



Two reports on clarifying the mechanical load by a PV cleaning system were made by Steinbeis-Transferzentrum Distributed Renewable Energy Systems in cooperation with the company Sunbrush

## **Test 1:**

### **Measuring Task:**

Test of PV modules to power losses and wear due to possible mechanical abrasion and scratches. The mechanical loading is produced by a PV-cleaning unit from Sunbrush GmbH. The brush cleaning system has cleaned the glass surface of the PV modules 4338 times without liquid additive. This simulates a load for about 20 years (manufacturer information Fa. Sunbrush GmbH)

To analyze the power values before and after the cleaning process the modules are examined by means of a flasher at different radiations. In addition the glass surface of the PV modules is visually examined with a microscope at defined measurement points according to the different purification steps.

### **Measuring devices:**

- flasher: Sun Simulator 3c, Serialnumber: PAA0325
- microscope
- PV-cleaning unit sunbrush
- Power Meter Christ CLM1000-Professional+

### **Measurements performed:**

#### **Measurement 1: state of delivery**

- Optical surface analysis, microscope at 16x and 25x magnification
- Performance measurement of PV-modules at an irradiation of 1000 W/m<sup>2</sup>, 700 W/m<sup>2</sup>, 400 W/m<sup>2</sup>, 200 W/m<sup>2</sup>.

#### **Measurement 2: wet cleaning**

- 50 cleaning cycles with wet surface
- Optical surface analysis, microscope at 16x and 25x magnification

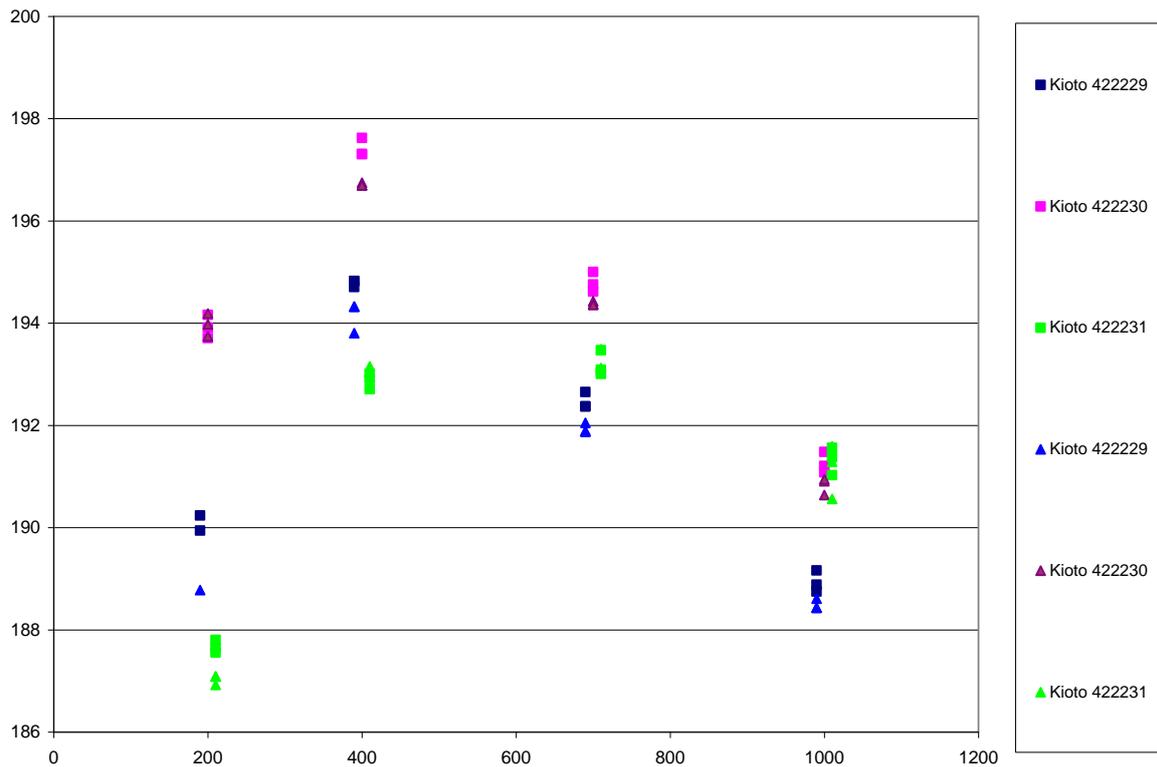
#### **Measurement 3: dry cleaning, 20-years simulation**

