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Web-based functionality check for solar heating systems

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Abstract

We develop a web-based functionality check using measurement data from the solar controller. The goals are:

- assure an ideal system operation
- support service and trouble-shooting of solar thermal systems
- communicate and visualise the successful operation of the solar systems

The function principle is quite simple: There exist solar controllers on the market that can measure and store all relevant system data. These data sets are uploaded periodically to a web portal where the intelligent functionality check is hosted. This web portal offers individual functions for system owners, service staff and manufacturers. It visualises the energy production of the system as well as the other measurement data sets. It performs a detailed operating analysis of solar circuit, storages, stagnation, pumps, volume flow and power. The results of these analyses are available for the service staff and give them significant hints for optimising and trouble-shooting the solar systems.

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1. Introduction

Solar thermal collectors can provide a substantial part of the heating energy of a building. But the owners of solar systems are mostly unaware of the amount of solar energy produced daily on their roof. So far, no effective and well-priced devices exist, which visualise and analyse the solar energy produced by solar thermal systems. Such a device is important for the owners, manufacturers and service-providers of solar thermal systems:

- Several field studies showed, that up to 1/3rd of the solar thermal systems in Switzerland are substantially less effective than predicted or do not work at all [1]. With an intelligent functionality-check the operational reliability of solar systems would be enhanced. Amortisation time of the systems could be reduced thanks to higher productivity.
- For photovoltaic systems it is a standard to visualize and control the solar electricity production with data loggers and web portals. This transparency makes photovoltaic systems more attractive to potential customers than solar thermal systems.
- To place a solar thermal system into operation is a difficult task, especially if no information about the actual operating conditions exists. And trouble-shooting gets a time-consuming try and error work if no measurement data are available.

1.1. Project team

Thus, five companies have started a common project to develop and test an intelligent web-based functionality-check for solar thermal systems. These companies are:

- Egon AG: An energy engineer office with experience in the development of web-based monitoring and control systems for energy consumption and production.
- Ernst Schweizer AG, Metallbau: One of the main manufacturers of solar thermal collectors in Switzerland. Ernst Schweizer AG also sells complete solar thermal systems, puts them into operation and provides technical support incl. trouble-shooting.
- Industrielle Werke Basel: The energy provider of the city of Basel offers a successful heating contracting. Industrielle Werke Basel owns and operates several hundreds of heating systems for their clients. A substantial part of them is equipped with a solar thermal system.
- Steca Elektronik GmbH: Besides other electronic equipment, Steca Elektronik GmbH manufactures solar thermal controllers. Some of them can store measurement data of all important control points. These data are stored on a SD card or transferred via internet to a web server and thus made available for visualization and analysis.
- Meteotest: This meteorological office is specialized into web-based meteorological services. An important business segment are services for the solar energy sector.

Besides these five companies, the project is also funded by the SFOE (Swiss Federal Office of Energy).

1.2. Goals

Together we will develop and test an intelligent web-based functionality check for solar thermal systems. With this check, the following goals shall be reached:

- Verify and confirm that the solar thermal systems work properly. Thanks to an ideal regulation of the solar system, the efficiency is enhanced and amortization time is shortened.
- Support service staff in case of trouble-shooting and putting systems into operation. Thanks to intelligent analyses, the check shall detect failures and potential for optimization. Early warnings in case of failures prevent from severe long-term damages of the system parts.
- Offers multifaceted possibilities to visualize the energy production and successful operation of the system to different user groups: to the service staff and the system owner, but in special formats also to the public, potential customers for solar thermal systems, authorities etc.

2. Method

2.1. Function principle

Main premise for visualization and analysis of solar thermal systems is the collection of measurement data. This can be performed without any extra costs: Several controller manufacturers (e.g. Steca Elektronik GmbH), offer solar controllers that do not only control the solar thermal system but at the same time store all operating sensor data on a SD card or transmit it via internet to a server of the manufacturer. Typical measurement data are 1-minute values of all relevant temperatures, pumps and switches, often also volume flow and energy production

The measurement data are regularly uploaded to the web-server hosting the functionality check. Additionally, concurrent meteorological data (ambient temperature and solar irradiance) are fetched from weather satellites and nearby weather stations. After each import of measurement data, the measurement values are visualized on the web page and the functionality of the system is checked. The analysis results are made available for the service staff. The web portal also generates yearly PDF-reports for each system, which summarize its energy production and condition.

The development of the web portal started in December 2012 and will be finished in autumn 2013.

