DIN/IEC/EN/ISO 17025:2005 accredited test laboratory for all relevant IEC standards and own developed test methods; accredited as CBTL for IEC/EN/ISO 61215, 61646, 61730 and all related standards as well as for CEC regulations and UL1703

Test-Report

Evaluation of GEVA-BOT cleaning device: Accelerated testing for Yingli modules installed in the Halutziot solar power plant

PI-Report-Number: 201602410Ra_V1_Yingli_GEVA-BOT

2017-01-27

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Proposal number:	20164330
Order number:	201602410
Order date:	2016-12-12
Delivery date:	GEVA-BOT: 2016-12-15 Test-modules: stored in the laboratory
Test start:	2017-01-03
Test end:	2017-01-23
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The test results in this report relate just to the test objects. This report is only valid with signature. The sampling was done by PI-Berlin selected out of an amount of 40 modules stored at the warehouse of PI-Berlin from a previous order with the designated module type.

1 Executive Summary

In this work an accelerated cleaning was performed in order to test the impact of the GEVA-bot device on YINGLI modules as installed in the Halutziot power plant in Israel. No major influence of the cleaning device could be recognized on the power output of the test specimen and mechanically on the cells. A change of the antireflective coating of the glass surface could be recognized, especially for one of the both. However, no major negative impact on the modules due to the application of the GEVA-bot is expected.

2 Introduction & motivation

This test project investigates the impact of the GEVA-BOT cleaning device on Yingli solar modules as installed in the 55 MW Halutziot Solar power plant in the Negev desert in Israel. The focus lies on the influence of the cleaning device on the module performance (power output at standard test conditions (STC)) and the mechanical impact on the cells (µ-crack development).
A special focus of this project is the investigation of the potential impact on the modules ARC (Antireflective Coating) which is correlated to the module reflectance.
For this purpose, an accelerated stress test which simulates 20 years of GEVA-BOT operation is performed at PI-Berlins outdoor test stand. The chosen test set up simulates the original mounting situation of the modules in the Halutziot plant. During the cleaning, the modules are regularly exposed to sand for the simulation of sand storms.

3 Methodology

3.1 Operating principle GEVA-BOT

The GEVA-BOT is powered by a battery and moves directly on the top and bottom module frame driven by a V-belt like drive system. Leadership roles, made out of rubber and not powered, are also installed on both sides of the robot but horizontal in the plane of the modules to keep the robot on track. For the cleaning operation the brush rotates over the module surface while the robot is moving and injecting water from one perforated metal rod.

Figure 1: GEVA-bot in operation in a solar field[1] (upper left); V-belt like drive system with leadership roles (bottom left); Water injection from a perforated metal rod (right)

3.2 Test Set up

The aim of the test set up at PI-Berlin was to create as best as possible the same conditions the modules are exposed in the Halutziot plant during the cleaning process.

[1] Picture taken from the GEVA-bot hompage: http://www.geva-bot.com/home (25.01.2017)

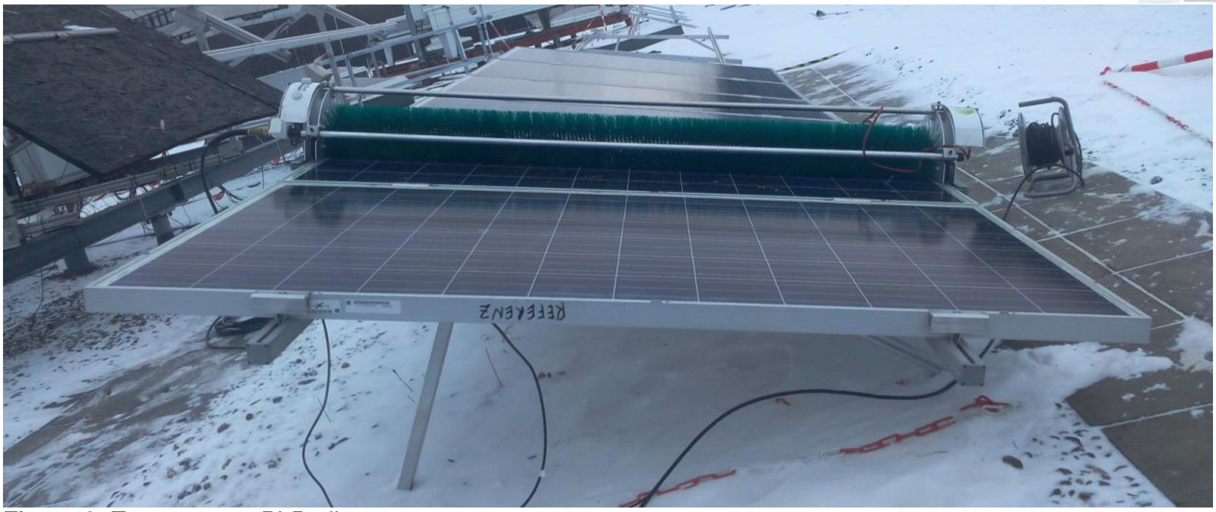

Figure 2: Test set up at PI-Berlin

First, the existing module mounting system was adapted in order to reach a low angle of inclination (about 17° as desired by GEVA bot) and contact points of the modules on the mounting system as they are in the Halutziot plant (see Figure 2 and Figure 3).

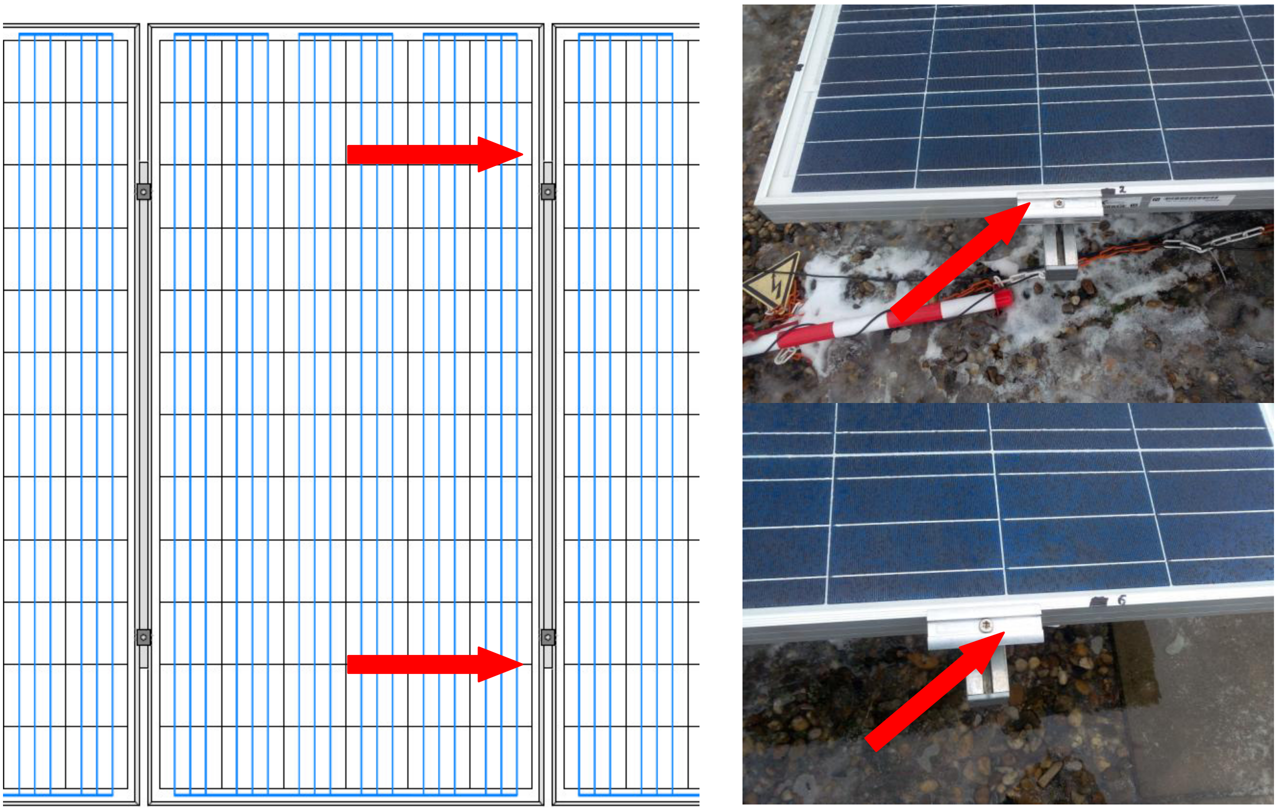

Figure 3: Extract of technical drawing module mounting Halutziot PV plant [2] (left); Top and bottom contact points of the test specimen at the mounting system at PI-Berlin (top and bottom right)

In operation, the robot is powered by a 1.14 kg heavy lithium battery integrated in the bottom side. Due to transport issues this battery was removed and the robot was powered at the testing by a rectifier. To replace the missing weight, metal nuts were put into the robot where usually the battery is installed (see Figure 4).

[2] Extract taken from “As-Built Revision” technical drawing named “String Posing Details” of the HALUTZIOT plant (drawn: 2014-08-21; checked: 2014-10-28), Project number: BV204, Drawing number: E504

Figure 4: The battery substitute made out of metal nuts

The robot is built for each module size individually. This robot was built by GEVA-BOT G.S.I. Ltd. in order to clean Yingli modules of the type YL305-35b with the size of 1970x990x50 mm. All presets (for example: distance of the fiber tips of the brush to the glass surface, position of the driving belt, etc.) of the robot were done by the customer before it was sent to PI Berlin.

3.3 Test Settings

The modules were installed on the adapted mounting system (as described in 3.2). As shown in Figure 5, the reference module (not cleaned in the test) was installed at the end of the rack (green frame) and stoppers were fixed on the bottom and top side of the module in front to the reference to stop the robot.

