Fraunhofer ISE

FRAUNHOFER-INSTITUTE FOR SOLAR ENERGY SYSTEMS, ISE

FINAL REPORT FUE 24266

Investigation of possible damage to solar modules by cleaning machine from Cleantecs GmbH

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Fraunhofer Institute for Solar Energy Systems
in Freiburg

FUE24266

Cleantecs GmbH
Grundweg 10
89250 Senden

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Ingrid Haedrich

Digital unterschrieben von Ingrid Haedrich
Datum: 2024.09.09 14:13:47 +02'00'

Dr Ingrid Hädrich
Group leader
Degradation analysis
and modelling

Thomas Kaltenbach

Digital unterschrieben von Thomas Kaltenbach
Datum: 2024.09.09 13:53:57 +02'00'

Thomas Kaltenbach
Research Associate Group
Degradation Analysis
and modelling

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1 Summary

In this project, PV modules are to be characterised before and after cleaning. The aim is to investigate whether and to what extent the cleaning systems from Cleantecs change the surface of the solar glass and whether this has an influence on the electrical output or the electrical safety of the solar modules.

2 modules were each cleaned in 50 cycles, which corresponds to a field service life of 25 years if cleaned twice a year. A lichen remover and the Solatecs W system from Cleantecs were u s e d for cleaning.

Result:
The cleaning of the modules

- did not lead to any change in module performance
- did not lead to any change in the insulation properties
- did not lead to any cell cracks
- did not cause any visible damage to the module edge

Microscope images have revealed *isolated* scratches in the anti-reflective coating of the glass in the area of cleaning with the Solatec W system. These are not visible to the naked eye and have *no* effect on the performance of the module. No glass damage could be detected in the areas of the lichen remover, even under the microscope.

2 *Project description*

2.1 Background and goals

In this project, PV modules are to be characterised before and after cleaning. The aim is to investigate whether and to what extent the cleaning systems from Cleantecs change the surface of the solar glass and whether this has an influence on the electrical output of the solar modules.

2.2 Test bench setup and test examination

This project investigated whether the cleaning of solar modules with the systems provided by Cleantecs (lichen remover and SOLA-TECS W) results in detectable damage to the modules. For this purpose, 2 solar modules (Heckert and JA Solar) were mounted at a 10° angle on a test stand at the Fraunhofer ISE in Freiburg.

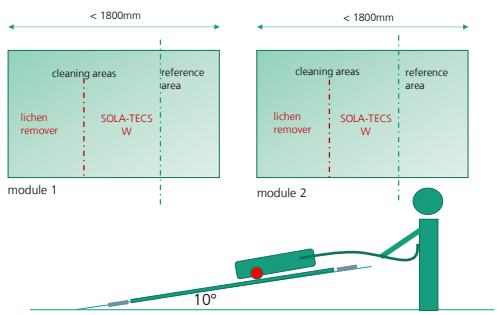


Figure 01 Left. Principle sketch of the division of the cleaning areas and the substructure Right: Heckert Solar and JA Solar module, each with masked cleaning areas

Figure 02 SOLA-TECS W

Figure 03 Lichen remover

The modules were each cleaned in 50 cycles, which corresponds to a field service life of 25 years if cleaned twice a year.

The modules were characterised before and after cleaning:

- *Power measurements (current-voltage characteristic)*
- *Electroluminescence images*
- *Wet and dry insulation testing and leakage current testing*
- *Light microscopic examination of the glass surface of the modules in order to visualise any changes to the surface*

3 *Results*

3.1 *Power measurement*

Heckert							
	Isc (A)	**Voc (V)**	**Impp (A)**	**Vmpp (V)**	**Pmpp (W)**	**FF**	**eta (%)**
M01 initial	17,66	27,63	16,84	23,04	**388,12**	79,54	19,93
M01 after cleaning	17,66	27,6	16,86	23,02	**387,99**	79,61	19,92
delta	0	-0,03	0,02	-0,02	**-0,13**	0,07	-0,01
delta rel.	*0,0%*	*-0,1%*	*0,1%*	*-0,1%*	***0,0%***	*0,1%*	*-0,1%*
JA Solar							
M03 initial	13,04	37,45	12,4	31,4	**389,36**	79,72	19,94
M03 after cleaning	13,06	37,36	12,41	31,28	**388,16**	79,53	19,88
delta	0,02	-0,09	0,01	-0,12	**-1,2**	-0,19	-0,06
delta rel.	*0,2%*	*-0,2%*	*0,1%*	*-0,4%*	***-0,3%***	*-0,2%*	*-0,3%*

Figure 04 *Power measurement on the Heckert and JA Solar modules, initial and after cleaning*

No significant performance degradation before and after cleaning can be detected.