2.2. Twelve months of field test with ten solar thermal systems

The intelligent web-based functionality check is tested until spring 2014 with 10 typical solar thermal systems. They are chosen from Industrielle Werke Basel's population of solar thermal systems. All systems are equipped with a solar controller that can store all operating data in 1-minute intervals. Additionally to the temperatures of the solar collector and the storage tanks, also temperatures of the solar flow and return are measured. To allow for a calculation of the energy production, the volume flow is measured too. Figure 1 shows pictures of two test solar systems.

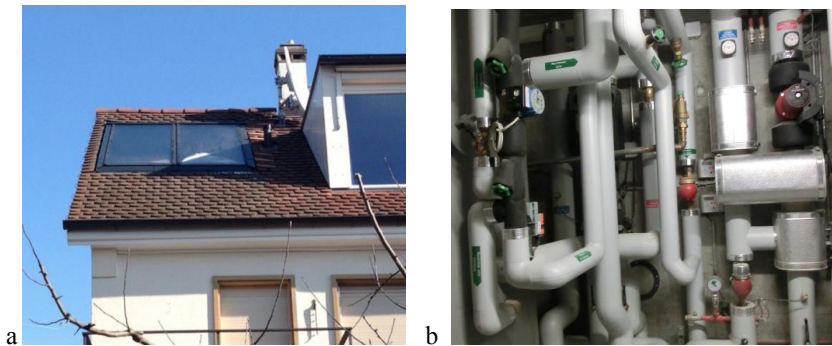


Fig. 1. (a) system “Kä” with two collectors. Source: Lützel Schwab GmbH; (b) pumps, pipes and controller of system “Ob”. Source: Egon AG

3. Results

A first version of the web portal is online now (<http://satherm.ch>). All ten test systems were registered in the satherm web portal. Measurement data of three test systems have been uploaded and analyzed until now. Table 1 gives an overview on the test systems and their project status.

Table 1. Overview on the test systems. * = existing solar controller can be used for measurement. n.m. = measurement has not started yet.

ID of test system	aperture area (m ²)	manufacturer of solar controller	Start date of measurements
Fr	23	Steca	September 2013
Ha	37	Resol*	September 2013
Hi	12	Steca	n.m.
Ho	7	Soltop*	n.m.
Kä	4	Soltop*	August 2013
Ob	20	Steca	n.m.
Pe	8	Steca	May 2013
Pu	32	Soltop*	April 2013
Ro	12	Steca	August 2013
So	18	Steca	n.m.

3.1. Detailed operating analysis of solar circuit, storages, stagnation, pumps, volume flow and power

All measurement data are aggregated on a daily and monthly basis to provide significant system information for the service staff. Which analyses shall be performed was intensely discussed with service staff for solar thermal systems. Table 2 shows all analyses and their results for the system “Pe” from 1st until 5th September 2013. Figure 2 shows the measurement data of the system “Pe” for the 5th September. Some of the analysis results have only informative character, e.g. the number of stagnation hours. Others detect system failures, e.g. the number of hours where stagnation occurred although the storage had not reached its maximum temperature yet. The analysis of system “Pe” shows, that the system works properly.

Figure 3 shows the measurement data of the system “Ro” for the 5th September 2013. The measurement data show, that the solar pump does not start although the storage temperature is below 50°C and the sun is shining. Thus the collector temperature rises to more than 170 °C and the storage temperature remains low. In the evening, surprisingly the storage temperature begins to increase although there is no solar input. As can be seen in table 2, these problems are dealt with in the following analysis methods:

- stagnation despite heat demand
- storage temperature increases without solar input
- pump off despite ΔT

This shows, that the functionality check addresses the relevant problems and has the potential to detect and identify system failures. At the moment, the above mentioned analyses are not fully implemented yet. So, analysis results for the system “Ro” are not yet available.

Table 2. analysis results for system “Pe” from the first until 5th September 2013