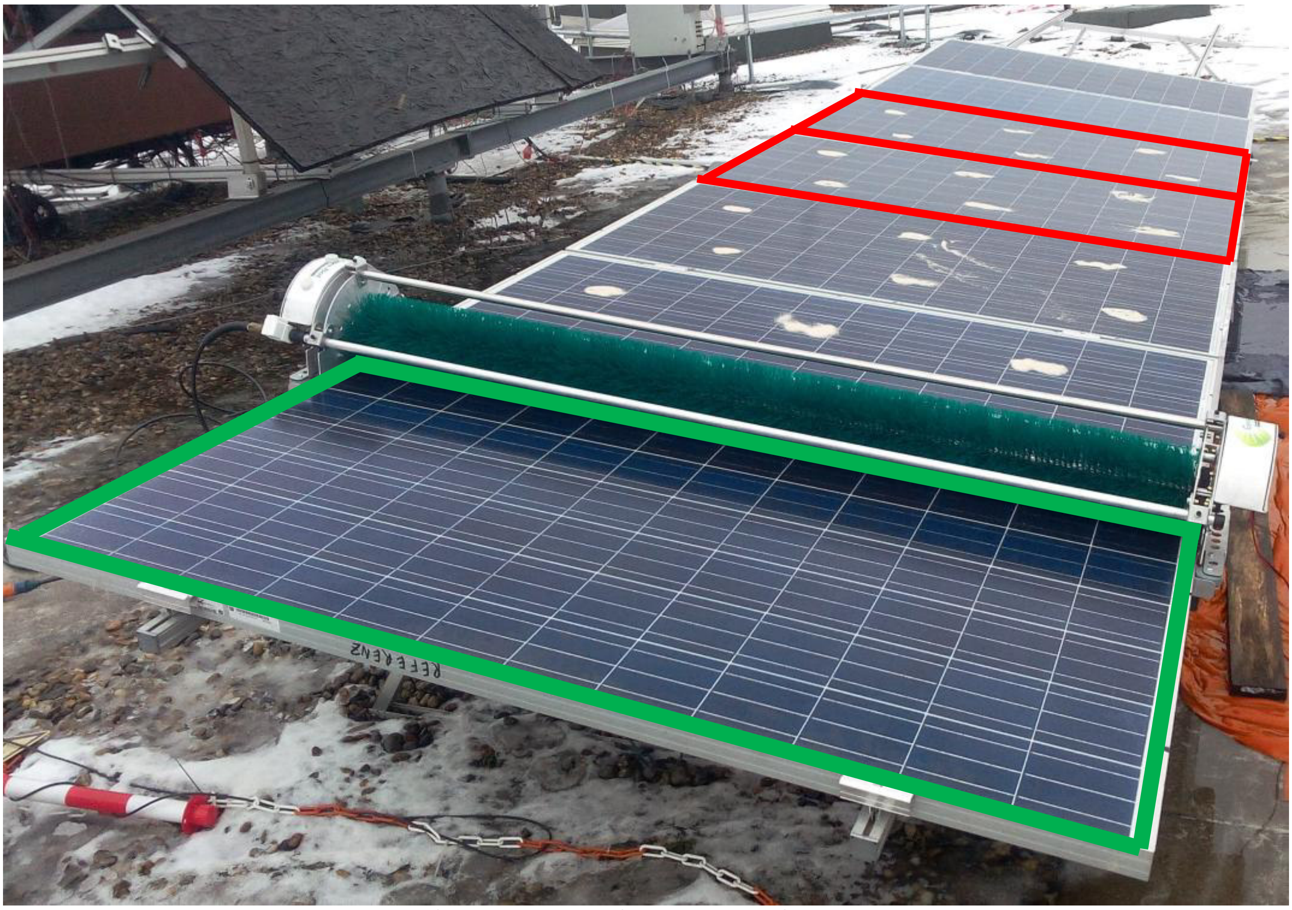

Figure 5: Test set up; test modules (red frame) and the reference (green frame) are highlighted

The test specimens were exposed all together to 400 cleaning cycles (1 cycle consists of back and forth movement over the test specimen) in order to simulate 20 cleaning cycles and 5 sand storms per year over a period of 20 years. After every 4th cycle 28 g of sand was distributed over a half module cell on 6 distinct positions where the reflection measurements were conducted. As requested by the customer, distilled water was used for the robot.
The two test modules, as well as the reference, have been characterized initially and after the accelerated testing in the laboratory (see next section).

3.4 Test Procedure

The following procedure has been applied for testing the impact on the modules of the accelerating cleaning. During the cleaning, sand was spread on the modules after every 4 cycles.
Two modules were tested by accelerated cleaning and one module was considered as reference and not exposed to cleaning. Initially and after finishing the 400 cleaning cycles, the modules were tested by visual inspection, performance measurements at STC (standard test conditions), electroluminescence and reflection measurements.

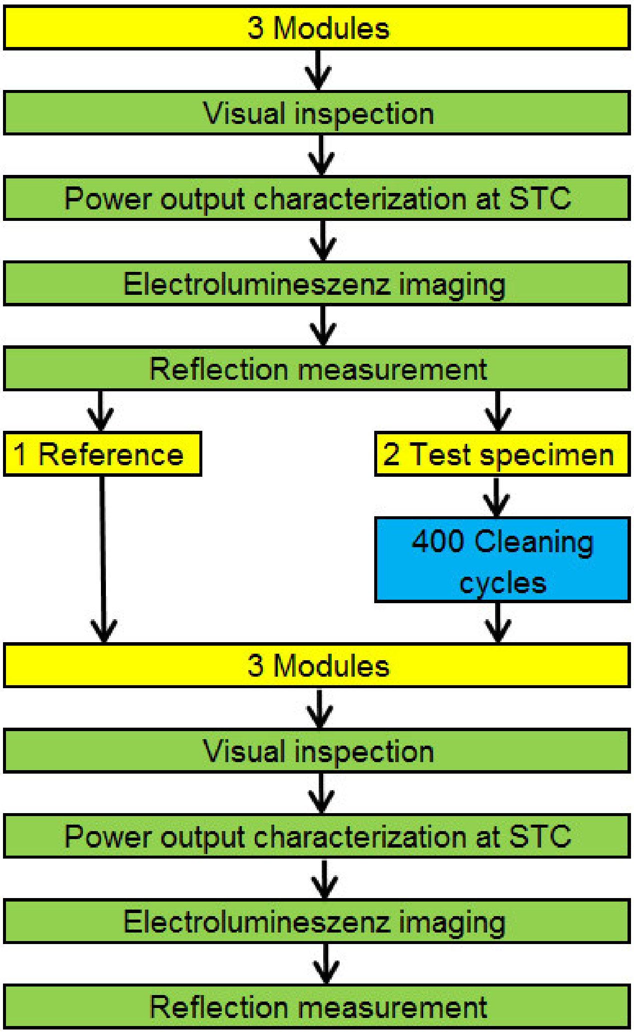

Figure 6: Test procedure

3.5 Module Characterization

Detailed information about the test descriptions “Visual Inspection”, “I-V Curve Determination at STC” and “Electroluminescence Analysis” can be found in section 2 of the laboratory report 201602410La_V1_Yingli_Solar.

3.6 Reflectance Measurements

This test is not under the scope of the accreditation of PI-Berlin.
The reflection measurements were performed with an Avantes spectrometer type AvaSpec-USB2 and the sensor AvaSphere-50-LS_HAL.
The sensor is a combination of an integrating sphere and a halogen light source. The sphere provides diffused halogen light on the sample and has a direct collimated SMA-port for collection of the reflection signal.
The 5 W halogen lamp is stabilized and cooled with forced airflow. The sphere has an internal diameter of 50 mm and the sample port a diameter of 7 mm.
The reflection measurements are performed in the wavelength range from 340 to 1100 nm. The integration time for each scan is of 3 ms and the resulting reflection curve for each point is given by an average of 300 scans.
Before each reflection measurement, a reference measurement was done on a white reference foil.
On each module the initial and final reflection were measured at the 6 positions indicated in Figure 7.
For each position, the measured deviation of the reflection after the stress test with respect to the initial measurement is calculated.
The average of the deviations over the 6 positions and over the wavelength range 400-1000 nm is given as final result for each module. The uncertainty on the final calculated reflection deviation is of ±3%.

The PI Berlin internal pass criteria is a reflection deviation smaller than 10%.

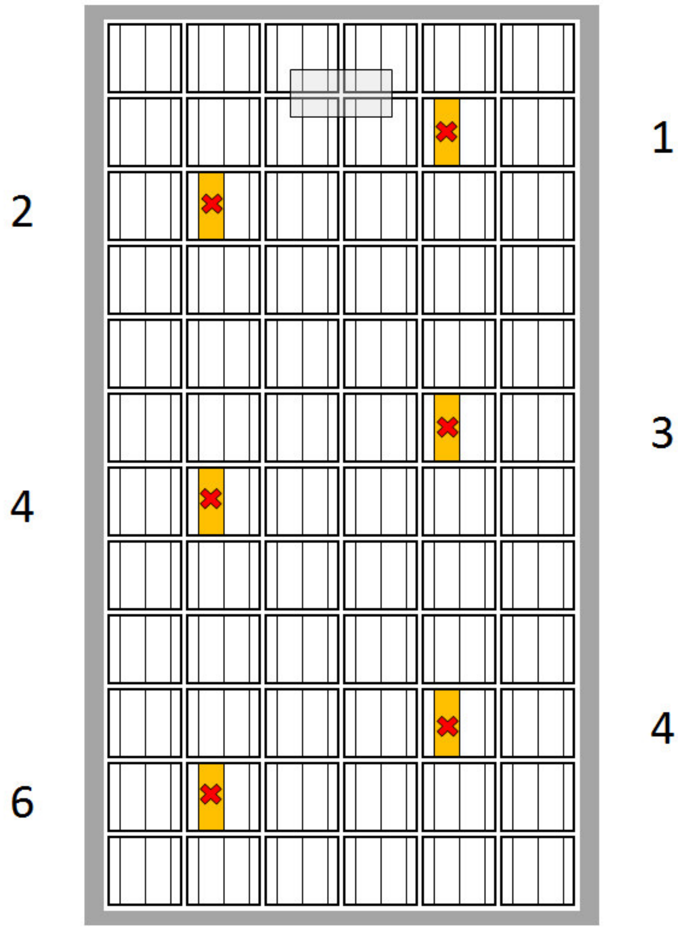

Figure 7: 6 positions on the module where the reflection measurements are performed

4 General Information about the Test Objects

Serial number	Producer	Type	Cell material	Number of cells	Module area [m²]
140403040304887 (Reference)	Yingli	YL305-35b	multi-c-Si	72	1.95
140403040301691	Yingli	YL305-35b	multi-c-Si	72	1.95
140403040303174	Yingli	YL305-35b	multi-c-Si	72	1.95

For further information about the test objects please refer to the laboratory report 201602410La_V1_Yingli_Solar.

5 Test Results

In this section, only the immediate relevant results will be presented. The detailed listing of the measurement results can be found in the laboratory report and it will be referred to the specific passage in that report when necessary.

5.1 YINGLI SN - 140403040304887 – Reference

Visual Inspection

No visual changes could be observed on the reference module at the measurements before and after the accelerated cleaning test (201602410La_V1_Yingli_Solar section 3.3.3).

Performance at STC

In the following diagram (Figure 8), the before and after comparison of the power output of the reference module is shown.

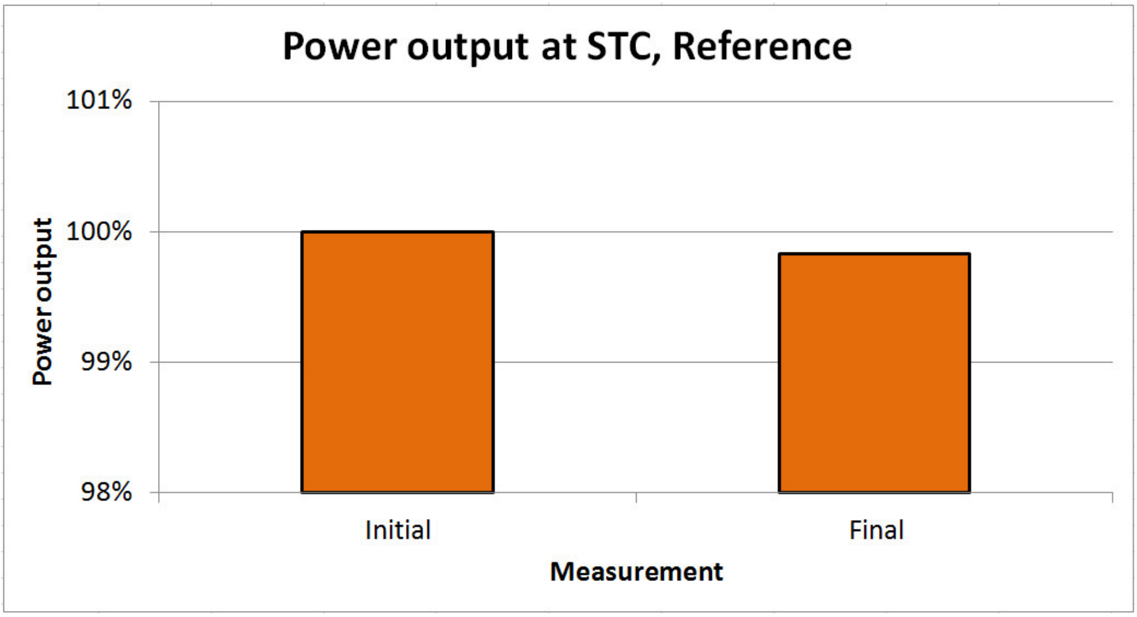

Figure 8: Comparison power output initial with final measurement

The comparison shows that the power output deviation is -0.17% to the initial measurement which is within the repeatability error of the flasher (0.33%). Therefore, no measurable change in power output could be proven.

