Imperial College London

DYNAMIC TESTING AND MODELLING OF SOLAR COLLECTORS

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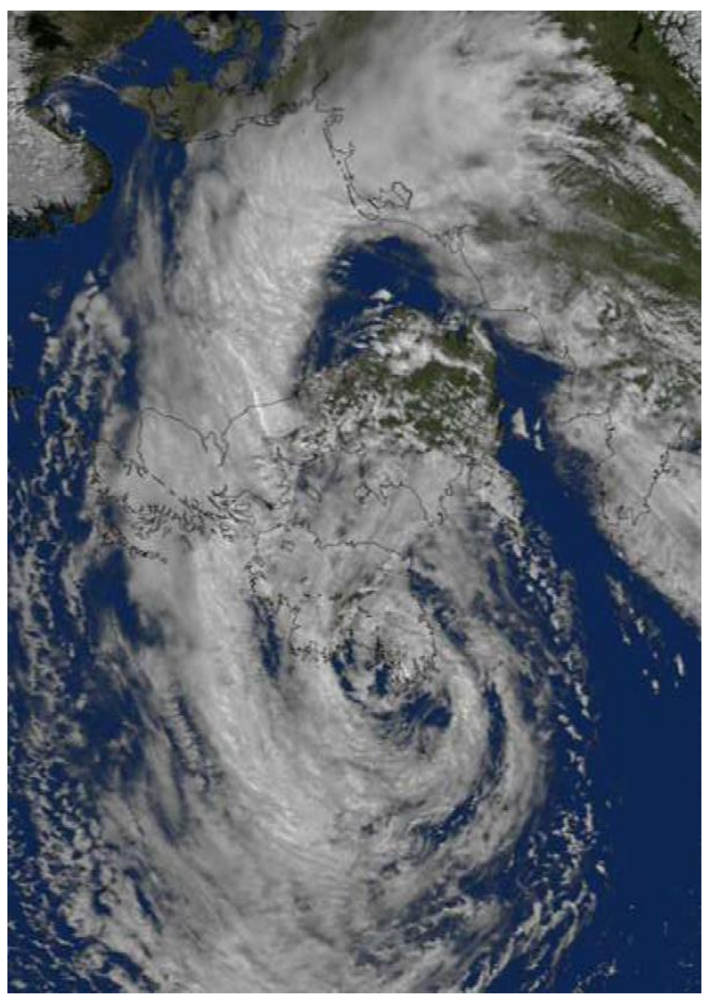


Figure 1: UK weather map

INTRODUCTION

Solar-thermal collectors operating under real conditions rarely reach steady-state operation due to temporal fluctuations in the climate/environmental conditions and thermal loads. Figure 1 shows typical UK weather map. The incident irradiance, the ambient temperature and the wind speed can vary during the day as shown in Figures 2-4. These figures show the data collected in London at a temporal resolution of 1-minute. As a consequence of the time-varying inputs, collector models that describe dynamic behaviour are required for the accurate prediction of the thermal output and for optimising the control strategy of such systems. We develop detailed 3-D thermal sub-models that can be adapted to various geometries or collector configurations, including vacuum-tube thermal collectors, sheet-and-tube thermal and PV/T collectors.

