Various Types of Rear Ventilation of crystalline PV-Modules with trough mounting, e.g. on flat roofs

Author:
Qualified Engineer Eberhard Zentgraf
at TEC-Institute for Technical Innovation

Scientific team, involved in planning, set-up, measurements and analysis:
E. Zentgraf, Mo. Göde, A. Höfling, A. Zentgraf, L. Lemons

Table of contents

1. Preface: reason for the study

The rear ventilation of photovoltaic modules, which supposedly aids with a better cooling and thus results in an increase in energy yield, has repeatedly been a topic in discussions on the optimizing of said energy yield.
In laboratory tests of some time ago, the team of TEC institute had already dealt with the topic of warming and cooling of solar cells and PV-modules. However, as mentioned before, these tests had been carried out in a lab. The newly planned tests were carried out under real-life conditions on a roof with standard PV-modules in feed-in mode.

2. Set-up and measuring series

In order to gain a high degree of significance, it was vital, that the test system as well as the reference system were operated under exactly the same conditions. We decided to use the monocrystalline module type ANTARIS ASM 180 for the reference system as well as the test system. In principle, any crystalline module of any manufacturer can be used for these tests as long as test and reference module are of the same kind. As we had dealt with 4 ANTARIS ASM 180 for a longer period of time in the context of other studies and tests and had learned that, under identical operating conditions in very narrow tolerances, their relative energy yield (related to the kWp) was the same, we choose them for the testing series.

Thus, the reference system as well as the test system consisted of respectively two PV-modules ANTARIS ASM 180, which both fed into the grid via an inverter (Mastervolt Soladin 600). Each two modules were wired up into a mini-string. Like this, we ensured that the two inverters worked within their Mpp-range and thus gained the optimal energy yield from the modules.
Furthermore, concerning the two systems, we paid attention to the following issues:

- Same cable lengths
- Absolutely no shading
- Calibrated feed in meter
- Calibrated direct current and direct voltage measuring devices; the respective energy yield of the modules was calculated from the values gained with these devices

- Calibrated temperature sensors
- Attached with optimum contact surface
- Centred on the underside of both modules of the test system

Both systems were located on the flat roof of our institute and were mounted on the approved mounting troughs ConSole by Ubbink Solar. The inclination angle was 25° (exactly) South (see fig. 1 and fig. 2). The ballasting of the mounting troughs was achieved with coarse gravel, as recommended by the manufacturer.

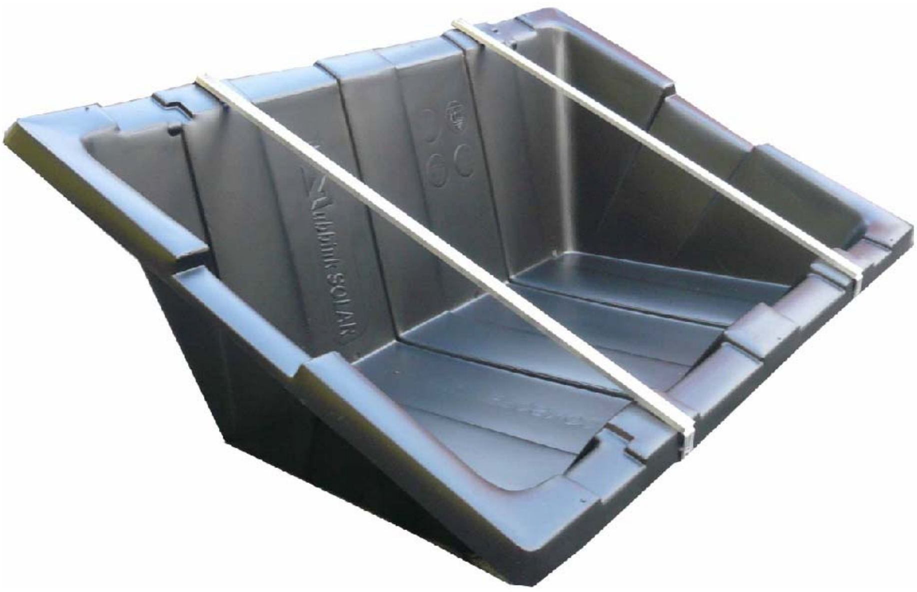

Fig. 1: mounting trough ConSole by Ubbink Solar

Fig: 2: Example for mounting on ConSole, Ubbink Solar

Both modules of the reference system were mounted on two original mounting troughs ConSole, by Ubbink Solar (as can be seen in fig. 1). There were no ventilation holes in the bodies of the troughs.

