turbine for the plant. The client Thai Solar Energy (TSE) who is responsible for the power block will own and operate the plant. The license for feeding the electricity into the public grid under the Very Small Power Producer (VSPP) regulation has already been granted.

The power plant construction began on Feb 2010. Nearly 30% of the solar field has been completed and the mechanical completion of the plant is expected for the first quarter of 2011.

2. Collectors

Developed from smaller scale parabolic trough collectors for process heat, the main innovative design feature of the SL4600 parabolic trough collector is a casted shell made of fibre glass and resin enclosing foam. It consists of single panels each 1m by 2.3m wide, which are glued together to form a segment. These segments form the basic element of the Solarlite solar field with gross dimensions of 12 m in length and 4.6 m in width (Figure 1). Up to ten of these segments are connected together to form a collector. The collector is tracked by a hydraulic drive system. To take the torsion forces a space frame is mounted at the back side of the collector. On the front side thin glass silvered mirrors are attached focussing on a vacuum receiver. The receiver has a slightly stronger wall thickness than “standard” oil receivers, as the solar field will be operated with direct steam generation and high pressures. The collectors have already been set up at the SERT in Phitsanulok, Thailand and at DLR in Cologne, Germany where performance testing on the Sopran test rig is foreseen.

Fig.1. Backside of the SL4600 Collector

3. Plant layout

3.1. Solar field general set-up

The total land area available for the 9 MWe plant is distributed in many lots adding up to about 460,000 m². The biggest lot of land with about 168,000 m² was chosen for the 5 MWe power plant. The solar field layout is mainly determined by the live steam conditions of the turbine and the steam generation concept. Due to land restrictions the solar field had to be adapted to the property line, but could be erected in north-south axis. Figure 2 shows two collector rows at the west side of the field.

Fig. 2. Collectors at the KTSE-9100 Power Plant

According to the thermal power input for the turbine the aperture area for the solar field has been fixed to a gross aperture area of 45,485 m². Solarlite has chosen for an innovative approach using direct steam generation to transfer the heat from the solar field to the turbine. It is being applied for the first time in a commercial solar thermal power plant producing superheated steam.

The number of collectors forming the evaporator and superheater loop and thus the choice of the loop lengths are based on the following criteria:

1. Maximum temperature difference in the receiver pipe below the German boiler code to ensure sufficient cooling of the absorber metal surface
2. Minimum massflux to be ensured in each loop for safety control reasons
3. Minimum pressure losses within a loop

After careful consideration of the above mentioned parameters, the solar field in Kanchanaburi is designed to have 12 evaporator loops and 7 superheater loops.

The evaporator solar field is located on the left side of the plot plan (Figure 3). The wet steam generated from the solar field is taken to the steam drum located in the solar field balance of plant (Number 3 in Fig. 1). The separated steam is then taken to the superheating part of the solar field. Although the system configuration appears to be complex, it follows closely the conventional boiler systems.