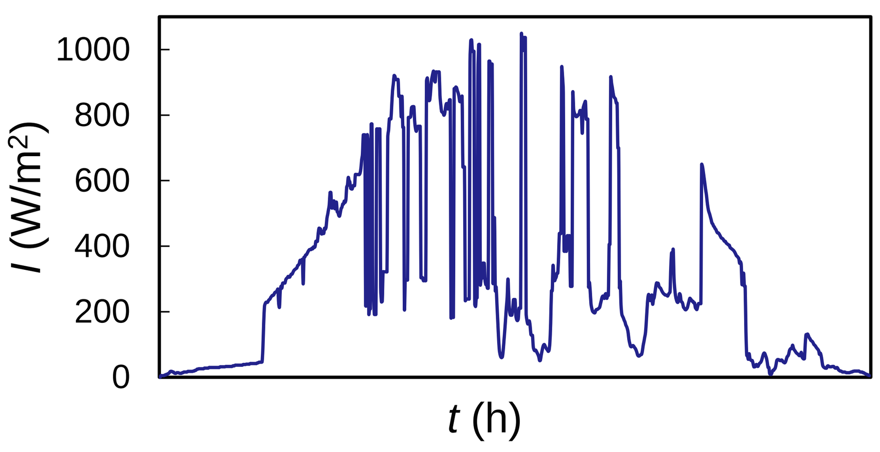


Figure 2: 1-min resolution data of solar radiation I

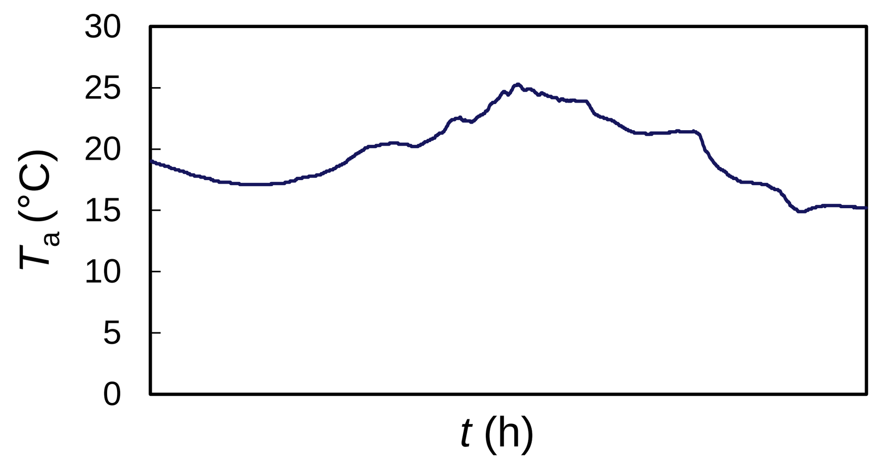


Figure 3: 1-min resolution data of ambient temperature T_a

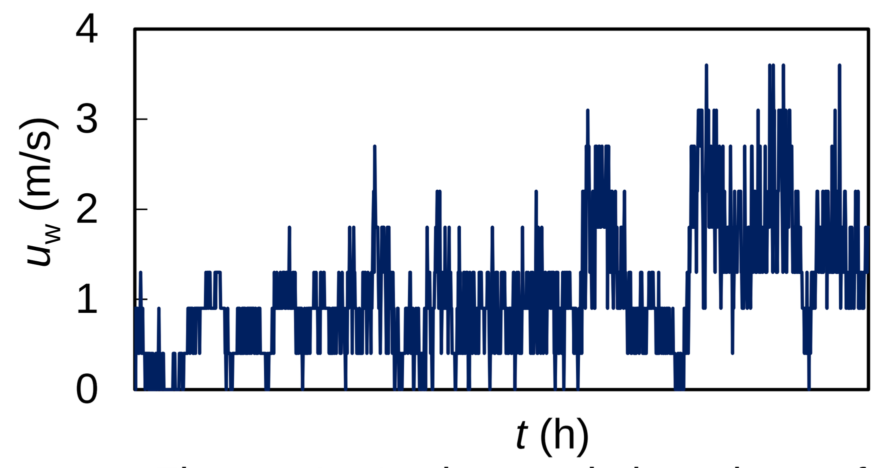


Figure 4: 1-min resolution data of wind speed u_w

NUMERICAL MODEL

A 3-D numerical model is developed for the coaxial vacuum-tube solar-thermal, for the sheet-and-tube solar-thermal and for the PV/T collectors [1].

The energy gains and losses to the environment are found by solving the resistance network in Figure 5. The model predicts the temperature distribution on the collectors, the fluid temperature and thermal efficiency by solving energy balances (Figures 6-9).

