Studies on Clearing PV Modules from Snow

Increasing Current Yields

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1. Objective of study

Repeatedly, our TEC Institut für technische Innovationen was consulted on whether or not it made sense clearing PV modules from snow in the winter to increase current yield. We therefore decided on performing studies to that effect.

Our focus was not on testing systems capable of melting snow by self-heating when reversing effects, which can already be purchased on the economy.

Our goal was a study on increasing earnings by mechanically / manually clearing modules from snow.

Since working on roofs can be quite dangerous we decided on open space test facilities. Thus the physical clearing from snow could be performed from the ground. The PV Company ANTARIS Solar agreed to provide two same sized PV arrays within their own 1.24 MW plant in Holysov, Czech for said studies.

2. Brainstorming

Primarily, we developed an estimate on a possible yield increase by snow removal obtaining long-term averages of annual PV yielding and global irradiance from the website of PVGIS (Photovoltaic Geographical Information System, (http://re.jrc.ec.europa.eu/pvgis/) of the Holysov location.
See figure 1.

Location: 49°35'36" North, 13°5'58" East, Elevation: 0 m a.s.l.,

Nominal power of the PV system: 1.0 kW (crystalline silicon)
Estimated losses due to temperature: 7.5% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 3.0%
Other losses (cables, inverter etc.): 14.0%
Combined PV system losses: 22.8%

Fixed system: inclination=35°, orientation=0°				
Month	E_d	E_m	H_d	H_m
Jan	1.03	32.0	1.21	37.6
Feb	1.74	48.6	2.09	58.4
Mar	2.45	76.0	3.04	94.2
Apr	3.23	96.8	4.17	125
May	3.62	112	4.81	149
Jun	3.48	104	4.69	141
Jul	3.75	116	5.09	158
Aug	3.43	106	4.64	144
Sep	2.76	82.8	3.61	108
Oct	2.15	66.6	2.71	84.0
Nov	1.00	30.0	1.21	36.4
Dec	0.70	21.7	0.83	25.8
Yearly average	**2.45**	**74.5**	**3.18**	**96.8**
Total for year		**894**		**1160**

E_d: Average daily electricity production from the given system (kWh)
E_m: Average monthly electricity production from the given system (kWh)
H_d: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)
H_m: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)

Fig 1: Average global irradiance, as well as PV yields (pertaining to 1 kWp system)

2.1 Theoretical calculations on basis of assumptions:

For the months with virtually complete snow covering, we determined the months of December and January. According to fig 1, column Em, a yield of 53.7 kWh (per kWp) is to be estimated as a long-term average for the duration of both months.

Based on an annual yield of 894 kWh (per kWp) on a long-term average, the two months December and January contributed a total of approximately 6% to the annual PV yields.

We therefore concluded that the difference of PV annual yields between the PV array cleared from snow and the array not cleared, within the months of December and January, wouldn't reach the theoretical 6%, but should indeed be close to that range. That is, of course, assuming that one section is permanently snow covered in December and January and the other section is permanently cleared from snow thru that time period.

3. Proceedings

3.1 Design

Both same sized arrays had each a nominal capacity of 32.4 kWp and consist of 180 pieces of PV modules type ANTARIS ASM 180. Both array sections had an exact same orientation towards south, the same inclination and no section was shaded. Also, the utilized wiring and inverters were identical in both arrays.

Both sections had been integrated in a monitoring of the entire site and could easily be read out and evaluated.

It was determined, that the staff of the maintenance personnel would once a day clear snow from the modules of the designated PV array, as soon as snow set in.

The other section remained untouched, no snow was removed.

3.2 Execution

The maintenance staff was furnished appropriate clearing tools and cleared the designated modules once a day when it snowed. See fig 2.

Fig 2: Maintenance worker clearing snow with appropriate tool.

Since snow was removed only once a day, it was likely that even immediately after cleaning the modules were covered with snow again. In this case, modules remained snow covered until scheduled time of cleaning next day. It should furthermore be considered, that snow was not removed on holidays (i.e. Christmas) and Sundays.

4. Test results

From November 20th, 2010 until January 25th, 2011 (68 days) one section was covered with 10 cm to 60 cm of snow.

The other section was regularly cleared from snow with mentioned restrictions, named in 3.2.

