
INVESTIGATION OF MECHANICAL LOADING OF PV MODULES BY CLEANING ROBOT 1

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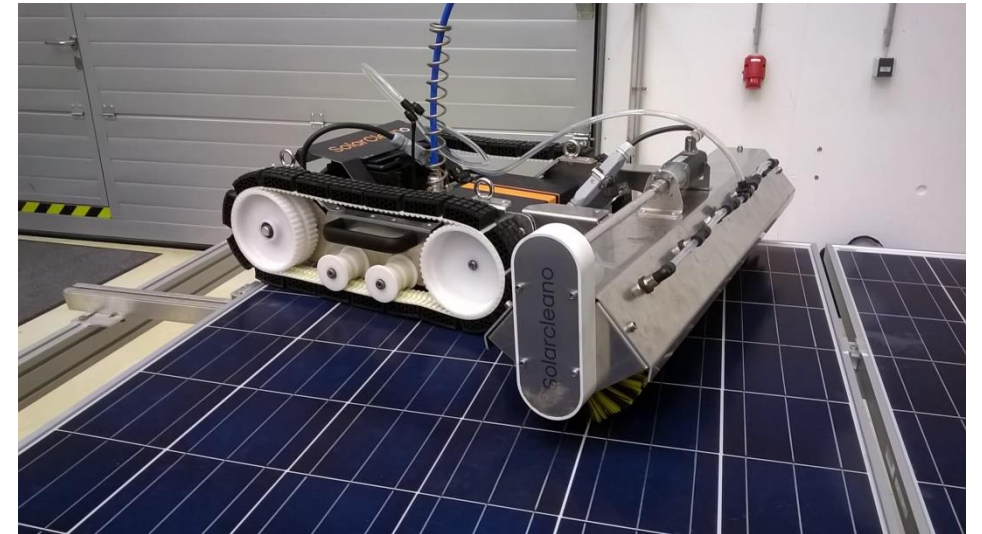
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Aim of investigation

- ➔ Evaluation and quantification of mechanical loading of PV modules during drive with Solarcleano robot 1



Cleaning robot 1 from Solarcleano

Result of investigation

- With Solarcleano robot 1 several cleaning drives were done over PV modules (mounted according manufacturer specs / data sheet).
- Before and after measurements of the STC power as well as electroluminescence images showed that the robot drives did not cause any cell cracks or corresponding power losses.
- The measured maximum deflection of the modules over all drives was 11.7 mm. This corresponds to a surface load on the entire module of about 1,100 Pa (compared to a wind load of 2,400 Pa; LAURA final report, funding code 0325716B).

Specimen

- Following PV modules (SOLUXTEC Multi Series FR60 250Wp) were used for this investigation:

Sample number	Serial number	Initial STC power [W]
CSP_AMEMey_1_P01	D9220916375090	262,5
CSP_AMEMey_1_P02	D9220916375088	262,7

Module characterization

Power measurement

- Equipment: Berger class AAA Module flasher
- Parameter:
 - STC (standard test conditions):
(25±1)°C, irradiation 1000 W/m²,
spectrum AM1.5
 - Measurement uncertainty ±2,5% without
reference module
 - Repetitive accuracy <0,3%
(95% confidence)
 - **Note:** modules were measured as delivered



Module characterization

Elektroluminescence

■ Equipment:

- Greateyes LumiSolarProfessional
- Stripwise image acquisition and stitching to obtain a complete image of the complete solar module

■ Parameters:

- Current injection: 8,5 A
- Exposure time: 5 s
- Aperture: 2.8



Specifications	
resolution	up to 8 Mpx/32 Mpx
Data depth	16bit = 65536 gray scales
Substrate	mono-Si, poly-Si, a-Si, micro-Si, CIS, CIGS, CdTe Cells, Strings or Modules
Size	max. 1.1 x 2.0 m
Sensor	cooled Back-illuminated CCD Model: GE 2048 512 BI MID Pixel size: 13.5µm x 13,5µm Max. Dynamic Range: 33333:1
Exposure times	0.3 sec - 60 sec

