Yield Measurements on PV-Modules at Inclination Angles of 25°and 12°

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Courtesy translation by Maria Moore

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1. Preface

In the course of 2008 TEC-Institute for technical Innovation published a report titled "Höhe des Energieertrags von Photovoltaik-Modulen unter verschiedenen Neigungswinkeln und Ausrichtungen"[1] (to be found on the web page www.tec-intstitut.de). These studies were carried out with scaled-down set-ups (with miniature modules). After said report was released, the question arose several times, whether we could repeat our studies with customary modules in feed-in mode. Thus, we decided to carry out a testing series over a minimum of one year. For these tests, we used PV-modules, which were aligned at inclination angles of 25° and 12° south.

2. Set up and implementation of the experiments

We chose the monocrystalline module type ANTARIS ASM 180. Two pairs of modules were each wired up into a mini-string. Feed-in was effected via respectively one adequately dimensioned inverter. One pair of modules was mounted at an inclination angle of 25° the other pair at an incli nation angle of 12°, both on a flat-roof carrier system, aligned exactly South (see also fig. 1). Direct current and direct voltage were measured on the direct current side for each module-pair. From these values, output and energy yield could be calculated. The measuring interval was one minute. Furthermore, we ensured equal conditions for both measuring set-ups (e.g. same cable length, same way of data recording and so forth). In order to be able to compare the different module types, the specific yield (kWh/kWp) was given (in our case the flashed kWp). To this end, all modules were measured with the sun-simulator (under STC).

[1] „Total amount of energy yield from PV-systems at different angles of inclination and with differing orientation"

Fig. 1: 25° and 12° set-ups

3. Measuring Results

The measurements were carried out between March 2009 and May 2010, over a period of 15 months. The monthly yields during that time are displayed in fig. 2.

