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Comparative experimental analysis of solar thermal energy counters

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Abstract

In order to monitor the energy yield of solar thermal systems, a thermal energy counter with connectivity must be installed. Multiple thermal energy counters and connectivity criteria are available. However, implementation and communication costs differ drastically from one to another. Taking into account market restrictions, in order to widely implement monitoring of energy yield of solar thermal systems these costs should be reduced as much as possible.

The paper presents an experimental comparison of the energy yield of a solar thermal system measured with different energy counters at communication time steps of one hour in order to reduce communication costs. These data are compared to those obtained from detailed measuring of the energy yield with time steps of 1 minute. The evaluated energy counters combine different technologies for the measuring of the flows and temperatures (ultrasound flow sensor, constant flow, single-jet flow meter, vortex flow sensors and RTDs).

Keywords: *solar thermal systems, energy counter, monitoring*

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1. Introduction

Recently, there is an increased market demand of low cost monitoring equipment for solar thermal systems in order to evaluate their performance. Energy yield of the solar thermal system is the most basic parameter to be monitored. In the market there are multiple thermal energy counter solutions with different communication procedures.

The authors have recently been working on the measuring of solar thermal energy yield at the primary circuit using low cost commercial energy counters with energy integration time steps of one hour in order to minimize volume of data, and therefore, costs.

A number of three low-cost energy counters have been analysed. They have been installed in the primary circuit of a solar thermal system. The energy counters use different sensors technologies. Temperatures at the thermal fluid are measured by RTD sensors directly immersed in the flow or assembled in a sheath or using multivariable vortex flow meter. Volumetric flow is measured by a single jet meter, a vortex-flow meter, or set at a constant pre-calibrated value. Additionally, detailed measuring of the energy yield of the system primary loops is also performed in time steps of one minute with a none-intrusive meter based on ultrasound technology for the volumetric flow measurement and RTDs for the temperature measurements.

Main technical parameters of the analyzed energy counters are described in section 2 and 3. Results obtained are presented in section 4 comparing the instantaneous and daily energy yield measured with the different energy counters. Some conclusions are finally also presented.

2. Conceptual description of a thermal energy monitoring system

A thermal energy monitoring system is an instrument that reads the thermal energy produced in a plant and transfers the energy value through any kind of communication channel (Ethernet, sim…) to a computer that

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collects the data and publishes it according to final user needs, where the user is any person that may be interested in the metered data.

Main components of the energy monitoring are the sensors, in-site device, communication and IT infrastructure. A conceptual scheme of the different parts of an energy monitoring system is shown in Figure 1.

The sensors are used to measure the temperature of the thermal fluid between the two points in which the thermal energy is to be measured, they will be here referred as Th (hot temperature) and Tc (cold temperature). Additionally, a sensor to measure the volumetric flow of the thermal fluid, V_{flow}, is also necessary. The in-site device reads the data from the sensors and calculates the thermal energy. The communication infrastructure reads the thermal energy in certain communication time steps, and transfers the data to the IT infrastructure. Finally, the IT infrastructure collects, processes and publishes the thermal energy data according to the user needs.

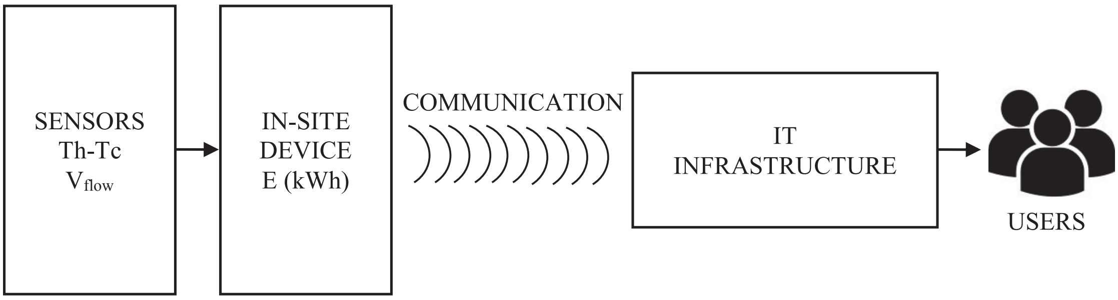


Fig. 1: Main parts of a thermal energy monitoring system. Conceptual scheme.