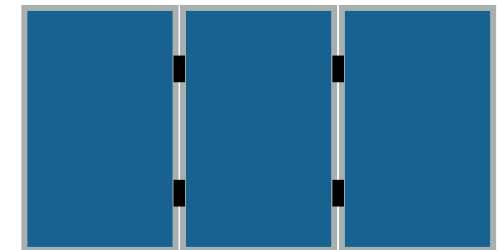
Setup & procedure

■ setup:

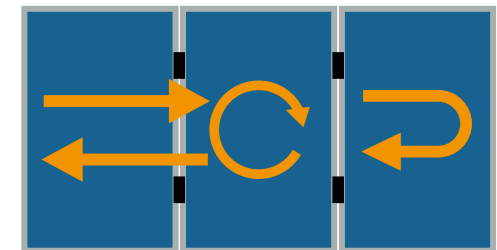
- Test setup with 3 horizontally placed/mounted PV modules
- Middle module as test module
- Edge modules as start and turn platform

■ procedure:

- Cleaning drive starting on start module (left)
- Passing over the test module
 - Straight line to illustrate the cleaning drive
 - Turning to illustrate cornering
- Turning on turning module



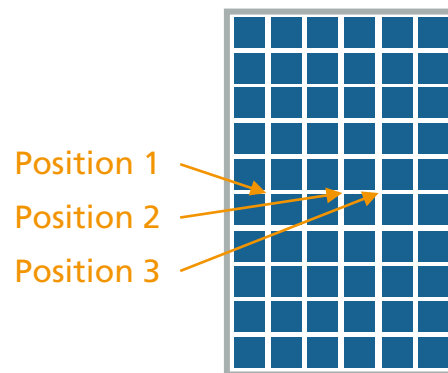
Test setup with 3 modules
(left: start module,
center: test module,
right: turning module)



Procedure of test drive (scheme)

Evaluation

- Evaluation:
 - Elektroluminescence (EL) images and STC power measurement of test module after test drive
 - Comparison of EL images before and after test drive to evaluate mechanical loading
 - Possible cell cracks as quantification criteria
 - Maximum deflection measurement at three positions



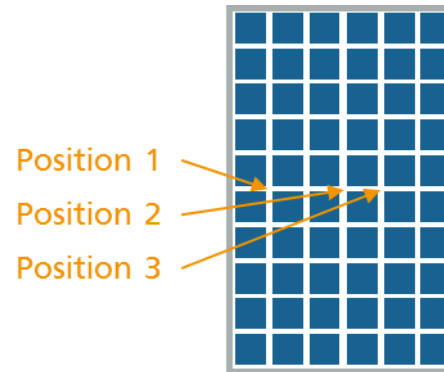
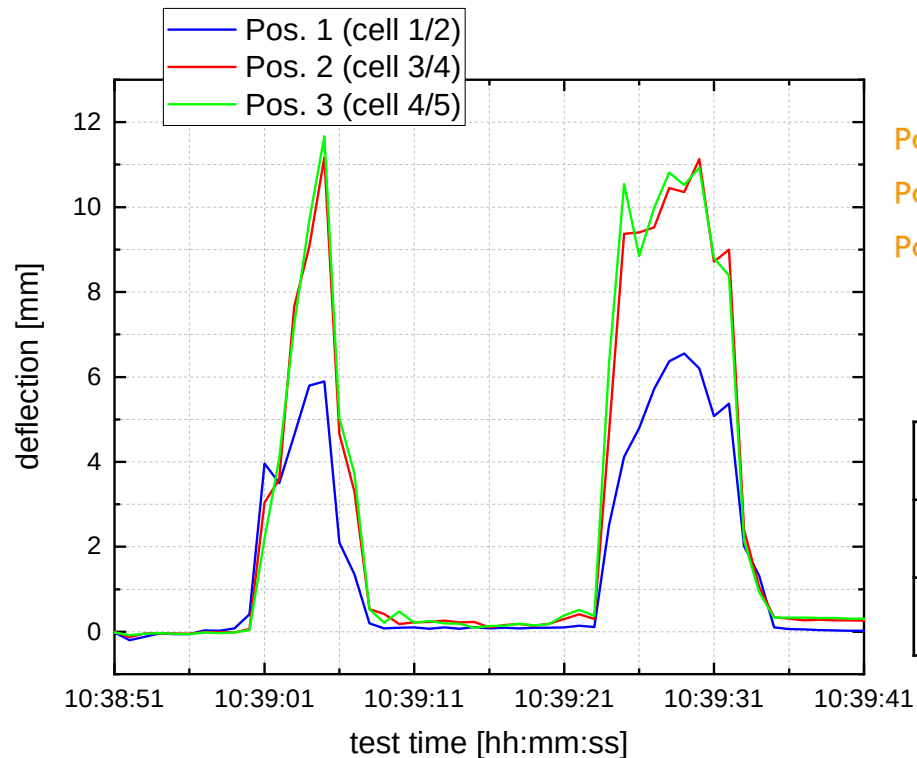
Positions of deflection measurement (left) and setup of mounting construction (without modules) displacement sensors (right)