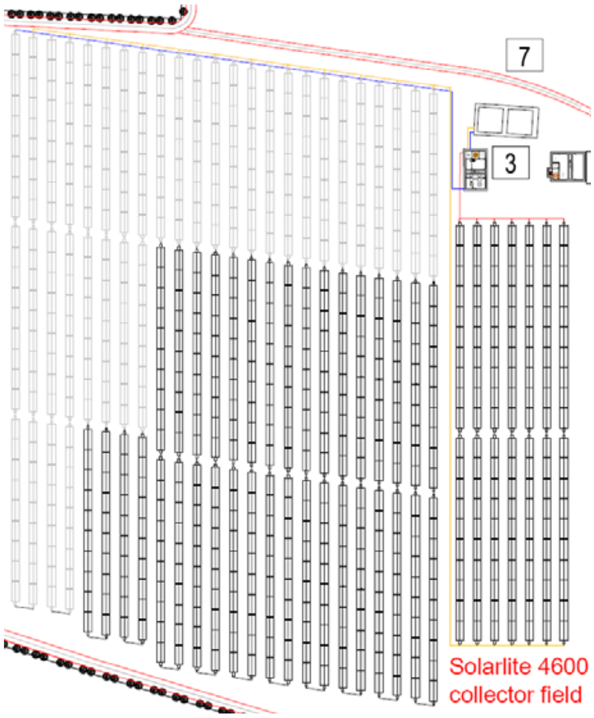

Fig. 3. Solar Field Layout

Solarlite DSG concept is based on the combination between the recirculation and the injection concepts for generating superheated steam. The advantage of combining these two concepts is better controllability of the process parameters even during fluctuating DNI conditions. The recirculation mode ensures that the receivers in the evaporator solar field are well cooled and the system pressure is maintained. The injection concept enables better temperature stability of the superheated steam. This combination results in a better controllability of the temperature and pressure of the superheated steam leaving the solar field to the turbine.

3.2. Solar field key system parameters at nominal and part load

DLR has set up a simulation model of the Kanchanaburi solar field based on information provided by Solarlite. The simulation model is implemented in IPSE-pro, a commercial simulation program for heat balance analysis. This approach allows the investigation of key system parameters at different steady state load conditions.

Due to the fluctuating irradiation conditions over the day and the year, the plant is regularly operated in part load. This has to be considered for the design of all major components. In this section the main process parameters are investigated in the expected operation range between 200 W/m² and 1000 W/m². The following values are displayed in Figure 4:

- Q_Thermal: Thermal power from collector field
- Q_Solar: Aperture related DNI
- Eta_Thermal: Expected collector efficiency
- Live Steam Mass Flux: Mass flux entering the turbine
- Maximum Pressure: Maximum pressure occuring in the solar field

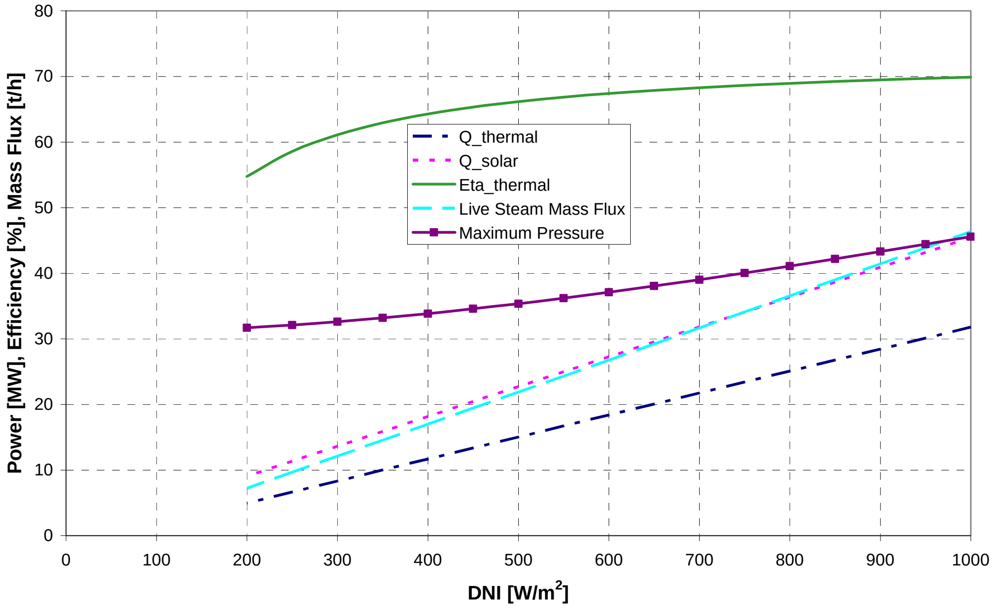

Fig. 4. Main Process Parameters during Part Load

Other process parameters are displayed in Figure 5. The mass flux in the recirculation line under design condition (@ 600 W/m2) is approx. 10 kg/s and can reach 18 kg/s if no de-focussing is applied. The pressure loss over the evaporation section (dp Evaporator) and the superheating section (dp Superheater) is quite similar.