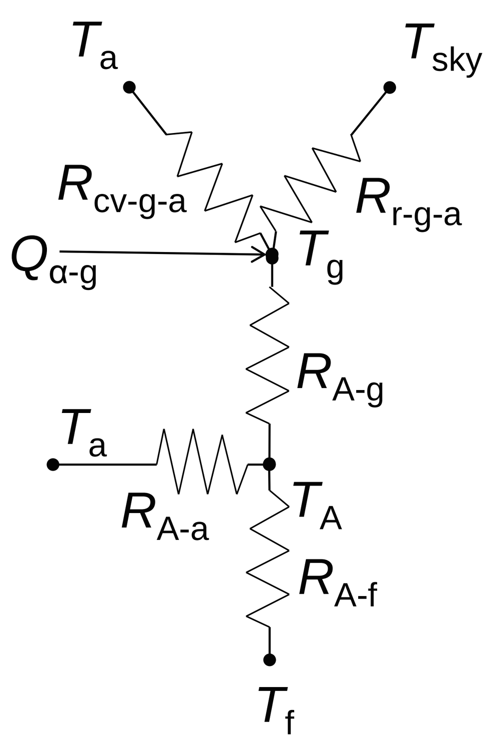


Figure 5: Network of thermal resistance

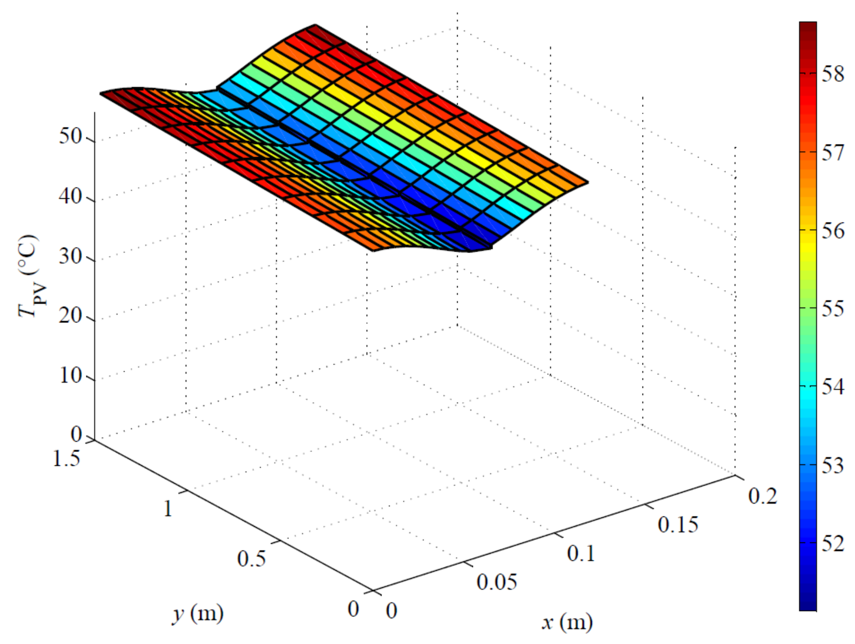


Figure 6: Numerical results of the temperature distribution on a sheet-and-tube PV/T collector

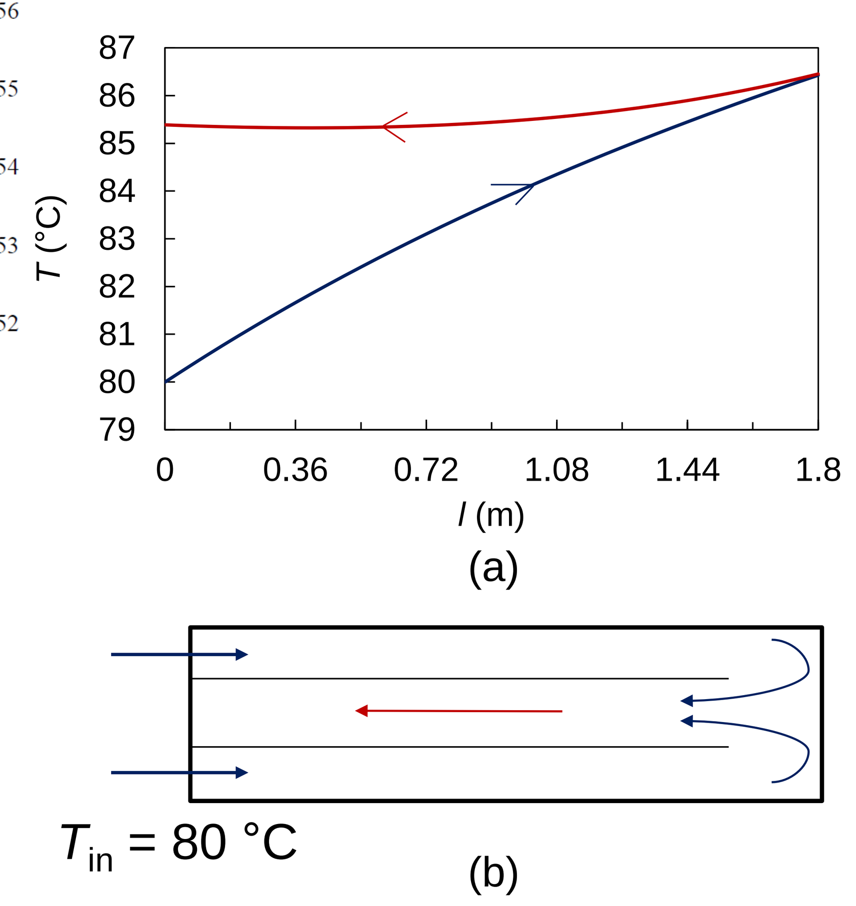


Figure 8: (a) Numerical results of the fluid temperature variation along the pipe length in a coaxial vacuum-tube collector. Blue: fluid flowing in the annulus entering the collector at T_{in}; red: fluid flowing into the inner tube as shown in (b).

