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A CSP plant combined with biomass CHP using ORC-technology in Brønderslev Denmark

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Abstract

A new CSP plant combined with biomass CHP, using ORC technology, will be built and taken into operation in Brønderslev, Denmark during spring 2017. The price for Biomass is expected to increase with more and more use of this very limited energy source and then CSP will be cost effective in the long run, also in the Danish climate. Oil is used as heat transfer fluid instead of steam giving several advantages in this application for district heating at high latitudes. Total efficiencies and costs, competitive to PV plants, are expected.

Keywords: *CSP, ORC, CHP, Biomass.*

1. Introduction

In the report "ORC og dampmotor til små flisfyrede varmeværker" [1] the potential for installing ORC-units in Danish district heating plants with wood chip boilers, is calculated to approximately 30 utilities with more than 20,000 MWh in yearly heat production. The first Danish plant (4 MW heat and 0.75 MW electricity) was implemented in December 2011 in Marstal. Aalborg CSP has developed a concentrating solar collector that has been demonstrated in pilot plants. 800m^2/0.6MW in Thisted, 1350m^2/0.8MW in Brønderslev and 4000m^2 / 2.8MW in a Combi plant in Tårs.

The Technical University of Denmark (DTU) has evaluated the performance of the parabolic trough array design in these plants at temperatures up to 350°C [2, 4]. The result was an array efficiency curve with a maximum efficiency of 0.75 and a total heat loss coefficient of only 0.04-0.06 W/m^2/K, in the temperature range 100-350 °C.

The Brønderslev district heating company expects lack of biomass in the future, resulting in higher prices. They therefore want to implement a CSP-plant, to supply the ORC with hot oil from a CSP collector array in periods with enough DNI (Direct Normal Irradiance).

2. The Plant Technology

The Italian Company Turboden will deliver the ORC-units for the CSP plant. In the last 15 years Turboden has implemented ORC-units in approximately 300 places. Of these, around 250 plants are heated up with oil from biomass boilers and of these 250 plants, 170 are placed in Germany, Italy and Austria. One plant using solar energy as heat source (parabolic trough) was implemented in Morocco in 2010 and 3 new plants using hot oil from parabolic troughs (PTC) are under implementation or planning in Italy. The technical efficiency when using solar as heat source is higher than 15%. Solar power with ORC is thus as efficient as photovoltaic systems.

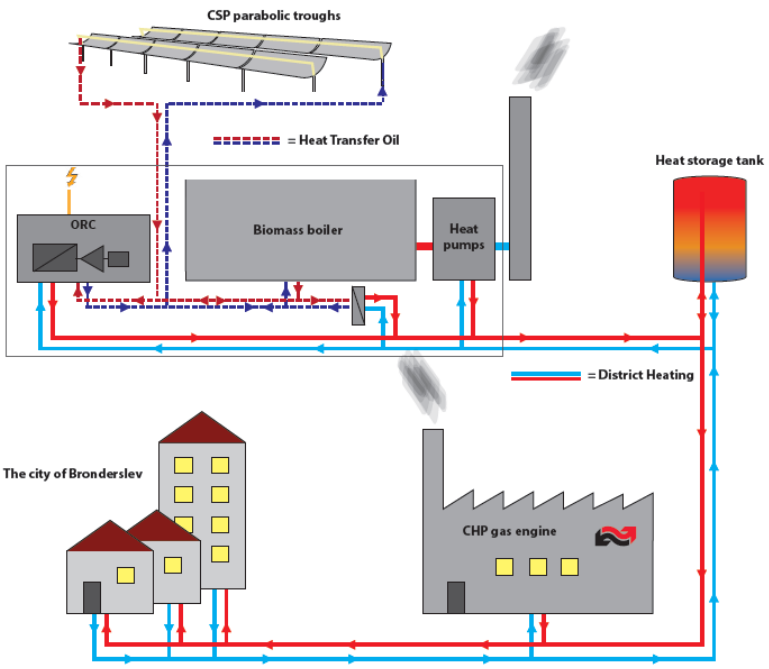

Fig.1. Flow duagram of the biomass CHP-plant with ORC-power unit and feed-in of solar thermal energy both to the ORC and District heating network. Drawing from http://www.aalborgcsp.com/

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Compared to steam systems, ORC has the following advantages:

1) Low mechanical stress (lower pressure and temperatures in the turbine).
2) No corrosion of turbine blades. Simple start procedure.
3) No demand from continuous supervision.
4) Easy maintenance.
5) Long lifetime (more than 20 years).
6) No use of demineralized water.
7) Possible with maintenance guarantee (95 % of running hours guaranteed).