- More than 3000 cleaning cycles with dry surface
- Optical surface analysis, microscope at 16x and 25x magnification
- Performance measurement of PV-modules at an irradiation of 1000 W/m<sup>2</sup>, 700 W/m<sup>2</sup>, 400 W/m<sup>2</sup>, 200 W/m<sup>2</sup>.



## Results

The solar power measurements of brand new modules compared with the measurements after more than 4000 cleaning cycles indicates no reduction in performance. Hence the cleaning brush caused no disturbance of the test modules within the 20 years simulation. It should be noted that the runs were carried out in the dry state corresponding to a higher mechanical load on the modules than in normal operation.



The square mark shows the three modules before the test run. The triangle mark shows the power measurements after to the test run. Three power measurements were carried out at each irradiation and each module. The difference between the measurements before and after the test run was +0.1 to -0.3%.

The absolute accuracy of power measurement is +/- 3%. The accuracy of the repeat measurement is 0.25-0.5% of the measured value.

The results of performance measurements were confirmed by the optical surface analysis of the modules.



## Conclusion

Cleaning with distilled water (measurement 2) reduced the dust and pollution deposition on the glass surface of the PV modules. The simulation of the 20-year dry-cleaning (measurement 3) shows no significant accumulation of scratches in the glass surface of the PV modules and no decrease in the electrical characteristics.



## Test 2:

### Measuring Task

Test of PV modules to power losses and wear due to possible mechanical abrasion and scratches. The mechanical loading is performed by a PV-cleaning unit from the company SunBrush GmbH. The brush cleaning system has cleaned the glass surface of the PV modules 1002 times under dry conditions with an addition of a defined amount of quartz sand per cleaning cycle.