Ventilation holes were added on the mounting troughs in the test system (see. fig. 3 and 4).

Fig. 3: drilling of ventilation holes

Fig. 4: trough with ventilation holes

Now, we had to think about which season (of 2009) would be the one most suited to be able to work under the same conditions. The months October, November, December, January, February and March were out of question because

a) the sun was to low

b) the temperatures were too low

c) the share of annual yield of the 6 months taken together, would only be 30% in the long-term average (see also fig. 5 and 6)

monthly energy yields to be expected (here: 10 kWp system)

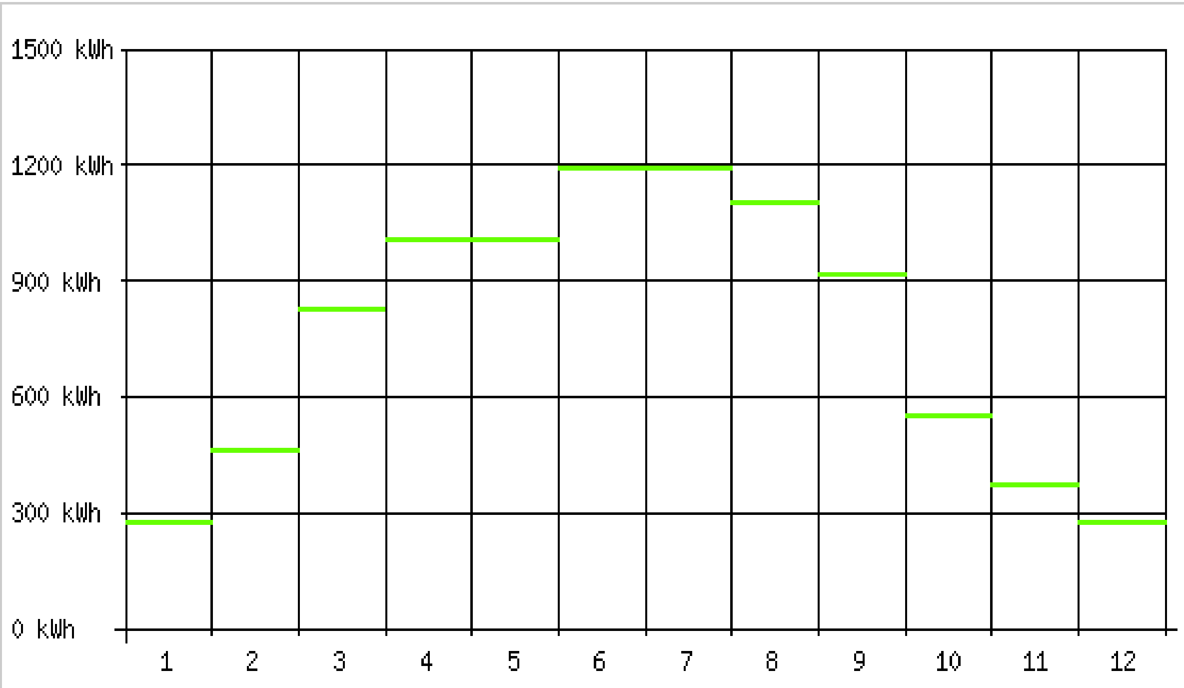

Fig. 5: monthly energy yields to be expected (here: 10 kWp system)

monthly temperatures 2008, outdoor temperatures at test-location [°C]