Disadvantages are the low electrical efficiency (19 – 20 %) compared to a high pressure steam turbine. Thus ORC is a proven technology and when the heat production from the cold side of the ORC unit is utilized – as it is from most biomass fueled plants – also an efficient technology.

CSP (Concentrated Solar Power) plants operating by temperatures higher than 300°C and producing power are already installed in Southern Europe. Aalborg CSP has installed several of these plants already and knows the technology.

The pilot CSP-plant in Thisted, in northern Denmark, was monitored and evaluated for high end district heating temperatures up to 120°C during July 2013 [2] see figure 2. The result was a maximum zero loss collector array efficiency of 75 % and an array heat loss coefficient as low as 0.04 $W/m^2/K$. Later higher temperature operation was investigated in the pilot test in Brønderslev 2015 [4] at up to 350°C giving the collector parameters 0.75 respectively 0.06 $W/m^2/K$.

Thus at a temperature difference of 300 K above ambient, assuming a heat loss coefficient of 0.06 $W/m^2/K$ will mean a total heat loss as low as 18 W/m^2. Even if the direct radiation level is as low as 100 W/m^2 the net production will still be 100 W/m^2 *0.75 – 0.06 $W/m^2/K$ *300K = 57 W/m^2. Therefore the plant will be able to deliver 300°C also with low DNI levels. Normal clear sky irradiation levels are in the range of 600-900 W/m^2. The main reason is the selective vacuum tube absorber, a very precise tracking mechanism, and stiff enough mirror- plus absorber support to keep the focal line on the absorber all the time.