3.2 *Electroluminescence images*

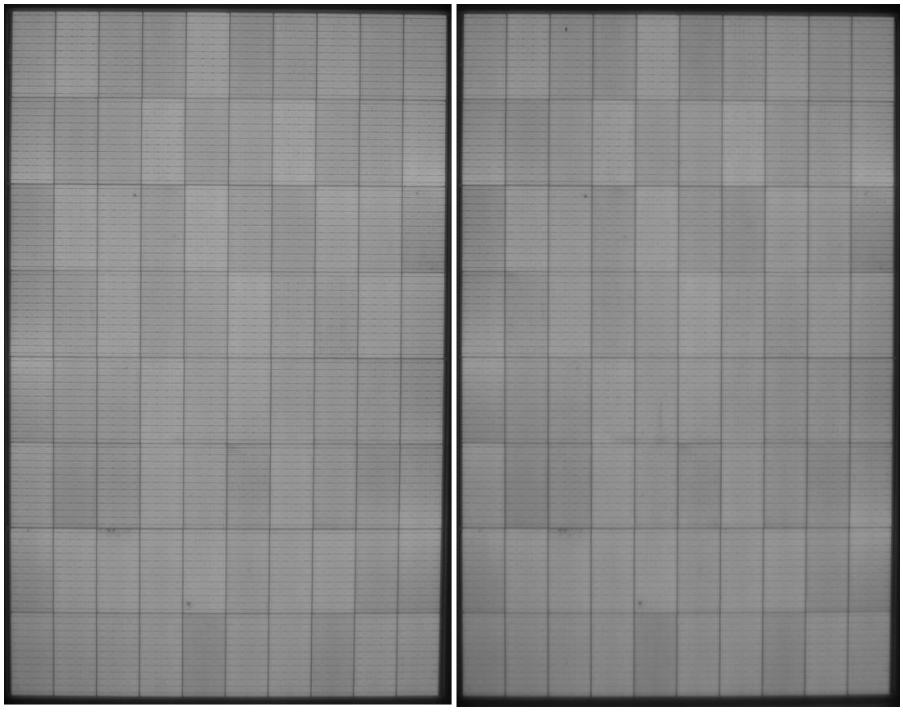


Figure 05 *Electroluminescenceimages M01 Heckert, initial (left) and after cleaning (right)*

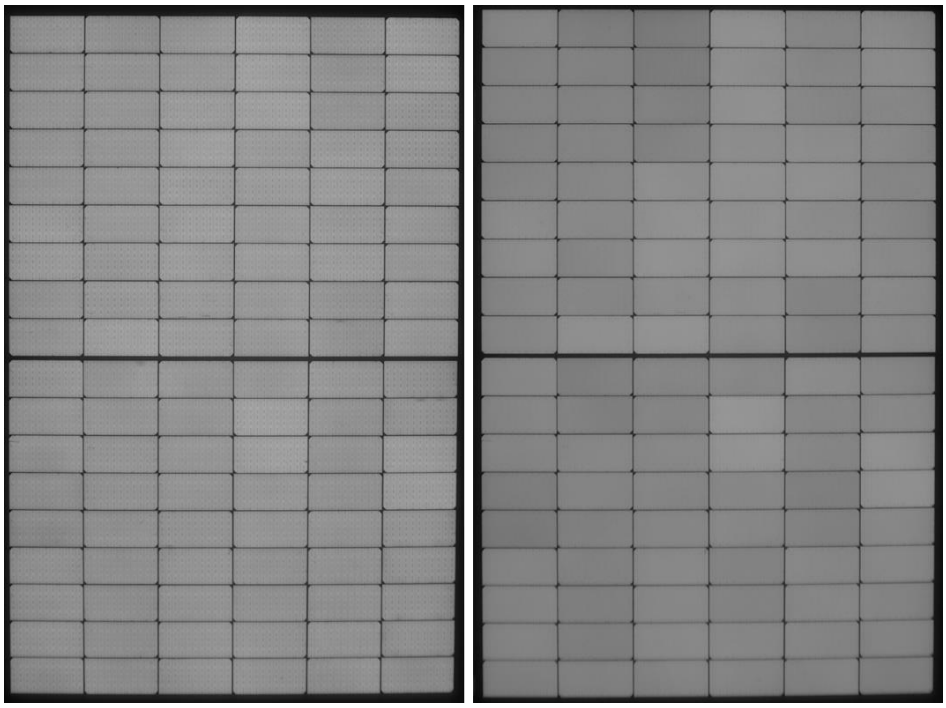


Figure 06 *Electroluminescence images M03 JA-Solar, initial (left) and after cleaning (right)*

No cell breakage can be detected before or after cleaning.