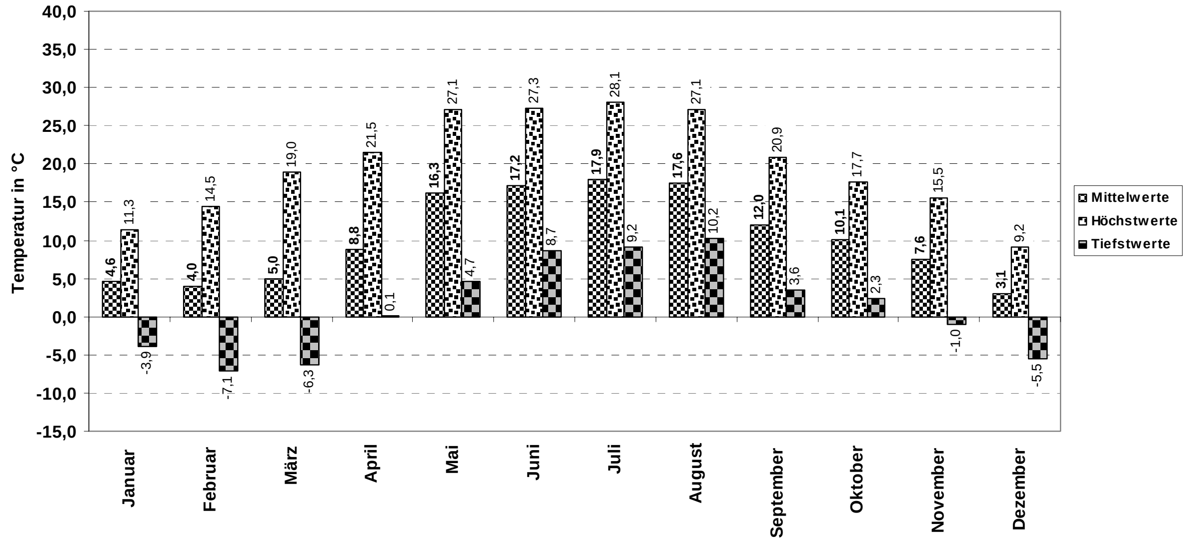

Fig. 6: monthly temperatures 2008, outdoor temperatures at test-location

Thus, primarily the four “hot” summer months May, June, July and August, in which high temperatures as well as high solar radiation occur, came into question for the testing period. The only consideration which remained was whether to include the months April and September into the testing period. As can be seen in fig. 6 (here: specifically 2008, but similar in the long term average), on average, April has a quite a high solar irradiance, however a relatively low exterior temperature, which cools down the modules without rear ventilation, too. In September, the mean temperature is usually a bit higher than in April, however, the solar irradiance decreases considerably. After all, the equinox is in September. Thus, we decided on the four months May, June, July and August for the testing period.

Referring to fig. 5, these four months are responsible for almost 50% of the annual energy yield.

In other words: During approximately 33% of the year (namely, the for summer months named above), almost 50% of the annual yield were generated.

During the months May, June and July 2009 the test system’s modules were mounted on the ventilated troughs (i.e. troughs with holes), see also fig. 7, while the reference system was mounted on standard troughs, without rear ventilation.

Fig. 7: test system is mounted on ventilated troughs

To record the temperature of both of the test system modules, (as mentioned above) a calibrated Pt 100-sensor was attached centred on the backside of both modules. In order to examine the temperature difference between ventilated trough and (with holes) and standard trough, we carried out a small test of July 1st 2009.

While all holes of one of the test system's trough were taped with a black foil on July 1st 2009 at 8:00, the holes of the test system's other trough remained open. One day later, on July 2nd 2009, we removed the foil around 10:40. Thereby, the effect which can be seen in fig. 8 arose:

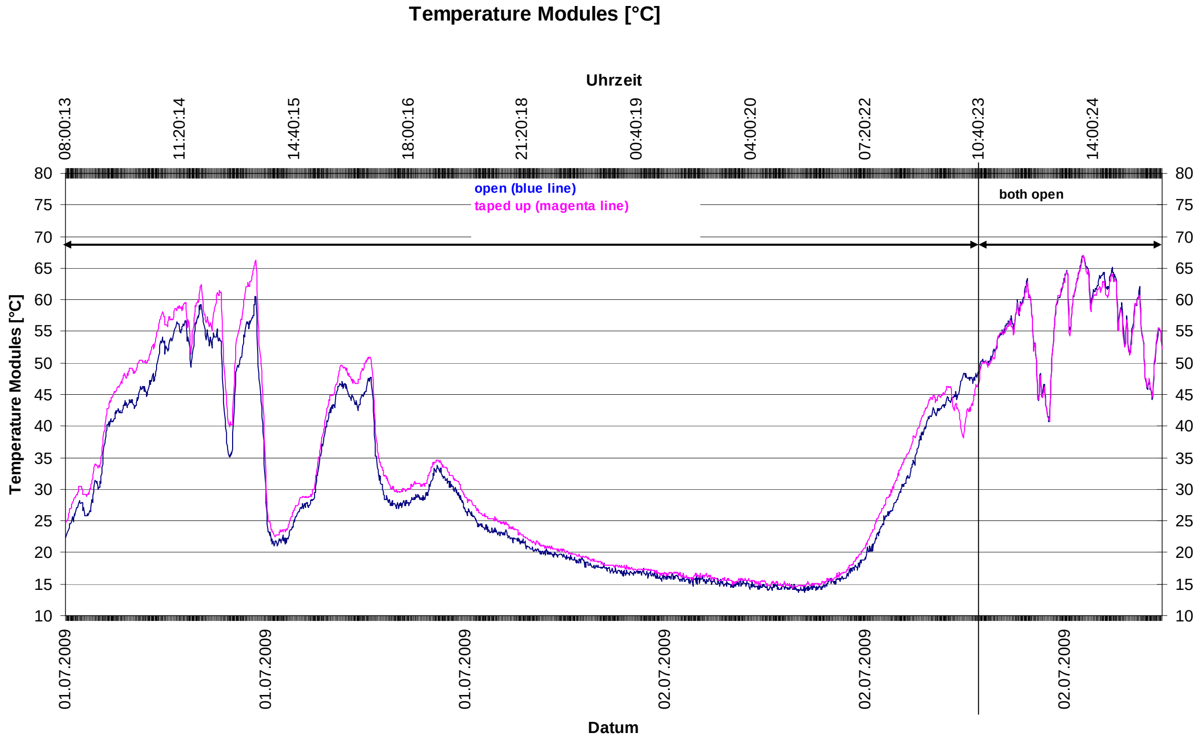

Fig. 8: test with an "open" and a "taped up" trough

It is clearly visible, that on the 1st of July, the module on the trough with the taped up holes had a temperature which around midday was 7° higher than the other module on the ventilated trough (with open holes). After removing the foil on July 2nd at around 10:40 (see fig. 8), the module temperatures were identical again.

Global solar irradiance in this measuring period can be seen in fig. 9.