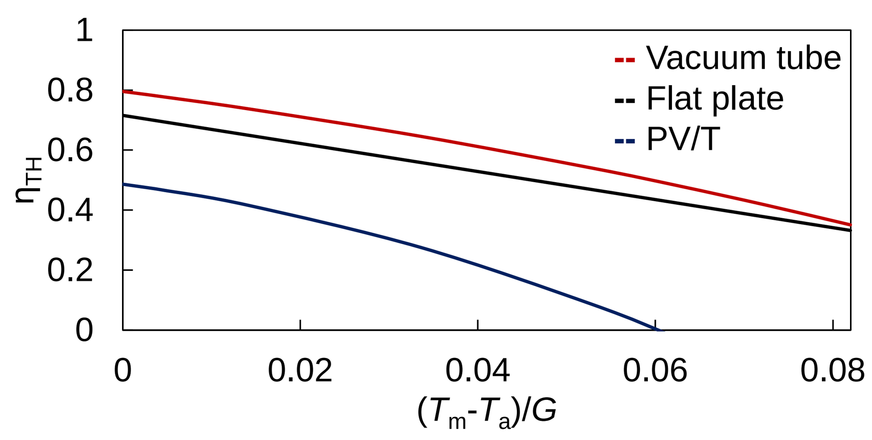


Figure 7: Comparison of the numerical results of the thermal efficiency of the three solar collectors [2]

OUTDOR STEADY-STATE AND DYNAMIC TESTING: EXPERIMENTAL SETUP

The experimental setup in Figure 9-10 was built to test a solar collector array consisting of 20 coaxial vacuum tubes according to EN 12975 [3].