Electroluminescence Analysis

The results have shown an occurence of one micro crack. Due to the fact that this module was used as the reference and not involved in the cleaning process, the micro crack can be attributed to the module handling (201602410La_V1_Yingli_Solar section 3.5.3).

Reflectance Measurements

In the following diagram (Figure 9) the reflection deviations with respect to the initial measurement, averaged over the six measured position, are shown.

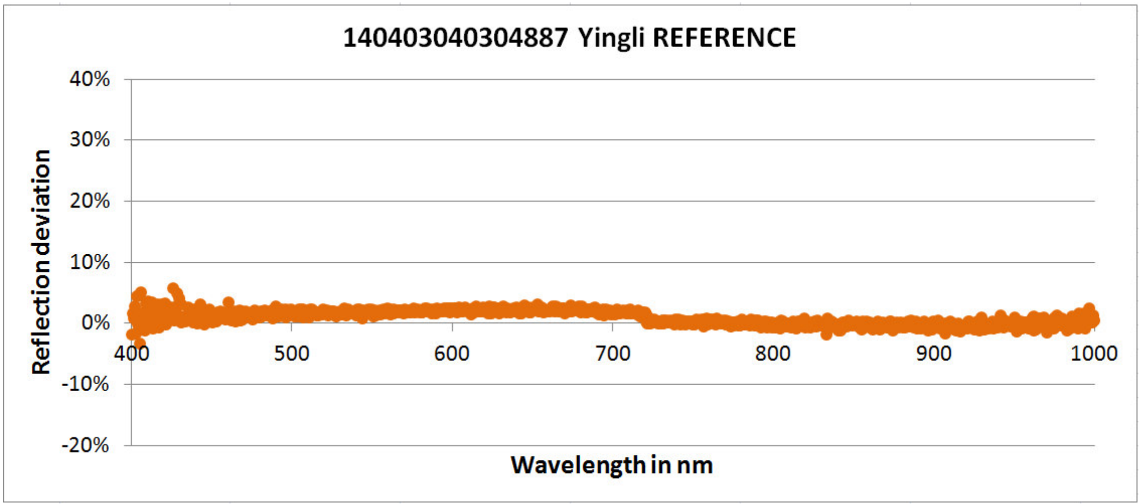

Figure 9: Results of the reflection measurement

All data points are located in the vicinity of the x-axis (the step at 720 nm is attributed to the use of two sensors and its imperfect merge). Furthermore, the average increase of reflection (over the whole range of wavelength and measured positions) is about 1% which is smaller than the measurement uncertainty of 3%. Therefore no change in reflection could be measured.

5.2 YINGLI SN - 140403040301691

Visual Inspection

Before the cleaning, no abnormalities regarding the glass surface could be noticed.
After the 400 cleaning cycles no scratches on the modules glass surface can be recognized at the visual inspection.
In the following comparison of the reference module with the test module a change of the surface reflection can be optically recognized after the accelerated cleaning. In the direction of the cleaning robot movement darker stripes can be recognized over the whole glass surface. Furthermore, the gloss of the surface has turned from blue into a darker shade (201602410La_V1_Yingli_Solar section 3.3.1).

Performance at STC

In the following diagram (Figure 10), the before and after comparison of the power output of the test specimen 140403040301691 is shown:

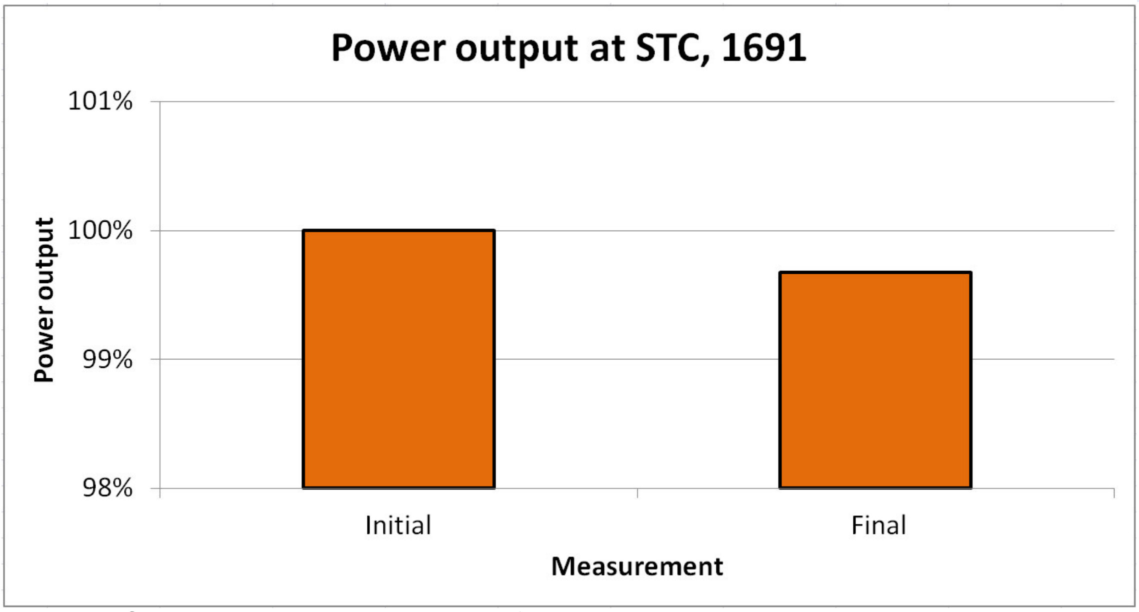

Figure 10: Comparison power output initial with final measurement

The comparison shows that the power output deviation is -0.32% to the initial measurement which is within the repeatability error of the flasher (0.33%). Therefore, no measurable change in power output could be recognized.

Electroluminescence Analysis

No changes of the cells could be recognized by the comparison of the EL-images. Please refer to section 3.5.1 in the laboratory report (201602410La_V1_Yingli_Solar).

Reflectance Measurements

In the following diagram (Figure 11) the reflection deviations with respect to the initial measurement, averaged over the six measured position, are shown.

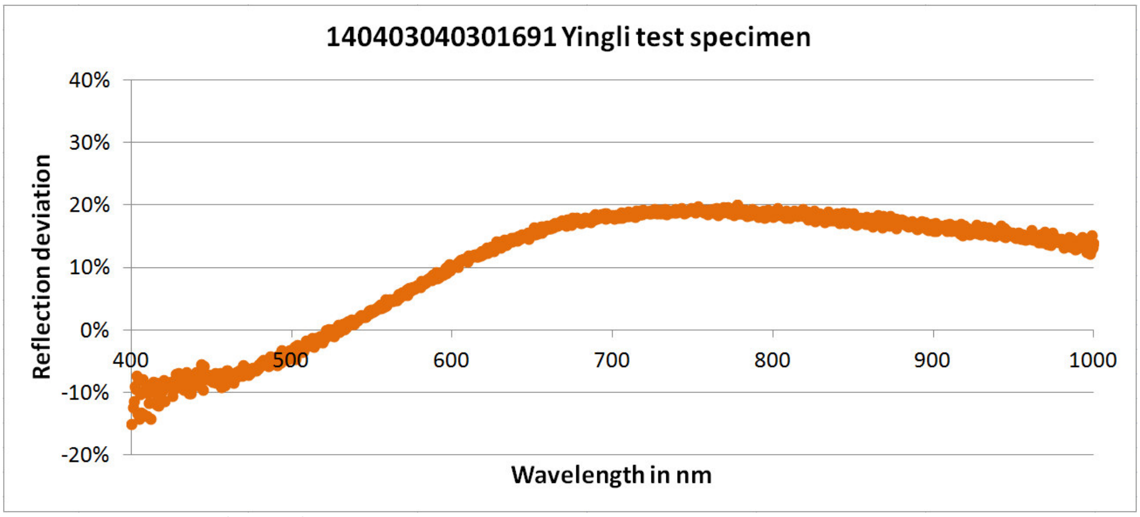

Figure 11: Results of the reflection measurement

The data points within the wavelengths < 550 nm reveal a slight decrease of reflection whereas for measurements > 550 nm clearly an increase of reflection is recognizable.
The average increase of reflection (over the whole range of wavelength and measured positions) is about 11%.

5.3 YINGLI SN - 140403040303174

Visual Inspection

Before the cleaning, no abnormalities regarding the glass surface could be noticed.
After the 400 cleaning cycles no scratches on the modules glass surface could be recognized at the visual inspection.
In the following comparison of the reference module with the test module a change of the surface reflection can be optically recognized after the accelerated cleaning. In the direction of the cleaning robot darker stripes can be recognized over the whole glass surface. Furthermore, the gloss of the surface has turned from blue into a darker shade (201602410La_V1_Yingli_Solar section 3.3.2).

Performance at STC

In the following diagram (Figure 12), the before and after comparison of the power output of the test specimen 140403040303174 is shown:

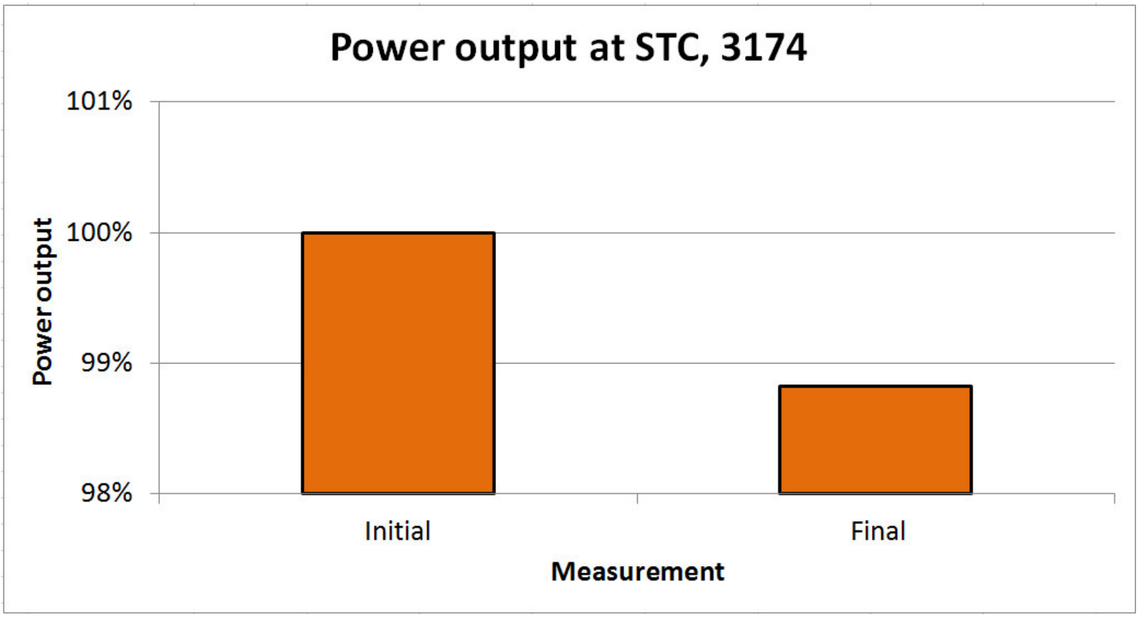

Figure 12: Comparison power output initial with final measurement

The comparison shows that the power output deviation is -1.18% to the initial measurement. A slight recognizable decrease of power output could be measured.