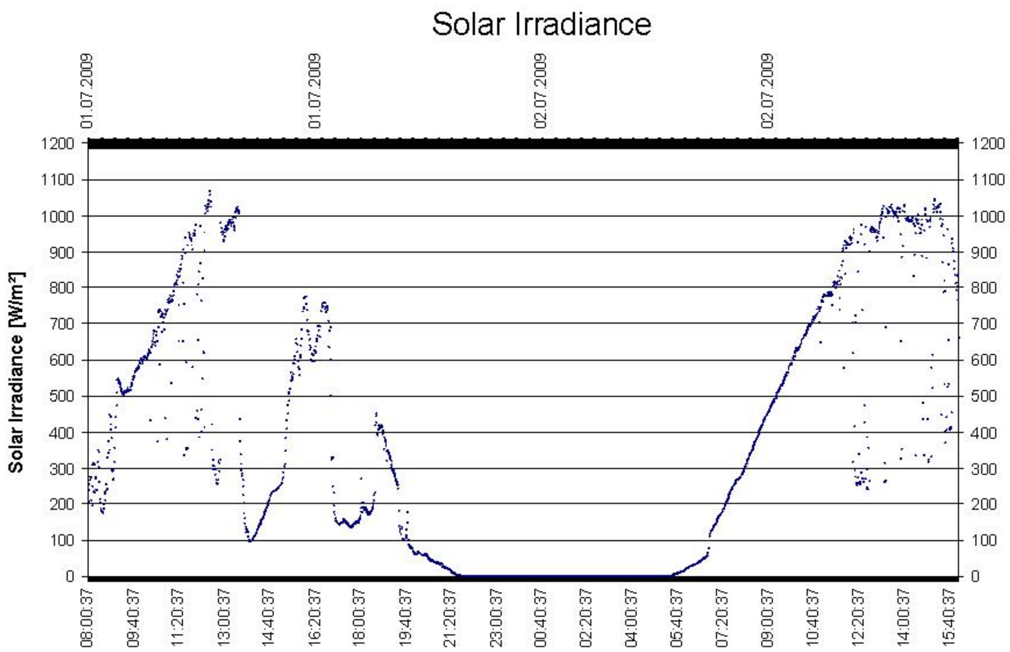

Fig. 9: global irradiance on July 1st and 2nd 2009

On August 3rd 2009 (August 1st and 2nd were a weekend), both troughs of the test system were taped with black foil completely, so the tests system was not ventilated at all, (almost) the whole of August.

Fig. 10: test system troughs, completely taped up with black foil.

In fig. 11 and 12, the absolute energy yields of the months May until August 2009 can be seen:

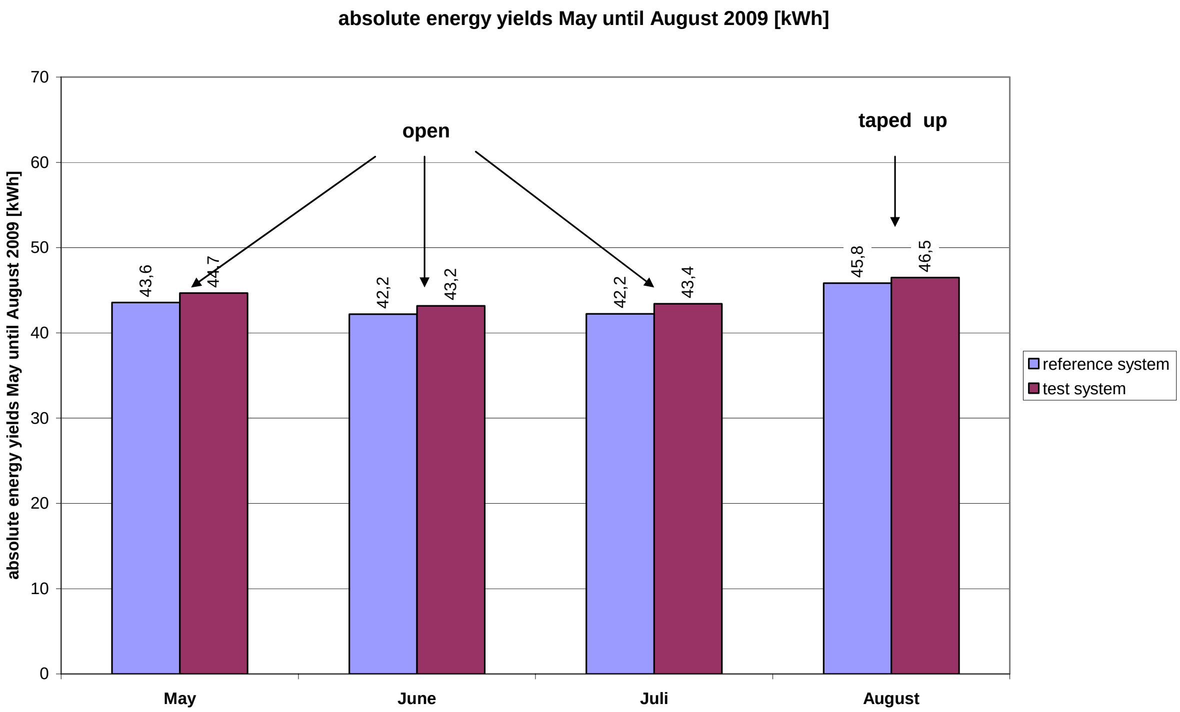

Fig. 11: absolute energy yields May until August 2009

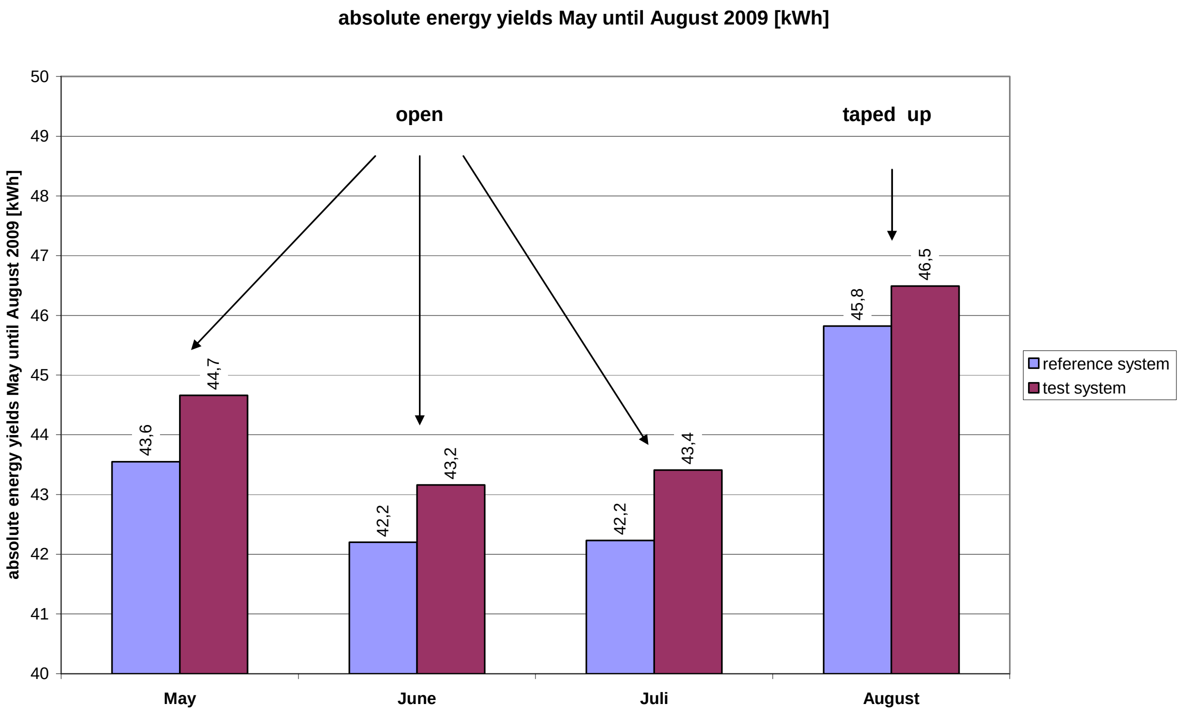

Fig. 12: zoomed in diagram of fig. 11

Result:

It is clear, that the reference system, which was NOT ventilated, always shows a lower energy yield compared to the test system. This is especially valid for the months May to July 2009, in which the test system was ventilated. When the holes in both of the test system's troughs were taped up in August 2009 (except the first two days), the surplus yield of the test system compared to the reference system decreased significantly.

More details can be seen in fig. 13 and 14. Here, the monthly surplus yield of the test system compared to the reference system is displayed.