In order to develop a low-cost thermal energy monitoring system, attention has to be paid in the four components previously described. Commercial thermal energy counters, normally offers a compact solution of sensors and in-site device with internet connection interface. Additionally, a communication and IT Infrastructure is also needed.

The authors have developed an IT Infrastructure based on the free, simple and fast platform www.omnilus.com (2016). OmniluS reads the hourly thermal energy produced with a resolution of 1kWh. This drastically reduces the volume of data to be transferred from the in-site device to the cloud resulting into very low communication costs. More detailed explanation on how OmniluS works as intelligent energy meter can be found in González Valero et al. (2016).

3. Analysed energy counters

Three energy counters making use of the OmniluS platform have been analysed. Additionally, energy measurements have also been obtained with a none intrusive energy counter installed in-site with metering time step of one minute and finer communication energy counting resolution

Main technical parameters of the four energy counters are presented in Table 1.

The energy counters A, B and C, are connected the cloud platform OmniluS, and provide thermal energy data in intervals of Δt=1h with a resolution of 1kWh. The in-site devices use finer resolution to count the energy, however communicated energy resolution is set at 1kWh. This means that if during the previous communication interval (last hour), the energy produced was for example 14.6 kWh, a value of 14 is communicated, and the difference, 0.6 kWh, will be added to the energy to be communicated in the following time step.

The retail price of the components of the energy metering systems A, B, C ranges from 250 to 500 Euro, while the communication to cloud costs are below 4 Euro per month including data communication and cloud services.

Tab. 1: Main technical parameters of the analysed thermal energy metering systems

Name	**Sensors**			**Communication**		**IT Infrastructure**
	Th	Tc	Vflow	Resolution	Δt	
A	PT1000 immersed	PT1000 immersed	single jet	1kWh	1h	OmniluS
B	PT1000 sheath	PT1000 sheath	constant pre-calibration	1kWh	1h	OmniluS
C	PT1000 sheath	vortex flowmeter	vortex flowmeter	1kWh	1h	OmniluS
R	PT100	PT100	ultrasound	0.01kWh	1min	In-Site

4. Results and conclusions

The analysed metering systems A, B and C have been installed together with the reference system R at a solar thermal plant placed at the premises of the authors. The plant consists of a solar field of flat plat solar thermal collectors that collect energy from the sun which is accumulated in a storage tank with an internal serpentine by means of a single loop, so called primary loop.

The volumetric and temperature sensors have been placed at the inlet and outlet of the serpentine in order to measure the solar thermal energy yield of the primary loop. All of them have been carefully insulated. Additionally, silicone thermal cream has been used whenever necessary to assure thermal contact between the thermal fluid and the thermal RTD sensors.

The sensors have then been connected to the corresponding devices that calculate the instantaneous thermal power, count the energy yield and communicate the thermal energy yield. The devices of the metering systems A, B and C, transfer the thermal energy yield in intervals of one hour to the cloud were the OmniluS platform lives. On the other side, the thermal energy yield and the instantaneous power measured by the reference metering system R are recorded in-site (no connection to the cloud) in intervals of one minute.

No specific calibration of the sensors and devices has been performed, therefore data has directly been obtained with the instruments and sensors as delivered by the manufacturers with no additional post processing.