Electroluminescence Analysis

No changes of the cells could be recognized by the comparison of the EL-images. Please refer to section 3.5.2 of the laboratory report 201602410La_V1_Yingli_Solar.

Reflectance Measurements

In the following diagram (Figure 13) the reflection deviations with respect to the initial measurement, averaged over the six measured position, are shown.

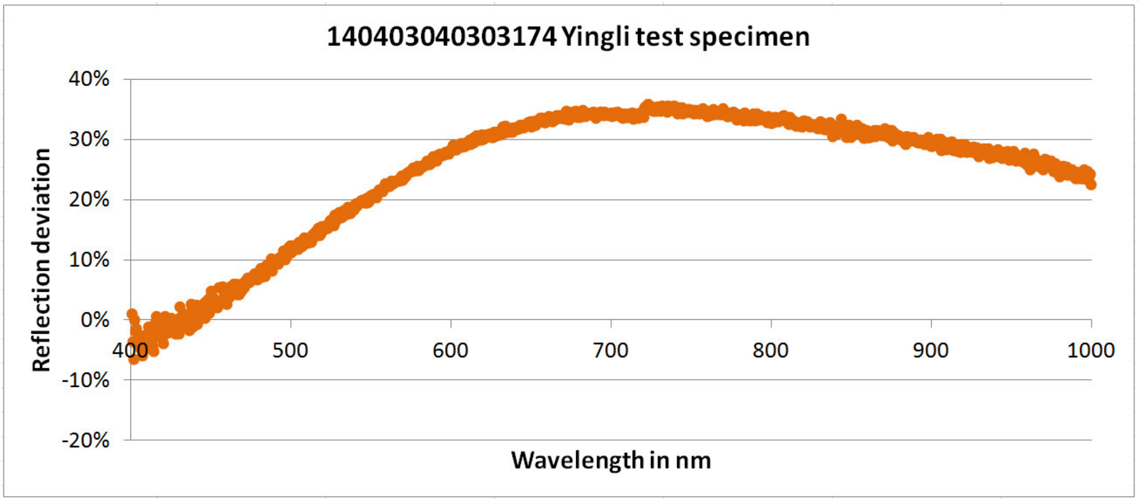

Figure 13: Results of the reflection measurement

The data points within the wavelengths < 450 nm reveal a very slight decrease of reflection whereas for measurements > 450 nm clearly an increase of reflection is recognizable.
The average increase of reflection (over the whole range of wavelength and measured positions) is about 25%.

6 Summary

6.1 Visual Inspection

From visual inspection it could be observed that the accelerated cleaning did not cause any scratches on the glass surface but a visible change of the module glare as well as darker stripes within the cleaning direction of the robot which indicates an influence of the robot on the antireflective glass coating.

6.2 Performance at STC

The reference and the module with the serial number ending #1691 have shown no recognizable power output deviations compared to the initial measurement. The module with the number #3174 reveals a slight decrease of -1.18% compared to the initial characterization by exceeding the repeatability error of the flashlight sun simulator (Figure 14).

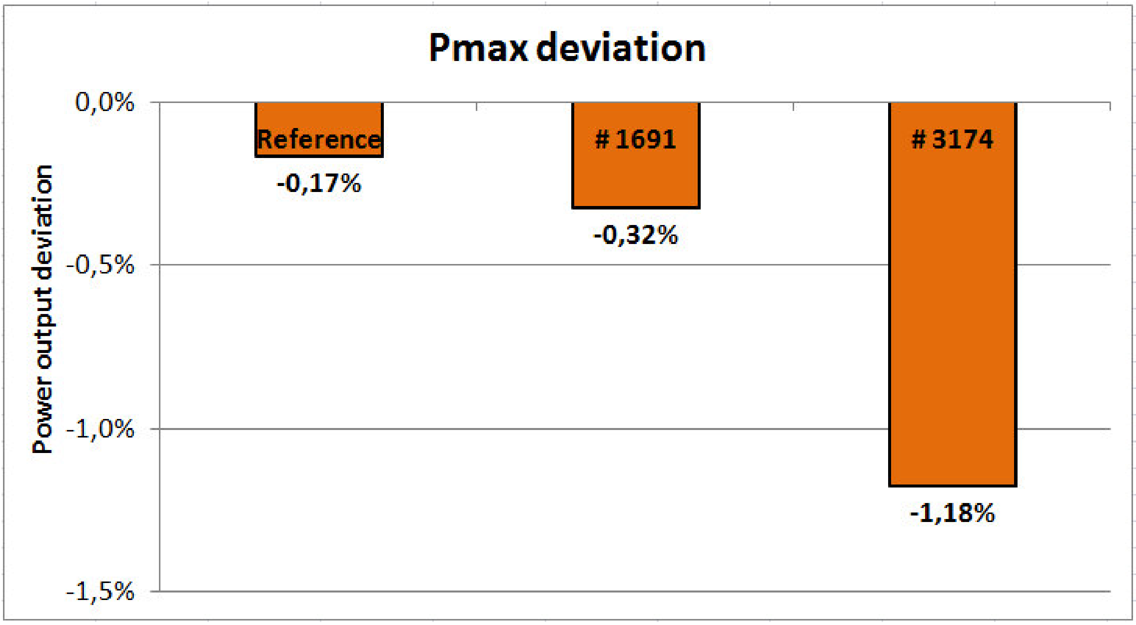

Figure 14: Comparison of maximum power output deviation after cleaning

6.3 Electroluminescence Analysis

The comparison of the EL pictures has shown no change regarding micro cracks or broken cells of the test specimen. No mechanical impact of the GEVA-bot on the modules could be recognized over the whole cleaning period of 400 cycles.

6.4 Reflectance Measurements

In the bar chart in Figure 15 the deviations of the measured reflection after 400 cycles, with respect to the initial measurements, are shown. Each value is given by the average over the six measured positions and the wavelength range 400 – 1000 nm.

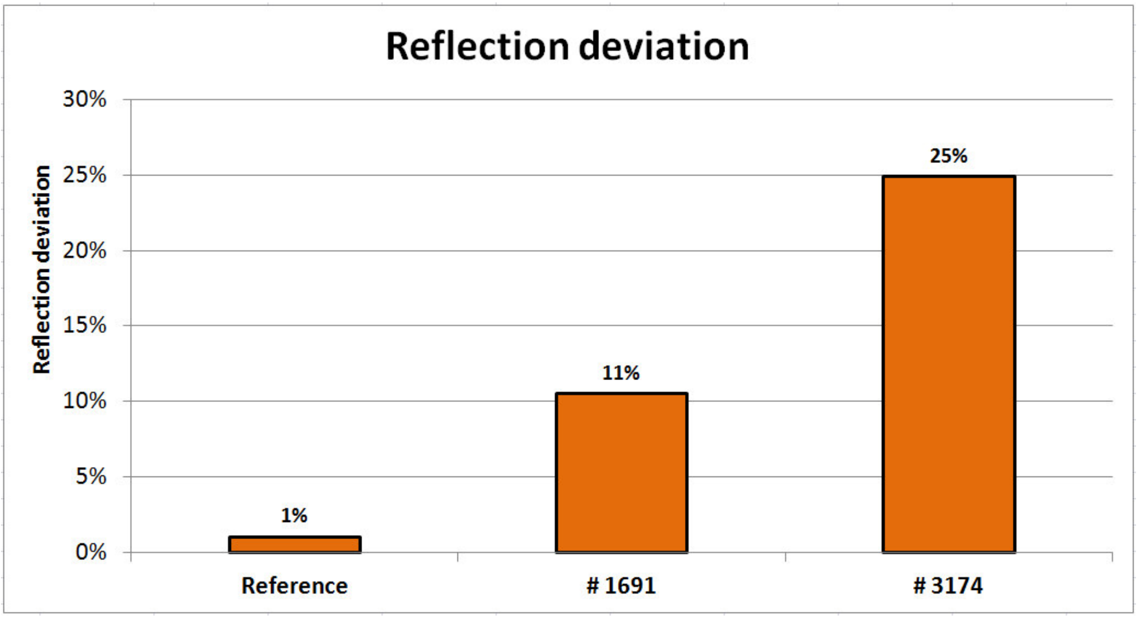

Figure 15: Comparison of reflection deviation after cleaning

This comparison shows that the increase of reflection is quite different of the both test specimen despite the equal mounting positions on the rack and next to each other. However, the results show that there is a measurable influence from the cleaning process on the modules antireflective coating, especially on the module with the serial number ending #3174. Taking into consideration the internal pass/fail criteria of 10% deviation and the measurement uncertainty of ±3%, only this one module fails.

7 Conclusions

In this work an accelerated cleaning was performed in order to test the impact of the GEVA-bot device on YINGLI modules as installed in the Halutziot power plant in Israel. Therefore, for a simulation of 20 years of operation with 20 cleaning cycles per year, all together 400 cleaning cycles were performed. For the simulation of 5 sand storms a year, sand was spread on the modules every 4 cycles.
Visual Inspection, Electroluminescence, Power Output and Reflection Measurements were performed initially and after 400 cleaning cycles.

The Electroluminescence images did not show any damage due to the cleaning on the cells of the modules. Therefore no relevant mechanical impact on the modules could be recognized due to the application of the GEVA-bot over the whole cleaning period of 400 cycles.
A slight decrease of power output could be recognized for the module with the highest increase of reflection.

The slight performance deviations, increase of reflection as well as the change of the modules surface gloss of the both test specimen correlates together and reveals an influence of the cleaning device on the antireflective coating. As the test specimen were mounted directly next to each other and were exposed to the exact same process, the reason for the different results cannot be explained here. Possible root causes for the different results (regarding the reflection increase) of the module with the number #3174 could also be attributed to fluctuations during the manufacturing process and therefore to a possible weaker adhesion of the coating. Further investigation would be necessary to investigate the root cause. Furthermore, a degradation of -1.18% over a testing period of 20 years due to the cleaning process can be stated as negligible small.

In the following table the final results are summarized according to the PI Berlin pass criteria (a reflection increase less than 10%) taking into account the measurement uncertainty of 3%.

Serial number	Producer	Type	Pmax dev. (%) after 400 cycles	Result	Reflection dev. (%) after 400 cycles	Result
140403040304887 Reference	YINGLI	YL305-35b	-0.17	**Pass**	1	**Pass**
140403040301691	YINGLI	YL305-35b	-0.32	**Pass**	11	**Pass**
140403040303174	YINGLI	YL305-35b	-1.18	**Pass**	24	**Fail**

According to the results, both test specimens pass the accelerated cleaning test regarding the power output deviation. Therefore, no major negative impact due to the cleaning process with the GEVA-bot on Yingli modules of the type YL305-35b as installed in Halutziot power plant is expected over a period of 20 years considering 20 yearly cleaning cycles.

8 Appendix

- 201602410La_V1_Yingli_Solar

DIN/IEC/EN/ISO 17025:2005 accredited test laboratory for all relevant IEC standards and own developed test methods; accredited as CBTL for IEC/EN/ISO 61215, 61646, 61730 and all related standards as well as for CEC regulations and UL1703

DAkkS Deutsche Akkreditierungsstelle D-PL-18919-01-00

BERLIN PI

Test-Report

PI-Report-Number: 201602410La_V1_Yingli_Solar

2017-01-27

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Proposal number:	20164330
Order number:	201602410
Order date:	2016-12-14
Delivery date:	2016-12-15
Test start:	2017-01-03
Test end:	2017-01-23
Responsible project manager:	Cyril Hinz, M.Sc. Project engineer

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Person in charge
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Project engineer

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Checked by
Dipl.-Ing. (FH) Carsten Leighton
Technical Management Laboratory

This report is only valid with signature. The sampling was done by the client.
The test results in this report relate just to the test objects.