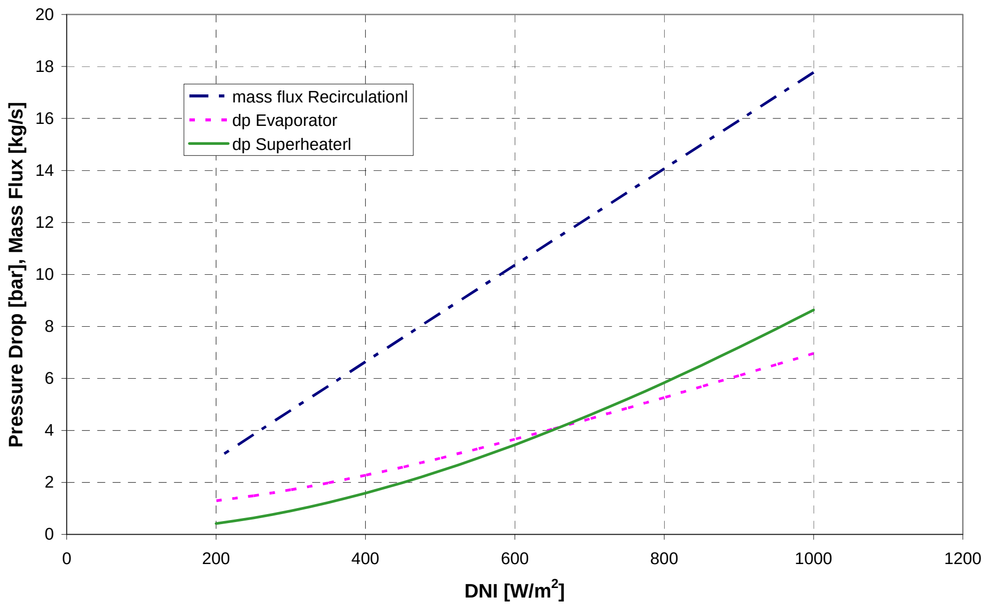

Fig. 5. Process Parameters during Part Load

3.3. Power block

The steam turbine of MAN Turbo, Type Marc 2 and the generator of the plant deliver 5 MW gross electrical power. The condenser operates with wet cooling. At a thermal input of 19.09 MW at 330°C and 30 bar the power block reaches an efficiency of 26,2%. Three tappings at the turbine can be used for degasification and one for pre-heating feed water.

4. Costs and feed-in-tariff

The basis for this project is the feed-in tariff law in Thailand introduced under the Very Small Power Producer (VSPP) regulations. The VSPP regulations allow customers with renewable energy generators (solar, wind, micro-hydro, biomass, biogas, etc.) to connect their generators to the grid and offset their consumption at retail rates. If a net surplus of electricity is generated, the VSPP regulations stipulated that Thai utilities must purchase this electricity at the same tariff that they purchase electricity from the state-owned generation company, EGAT. In autumn 2006, this rate (including Fuel Price charge) worked out to be about 3.8 baht (9.2 €cent, based on exchange rate in August 2010) per kWh for on-peak hours (weekdays 9 am to 10 pm) and about 2.0 baht/kWh (4.8 €cent) for off-peak hours (weekends, holidays and night time). In case of solar thermal electricity, the price is 8 baht/kWh (19.4 €cent) plus the peak/non-peak hour rates. The law has a limitation on the maximum capacity of the plant which should not exceed 10 MW electrical. The current scenario is that the additional feed-in tariff of 8 baht/kWh is fixed for the next 10 years from the day the plant goes into operation. There is discussion about a further extension of this period to another 10 years thus providing the 8 baht adder for 20 years. After this period, the electricity is to be sold for the basic electricity price prevailing during that time.

The complete power plant is planned to be constructed within a budget of approx 20 million €. This includes the solar field, turbine-generator, balance of plant, land, site preparation, infrastructure and project development costs. The solar field reaches a price of below 300 € per m².

5. Outlook

The site preparation, ground works and infrastructure for the power plant were completed during the beginning of 2010. The solar field collector foundations are almost completed and expected to be finalised until the end of August 2010. By then also 30% of the evaporator solar field is expected to be completed. The turbine house and balance of plant buildings are under construction (status August 2010).

The complete solar field is expected to be completed and available for cold commissioning during Feb 2011. Depending on the availability of the turbine and balance of plant components, the hot commissioning will begin in March/April 2011.