	unit	1 st Sept.	2 nd Sept.	3 rd Sept.	4 th Sept.	5 th Sept.
quality of measurement data		complete and plausible	complete and plausible	complete and plausible	complete and plausible	complete and plausible
solar irradiance	kWh/m2	3.5	4.7	5.3	5.2	5
average ambient temperature	°C	16.5	15.2	17.3	19.8	21.2
collector circuit	unit	1st Sept.	2nd Sept.	3rd Sept.	4th Sept.	5th Sept.
average collector temperature	°C	46.5	60.2	52.8	55.1	52.1
average storage temperature	°C	33.8	43.9	36.4	37.9	35.4
average solar flow temperature	°C	41.6	53.6	46.4	48.5	45.9
average solar return temperature	°C	32.9	43	35.4	37.8	35.3
deviation solar flow - solar return	°C	8.7	10.7	11	10.7	10.6
deviation solar circuit - storage	°C	3.4	4.3	4.5	5.3	5.2
deviation collector - solar flow	°C	4.9	6.5	6.4	6.5	6.2
stagnation	unit	1st Sept.	2nd Sept.	3rd Sept.	4th Sept.	5th Sept.
maximum collector temperature	°C	58	72	66	70	66
maximum temperature solar flow	°C	56	66	60	68	60
maximum temperature solar return	°C	42	58	49	55	51
stagnation	h	0	0	0	0	0
storage	unit	1st Sept.	2nd Sept.	3rd Sept.	4th Sept.	5th Sept.
maximum storage temperature	°C	44	58	51	56	53
storage reached maximum temperature	d	0	0	0	0	0
storage temperature increases without solar input	h	0	0	0	0	0
solar pump	unit	1st Sept.	2nd Sept.	3rd Sept.	4th Sept.	5th Sept.
measured runtime 100%	h	8.5	9	9.1	9.2	9.2
total measured runtime	h	8.7	9.3	9.1	9.3	9.4
expected runtime	h	8.8	9.1	9.1	9.2	9.6
pump off desp. delta T	h	0	0	0	0	0
pump on without delta T	h	0	0	0	0	0