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1 General Information about the Test Objects

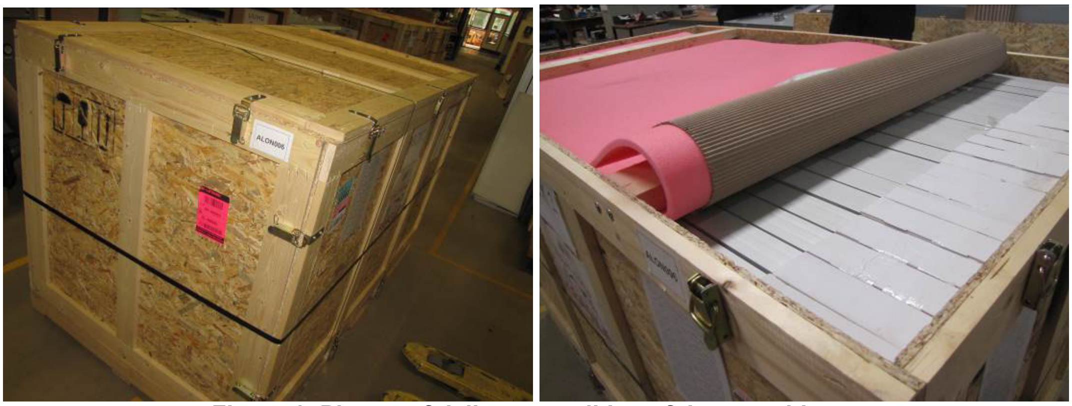


Figure 1: Picture of delivery condition of the test objects.

Serial number	Producer	Type	Cell material	Number of cells	Module area [m²]
140403040301691	Yingli	YL305P-35b	multi-c-Si	72	1.95
140403040303174	Yingli	YL305P-35b	multi-c-Si	72	1.95
140403040304887	Yingli	YL305P-35b	multi-c-Si	72	1.95

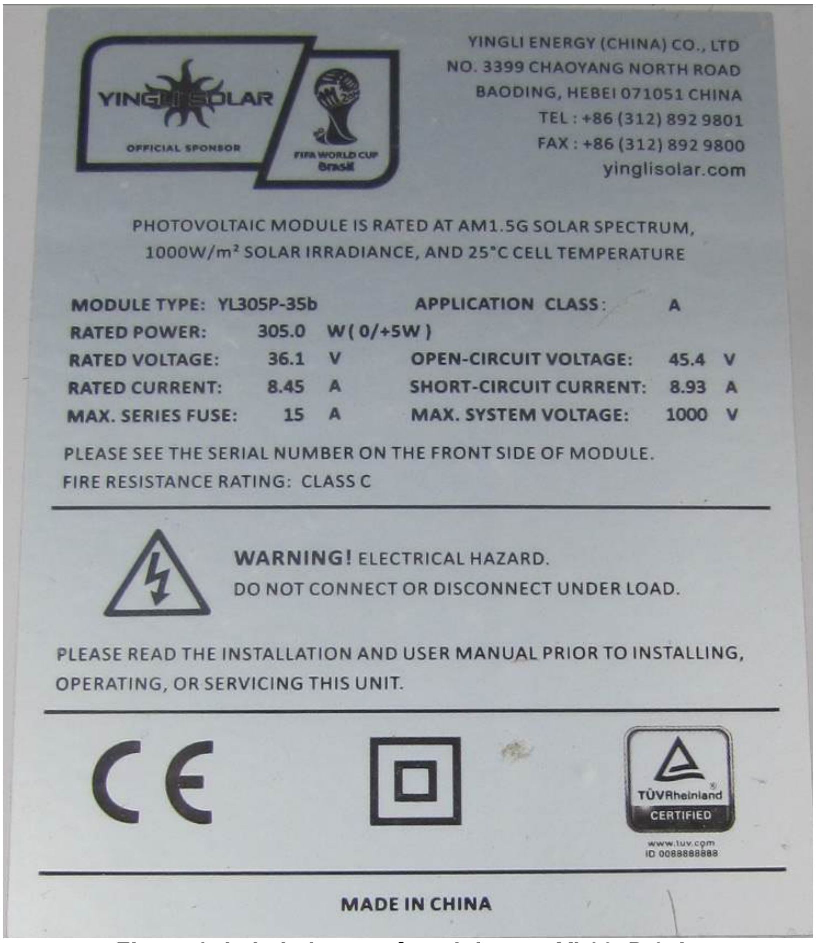


Figure 2: Label picture of module type YL305P-35b.

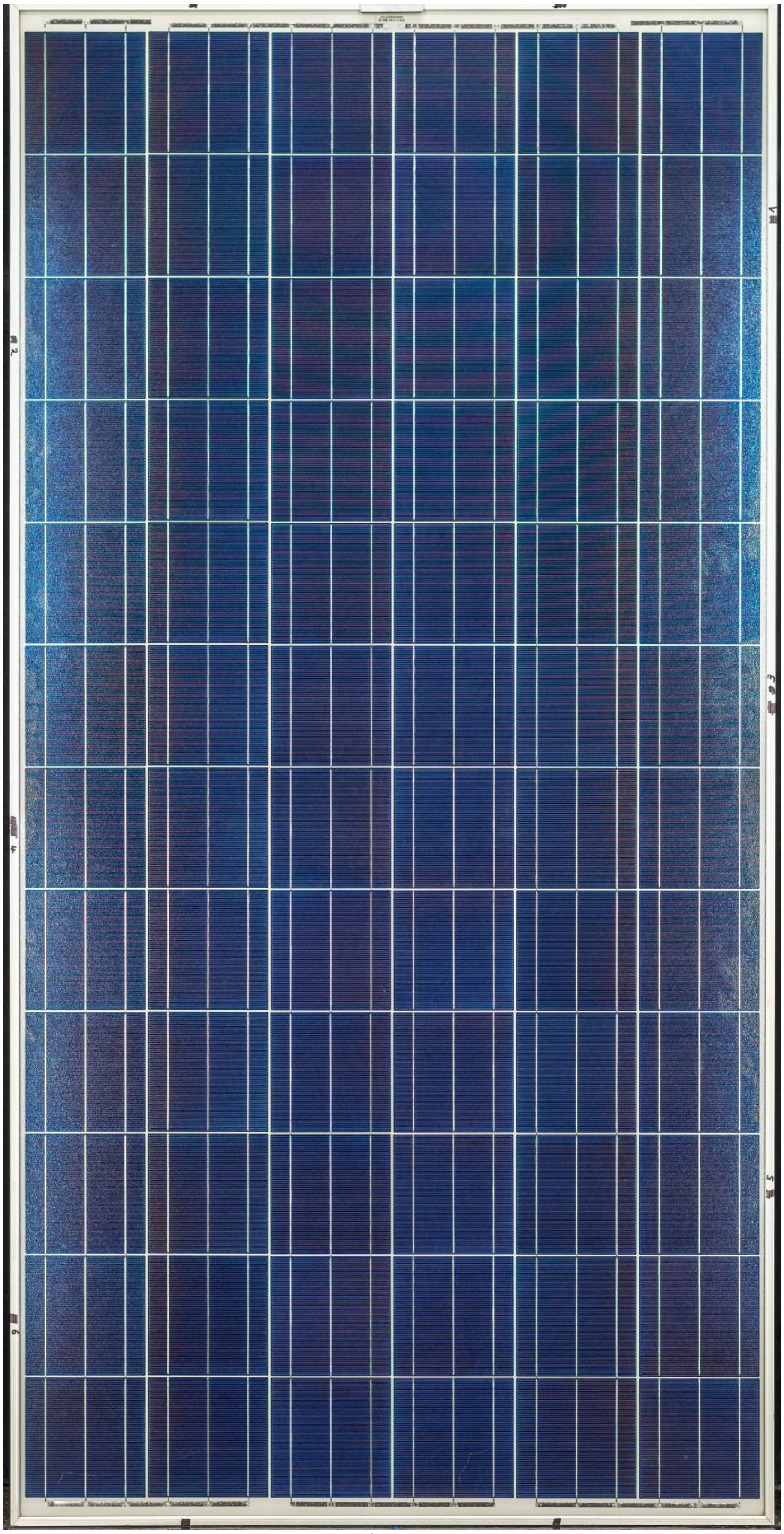


Figure 3: Front side of module type YL305P-35b.

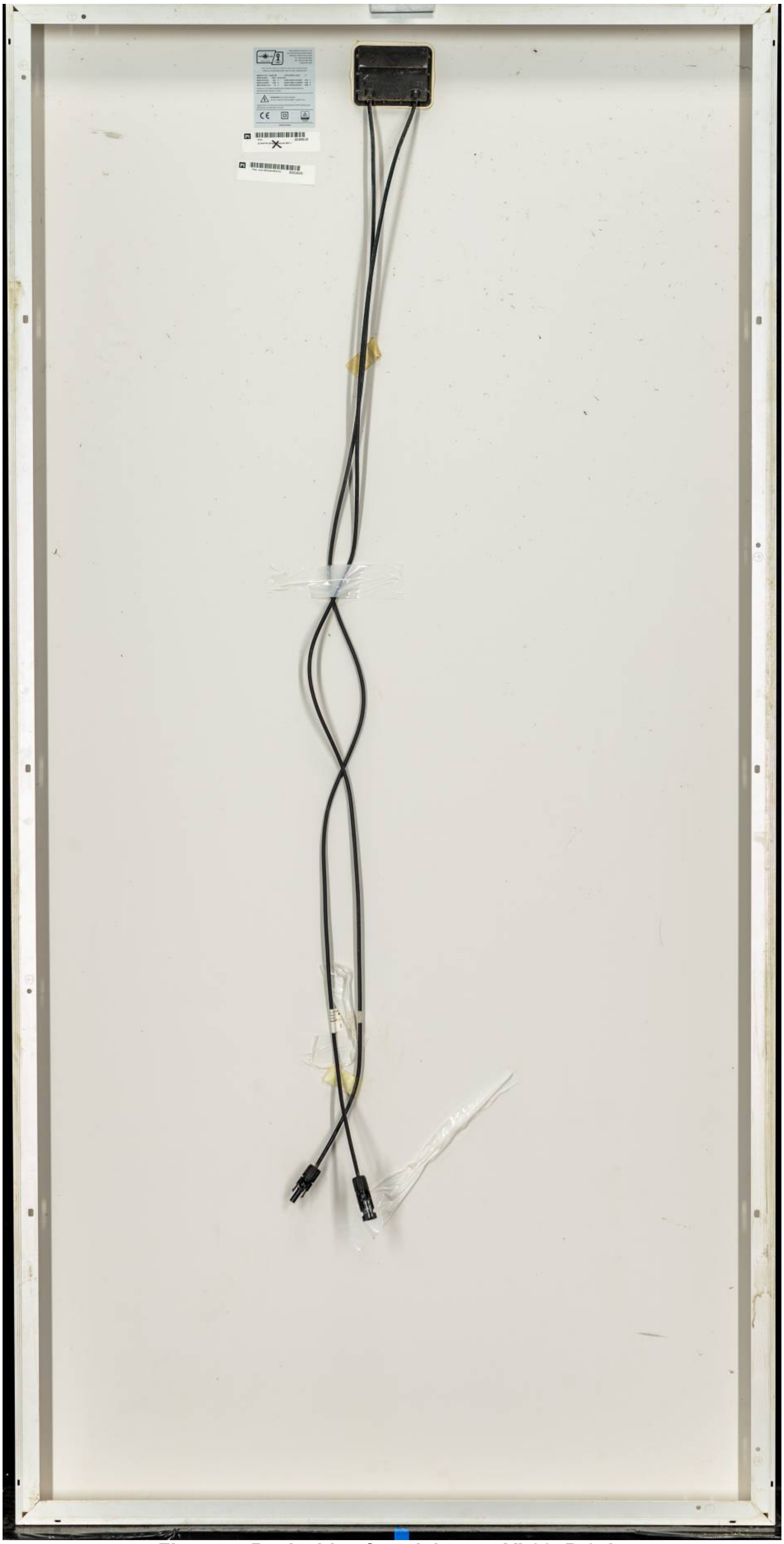


Figure 4: Back side of module type YL305P-35b.

