Field test results of an innovative PV/T collector for an outdoor swimming pool

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Abstract

Hybrid solar PV/T has the potential to become a major player in the renewable energy sector, but one of the most important barriers is the lack of a proven track record in terms of reliability and performance. In order to address this issue, a study was conducted to monitor field energy performances of an outdoor swimming pool installation near Geneva (Switzerland) equipped with an innovative unglazed PV/T collector (1.64m², 250Wp, 912Wth).

For a 3000 m^3 outdoor swimming pool and 8000L/day of hot water needs, the installation of 300 m² of PV/T collectors generated 55MWh of thermal production from mid-May to mid-September and 52MWh annual photovoltaic production. Performances were higher than expected from the TRNSYS study.

Keywords: Photovoltaic thermal (PV/T) collector; Field test; Energy performance,

1. Introduction

PV/T is not a new technology, as Kern and Russell published a report for the MIT already in 1978. Hybrid collectors have been optimized over the years, and even in 2003 Zondag et al. gave a large review of possible designs for collectors. Since the 2000s commercial collectors have been launched, some manufacturers had underestimated the technological difficulties but in the 2010s, the commercial products have become more reliable and at the end of 2013, the norm ISO 9806 proposed a procedure to test the hybrid collector reliability and performances. More recent reviews of PV/T technologies has been done by Zhang et al. (2012), Good et al. (2015), Wu et al. (2016) or Das et al. (2018).

The photovoltaics dropped its price, the competitiveness of the hybrid solution has become more and more obvious. But Dupeyrat et al. noted in 2014 that only a few study with a global system approach with data from the field confirming a competitive application for the technology. This study wants to contribute with data for PV/T collectors heating an outdoor swimming pool.

2. PV/T characteristics

The PV/T module in the study is based on the unglazed flat-plate liquid design described in the reviews. It is 1677×990×40mm^3 and has 60 monocrystalline cells for a nominal power of 250Wp (power loss -0.44%/°C). The thermal characteristics (η_0=57.8%; b_U =0.028 s/m; b_1=12.08 W/K/m²; b_2=1.842 W.s/K/m^3) were determined by tests conducted at the TÜV Rheinland laboratory following the Solar Keymark certification rules (ISO 9806 : 2013).

Table 1. Electrical and thermal characteristics

Dimensions	1677×990×40 mm^3
Number of cells	60
Type of cells	Monocrystalline (6 inches)
Nominal power (P_{mpp})	250 Wp
PV module efficiency (η_{PV})	15,40% (Tolerance : -3%/3%)
Power loss /°C (β_p)	-0,44% / °C

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Heat transfer fluid (HTF)	Water/glycol mix
Absorber surface area	1,58 m²
Conversion factor (η_0)	57,8%
Heat loss coefficient (b_1)	12,08 W/K/m²
Wind dependency of collector efficiency (b_U)	0,028 s/m
Wind dependency of heat loss coefficient (b_2)	1,842 W.s/K/m^3
Stagnation temperature (T_{stagn})	74,7 °C

3. Presentation of the field test

Indoor swimming pool systems coupled with PV/T collectors have already been studied by simulation by Buonomano et al. (2015), but few experimental works have confirmed the expected performances with real installations, as has been done in this study.

In order to verify the in-situ reliability and performance for outdoor swimming pools of the innovative hybrid solar PV/T module, an installation was monitored near Geneva in the South of Switerland (Lat/ Long 46.2 / 6.1) with 187 PV/T modules (picture Fig.2) from July 2017 to June 2018. The PV/T modules are connected to heat exchangers and are used to preheat the water for the showers and to heat the pools (Fig.2). In order to monitor the system, Aquametro CALEC calorimeter is placed just before the solar heat exchangers (average data every 4 days).

Key parameters of the solar installation are provided in Table 2.

Fig. 2: picture of the installation

Tab. 2: picture and parameters of the installation

Number of unglazed PV/T	187 (~300 m²)
Integration type	Superimposed
Orientation (0° = South)	South (0°)
Slope	11.6 °
Shower needs	~ 8000L/day
Swimming pools dimensions	1960 m² for 3000 m^3
Pool temperature setup	29 °C

The solar energy goes to hot water preheating if the temperature of the panels is 5°C higher than the bottom of the sanitary tank or to the pool if it is higher than 30°C.

4. TRNSYS study and field test results

Simplified hydraulic installed system is given in Figure 3. A TRNSYS model has been performed, and the used diagram is given in Figure 4.