Figure 9: 20 coaxial tube solar collector array

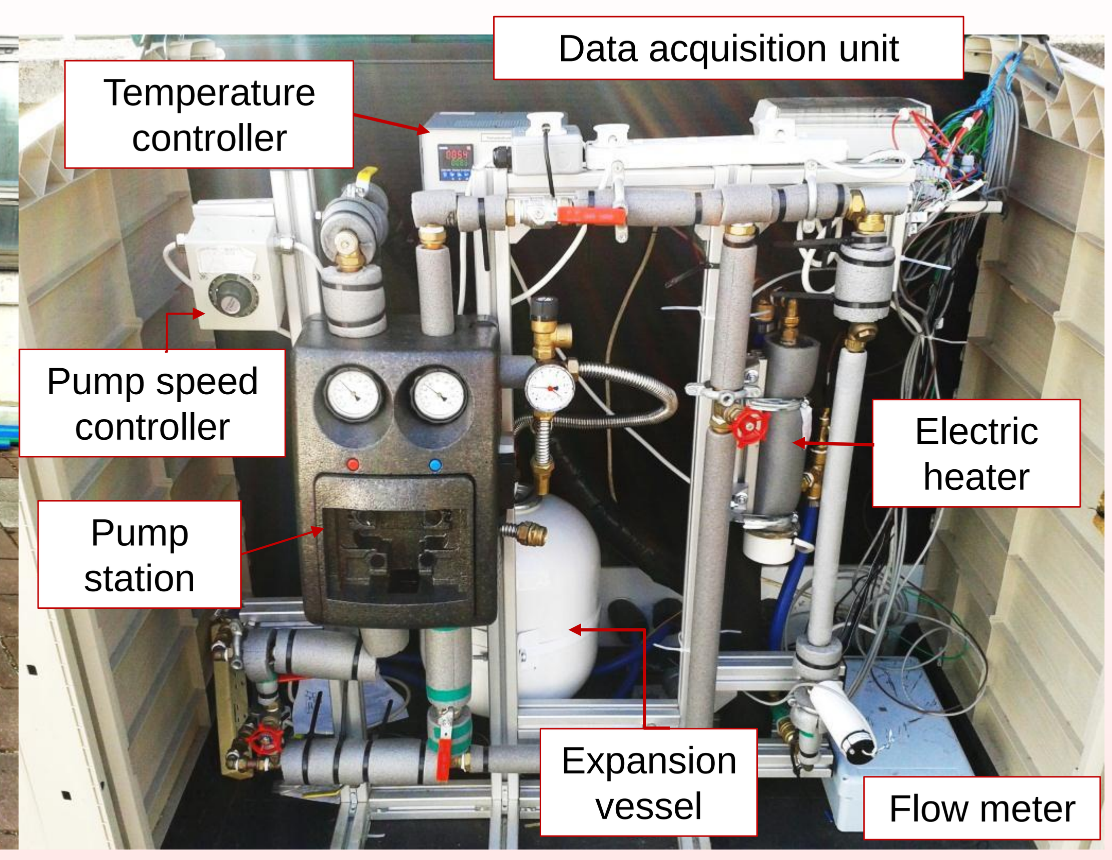
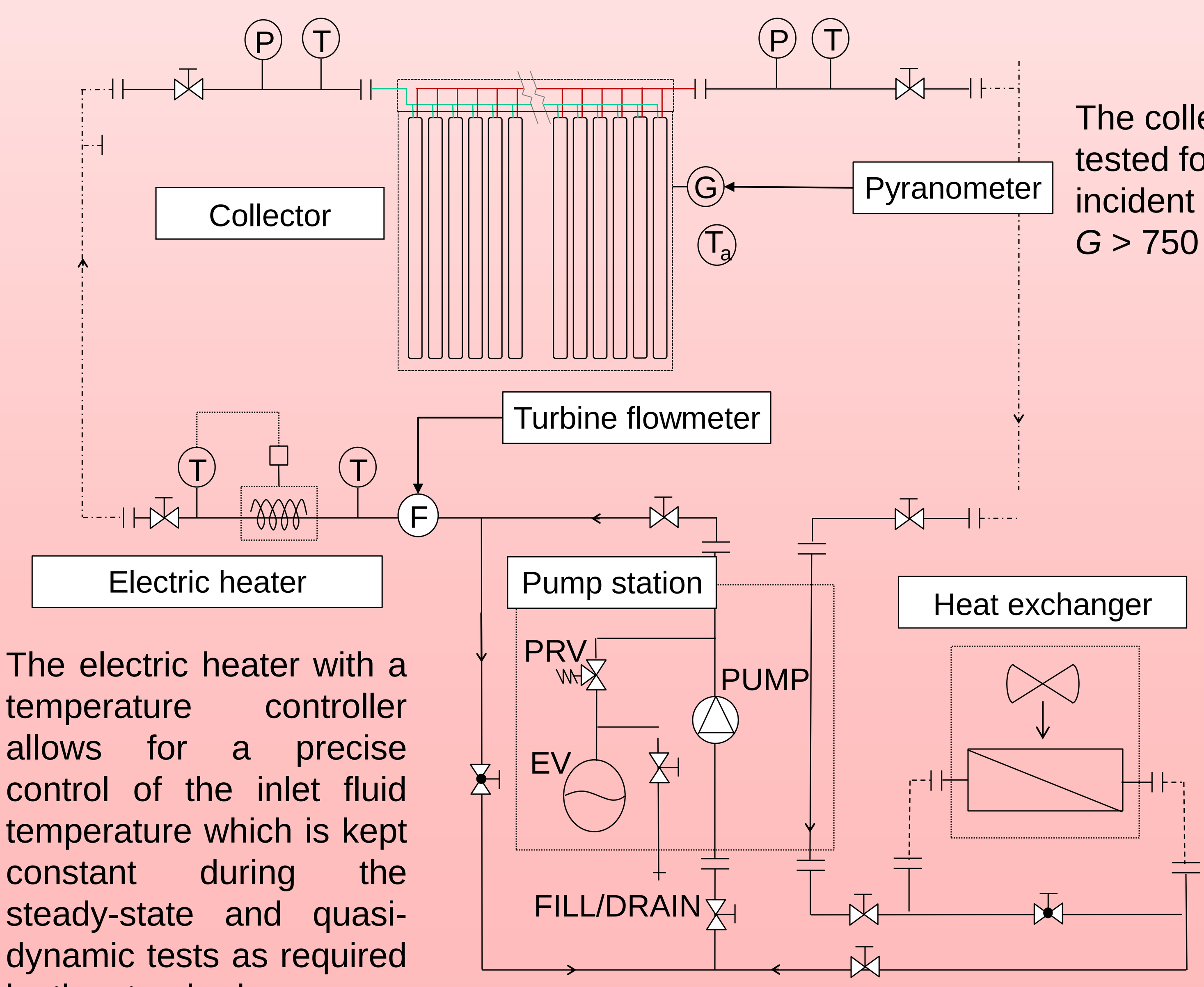


Figure 10: Collector hydraulic loop consisting of the pump station, heater and instrumentations



The collector is tested for an incident irradiance $G > 750$ W/m².