2 Test Descriptions

2.1 Visual Inspection

Visual Inspection is performed according to IEC 61215 2nd Edition: 2005.
Each module is carefully inspected under an illumination of not less than 1000 lux for the following conditions:
– cracked, bent, misaligned or torn external surfaces;
– broken cells;
– cracked cells;
– faulty interconnections or joints;
– cells touching one another or the frame;
– failure of adhesive bonds;
– bubbles or delaminations forming a continuous path between a cell and the edge of the module;
– tacky surfaces of plastic materials;
– faulty terminations, exposed live electrical parts;
– any other conditions which may affect performance.

Requirements:

There is no visual evidence of a major defect:

– broken, cracked or torn external surfaces, including superstrates, substrates, frames and junction boxes;

– bent or misaligned external surfaces, including superstrates, substrates, frames and junction boxes to the extent that the installation and/or operation of the module would be impaired;

– a crack in a cell whose propagation could remove more than 10% of that cells' area from the electrical circuit of the module;

– bubbles or delamination forming a continuous path between any part of the electrical circuit and the edge of the module;

– loss of mechanical integrity, to the extent that the installation and/or operation of the module would be impaired;

2.2 I-V Curve Determination at STC

General information about the measuring system

The I-V curve has been determined at Standard Test Conditions (STC) in accordance with IEC 60904-3. Thereby a solar simulator Class A type Pasan SS3b has been used. The calibration of the solar simulator has been performed with a stabilized cell with WPVS (World Photovoltaic Standard) cell format calibrated by PTB.
For reasons of quality assurance round robins with other accredited laboratories are carried out regularly in order to verify the measurement results.
The spectrum of the simulator is always verified with an internal spectrometer calibrated by PTB.
The measuring system error referring to the maximum power is < ±3%. The mismatch correction value for multi-c-Si and the solar simulator mentioned above is 1.010.

Correction

Corrected with STC-Tool-Version: 3.0.2

Temperature coefficient (from Yingli Solar's data sheet)	Value
T_{coeff} (V_{oc})	-0.33 %/K
T_{coeff} (I_{sc})	0.06 %/K

Statement of the estimated uncertainty of the test results

Updated: 2011-03-23

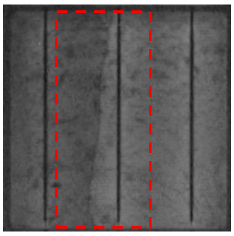
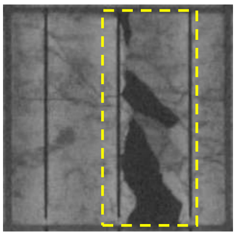
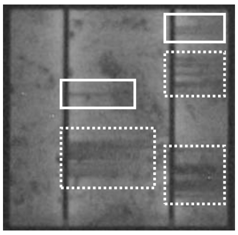
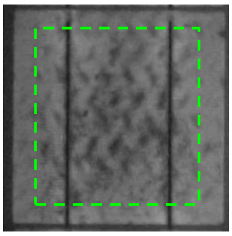
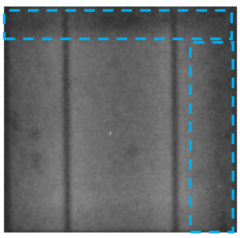
Measurand	Measurement uncertainty	Repeatability
P_{MPP}	2.9%	0.33%
V_{OC}	1.3%	0.12%
I_{SC}	2.2%	0.13%

Flasher equipment list

Component	Calibration sign	Date of next calibration
WPVS cell	47021-PTB-15	Feb 17
Electronic load "High Light 3"	SCS 002 14634	May 18
Temperature sensor 1 (Pt100)	415.01_20160531	Jan 18

2.3 Electroluminescence Analysis

Electroluminescence Analysis is a powerful tool to identify module abnormalities on the cell level caused by cell production, module production, transport and stress tests.
For c-Si modules a current in the range of the I_{SC} is applied to the module and a NIR-picture is recorded with a special EL camera.
The main focus of the analysis is the distribution of micro cracks and broken cells. Therefore, not every detail concerning other abnormalities will be mentioned.
In the following table common cell abnormalities are shown and their probable origin is explained besides.

	Micro cracks: The EL picture shows a cell with a typical micro-crack which can be generated during the cell and module production. Due to mechanical or thermal stress cells with micro-cracks can develop into broken cells. A broken cell is one of the sources of power loss at the cell and module level. Branched micro cracks occur due to an impact or several shocks which are mostly caused by transportation or installation and not by the production.
	Broken cells: This EL picture reveals a broken cell. The dark areas of the cell are electrically isolated. These areas are limiting the current in the cell and therefore the current in the whole string. Broken cells reduce the power of a module.
	Finger interruptions: Finger interruptions are visible in this EL picture. Semi transparent or sporadic interruptions are not critical in respect to power losses (white squares). In contrast, very dark finger interruptions which usually occur due to a bad soldering process induce power losses (white dashed squares). Finger interruptions occur sometimes at the same position on cells. That indicates a problem in the cell production. The module reliability is not affected by finger interruptions.
	Band-conveyor pattern: This cell shows a patterning. It is unclear if it reduces the efficiency of the cell (evident by dark areas). This kind of pattern reveals inhomogeneous temperatures on the cell during firing of the grid-fingers, while the conveyor-belt of the furnace is imprinted on the cell.
	Impurities : A wafer which is located on the edge of a casted ingot can show impurities. These impurities reduce the EL signal and may reduce the efficiency within small range.

Remark: The resolution of the EL pictures in the report is not as high as the resolution of the original EL pictures. Therefore it could be difficult to recognize every mentioned detail at the pictures in the report.

3 Test Results

3.1 Result Compilation of Visual Inspection

Serial number	Level	Condition
140403040301691	Initial	Apart from scratches here and there on the front side, there is no major defect to report (refer to following pages for details).
	Final	Change in the anti-reflexion coating (refer to the following pictures for details). It is also visible only when these areas are exposed to direct light, at these particular areas the light reflexion is changed.
140403040303174	Initial	Apart from scratches here and there on the front side, there is no major defect to report (refer to following pages for details).
	Final	Change in the anti-reflexion coating (refer to the following pictures for details). It is also visible only when these areas are exposed to direct light, at these particular areas the light reflexion is changed.
140403040304887	Initial	Apart from scratches here and there on the front side, there is no major defect to report (refer to following pages for details).
	Final	No change to report. This module was not subjected to the accelerated test.

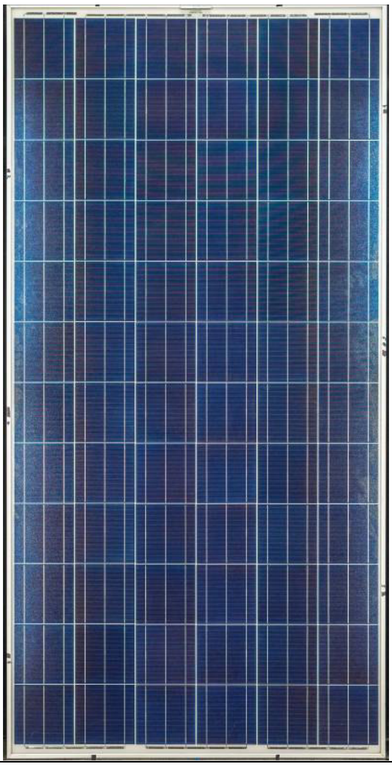
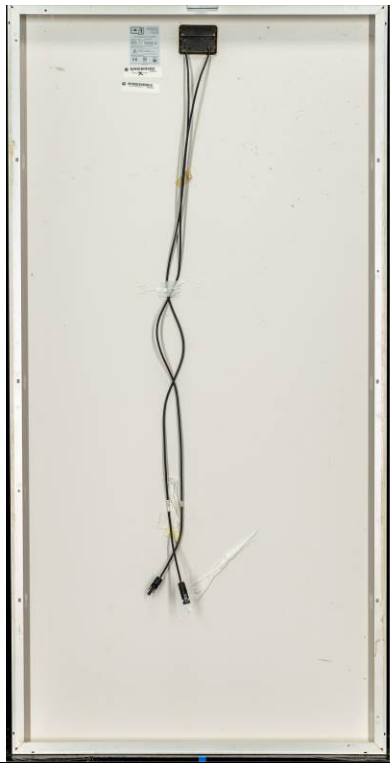
3.2 Result Compilation of I-V Curve Determination at STC

Serial number	Level	P_{MPP} [W]	V_{MPP} [V]	I_{MPP} [A]	V_{OC} [V]	I_{SC} [A]	FF [%]	Power deviation to label*/ to initial meas. [%]
140403040301691	Initial	287.7	35.61	8.080	44.88	8.744	73.32	-5.6*
	Final	286.8	35.54	8.070	44.87	8.715	73.34	-0.3
140403040303174	Initial	290.0	35.71	8.123	45.07	8.677	74.17	-4.9*
	Final	286.6	35.87	7.990	45.09	8.543	74.42	-1.2
140403040304887	Initial	286.7	35.71	8.028	44.90	8.629	74.00	-6.0*
	Final	286.2	35.54	8.053	44.86	8.622	73.98	-0.2

3.3 Detailed Results of Visual Inspection

3.3.1 Visual Inspection – SN: 140403040301691

Initial Visual Inspection:

Serial number:	140403040301691
Front side of the module 	Back side of the module 
 	N/A
Minor defects: Scratches on the front glass	No defect to report on the backside

Visual Inspection after accelerated test::

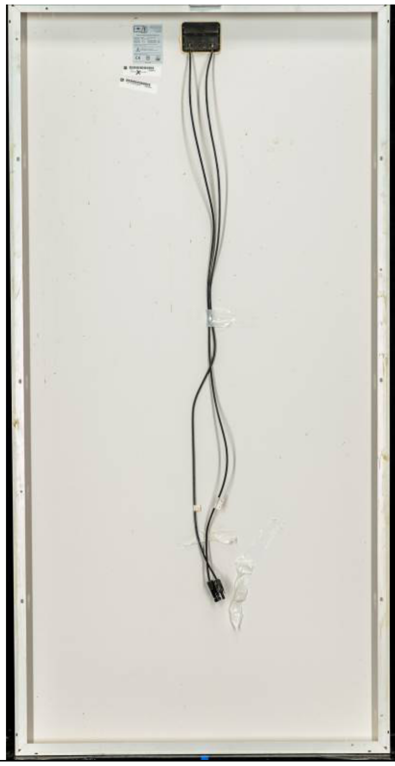
Serial number:	140403040301691

Front side of the module

Exposed to natural sunlight, an inhomogeneous reflexion of the light is visible across the module.
This was also noticeable with in-door standard conditions of the visual inspection, but it was not possible to obtain a clear picture.