3.3 *Electrical safety*

The electrical safety in dry and damp conditions was determined.

	M01	M02	M03	M04
insulation resistance test dry/wet	✓/✓	✓/✓	✓/✓	✓/✓
Leakage current test dry/wet	✓/✓	✓/✓	✓/✓	✓/✓
After Cleaning:				
insulation resistance test dry/wet	✓/✓	-	✓/✓	-
Leakage current test dry/wet	✓/✓	-	✓/✓	-

Figure 07 *Insulation resistance test and leakage current test on the Heckert and JA Solar modules, initial and after cleaning*

No changes in the insulation and leakage current behaviour before and after cleaning can be determined.

3.4 *Light microscopic examination*

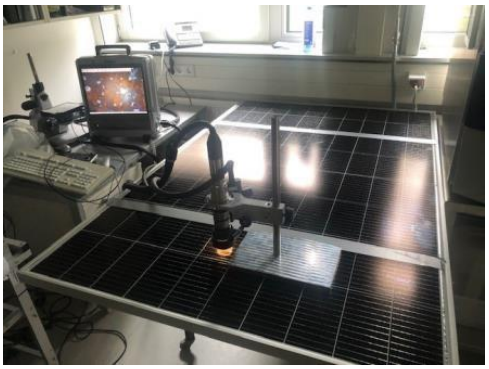
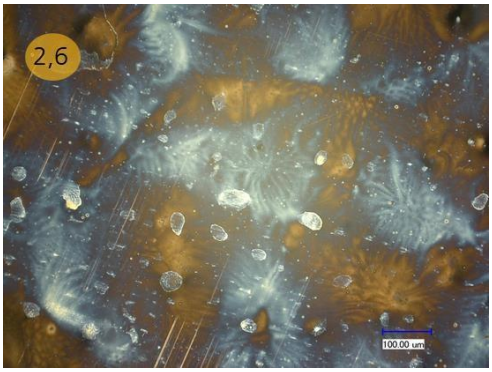
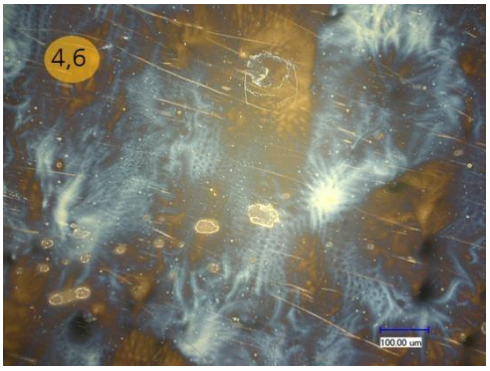


Figure08 *Top left: Module M01(Fa.Heckert) during imaging with the light microscope attachment Top right: Module M01 with the analysed measuring positions Bottom left: Allocation of the surfaces to the cleaning systems used or Reference area*

The cleaning level of the cleaning is from right to left. A magnification of 100x was selected, X100.





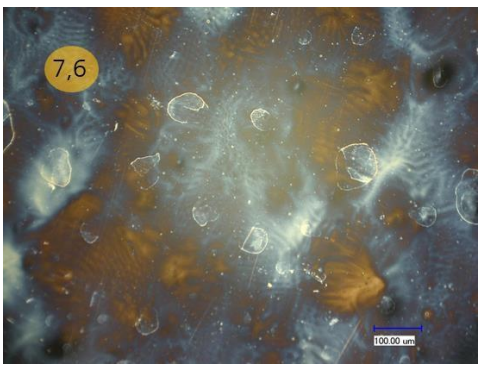


Figure 09 *Light microscope images, X100, at M01 Heckert, in the 3 analysed areas*

Isolated scratches were found in the reference region (i.e. the non-cleaned area). These may have been caused by transport or handling. There are

Scattered scratches are still visible in the area cleaned with Soltacs W. No damage is recognisable in the area treated with the lichen remover.