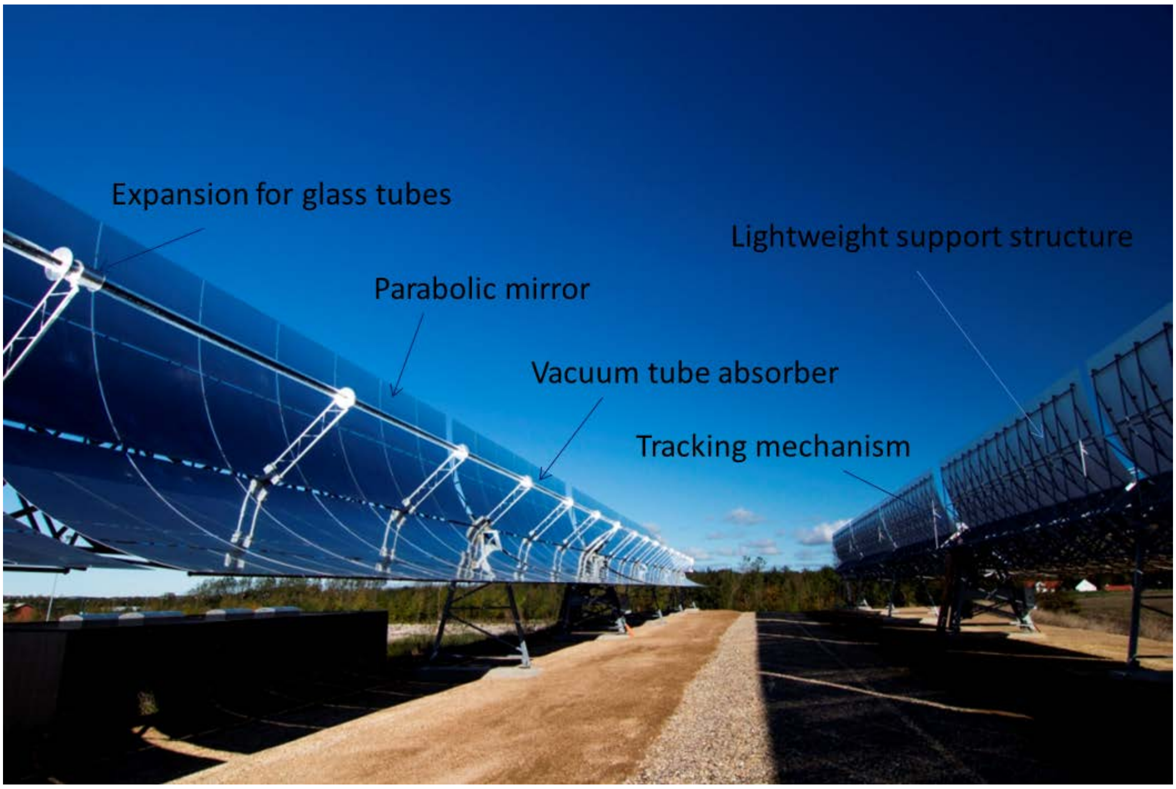

Fig.2. Close up of the Aalborg CSP concentrating collector array in Thisted (Ref. 2).

The Bøndereslev plant is now under intensive construction. See figure 3 and 4. Small improvements of the collectors have been done during the final design and construction phase of the plant that will improve the performance.

Fig 3. Photo of the CSP collector field, under construction. The collector rows are 240 m long and a total length of 480m of collectors are series connected in each series loop. (No absorbers or connecting pipes are installed in this photo).

Fig 4. Close up of one mirror element of the CSP collectors. The width is almost 6 m. Glass mirrors are used. The metal structure is optimized for low material use, but till enough stiffness in windy conditions.

3. Collector field modelling

A detailed TRNSYS model has been developed for the full size collector field, so that control and performance can be investigated in detail. The TRNSYS model is based on the modelling experiences for the 0.8 MW pilot plant in Brønderslev.

Later when the plant is in operation the model will be precisely validated and then used to check and optimize the whole plant operational performance. Then effects of for example weather and operating conditions like deviations in operating temperature from design, can be exactly taken into account and a true performance check of the collector field can be made. Also the 30 degree offset of the tracking axis from south can be accurately taken into account.

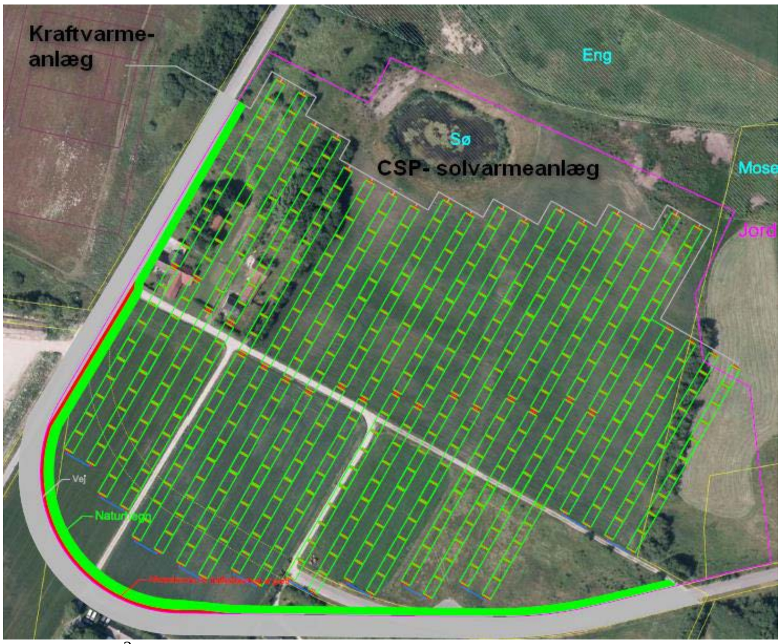

Fig 5. Photo of the 27000 m^2 CSP collector field with row layout in Brønderslev. Note that the troughs are turned approximately 30 degrees from south to match the available land area. This has been found to reduce the annual performance relatively little and was a finding in [2] giving a large flexibility in installation of such plants.