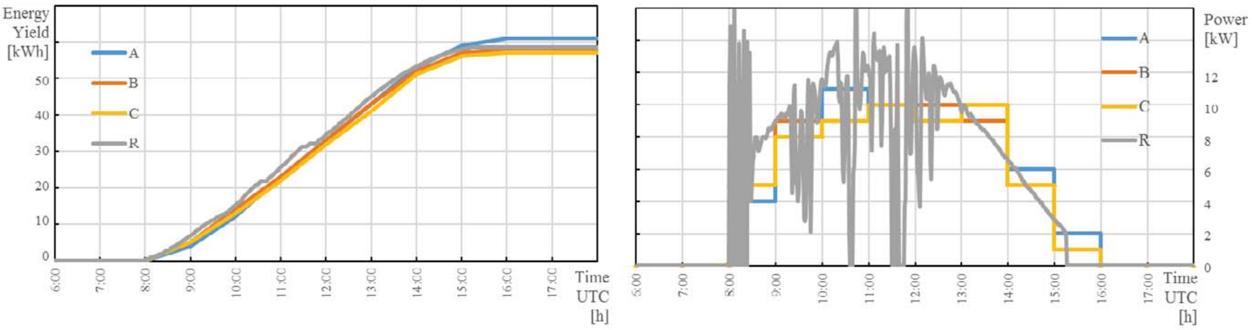
Data for seven different days is here presented in Figures 2 and 3 and Table 2. For each day, daily evolution of the energy yield and power measured with the four analysed metering systems A, B, C and R are shown in Figures 2 and 3.

Measured daily values of the energy yield are presented in Table 2. Additionally, absolute and relative differences of the daily energy yield are also shown by using the data measured by the system R as reference value.

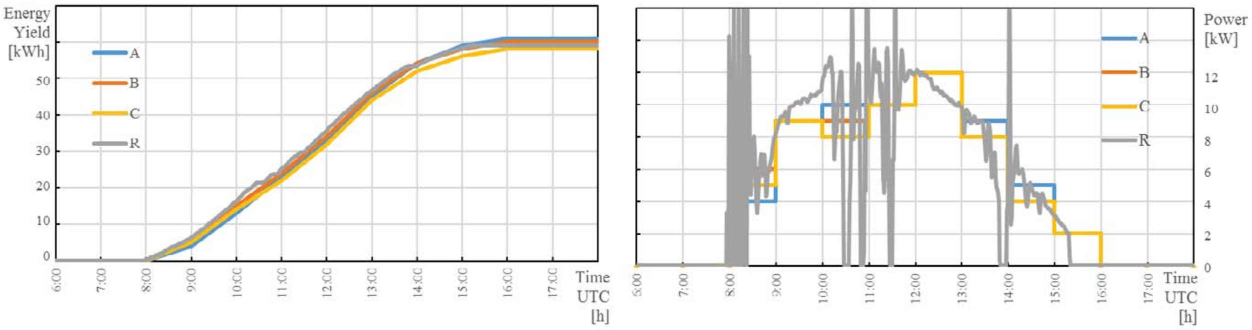
As observed, although communication time steps and resolution in the systems A, B, C are large, the evolution of the cumulative daily energy yield measured with these systems pretty well reproduces the evolution of the cumulative daily energy yield measured with the detailed metering system R.

Of course the systems A, B and C cannot measure small time scale (minutes) phenomena and are therefore not appropriate for a detailed audit of the thermal system. However, they are able to predict the daily energy yield reasonably. As shown in Table 2, absolute differences of the daily energy yield measured with the systems A, B and C with respect with the data obtained with system R are below 2.5 kWh per day, which results into relative differences of the measured daily energy yield of 5%.