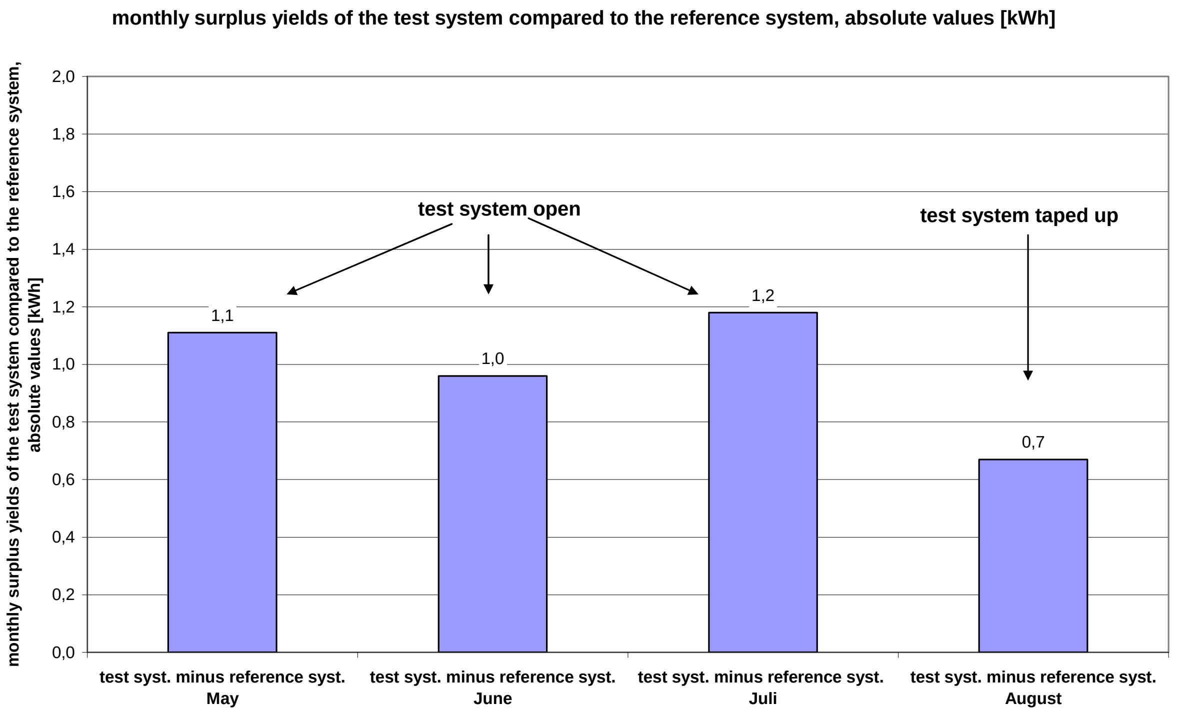

Fig. 13: monthly surplus yields of the test system compared to the reference system, absolute values