Remark to this:
We quickly had to put aside our theoretical, idealized assumption, mentioned in item 2.1, that one section would permanently be covered with snow for a longer period of time, since the snow on the not cleared modules slid down off parts of the modules again and again uncovering them on its own. This caused the modules to produce energy, if only at a low performance range, similar to modules that are shaded.

This resulted in energy yields shown on Fig 3.

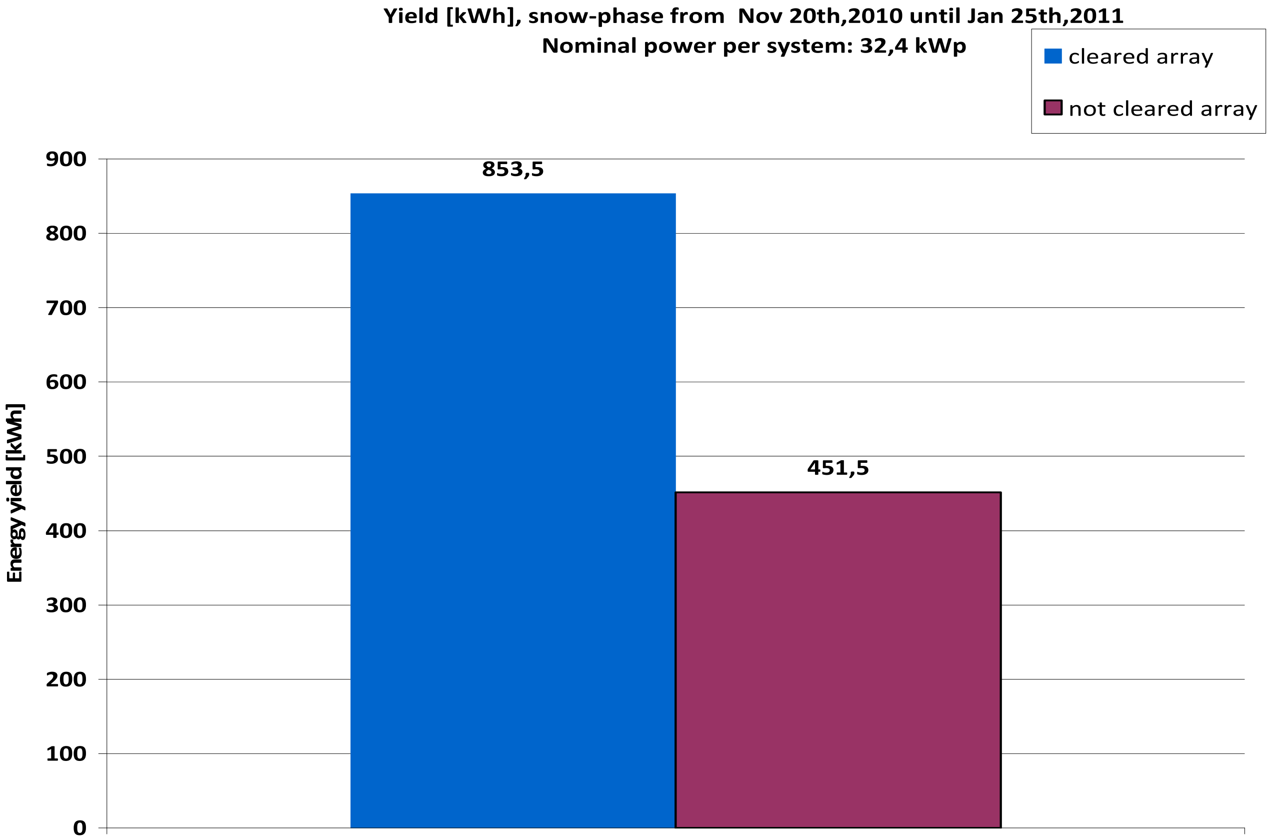

Fig 3: Energy yields during the time of snow covering

The section which was not cleared yielded 451.5 kWh, the cleared section 853.5 kWh.

Figure 4 displays the yield of both arrays, from beginning of snow set in (November 20th, 2010) until the end of the year (December 31st, 2010).