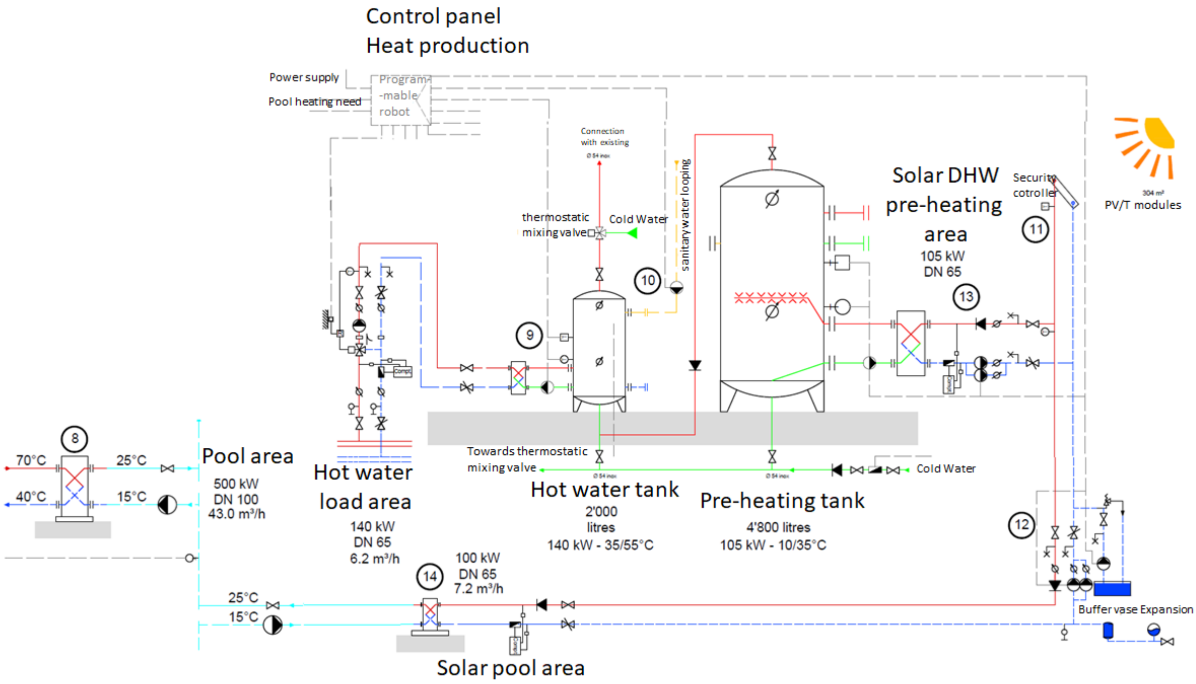

Fig. 3: Simplified hydraulic installed system

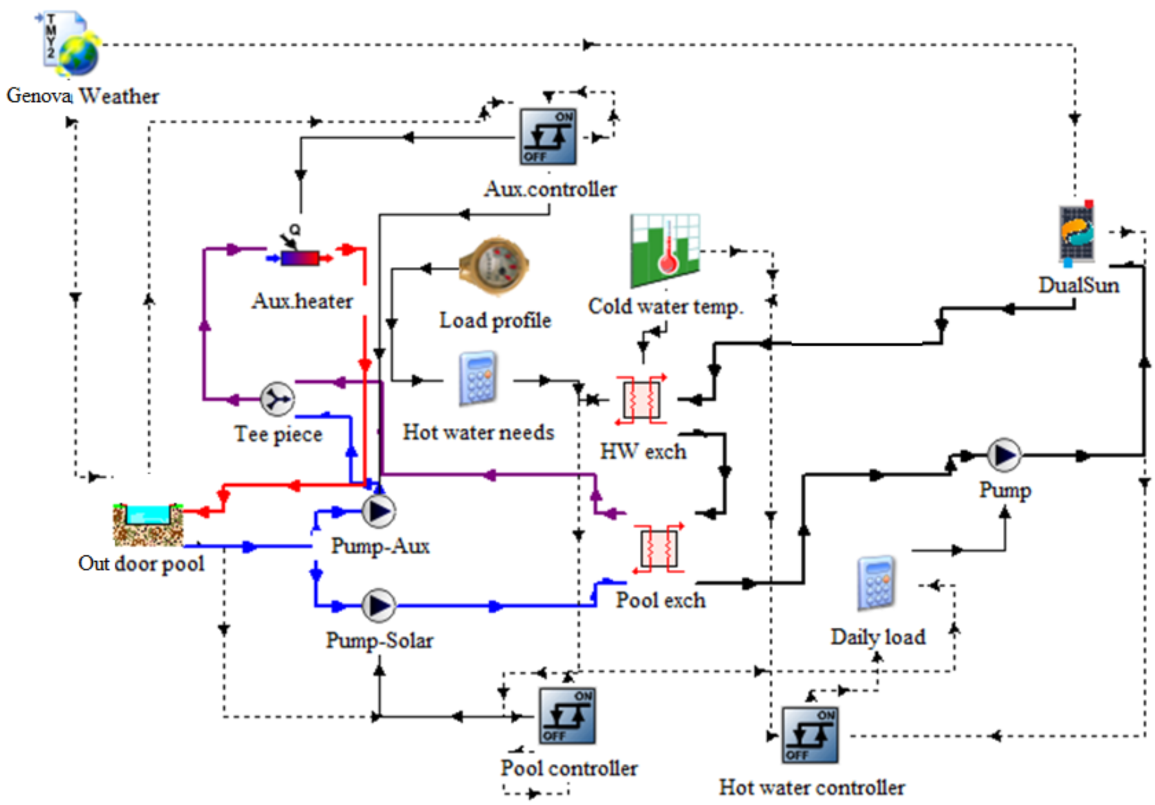

Fig. 4: The TRNSYS diagram of the installation

Photovoltaic and Solar heat for hot water needs are really near to predictions over the opening season (mid-May to mid-September) with respectively a real production of 102% and 106% of the simulation result. The monitoring of the solar heat for pools was not yet functionnal but will be in a near future.

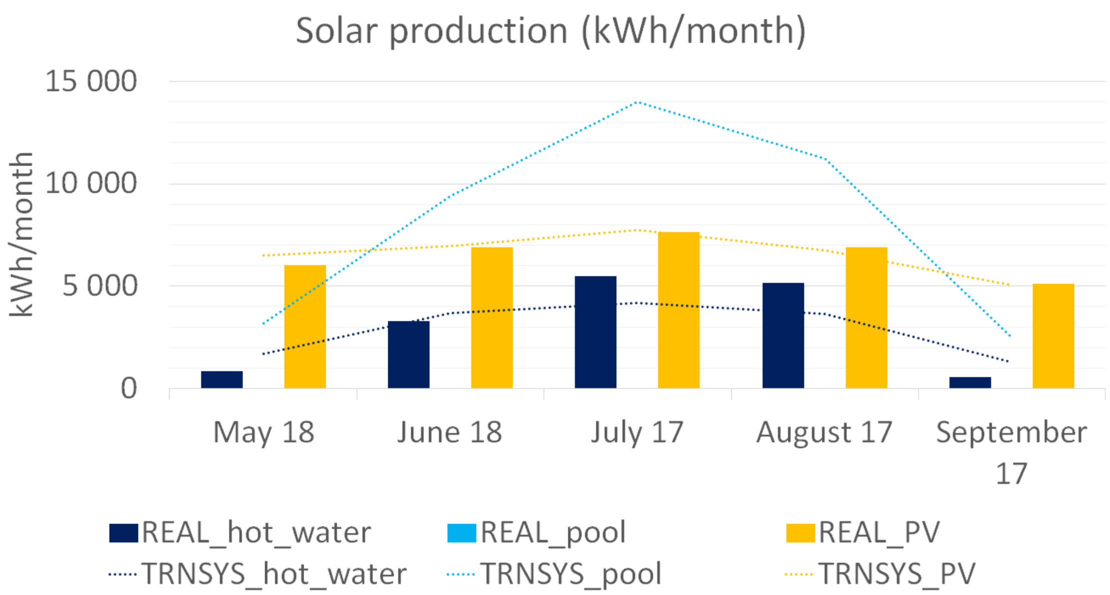

Fig. 5 : Comparison with monitored results (July 2017 to June 2018)

The cost of the installation was approximately 205.000€ for 52MWh of electricity and 55MWh of solar heat generated per year, not including the subsidies. This leads to a cost of energy of 9,6c€/kWh if we assume a stable production over 20 years, neglecting inflation and maintenance costs.

5. Conclusion

The 300m² PV/T panels provide 30% of the energy for the 8000L/day for shower needs and 30 % of the heating needs for the 3000m^3 outdoor swimming pool during 4 months of the year (Mid May – Mid September) and 52MWh/yr of photovoltaic electricity. The measured results of the PV/T panels for the photovoltaic and the heat for the showers are very close – and even slightly higher (respectively +2% and +6%) from what predicted with the TRNSYS model for the first opening season, the monitoring of the heat for the pool was not yet available but would be soon.

The cost of the energy with this hybrid solution for outdoor swimming pool is already around 10c€/kWh and will continue to decrease and may be competitive without subsidies in a few years.

6. References

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