The electric heater with a temperature controller allows for a precise control of the inlet fluid temperature which is kept constant during the steady-state and quasi-dynamic tests as required by the standards.

By changing the pump speed, the collector can be tested over a range of flow rates.

DYNAMIC TEST RESULTS

The dynamic tests involve measuring the response of the collector to a step variation in the ambient conditions as shown in Figure 11. During these tests, the collector is initially covered with a reflective cover until it reaches steady-state conditions. The cover is then removed and data are collected until the collector reaches a new steady condition. The numerical results are validated against the experimental data.

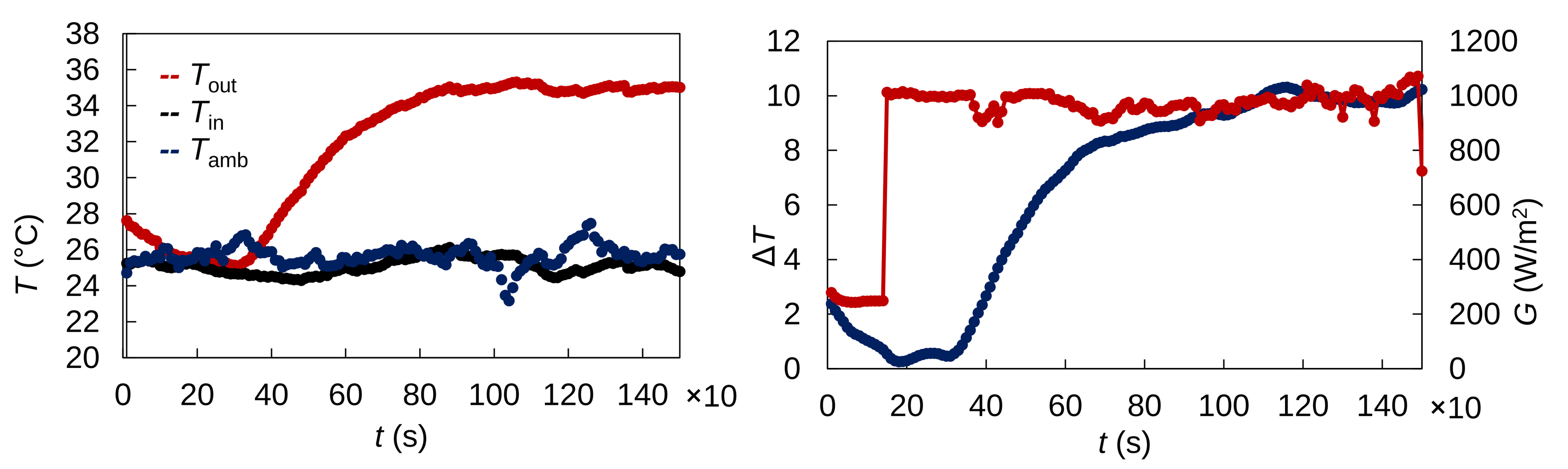


Figure 11: Response of the solar collector to a step variation of the incident irradiance. The tests are done at constant inlet temperature (left) and for a step increase of incident irradiance G (right).

REFERENCES

[1] Guarracino, I., Markides, C. N., and Ekins-Daukes, N. J. , Thermal and electrical model of the sheet-and-tube hybrid photovoltaic/thermal (PV/T) collector. In: *Proceedings of the ASME-ATI-UIT Conference on Thermal Energy Systems: Production, Storage, Utilization, Environment*, Naples, Italy (2015).

[2] Freeman, J., Hellgardt, K., and Markides, C. N., An Assessment of Solar-Thermal Collector Designs for Small-Scale Combined Heating and Power Applications in the United Kingdom. *Heat Transfer Engineering* 36.14-15 (2015): 1332-1347.

[3] European Standard EN 12975-2, CEN, European committee for standardisation (2006).