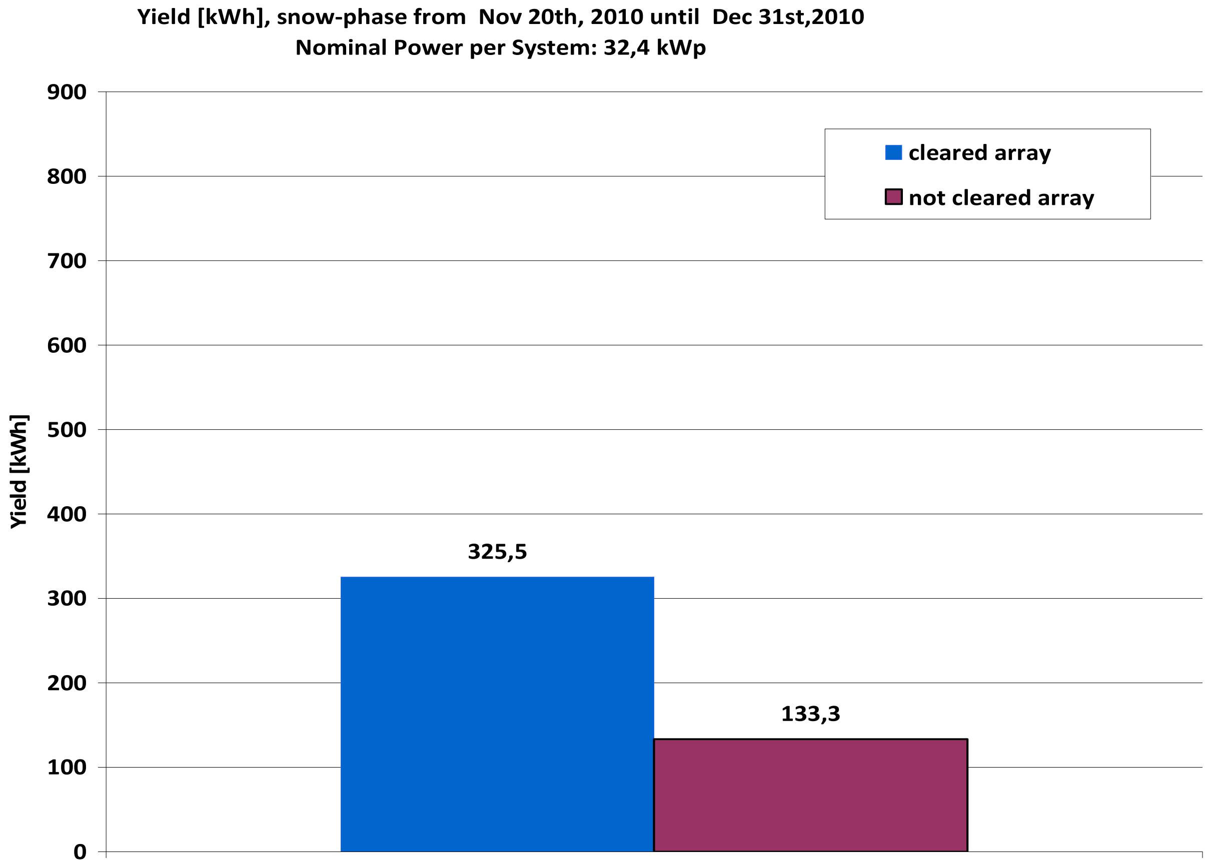

Fig 4: Yields from beginning of snow phase until the end of the year 2010.

For comparison:
The section that was cleared from snow in the winter produced 5009.9 kWh in the month of July 2010 and the section not cleared from snow in the winter produced 4939.0 kWh. They only differed by 1.4%, which is absolutely within a permitted tolerance, also see Fig 5.

The array that was not being cleared from snow in the wintertime, reached a yield of 28773.2 kWh throughout 2010. The array, however, that was cleared from snow, yielded 28396.9 kWh, even considering, that from November 20th, 2010 until December 31st, 2010 the yield was higher than from the other array. Thus 192.2 kWh were deducted accordingly (see Fig 4 and Fig 5).