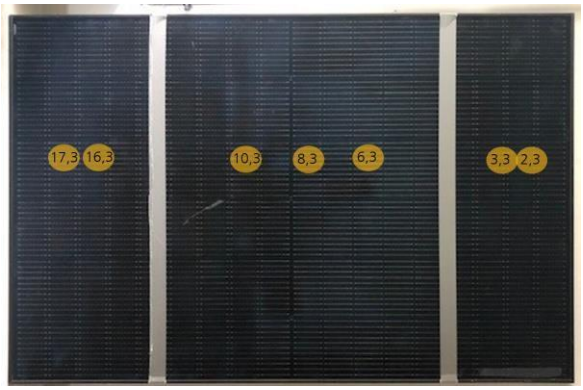
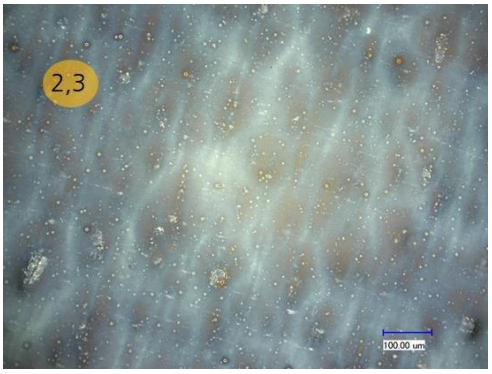
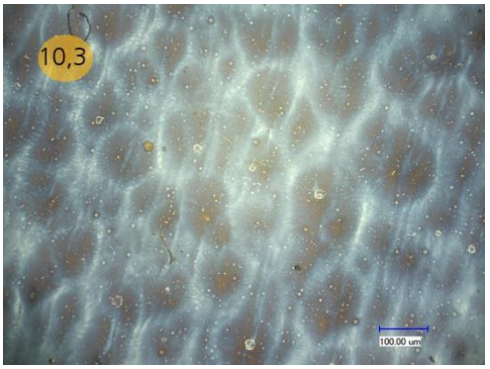


Figure 10 *Module M03 (JA Solar) with the analysed measuring positions*





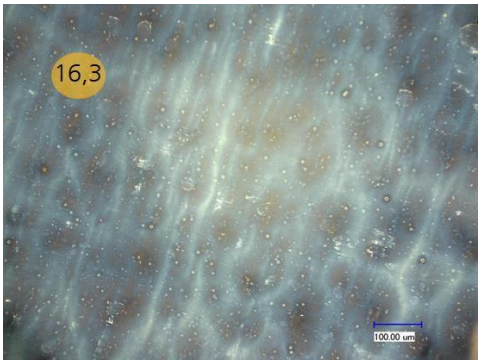


Figure 11 *Light microscope images, X100, on M03 JA-Solar, in the 3 areas analysed*

No abnormalities are visible before and after cleaning.