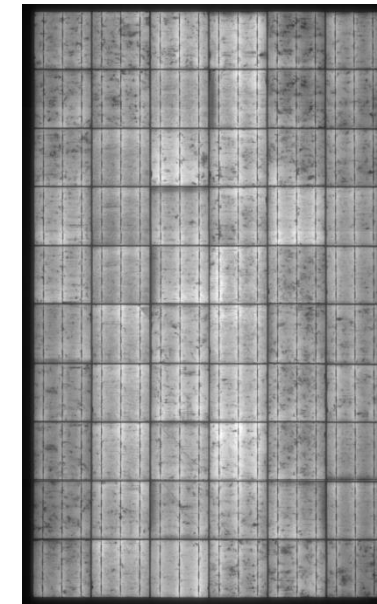
Test drive 01

■ Specimen: CSP_AMEMey_1_P02

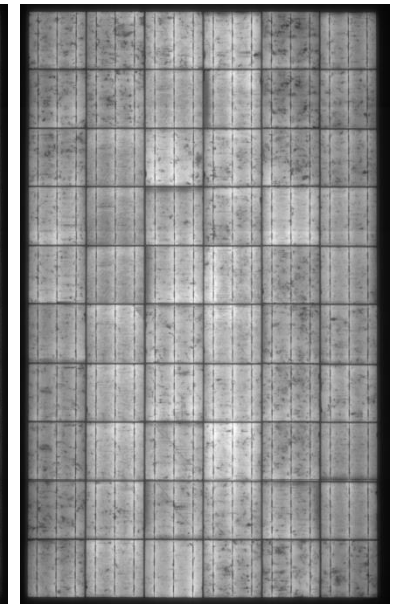
- ➔ No additional cell cracks, no significant power losses
- ➔ Max. deflection = 11.7 mm



STC power before test drive	262,7 W
STC power after test drive	261,6 W
Change of STC power	-0,4%