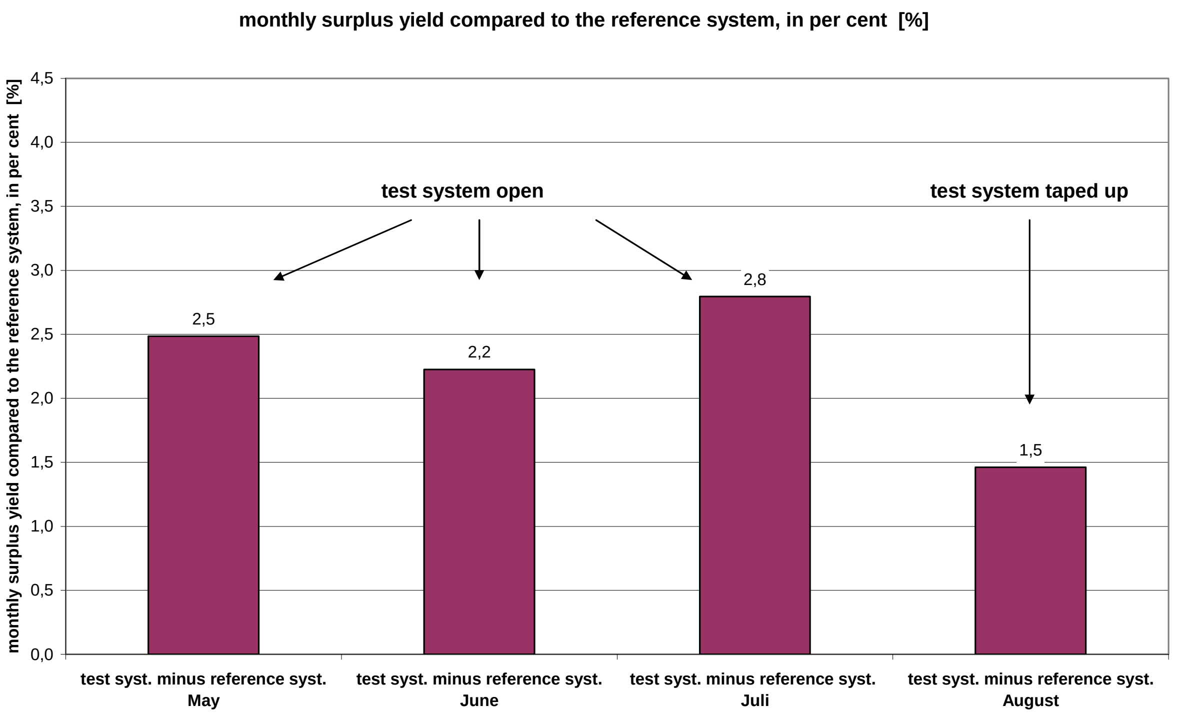

Fig. 14: monthly surplus yield compared to the reference system, in per cent

Conclusion:

In a ventilated state (months May to July 2009), the test-system's energy yield exceeded that of the reference system by 2%. However, when the test system was no longer ventilated in August 2009, i.e. test system and reference system were operated under exactly identical conditions, the test system's surplus yield decreased compared to the reference system and only amounted to 1.5% above the reference system.

Note:

Related to the datasheet nominal values, most module manufacturers name an area of +/- 3% for the deviation of the performance values (and thus, of the output values under identical operating conditions). Considering this, the examined reference and test modules (all ANTARIS ASM 180) - under identical operating/cooling conditions – lie (with a deviation of 1,5%) very much inside these tolerances.

3. Interpretation of the results and conclusion

What does this imply, concerning the efforts necessary for rear ventilation? During the months May to July 2009, the percentage yield benefit of the ventilated test system compared to the ventilated reference system is 2.5% on average. Under identical cooling conditions – both systems non-ventilated – the test system's yield benefit is only 1.5%. It follows, that the surplus yield won by rear ventilation (with the described test set-up) is 1% on average.

Note:

This is true for the four hot summer months (May to August). During these 4 months, which time wise make up 33.3% of the year, almost 50% of the annual energy yield is generated.

From this it can be concluded:

Assuming, that there is no yield benefit due to rear ventilation during the "remaining" 8 months, as the exterior temperatures are too low, the result would be, that rear ventilation referring to the whole year (12 months) would result in an energy surplus yield of around 0.3%.

However:

For the months April, September and may be October, minor yield benefits occur due to ventilation. However, these are visibly lower than the months May to August, so than the annual advantage of 0.3% is exceeded.

Furthermore:

In breezy locations (e.g. on the coast) a certain increase of the cooling due to ventilation is to be expected. However also there, the front (top) of modules without ventilation are cooled by the prevailing winds, so that a certain relativization sets in.

Concluding:

Even when interpreting the measuring results very optimistically, the yield benefit from the kind of ventilation examined, will be significantly less than 2% (for Central Europe, including large parts of Germany).

4. Equipment

Device:	Manufacturer:	Type:
- PV-Panel	ANTARIS	ASM 180
- Mounting System (trough)	Ubbink Solar	ConSole
- Inverter	Mastervolt	Soladin 600
- Multimeter	Voltcraft	VC 820
- Electricity Meter	AEG	Form J16 G
- Measuring Computer	Dell	Modell DHM
- Software	Microsoft	VB 6.0
- Software	Microsoft	EXCEL 2003

Waldaschaff, 5th of November 2009

Eberhard Zentgraf
Qualified Electrical Engineer. (FH) Eberhard Zentgraf
TEC Institute for Technical Innovation