3.3.2 Visual Inspection – SN: 140403040303174

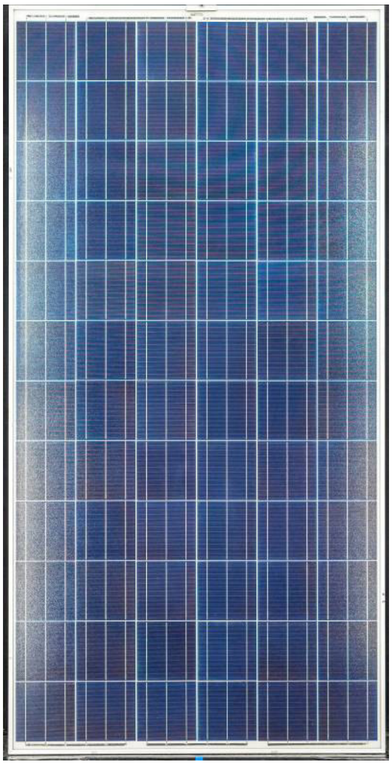
Initial Visual Inspection:

Serial number:	140403040303174
Front side of the module 	Back side of the module 
 	N/A
Minor defects: Scratches on the front glass	No defect to report on the backside

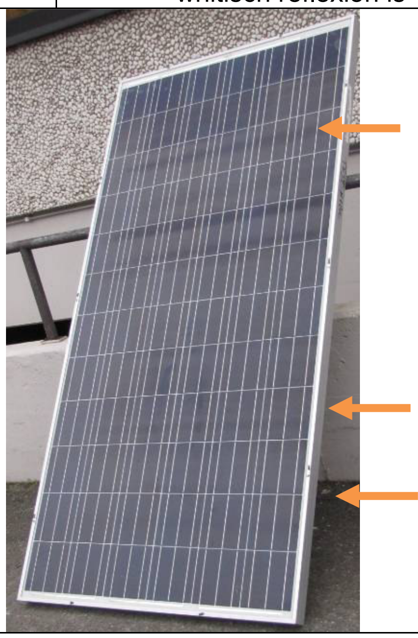
Visual Inspection after accelerated test:

Serial number:	140403040303174

Front side of the module



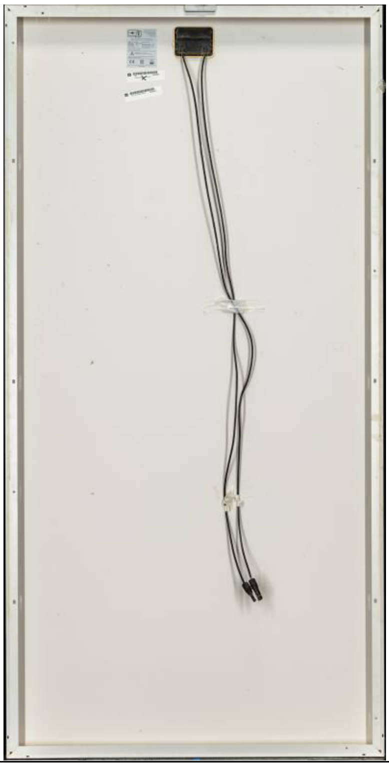
The bluisch reflexion is visible on the reference module (firstly left on the upper picture, then right the lower picuture), the whitisch reflexion is visible on the test module.



Exposed to natural sunlight, an unhomogeneous reflexion of the light is visible across the module. This was also noticeable with in-door standard conditions of the visual inspection.

3.3.3 Visual Inspection – SN: 140403040304887

Initial Visual Inspection:

Serial number:	140403040304887
Front side of the module 	Back side of the module 
 	N/A
Minor defects: Scratches on the front glass	No defect to report on the backside

<u>Visual Inspection after accelerated test:</u>

Serial number:	140403040304887
Front side of the module 	
	
Exposed to natural sunlight, the reflexion of the light is homogeneous across the module. This module was not subjected to the acclerated test.	

3.4 Detailed Results of I-V Curve Determination at STC

3.4.1 I-V Curve Determination at STC – SN: 140403040301691

Initial I-V Curve Determination at STC:

The measurements are accomplished at an irradiance of 1000 W/m² and a sweep time of 8 ms (1-flash). The results are then corrected to 25°C.

	Label data	Test results	Deviation to label [%]
Producer:	Yingli		
Serial number:	140403040301691		
Module type:	YL305P-35b	**Test results**	**Deviation to label [%]**
P_{MPP} [W]:	305.0	287.7	-5.7
V_{MPP} [V]:	36.1	35.61	-1.4
I_{MPP} [A]:	8.45	8.08	-4.4
V_{OC} [V]:	45.4	44.88	-1.2
I_{SC} [A]:	8.93	8.744	-2.1
FF [%]:	75.24 (PI calculated)	73.32	-2,5

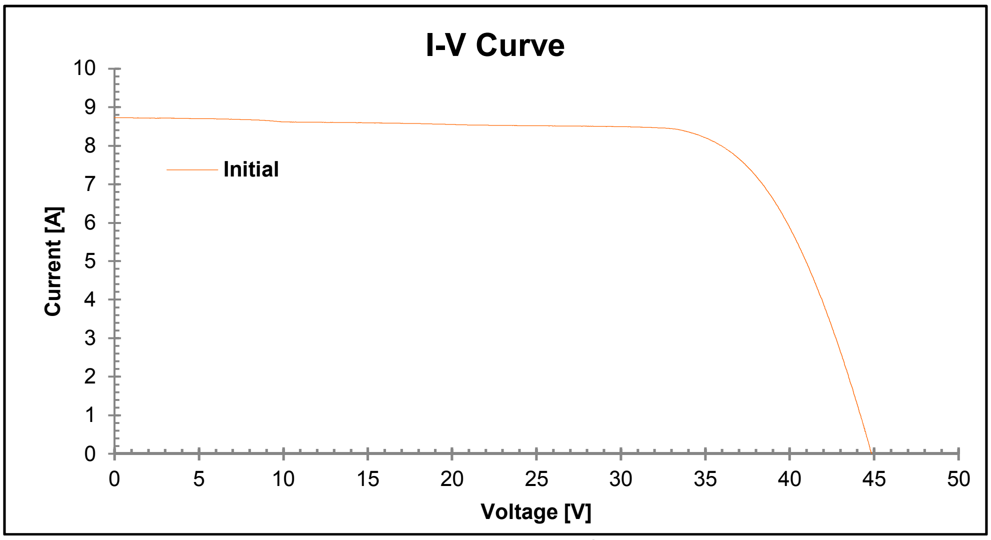


Figure 5: Temperature corrected I-V curve of module 140403040301691.

I-V Curve Determination at STC after accelerated test:

The measurements are accomplished at an irradiance of 1000 W/m² and a sweep time of 8 ms (1-flash). The results are then corrected to 25°C.

	Initial test results	Test results	Deviation to initial test results [%]
Producer:	Yingli		
Serial number:	140403040301691		
Module type:	YL305P-35b		
P_{MPP} [W]:	287.7	286.8	-0.3
V_{MPP} [V]:	35.61	35.54	-0.2
I_{MPP} [A]:	8.08	8.070	-0.1
V_{OC} [V]:	44.88	44.87	0.0
I_{SC} [A]:	8.744	8.715	-0.3
FF [%]:	73.32	73.34	0.0

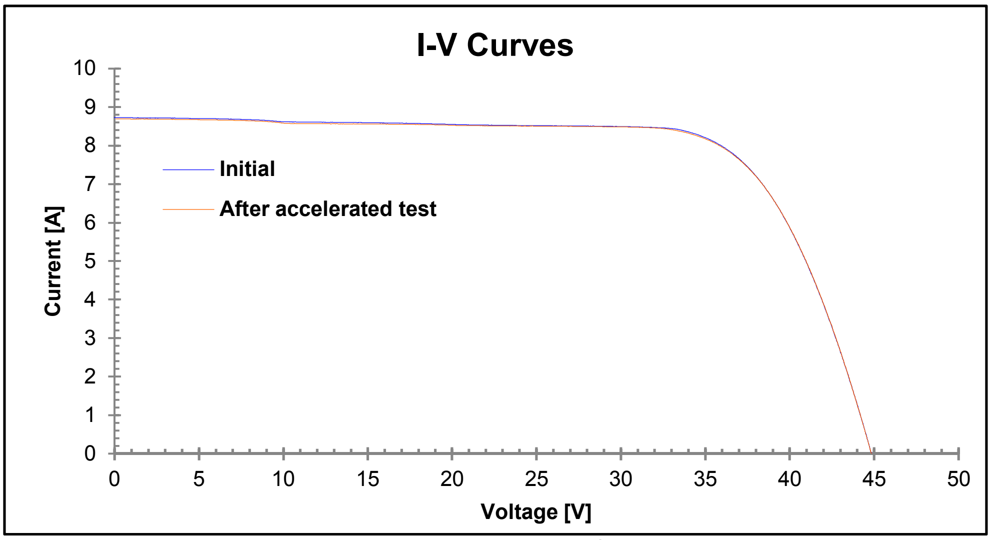


Figure 6: Temperature corrected I-V curves of module 140403040301691.

3.4.2 I-V Curve Determination at STC – SN: 140403040303174

Initial I-V Curve Determination at STC:

The measurements are accomplished at an irradiance of 1000 W/m² and a sweep time of 8 ms (1-flash). The results are then corrected to 25°C.

	Label data	Test results	Deviation to label [%]
Producer:	Yingli		
Serial number:	140403040303174		
Module type:	YL305P-35b	**Test results**	**Deviation to label [%]**
P_{MPP} [W]:	305.0	290.0	-4.9
V_{MPP} [V]:	36.1	35.71	-1.1
I_{MPP} [A]:	8.45	8.123	-3.9
V_{OC} [V]:	45.4	45.07	-0.7
I_{SC} [A]:	8.93	8.677	-2.8
FF [%]:	75.24 (PI calculated)	74.17	-1.4

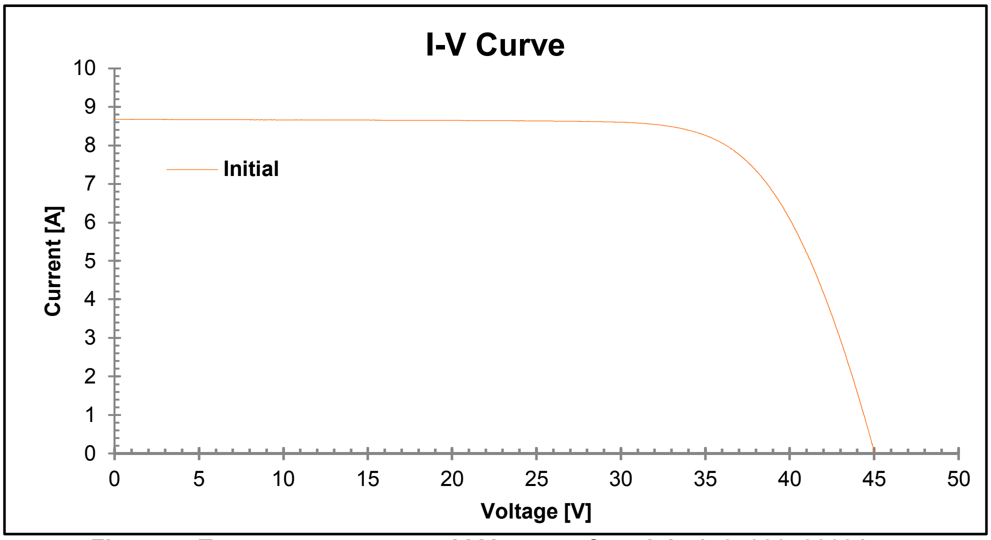


Figure 7: Temperature corrected I-V curve of module 140403040303174.

I-V Curve Determination at STC after accelerated test:

The measurements are accomplished at an irradiance of 1000 W/m² and a sweep time of 8 ms (1-flash). The results are then corrected to 25°C.