The simulation tool in TRNSYS see fig 6 and 7, is now up and running, but we await further final design information, after the construction of the plant is finished. The aim of the TRNSYS tool is also to be able to use the TRNSYS setup for continuous plant performance check and optimization of control and operation.

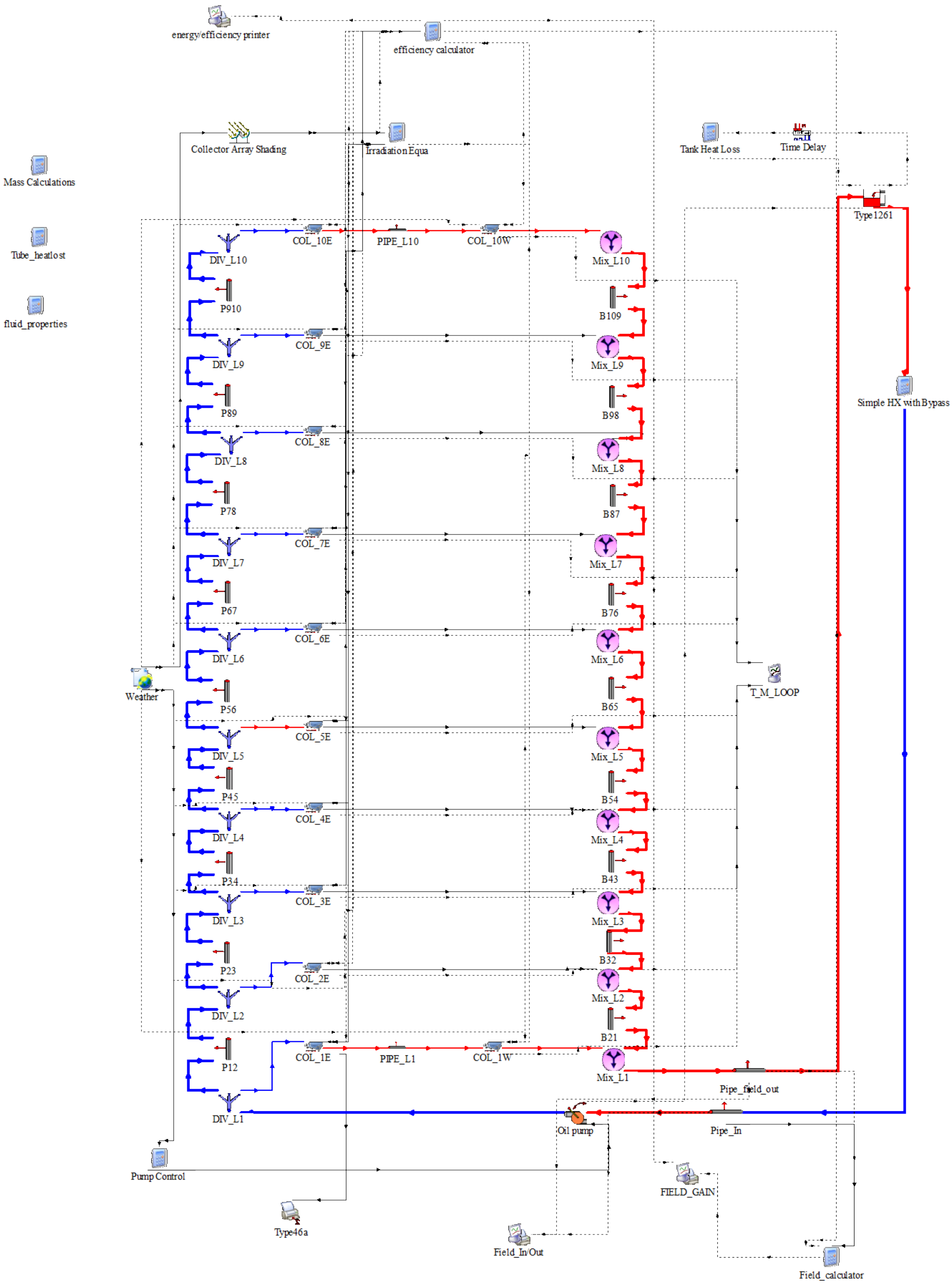

Fig 6. The TRNSYS 17 dynamic model of the collector field with all pipes and collectors included to give a very realistic simulation including transient behavior under variable weather conditions.