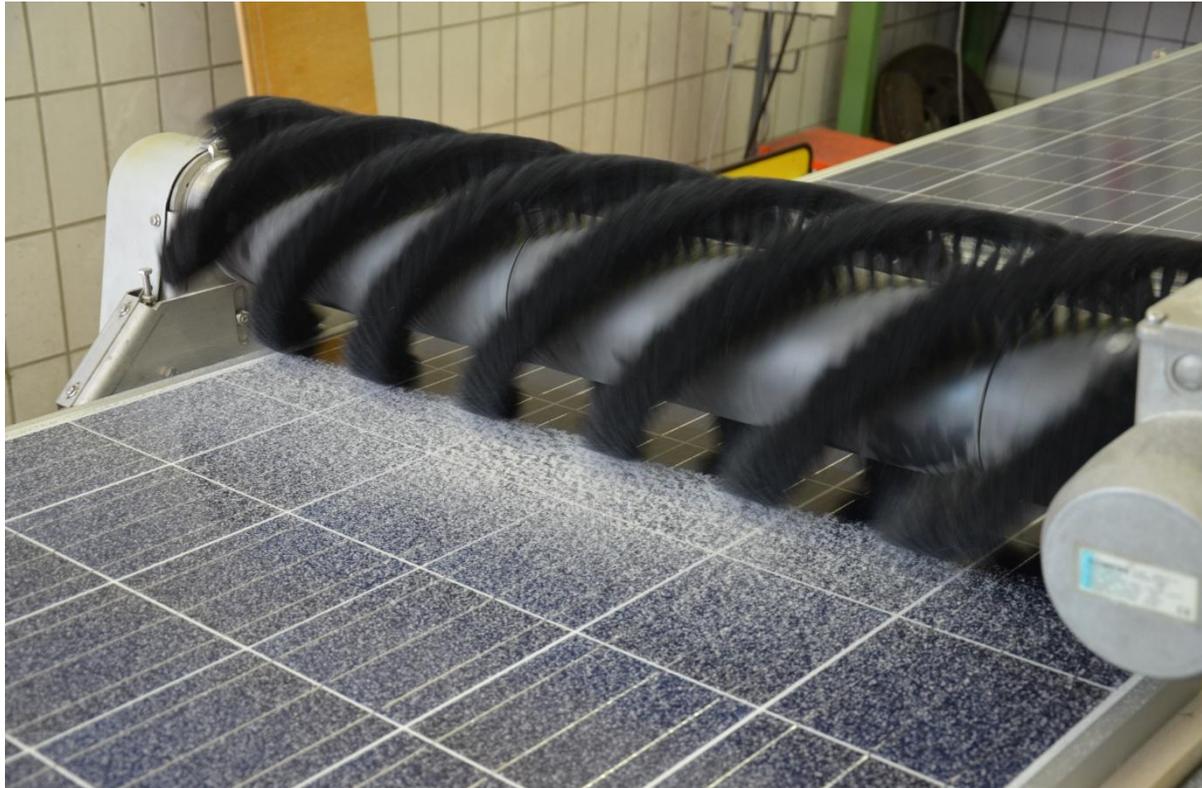


Figure 1: Dry cleaning process with the SunBrush-cleaning unit.

The following measurements were carried out before and after the cleaning process to analyze the impact on the solar modules:

- Performance measurements by determining the U / I characteristic curve with a flasher at different irradiation
- electroluminescence measurement with the EL camera
- Optical surface analysis of the glass surface of the PV modules with a microscope at defined measurement points



## Measuring devices

- Solar modules Kioto Solar serial nr. : 422229, 422230, 422231(AR coated)
- flasher: Sun Simulator 3c, Serialnumber: PAA0325
- EL-Kamera, Cool Samba HR-830
- microscope, Auflicht-Digital-Zoom-Mikroskop Di-Li 2001
- solar cleaning unit SunBrush
- quartz sand

## Measurements performed

### Measurement 1: initial state

- Optical surface analysis, microscope at 20x and 40x magnification
- Performance measurement of PV-modules at an irradiation of 1000 W/m<sup>2</sup>, 700 W/m<sup>2</sup>, 400 W/m<sup>2</sup>, 200 W/m<sup>2</sup>.
- electroluminescence measurement

### Measurement 2: dry cleaning, quartz sand

- More than 1000 cleaning cycles with dry surface with an addition of ca.140g of quartz sand per cleaning cycle
- Optical surface analysis, microscope at 20x and 40x magnification
- Performance measurement of PV-modules at an irradiation of 1000 W/m<sup>2</sup>, 700 W/m<sup>2</sup>, 400 W/m<sup>2</sup>, 200 W/m<sup>2</sup>.
- electroluminescence measurement
- determination of energy consumption

## Results

The comparison of solar power measurements of various modules with the measurements after 1002 dry cleaning passages shows no reduction in performance compared to initial state. Also there were no changes detected using the electroluminescence measurement.

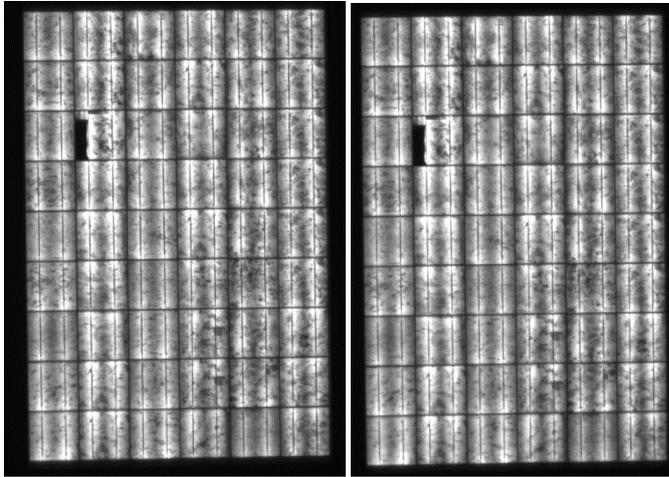


Figure 2: Picture of Kioto Solar Seriennr. : 422229 before (left) and after (right) the test uptake by the EL camera

The optical surface analysis of the modules detected visible streaks after the cleaning cycles, which could completely be removed with organic cleaning water.