3.5 *Lower module edge, photo documentation*

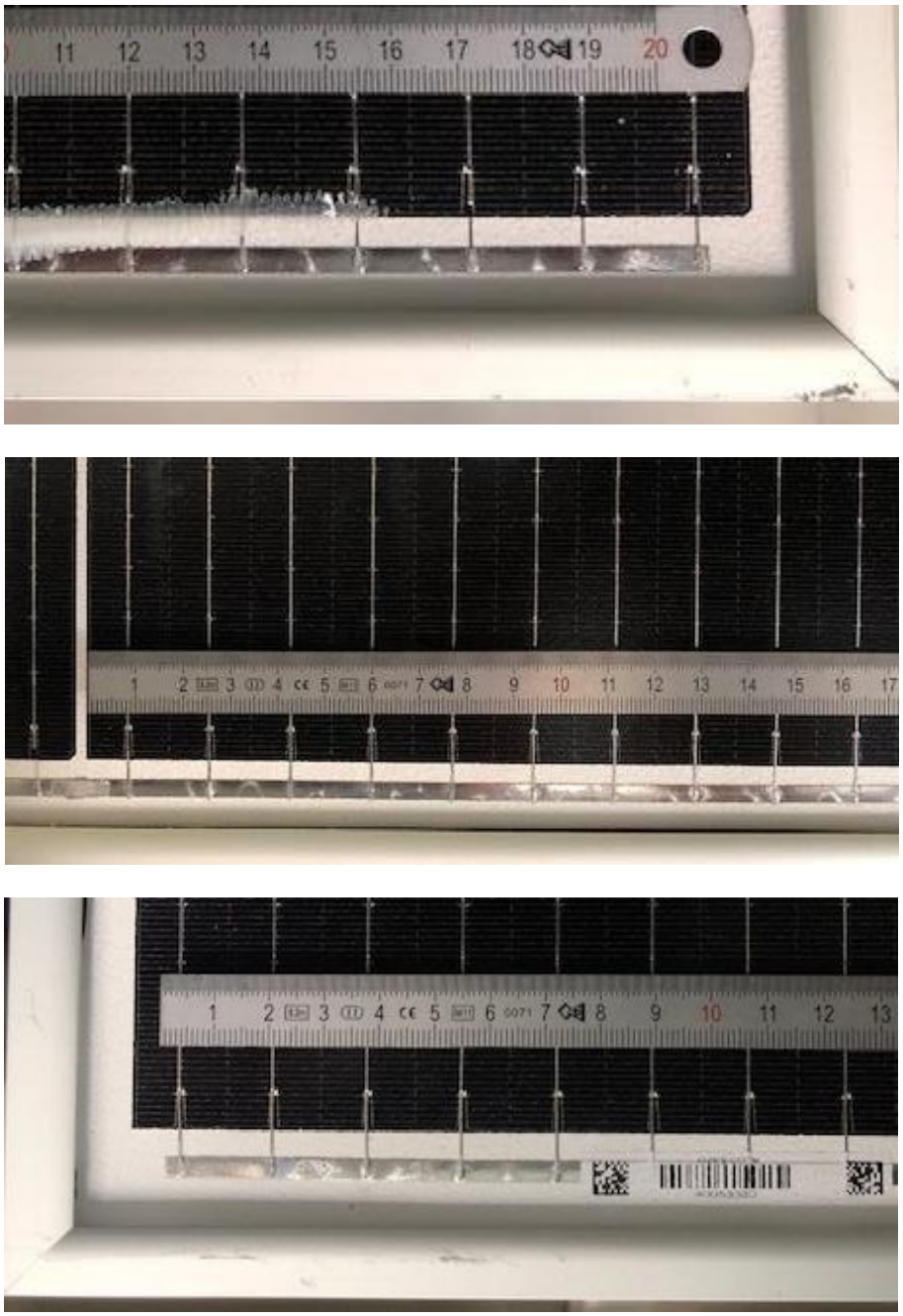


Figure 12 *Photographs at M01 Heckert, initial (top), after brush cleaning (centre) and after lichen cleaning (bottom)*

There is no visible damage to the lower edge of the module as a result of cleaning.