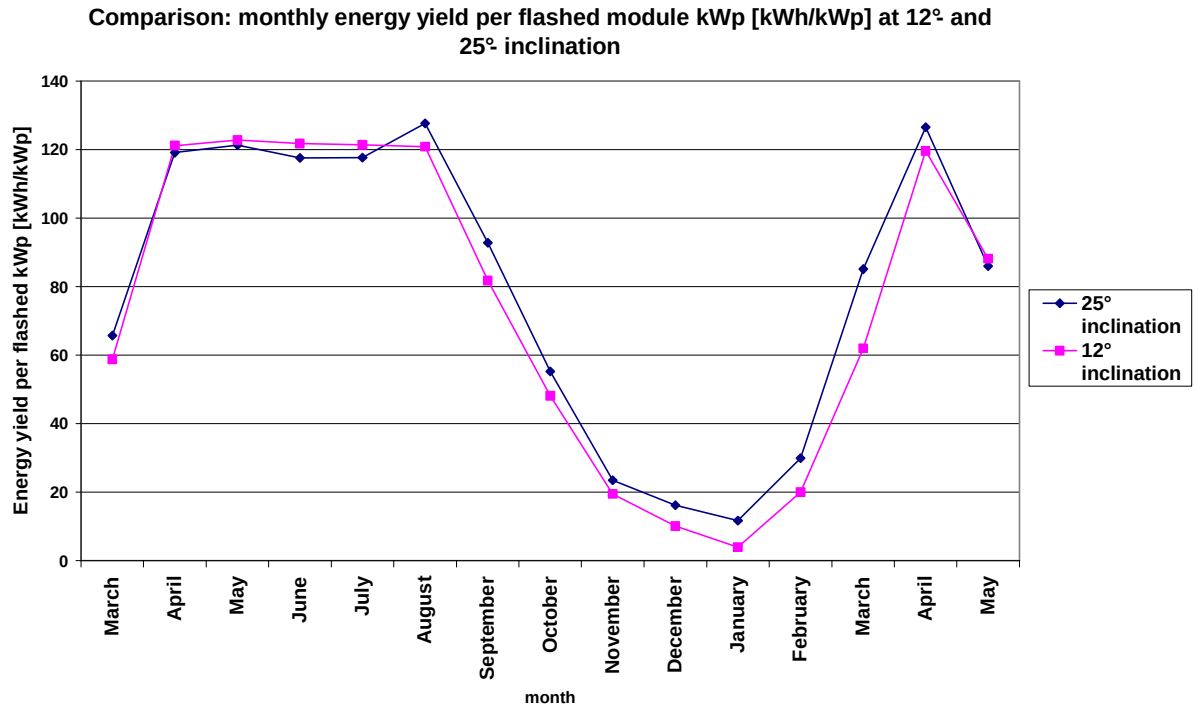

Fig. 2: monthly energy yield from the 25° and 12° s et-ups

The above mentioned time period, resulted in an energy yield sum of:

- module pair at 25° inclination: 1195,96 kWh/kWp
- module pair at 12° inclination: 1119,99 kWh/kWp

As examples for the different positions of the sun depending on the season and the corresponding yields, different day performance curves are shown in fig. 3, 4 and 5. In fig. 3, these are the day performance curves of June 16th and 17th 2009 (i.e. virtually the highest position of the sun).

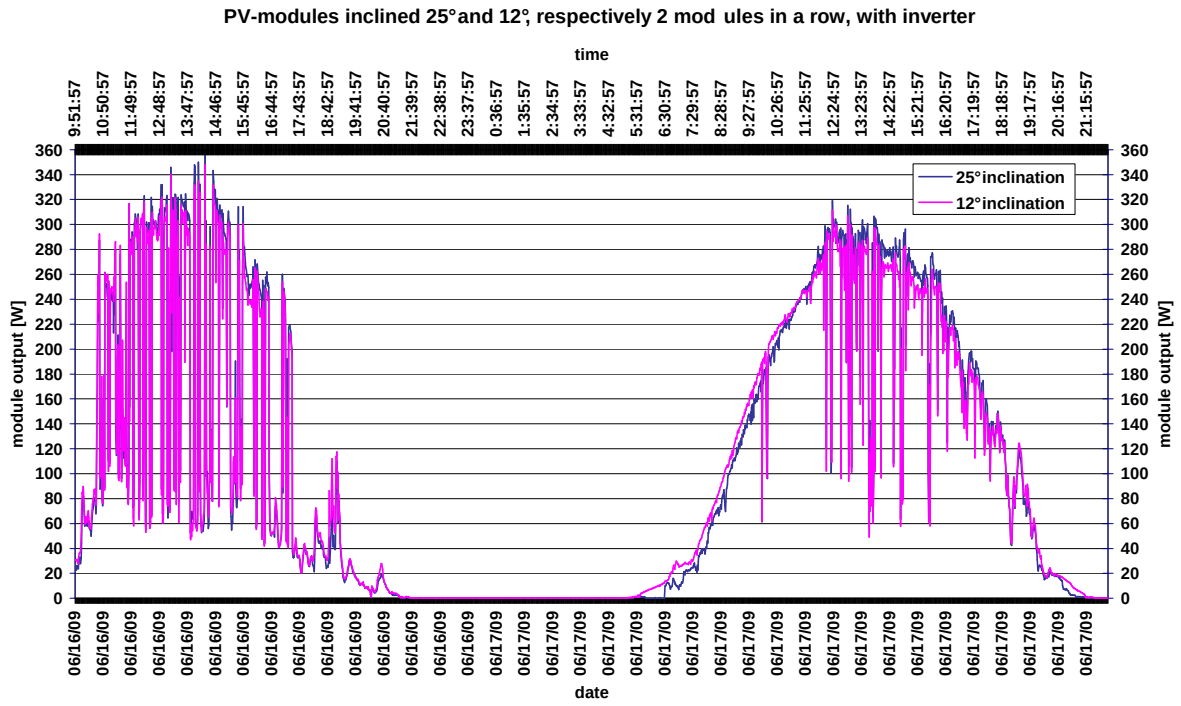

Fig. 3: day performance curves in June 2009

Both days had some sunshine as well as cloudy periods. The curves of the modules which were inclined at 25° and 12° are almost identical, in full sunshine as well as in cloudy conditions.

