

Survey on the output enhancement of SOLARA S-class photovoltaic modules achieved by Sunarc antireflection treated solar glass

The invisible secret of surplus

I. Summary:

- With SOLARA S-class you obtain premium quality “Made in Germany” with integrated Sunarc antireflection treated solar glasses (see V.).
- Thanks to its surface treated anti-reflex solar glasses Sunarc technology reaches an increased energy output of PV modules by up to 6,6%.
- To verify this output enhancing effect both SOLARA Sonnenstromfabrik Wismar GmbH (see II.) and the Technical University in Lyngby (Denmark, see IV.) accomplished at their test plants the underneath described measurements:



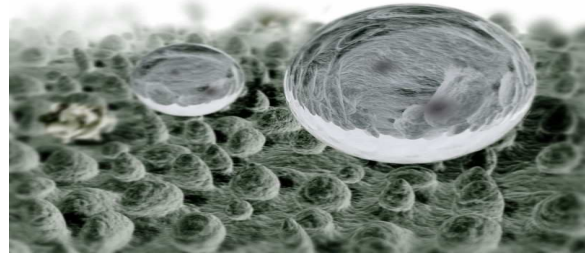
picture 1: more transparency with Sunarc anti-reflex coating in the lower part

Sunarc anti-reflex glass makes it possible to reduce the glass reflexes so much, that the translucency for sunlight increases from 91% to 96%.

This effect is reached by an etch procedure, which produces a nano-structure and increases the transmittance by 5%.

Further a water- and dust-resisting lotus-effect takes place. It is caused by the surface structure. The adhesivity between surface and water drop is so low that water can easily slide away (see picture 2). Dust particles, which have also only a small contact surface, are being carried or rinsed away.

Additionally this nano-structure improves the transmittance even in case of oblique incidence of light (for example in the winter months, when the sun stands very low) – depending on the angle up to 9%. The higher light transmittance improves the efficiency of the module.



picture 2: (nano-structure with overlying waterdrops)

II. Outdoor test executed by Sonnenstromfabrik Wismar

Test method: First of all 16 identical modules (nominal power 170 W_p, power tolerance +/- 3%, polycrystalline) were taken from the production. Eight modules were manufactured with the Sunarc© surface treated special solar glass “St. Gobain Albarina” (S870TI). The remaining modules were manufactured for this test without this special Sunarc© surface treatment (S870TI/A).

Even if all modules of the test array do not reveal any differences in respect of their construction, their electrical parameters vary within certain margins (crystalline product tolerances). Short-circuit currents, open current voltage and the mpp are slightly different from module to module.

In order to be able to compare the instantaneous power, i.e. the energy output the standard test conditions were ascertained by the optosolar flashlight simulator. With this device the reproducibility of one measurement is about 99.5%. In this case the absolute accuracy of measurement plays a minor part, as all modules are being measured shortly after another under the same test conditions compared to the same reference.

That means that the reproducibility of the measurement is decisive for the accuracy of the values. Later on the ascertained power figures provide the calibration of the values.

Picture no. 3 shows the test facility on the roof of the production hall. The eight modules as well as eight modules underneath are series connected. The measurement level is fixed to the south side at an inclination angle of 30°.



picture 3 – test facility on the roof of SOLARA Sonnenstromfabrik Wismar GmbH

Both surrounding and module temperature were recorded by PT100 sensors to ensure, that all modules are exposed to the same temperature influence.

A sensor that is fast responding on alternating irradiation intensity is fixed. In contrast to pyranometers it reacts faster on varying illuminance.

The instantaneous power of the upper and the lower module row is being filed in a data logger together with the temperature and the intensity performance data each 15 minutes.

It is evident that the lower module row with its treated glasses appears in different colours. Embedded under the Sunarc© treated glass the solar cells are clearly visible. This fact itself proves the enhanced oblique light transmittance. The following close-up in picture No. 4 makes this clear.



picture 4 – close-up of the test modules (modules above with normal solar glass and below modules with Sunarc anti-reflex coating)

The effective difference in the output reached by surface treatment can be exactly determined, as soon as the standard test conditions are known.

Two facilities with different module efficiency, which is always caused by product tolerances, can be compared only indirectly. For this reason the measured instantaneous performance with its STC Pmpp value² is standardised, the difference between both standardised performances established. These

standardised performance differences characterise the power increase caused by the surface treatment.