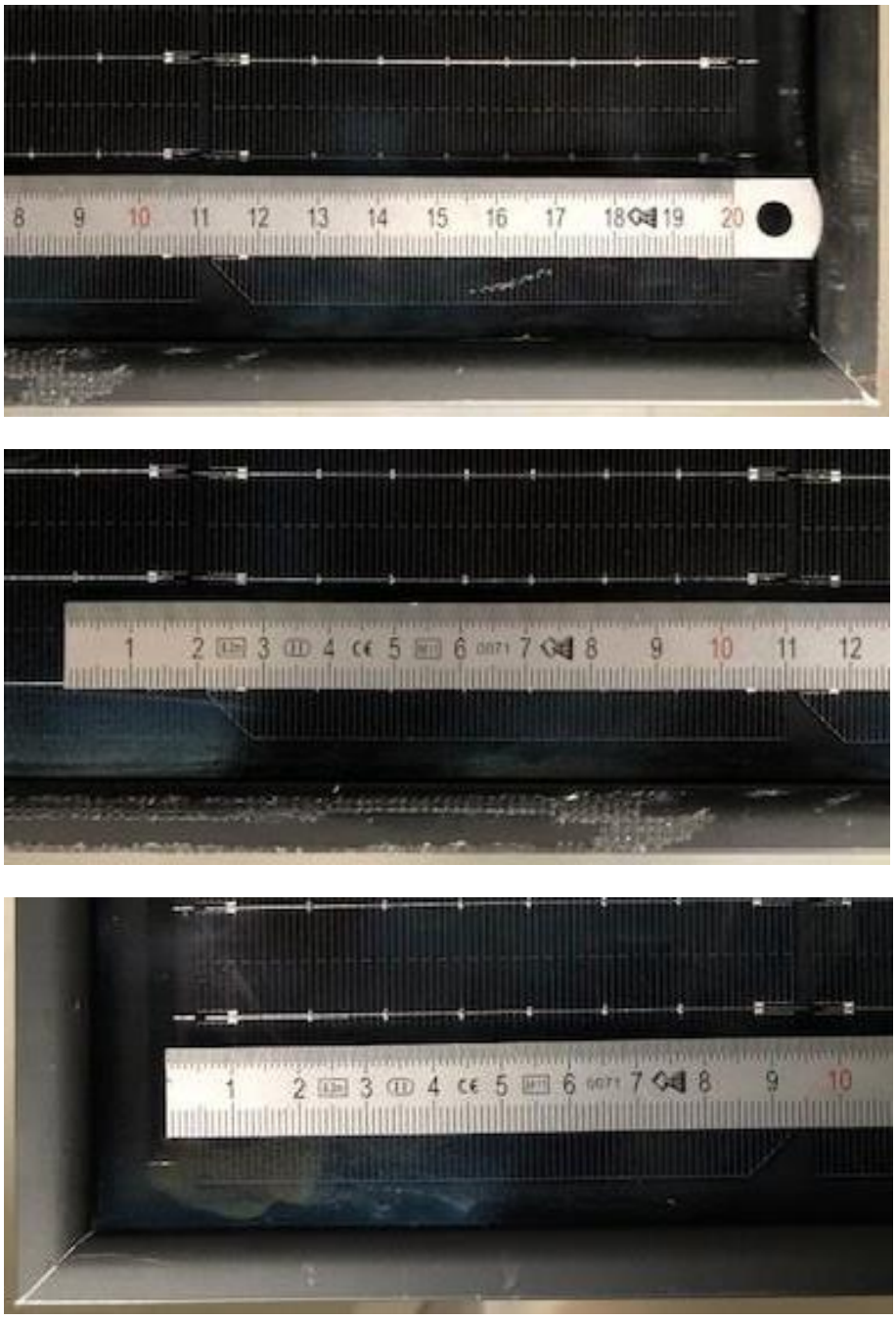


Figure 13 *Photographs of the M03 JA-Solar, initial (top), after brush cleaning (centre) and after lichen cleaning (bottom)*

There is no visible damage to the lower edge of the module as a result of cleaning.

Appendix

Characterisation measurements

Characterisation measurements are carried out before, after and between load tests. These measurements make it possible to assess the resistance of the modules to the load tests carried out.

Visual inspection in accordance to IEC 61215-2:2021, MQT 01

The visual inspection is used to detect visible damage within a PV module. Each visual inspection is documented with a photo of the front and rear. If necessary, detailed images of damage or changes are taken. All images can be made available to the customer in electronic form.

During the visual inspection, the PV module is subjected to a careful visual inspection for the following conditions at an illuminance of at least 1000 lux:

- *Broken, cracked or torn outer surfaces*
- *Bubbles or detachments that form a continuous path between part of the circuit and the edge of the module*
- *A crack in a cell whose propagation could disconnect more than 10% of the cell area from the module's circuit*
- *Loss of mechanical integrity to such an extent that installation and/or operation of the module would be impaired.*

Power at STC according to IEC 60904 (-1 and -3)

During the power measurement, power differences to the power according to the type plate and before and after the load tests can be determined. The performance of the modules is determined under standardised conditions (STC - Standard Test Conditions) in a flash simulator:

Irradiance:	*1000 W/m²*
Module temperature:	*25 °C*
Spectrum of the simulator:	*AM 1.5 global*
class (according to IEC60904-9):	*AAA*

Leakage current test / insulation resistance test under wet conditions in accordance with IEC 61215-2:2021, MQT 15

*A leakage current test is used to determine whether the module is sufficiently well electrically insulated between the live components and the frame or other accessible parts of the module, even when wet. To do this, the module is immersed in a water bath and the maximum permissible system voltage is applied between the cells and the water bath. After a certain holding time, the insulation resistance of the module is measured. The product of the measured insulation resistance and the module area must not be less than 40 MΩ*m².*
*Minimum resistance requirement: 40 MΩ*m² / 2.70 m² = 14.81 MΩ*

Electroluminescence measurement

In electroluminescence testing, the module is operated in reverse current. As a result, it emits radiation that is invisible to the human eye.

The number of emitted charge carriers is proportional to the cell current. Damaged or poorly contacted areas of a cell appear as dark areas on an electroluminescence image.

An electroluminescence measurement can be used to visualise cell fractures or defective rear contacts as well as defective current collection fingers (grids). Low-performance cells in an array can also be detected.