Fig. 4 shows the day performance curves on the day of the equinox of March 21st and March 22nd 2009 (corresponding also to September 21st and September 22nd 2009).

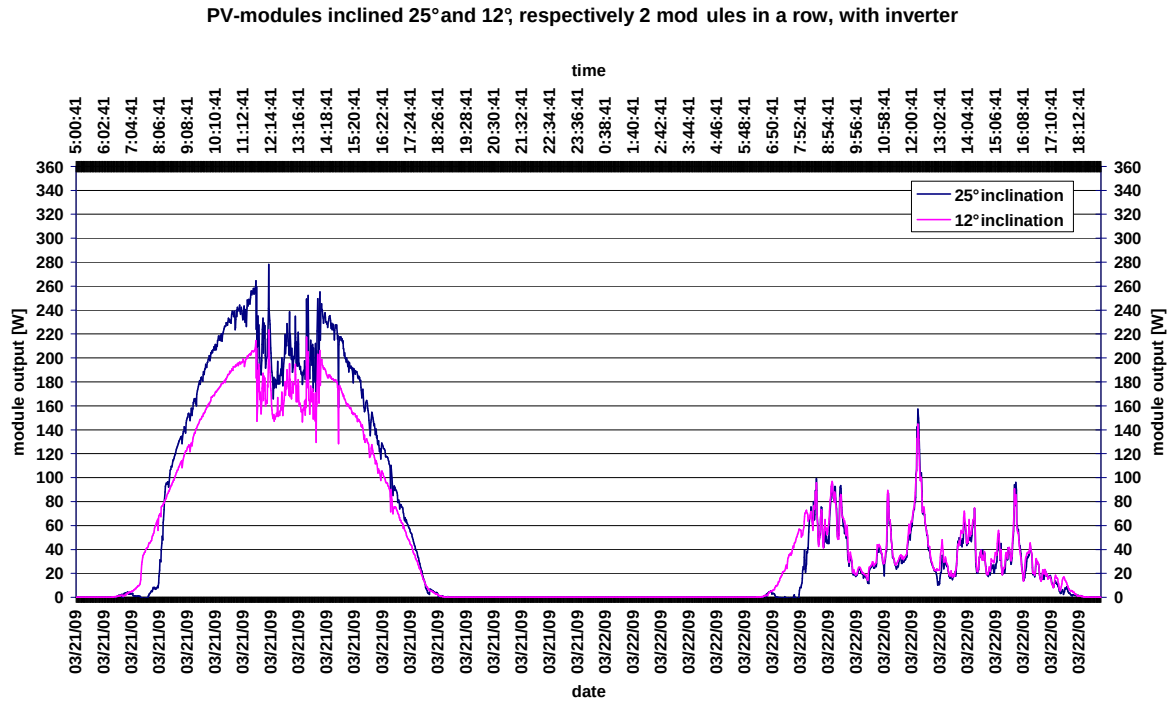

Fig. 4: day performance curves in May 2009

It is quite clear, that the curves of the 25°- and 12°- inclination match on overcast days. On sunny days, the performance curve of the modules inclined at 25° is clearly above the modules inclined at 12°.