Measured data: The standardisation data result from the sum of all STC values for each module class:

| | Pmpp [Wp] | Ump p [V] | Impp [A] | Uoc [V] | Isc [A] | FF |
|----------------------|-----------|-----------|----------|---------|---------|------|
| standard solar glass | 175,52 | 24,20 | 7,25 | 30,24 | 7,69 | 0,75 |
| | 175,85 | 24,16 | 7,28 | 30,27 | 7,76 | 0,75 |
| | 175,62 | 23,99 | 7,32 | 30,18 | 7,70 | 0,76 |
| | 176,21 | 24,16 | 7,30 | 30,21 | 7,65 | 0,76 |
| | 174,94 | 24,06 | 7,27 | 30,17 | 7,69 | 0,75 |
| | 176,88 | 24,10 | 7,34 | 30,19 | 7,76 | 0,76 |
| | 175,78 | 24,11 | 7,29 | 30,20 | 7,66 | 0,76 |
| | 176,26 | 23,96 | 7,36 | 30,19 | 7,94 | 0,74 |
| 1.407,06 | | Wp | | | | |

table 1: flash data of the eight modules above, Solara class S8xxTI/F (without Sunarc© coating)

| | Pmpp [Wp] | Ump p [V] | Impp [A] | Uoc [V] | Isc [A] | FF |
|--------------------|-----------|-----------|----------|---------|---------|------|
| Sunarc solar glass | 178,33 | 23,96 | 7,44 | 30,17 | 7,74 | 0,76 |
| | 176,11 | 24,09 | 7,31 | 30,11 | 7,70 | 0,76 |
| | 177,47 | 24,07 | 7,37 | 30,17 | 7,75 | 0,76 |
| | 171,64 | 23,91 | 7,18 | 30,08 | 7,73 | 0,74 |
| | 178,27 | 24,01 | 7,42 | 30,19 | 7,88 | 0,75 |
| | 176,93 | 24,00 | 7,37 | 30,23 | 7,81 | 0,75 |
| | 178,79 | 24,05 | 7,43 | 30,22 | 7,88 | 0,75 |
| | 179,06 | 24,16 | 7,41 | 30,24 | 7,77 | 0,76 |
| 1.416,61 | | Wp | | | | |

table 2: flash data of the lower eight modules, Solara class S8xxTI (with Sunarc© coating)

The output correction factor results from of the standardisation ratio, which is 0.9932. Only this correction factor makes it possible to compare the output of both module classes.

From the 17th of May 2006 until 25th of July 2006 the facility with the surface treated solar glasses was producing 2230.07 kWh. Valuated with the output correction factor and compared to the energy output of the second facility with 2132.8 kWh³ in the same period the output increase is 3.85%. The output of the module class with non-treated solar glasses provides the data basis. If we exclude the output correction and if we compare the yields directly with each other, the output of the modules with surface treated glass is 4.56%.

Due to the system the measurements are flawed. Consequently as an example the instantaneous power values are stressed by an offset, which is caused by a quantisation error of the analogue-to-digital converter in the data logger. In order to equalize this impact, only those data were considered that were achieved at a global irradiance higher than 40W/m².

² Mpp: maximum power point

³ measured at the DC side with data logger

The following diagram shows the developing of the comparative instantaneous power difference of both devices from the 15th of July 2006 until the 19th of July 2006. The measurements of both devices appear as data pairs that have been measured at the same time.

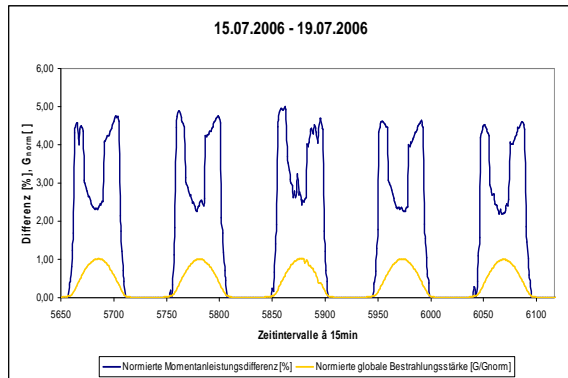


diagram 1 – comparative instantaneous power differences and the standardized global irradiance

Discussion: It was expected, that the lower module row with its Sunarc etched glass surface would supply more power in the same period than the one above. This could be approved. It is also obvious that in the early morning and in the late afternoon the comparative instantaneous power difference is growing.¹

The U-shaped developing of the curve confirms that modules with Sunarc glass produce up to more than 5 percent electricity than modules with untreated solar glass.