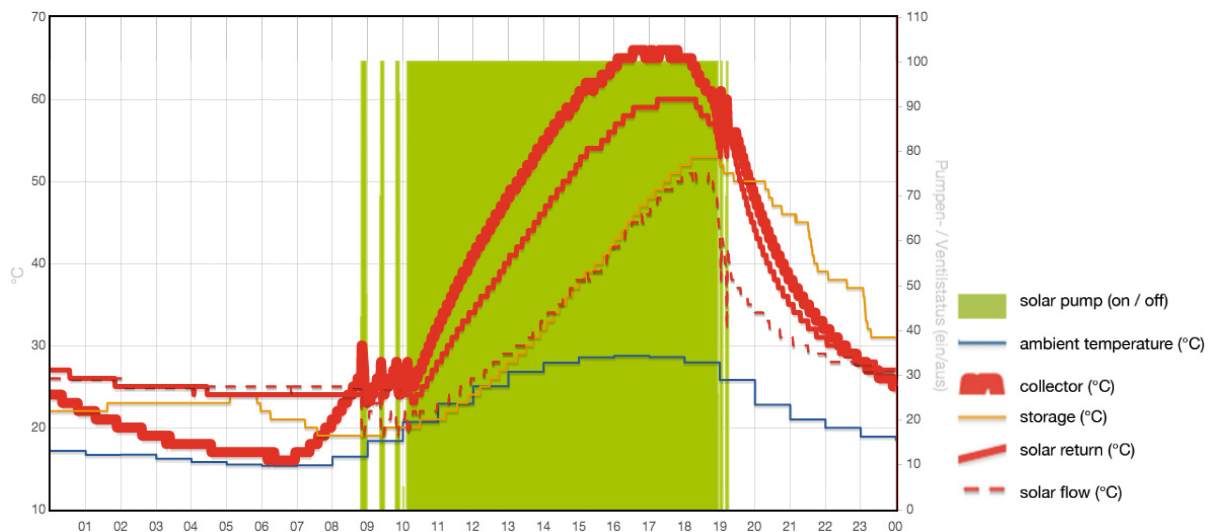


Fig. 2. Measurement data of system “Pe” on 5th September 2013

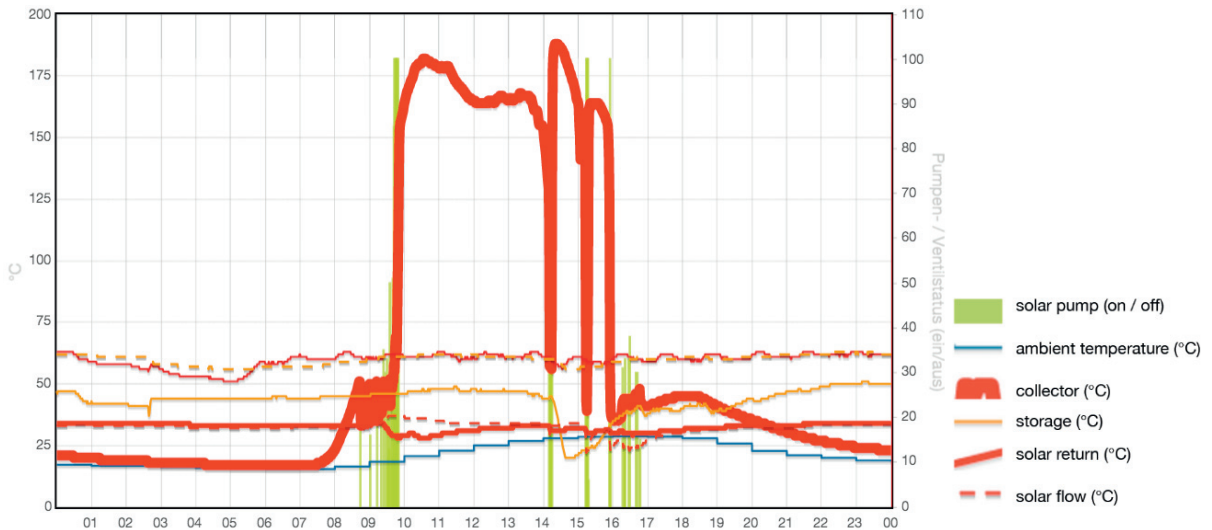


Fig. 3. Measurement data of system “Ro” on 5th September 2013

3.2. Comparison of measured and expected yield

Irradiance and ambient temperature are not measured on site but at nearby national meteorological stations. Figure 4 shows measured and expected yield of the system “Pe” on 5th September 2013. The expected solar yield is calculated based on solar irradiance and ambient temperature with the following formula:

$$Y = A \times R \times \left[I \times \eta_0 \times IAM - a_1 \times \left(\frac{T_F + T_R}{2} \right) - a_2 \times \left(\frac{T_F + T_R}{2} \right)^2 \right] \quad (1)$$

where: Y = reference yield (Wh)

A = total aperture area of the solar system (m²)

η_0 = optical efficiency (-)

a_1 = 1st order heat loss coefficient (W/m²/K)

a_2 = 2nd order heat loss coefficient (W/m²/K²)

R = expected runtime (hours)

I = irradiance on collector plane (W/m²)

IAM = incidence angle modifier (-)

T_F = temperature of solar flow (K)

T_R = temperature of solar return (K)

The comparison of measured and expected yield gives further opportunities to detect system malfunctions.

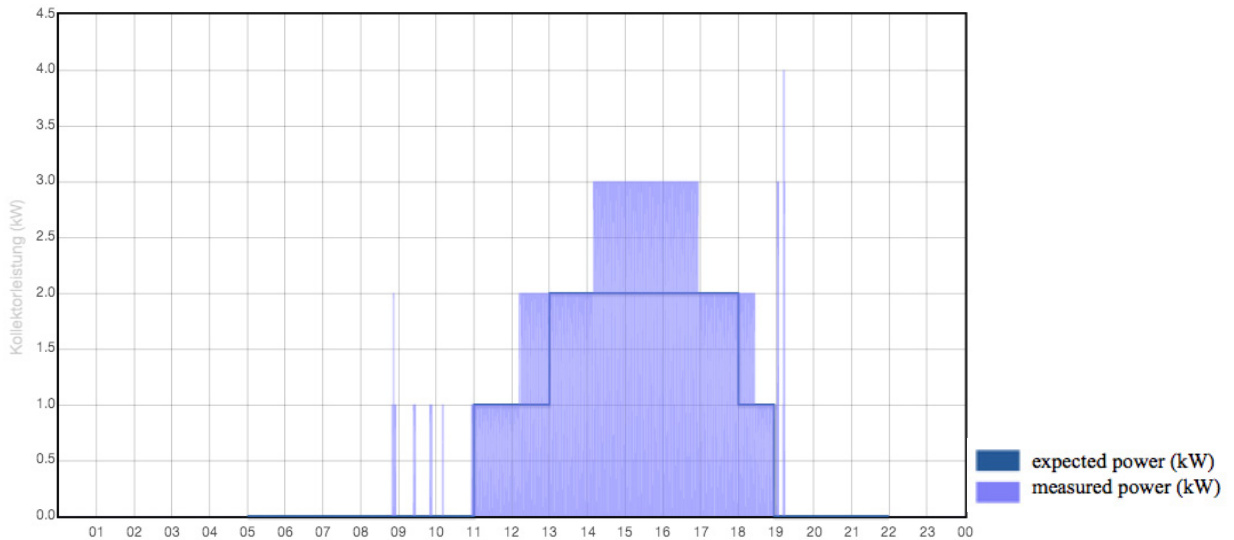


Fig. 4. Measurement data of system "Ro" on 5th September 2013

4. Conclusions

The functionality check will be further developed and tested with data from the ten test systems. Two of the project partners - Ernst Schweizer AG, Metallbau and Industrielle Werke IWB will use the functionality check in their everyday work for setting up the optimum operation of their systems and for trouble shooting. As of middle of next year, the functionality check will also be available for companies outside the project team.

Acknowledgements

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