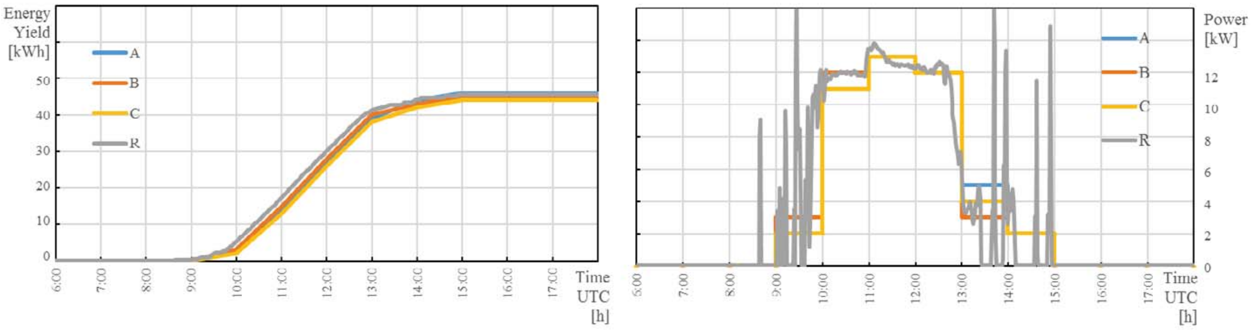
Day 1



Day 2



Day 3



Day 4

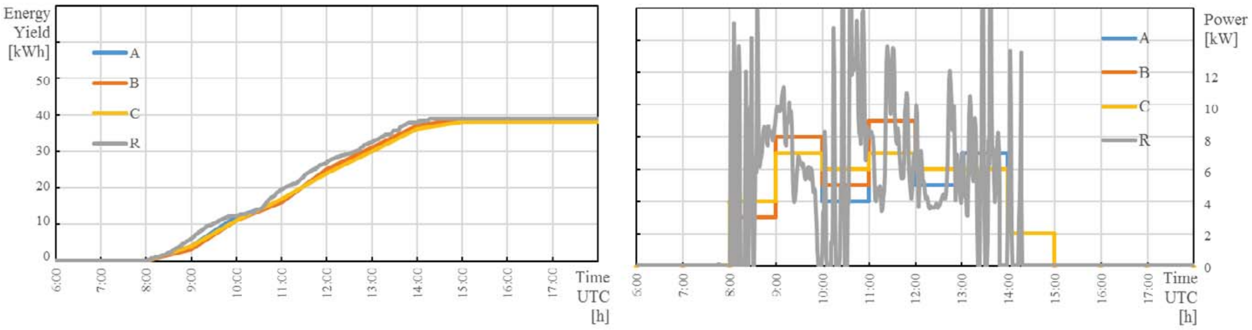
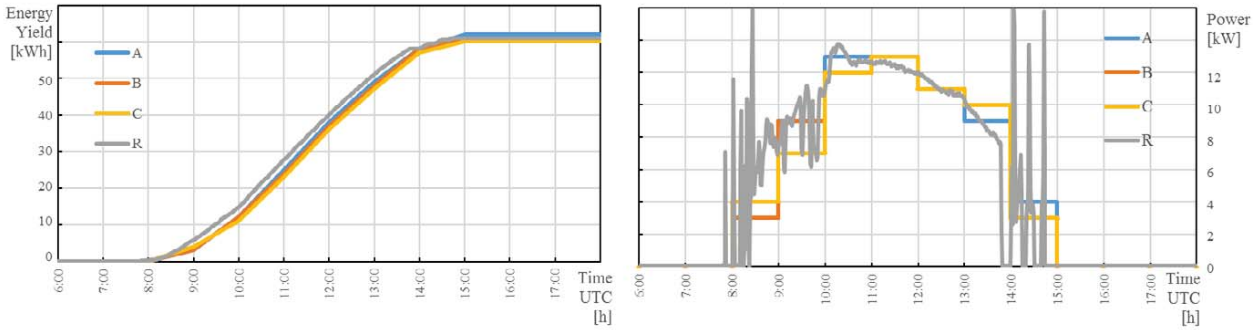
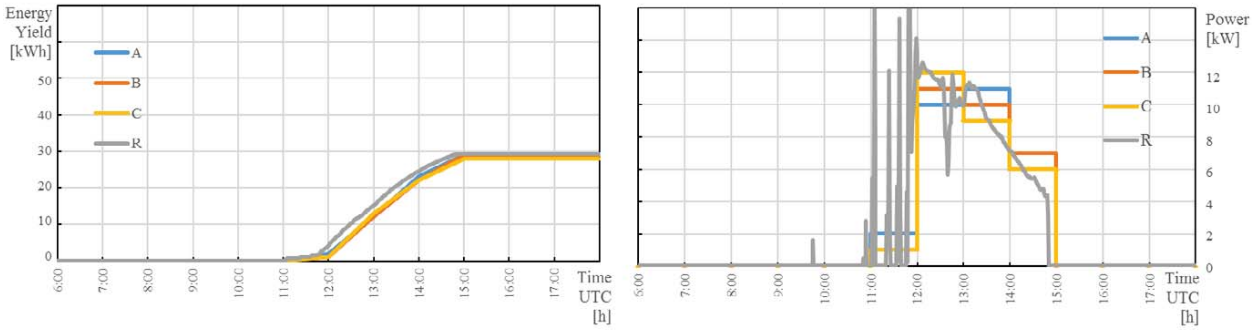


