Thermal performance analysis of a CPC solar collector array with series connection to the flat plate solar collector field in Sæby solar heating plant

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Publication date:
2019

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Kong, W., Furbo, S., Perers, B., & Englmair, G. (2019). *Thermal performance analysis of a CPC solar collector array with series connection to the flat plate solar collector field in Sæby solar heating plant*. Poster session presented at ISES Solar World Congress 2019 and IEA SHC conference 2019, Santiago, Chile.

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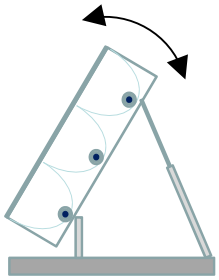
A novel Compound Parabolic Collector (CPC) :

- Four identical parabolic-troughs are placed inside the flat panel
- Automatic one-axis tracking
- Designed for operating in solar heating plants at the temperature range of 60 - 120 ºC



- Four CPC collectors connected in series are operating together with flat plate solar collectors in Sæby solar heating plant.
- The operation of both CPC collectors and four flat plate collectors in front have been monitored since May 2017.

CPC collector testing :

The CPC collectors were tested at Technical University of Denmark (DTU) in 2016 according to the Quasi-Dynamic Testing (QDT) method. The test results are shown in the Table below. The parameters of the flat plate solar collector operating in Sæby solar heating plant were also added in the table below for comparison. The data was extracted from the data sheet.

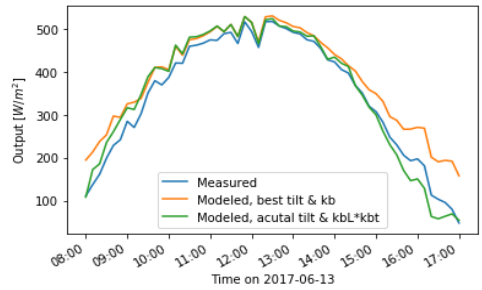
Parameter/collector	CPC Collector	Flat plate collector
Peak collector efficiency (-)	0.65	0.815
Incident angle modifier for beam radiation (-)	0.25	0.11
Incident angle modifier for diffuse radiation (-)	0.27	0.90
Heat loss coefficient (W/m²K)	0.92	3.43
Temperature dependence of the heat loss coefficient (W/m²K²)	0.0148	0.0145
Effective thermal capacity (J/m²K)	7518	8028
Collector aperture area (m²)	13.91	13.88

Daily thermal performance comparison for CPC collector:

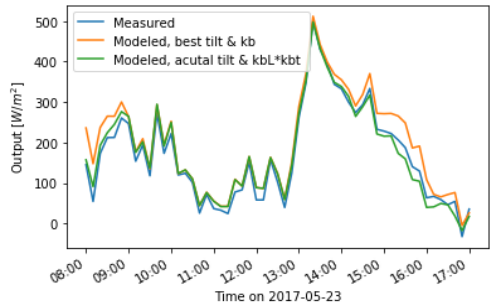
The measured heat output was calculated by measured inlet and outlet temperatures, flow rate and fluid properties with a time step of 10 s. The modelled energy output was calculated based on the QDT model, tested collector parameters and measured weather data.

The CPC collector array has two modelled power outputs because the control had a small error in that period which caused a relative big deviation between the measured and targeted transversal angles in the early morning and in the late afternoon. The orange curve shows the best potential for heat output without control error.

On a typical sunny day



On a typical cloudy day

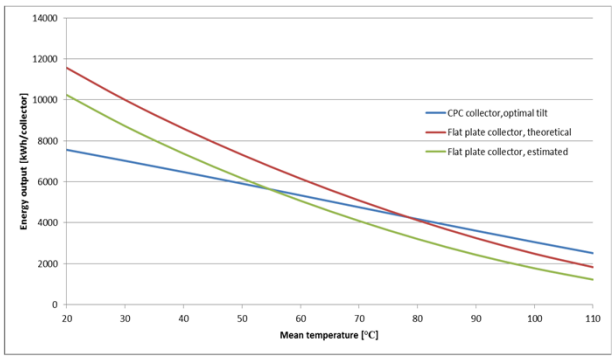


Monthly thermal performance summary for both collectors:

Month/ Measured days	CPC Measured heat output	CPC Modelled heat output with actual/best tilt angles	Flat plate Measured heat output	Flat plate Modelled heat output with estimated/ theoretical collector parameters
	(kWh/m²)	(kWh/m²)	(kWh/m²)	(kWh/m²)
05. 2017/5	7.4	8.3/9.5	12.6	13.2/16
06. 2017/30	41.2	48.6/55.7	67.9	76.2/92
07. 2017/7	9.0	11.2/12.6	14.6	17.6/21
08. 2017/17	21.7	27.0/29.2	34.7	38.9/47
Sum/59	**79.3**	**95.2/106.9**	**129.7**	**146/176**

Modelled heat output of the flat plate collectors using an estimated reduced peak efficiency of 0.72. Other parameters are unchanged. Theoretical parameters are all from the data sheet.

Predicted annual thermal performance comparison:



Conclusions:

- The developed QDT model for both the CPC solar collector array and the flat plate collector array is valid.
- The annual thermal performance of the CPC collector is higher than that of the flat plate collector if the mean fluid temperature is higher than 78 ° C in theory, in practice if the temperature is higher than 55 ° C.