EL image before
test drive



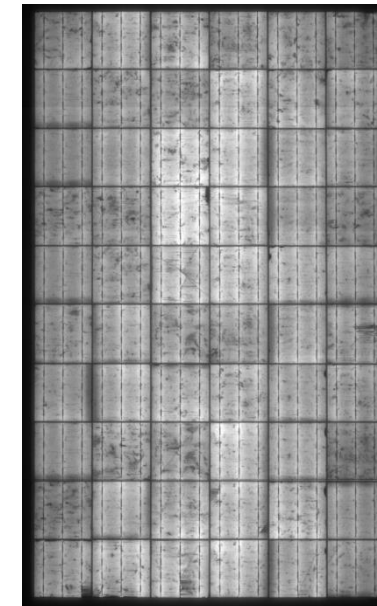
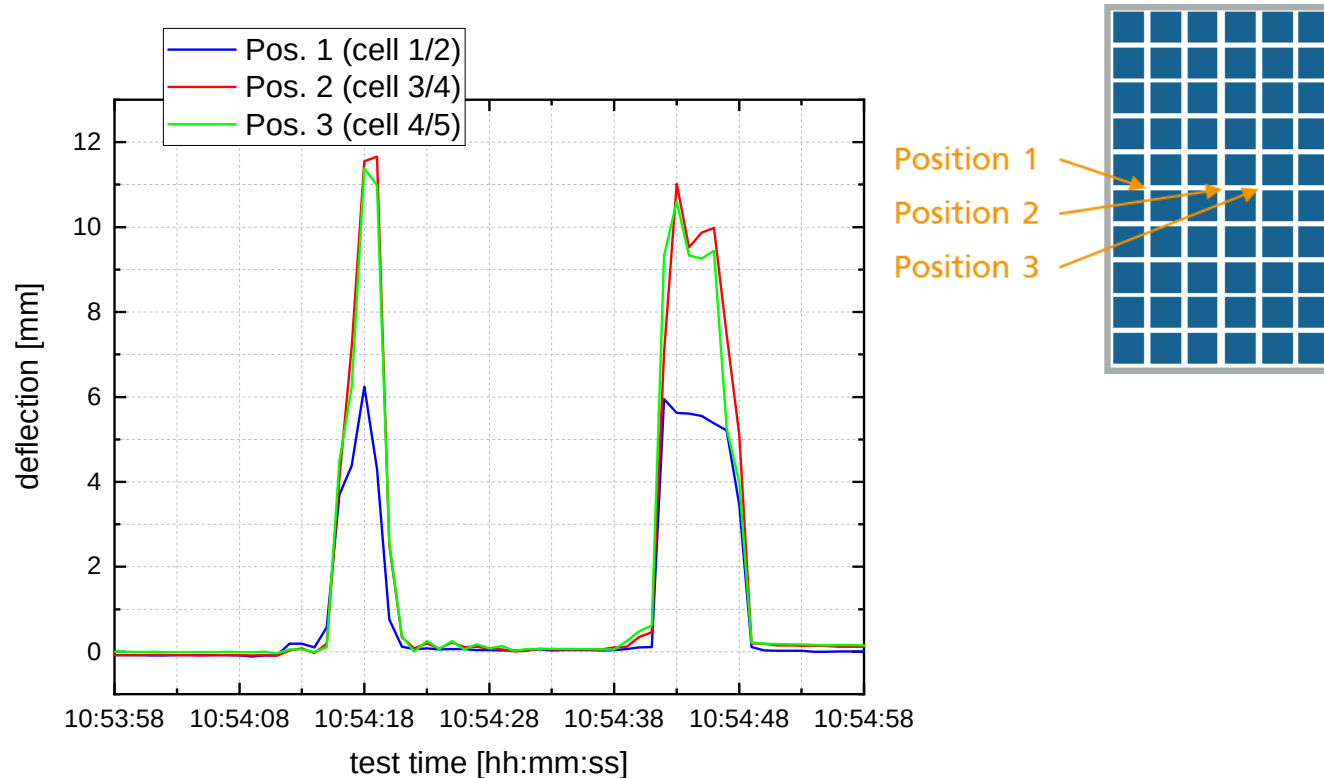
EL image after
test drive

Test drive 02

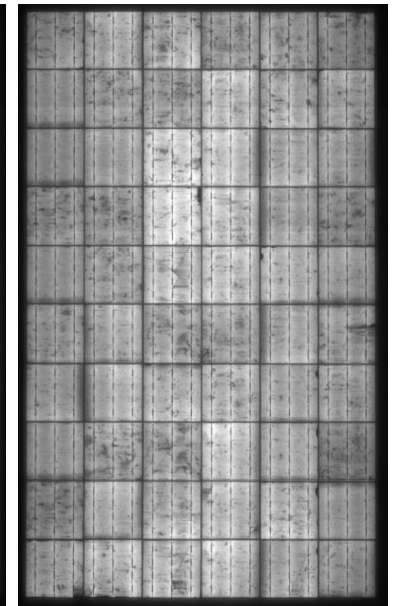
■ Specimen: CSP_AMEMey_1_P01

➔ No additional cell cracks, STC measurement omitted

➔ Max. deflection = 11.7 mm



EL image before
test drive



EL image after
test drive

Evaluation of test drives

- Test drives 01 und 02 done over PV modules (mounted according manufacturer specs / data sheet).
- Both test drives without additional cell cracks
- Both test drives without significant power losses of individual measurements
- maximum deflection of the modules over all drives of 11.7 mm
(corresponds to a surface load on the entire module of about 1,100 Pa, compared to a wind load of 2,400 Pa; LAURA final report, funding code 0325716B)