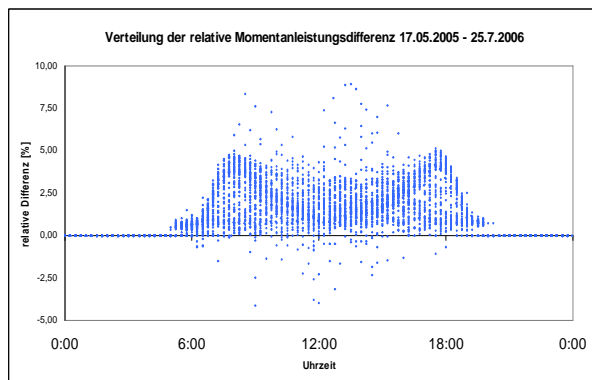


diagram 2 – data point distribution of the reactive instant power difference

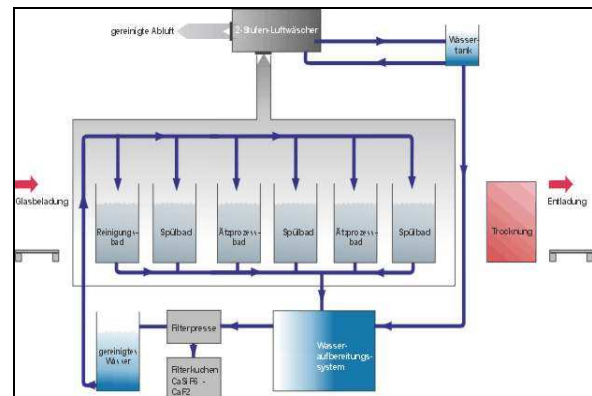
As this increased performance appears independently from the environmental temperature, oblique light becomes usable for the solar cells in all typical situations (wintertime, clouds, dusk and dawn).

III. Production of Sunarc® AR Glas5

On a ceiling transport system the glass passes fully automated cleaning, etching and rinsing stations. The resulting AR surface is a micro porous structure of approximately 100 nm thickness on both sides of the glass.

The whole production process does not pollute the environment and is not harmful to the employees' health. Waste is being disposed as non-toxic material.

For the production of Sunarc AR glass both untreated and also tempered glass can be utilized, because no special heat treatment is required.



picture 5: automatic production of Sunarc® AR glass (source: Sunarc technology A/S)

IV. Sunarc® AR glass under test conditions

Sunarc® AR Glass investigations, made in 2004 by the Technical University Denmark in Lyngby, yielded the following results:

- In case of diffuse irradiation the cell efficiency increases by approximately 1%. In relation to the cell efficiency reached with ordinary glass this is an increase of 7%.
- In case of direct irradiation the cell efficiency increases by approximately 0.4%, which corresponds to an increase of 3% - again in relation to the cell efficiency reached with ordinary glass this is an increase of 7%.
- The more angle of light incidence exceeds 60° (diverging from the perpendicular), the more noticeable becomes the advantage of Sunarc® AR glass.
- Based on DRY (Danish Design Reference Year) the calculations of the annual performance of PV modules (kWh/a) with weather data from Stockholm (Sweden), Copenhagen (Denmark), Davos (Switzerland) and Athens (Greece) show that for these places the average yield increase by utilizing an antireflection treated glass cover is 6,6%!



⁵ Source: Sunarc Technology A/S

The advantages of of Sunarc® AR glass⁶

- Enhanced light transmission even in case of high inclination angles
- Enhanced PV system performance with improved annual energy output
- Improved price-performance ratio
- Reduced light reflection
- A technically mature product
- Proven durability
- Dirt and water resistant thanks to nano-structure (lotus effect)

Already since 2002 SOLARA has made positive experience with the anti-reflex coated glasses, and the S-class Sunarc® modules show their high performance especially in the Northern European countries and especially in the wintertime.



V. Solar energy without ifs and buts

The SOLARA S-class is produced in order to meet highest demands and to withstand most extreme climate conditions: ice, hail, snow, storm, extreme humidity, strong variations in temperature. Even heat and cold cannot affect the SOLARA S-class. Reliably it utilizes the maximum of the available light.

Highest output

The SOLARA S-class consists of polycrystalline or monocrystalline high performance cells of renowned manufacturers. Reliably they convert sunlight into electricity, even under diffuse light conditions and during sunless months.

Energy and quality

Our quality demands are as high as yours. This is the reason why each SOLARA module is being tested and measured individually by us. Only if it has passed all testing criteria, the product gets an embedded serial number. This is how we prove to you our quality demands: five years SOLARA product warranty and 26 years SOLARA performance guarantee.

Quality:

- Produced at SOLARA Sonnenstromfabrik Wismar, Mecklenburg-Vorpommern
- With more than 10 years of production experience one of the most experienced photovoltaic manufacturers in Germany
- Manufacture at highest quality standards (DIN standards)
- Measuring and recording of each SOLARA module after the production process
- Unchangeable serial number related to the flash report
- ECB 1215, TÜV-UDE

- Output tolerance $\pm 3\%$

Easy mounting:

- SOLARA modules with its ruggedly designed aluminium extrusion profile.
- The hollow section of the frame enhances the stability and makes the mounting easier.
- Easy mounting on the front side thanks to clamp fastenings on a substructure
- Loading system with special connections and cable length of 900 mm
- Fast and variable combining of the modules
- Three bypass diodes with 10 A each

Among others the following tests were performed successfully:

- IEC 61215 and protection class II by TÜV Rheinland
- EC conformity declaration

Sources:

"Advantages by utilizing antireflection treated glass covers for PV modules" certificated by the Technical University of Denmark, Department of Civil Engineering, Sonnenstromfabrik Wismar GmbH, SOLARA AG Hamburg

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