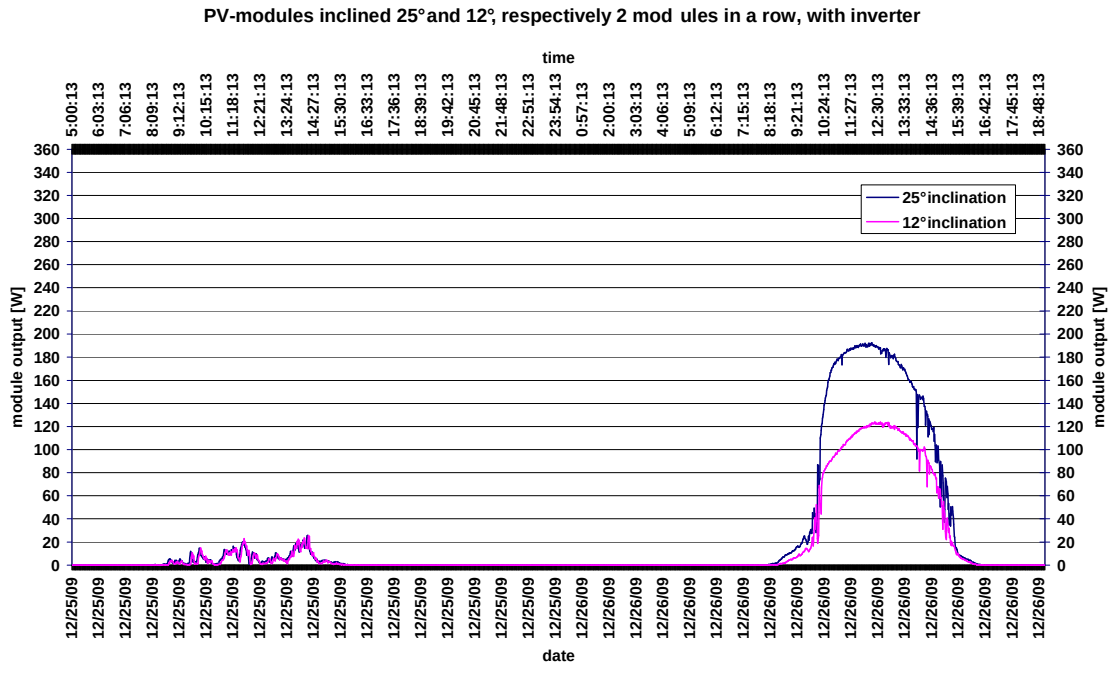

Fig. 5: day performance curves shortly after winter solstice

Fig. 5 shows the conditions at approximately the time of the lowest position of the sun (winter solstice). While the curves are identical on overcast days as well, on sunny days, the set-up which is inclined at 25° ranges ap proximately 35% (max.) above the set-up which is inclined at 12°.

4. Analysis

The 12° set-up achieves 93.7% (i.e. approximately 9 4%) of the energy sum of the 25° set-up during the whole measurement period (see also fig. 2). This complies almost exactly with the value which was expected. During the summer months (as well as in late spring and early autumn) the yield of both set-ups is almost the same. During the year's remaining months (late autumn, winter, early spring) the 25° set-up is clearly in front of the 12° set-up on sunny days . But because skies are mostly overcast in our latitudes from November until March, the loss in yield of the12° set-up has almost no influence on the annual yield compared to the 25° set-up (see fig. 2, 3, 4, 5).

Shading problems:

It comes to a big advantage, that on flat roofs, modules can be mounted much closer to each other with a 12° elevation, than with a 25° elevation. The distances between the modules halve. The energy yield increases significantly.

5. Conclusion

In the course of the last months we received numerous inquiries and suggestions, to try other orientations under real-life (feed-in) conditions than the southern orientation. As a result, we have another measuring series running since a few months, which determines differences in yield comparing an orientation towards the west with an orientation towards the south in feed-in mode.

6. Equipment

Equipment:	Type:	Manufacturer/Supplier:
Multimeter	Fluke 45	Fluke
Mulitmeter	Fluke 89IV	Fluke
Inverter	Soladin 600	Mastervolt
Electrical Network Monitoring	ENS 26	UfE
Measuring Computer	GX 260	Dell
Software	MS Visual Basic 6.0	Microsoft
Software	MS Excel 2003	Microsoft
PV-modules	ASM 180	ANTARIS

Waldaschaff, 6/15/2010

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