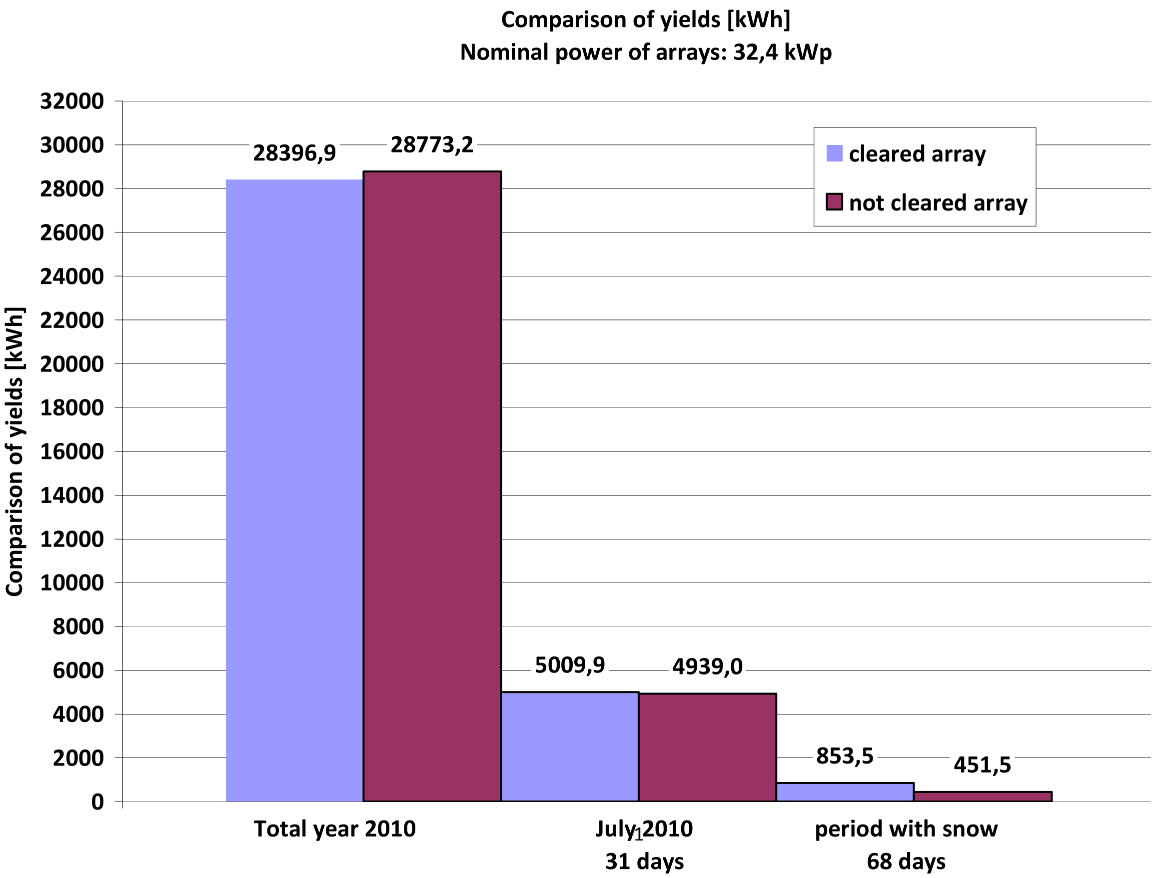

Fig 5: Comparison of yields within the different time periods

Fig 5 displays the difference in annual yields by 1.3% between the two arrays (provided, one section was cleared from snow). Again, this is absolutely within acceptable tolerances.

Comparing the yields of both arrays during the snow period with the individual annual yields is therefore quite interesting,

The snow period (November 20th, 2010 until January 25th, 2011) extended through the entire month of December and almost the entire month of January. A short period was already in November. The snow period lasted 68 days, a little more than 2 months. Thus, this period can very well be compared with the observations in section 2.1.

What was the actual benefit of clearing the modules from snow?
Clearing the modules from snow for two months (essentially December and January) contributed 3% to the annual yield.

The yield from the array that was not cleared from snow contributed 1.6% to the annual yield in the same period of time (see data in Fig 5).

Result:
An annual yield increase of merely approximately 1.4% was brought about by removing snow.

5. Conclusion:

These results are far from the idealized assumption that an increase of 6% could be achieved by clearing one array from snow while leaving the other array completely covered with snow during those two months. Of course, the clearing leaves room for optimization. Snow could be removed on Sundays and holidays as well. Or, should snowfall set in immediately after removal, it could be repeated several times a day.

However, the fundamental question is, whether or not the costs for snow removal exceed the gained increase in energy yield.

Similar careful considerations should be made, when envisaging automated snow removal or defrosting systems.

Waldaschaff, October 20th, 2011

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