Fig. 2: Experimental results. Daily cumulative solar energy yield and instantaneous power obtained with the four analysed thermal energy metering systems: days 1, 2, 3 and 4.

Day 5



Day 6



Day 7

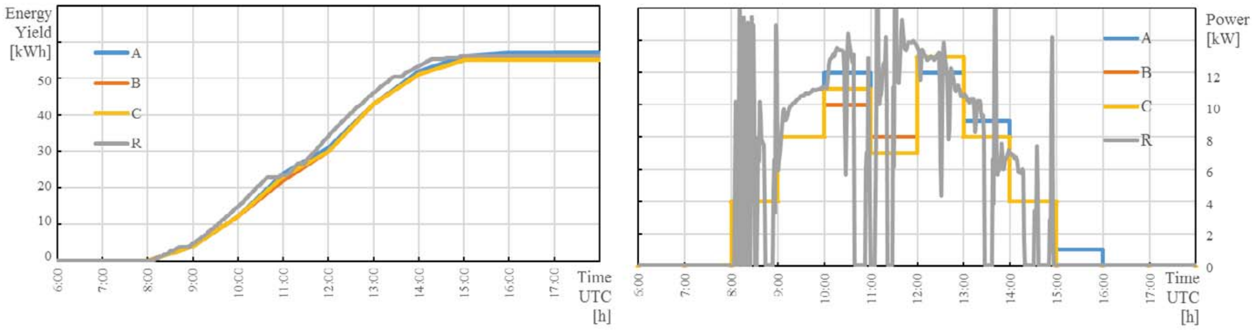


Fig. 3: Experimental results. Daily cumulative solar energy yield and instantaneous power obtained with the four analysed thermal energy metering systems: days 5, 6, and 7.

Tab. 2: Experimental results. Daily energy yield measured with the metering systems A, B, C and R. Analysis of absolute and relative differences of the daily energy yield of the systems A, B and C respect to the value measured with the system R.

	A			**B**			**C**			**R**
	Value	Difference		Value	Difference		Value	Difference		Value
Day	[kWh]	Abs [kWh]	Rel [%]	[kWh]	Abs [kWh]	Rel [%]	[kWh]	Abs [kWh]	Rel [%]	[kWh]
1	61	2,5	4,2	58	-0,5	-0,9	57	-1,5	-2,6	58,5
2	61	1,9	3,3	60	0,9	1,6	58	-1,1	-1,8	59,1
3	46	0,4	0,9	45	-0,6	-1,3	44	-1,6	-3,5	45,6
4	39	0,1	0,3	39	0,1	0,3	38	-0,9	-2,3	38,9
5	62	1,0	1,7	61	0,0	0,0	60	-1,0	-1,6	61,0
6	29	-0,2	-0,6	29	-0,2	-0,6	28	-1,2	-4,0	29,2
7	57	0,9	1,6	55	-1,1	-1,9	55	-1,1	-1,9	56,1

5. Acknowledgements

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6. References

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