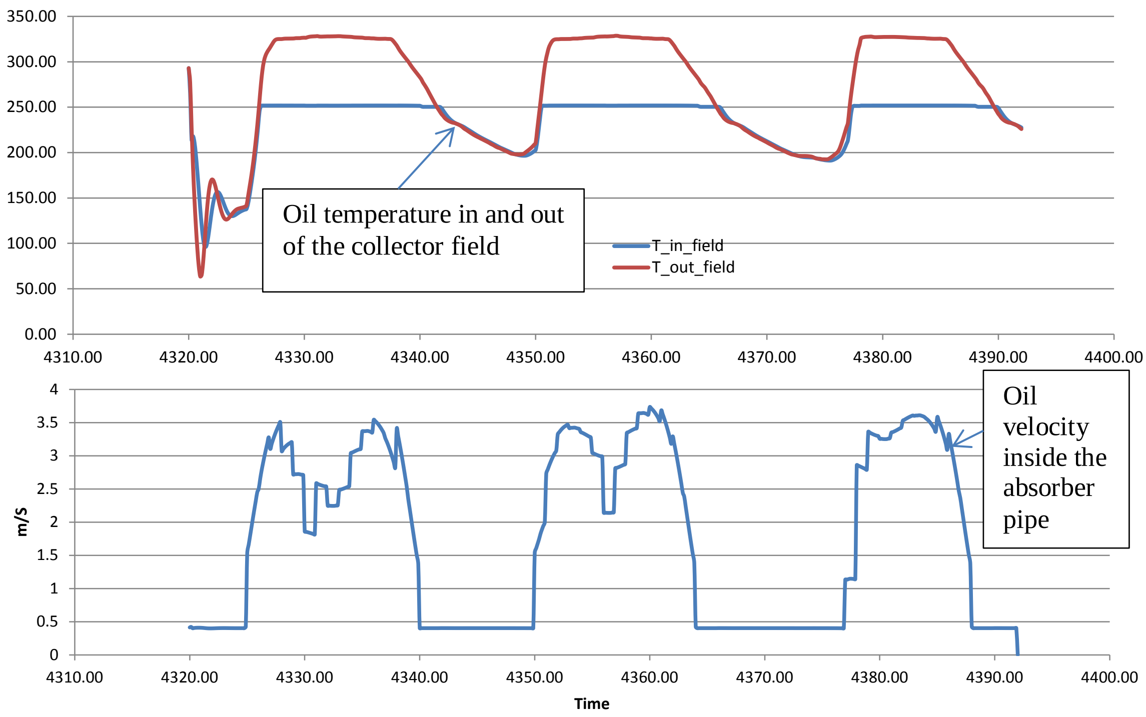

Figure 7: Simulation results for a few days in summer with variable solar radiation during the days. The flow control (lower curve) gives a constant output temperature of 330 °C (upper curve) by varying the flow according to the available radiation level and collector design parameters.

4. Conclusions

The CSP, ORC and CHP technology will be evaluated together in the Brønderslev plant in Denmark. The previous demonstration plants built in other climates indicates favorable long term performance and economy.

Pilot testing of a 0.8 MW sub array of the plant [4], show very good performance, even at these very high operating temperatures, above 300°C, in the Danish climate.

The construction work is ongoing and can be seen online [6].

5. References

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[6] Web camera at Brønderslev showing the construction work.

http://www.bronderslevforsyning.dk/da/Aktuelt/solvarmeogbiomasseanlaeg.aspx