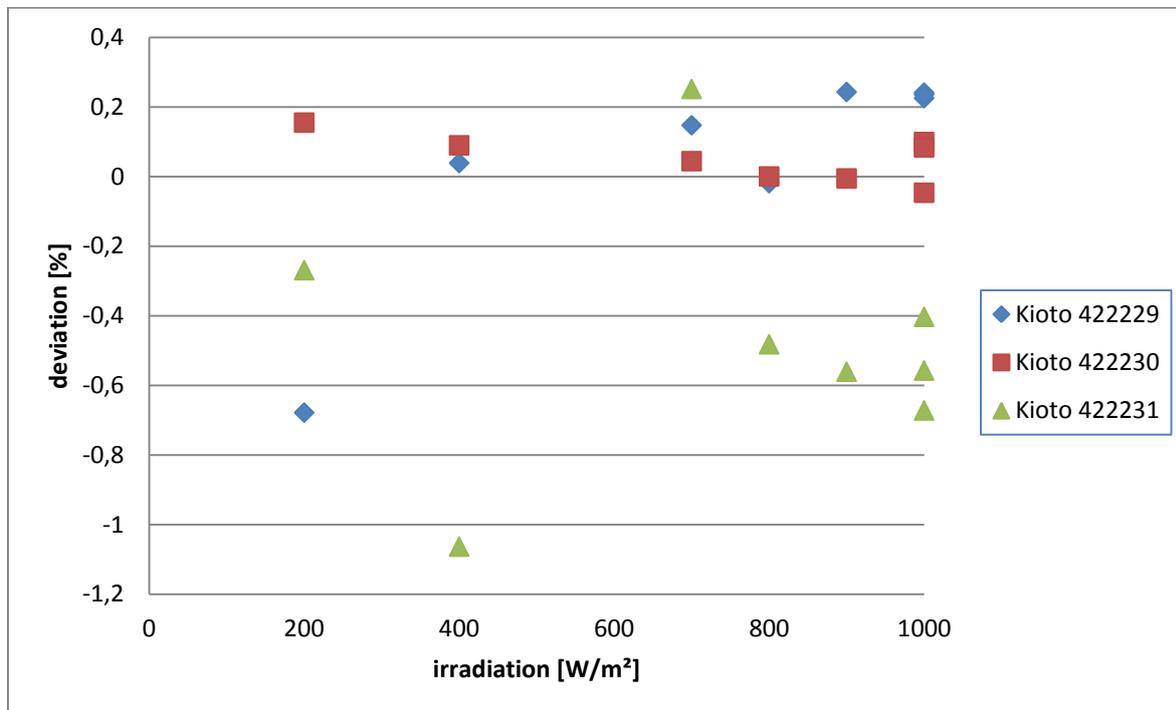


Figure 3: The results of the performance measurements of the three test modules before and after 1002 passes at different irradiances. Two modules show a performance increase of about 0.1%. The third show a performance decrease of about -0.5%.

The graphic presents the deviations in percentage before and after 1002 dry cleaning runs on the solar modules. The deviations of the measurements of the three solar modules at the six different



irradiations were at +0.25 to -1.1%. The absolute accuracy of power measurement is +/- 3%. A temperature change of 1 ° already causes a change in power output of 0.5%! The performance measurements were carried out at the solar modules immediately after the cleaning cycles prior to removal of streaks.

It can be seen that no reduction in performance of the PV modules can be measured after the 1002 dry cleaning cycles with the SunBrush cleaning system with the addition of quartz sand. Also the electroluminescence analysis and control of solar modules with a microscope shows no changes to the solar modules.

The Kyoto modules examined in the cleaning process were already used in the first test without quartz sand in 2010 with 4338 cleaning cycles with the cleaning brush from SunBrush GmbH.