	Initial test results	Test results	Deviation to initial test results [%]
Producer:	Yingli		
Serial number:	140403040303174		
Module type:	YL305P-35b		
P_{MPP} [W]:	290.0	286.6	-1.2
V_{MPP} [V]:	35.71	35.87	0.5
I_{MPP} [A]:	8.123	7.990	-1.6
V_{OC} [V]:	45.07	45.09	0.0
I_{SC} [A]:	8.677	8.543	-1.5
FF [%]:	74.17	74.42	0.3

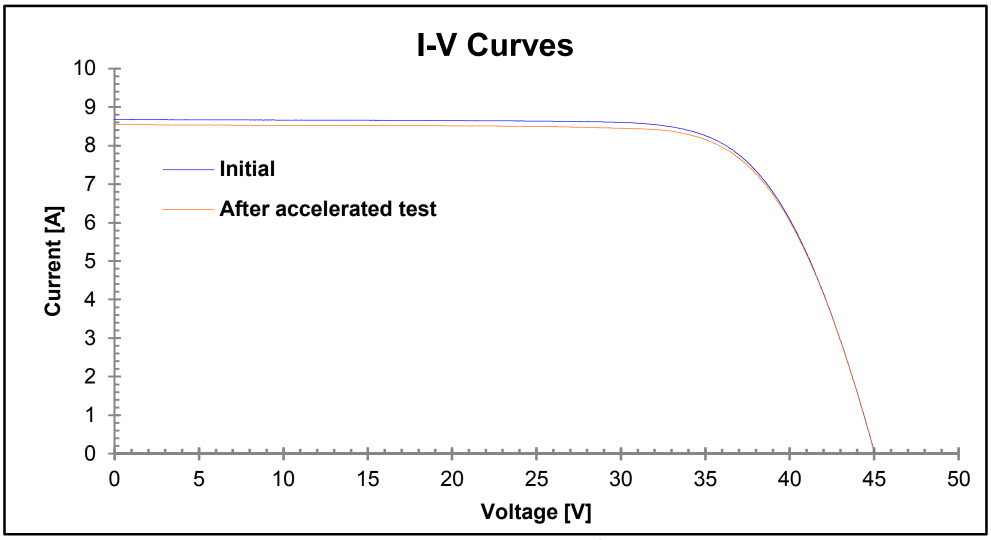


Figure 8: Temperature corrected I-V curves of module 140403040303174.

3.4.3 I-V Curve Determination at STC – SN: 140403040304887

Initial I-V Curve Determination at STC:

The measurements are accomplished at an irradiance of 1000 W/m² and a sweep time of 8 ms (1-flash). The results are then corrected to 25°C.

	Label data	Test results	Deviation to label [%]
Producer:	Yingli		
Serial number:	140403040304887		
Module type:	YL305P-35b	**Test results**	**Deviation to label [%]**
P_{MPP} [W]:	305.0	286.7	-6.0
V_{MPP} [V]:	36.1	35.71	-1.1
I_{MPP} [A]:	8.45	8.028	-5.0
V_{OC} [V]:	45.4	44.89	-1.1
I_{SC} [A]:	8.93	8.629	-3.4
FF [%]:	75.24 (PI calculated)	74.00	-1.6

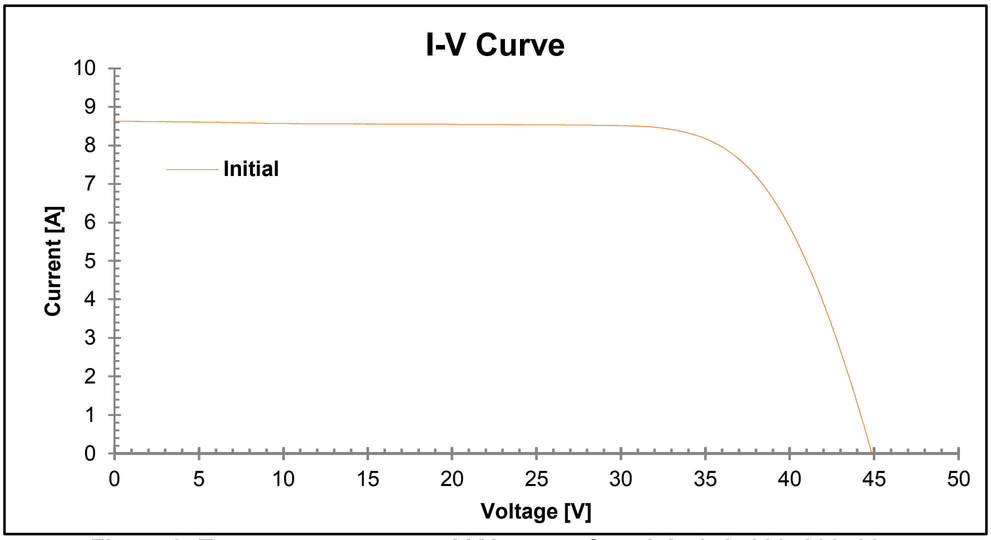


Figure 9: Temperature corrected I-V curve of module 140403040304887.

I-V Curve Determination at STC after accelerated test:

The measurements are accomplished at an irradiance of 1000 W/m² and a sweep time of 8 ms (1-flash). The results are then corrected to 25°C.

	Initial test results		
Producer:	Yingli		
Serial number:	140403040304887		
Module type:	YL305P-35b	**Test results**	**Deviation to initial test results [%]**
P_{MPP} [W]:	286.7	286.2	-0.2
V_{MPP} [V]:	35.71	35.54	-0.5
I_{MPP} [A]:	8.028	8.053	0.3
V_{OC} [V]:	44.89	44.86	-0.1
I_{SC} [A]:	8.629	8.622	-0.1
FF [%]:	74.00	73.98	0.0

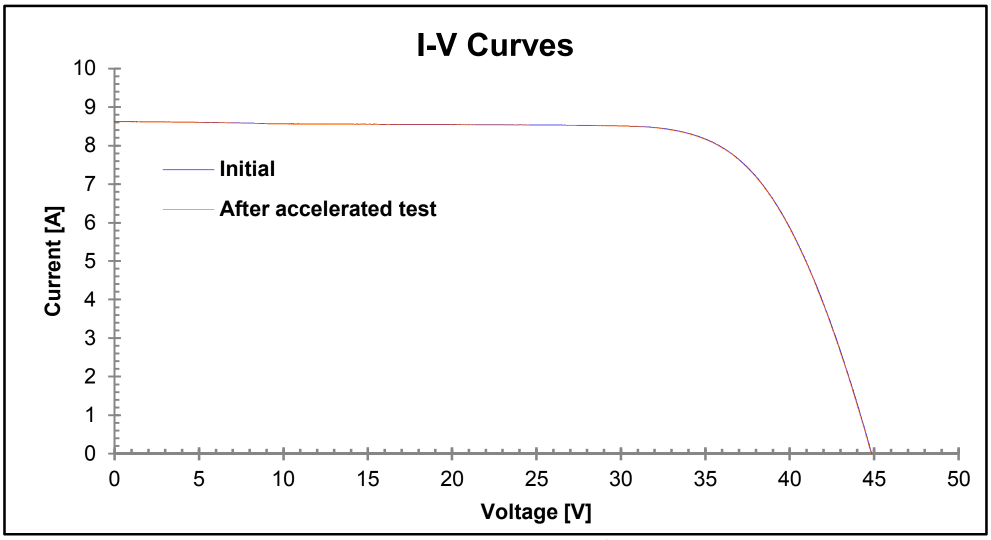


Figure 10: Temperature corrected I-V curves of module 140403040304887.

3.5 Detailed Results of Electroluminescence Analysis

3.5.1 Electroluminescence Analysis – SN: 140403040301691

Initial EL Analysis:

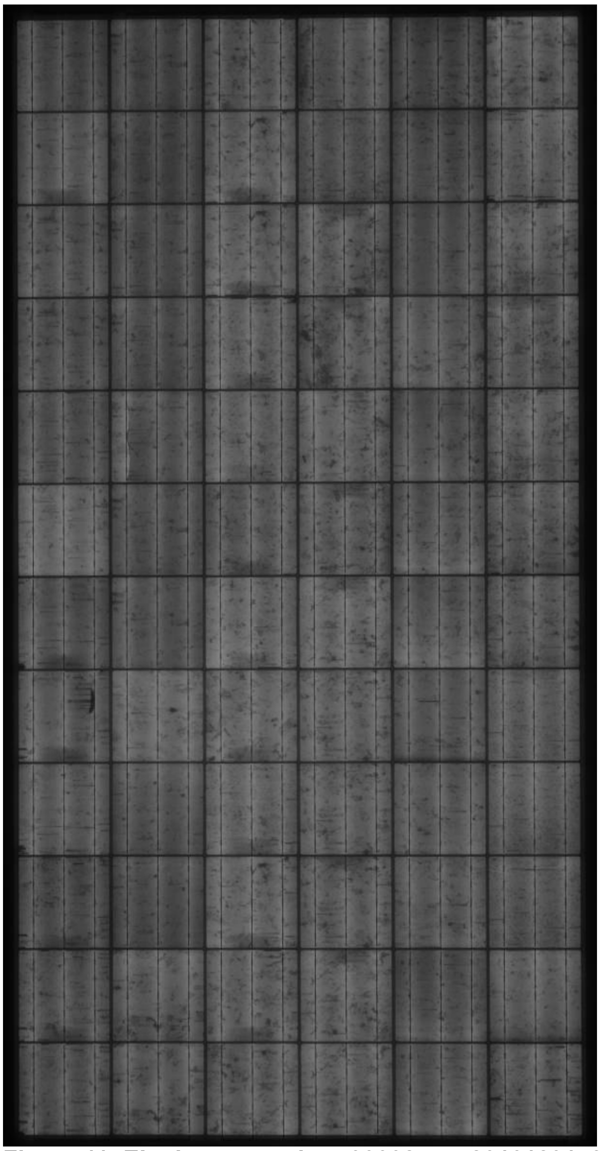


Figure 11: EL picture number: 00008747_2016120153_140403040301691_Initial.jpg.

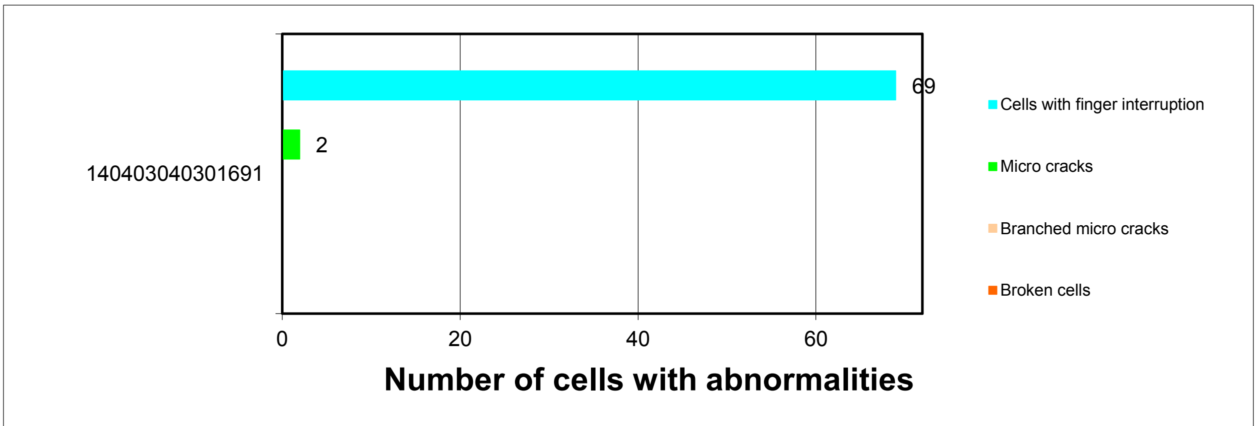


Figure 12: Overview of cell abnormalities of the module: 140403040301691.

EL Analysis after accelerated test:

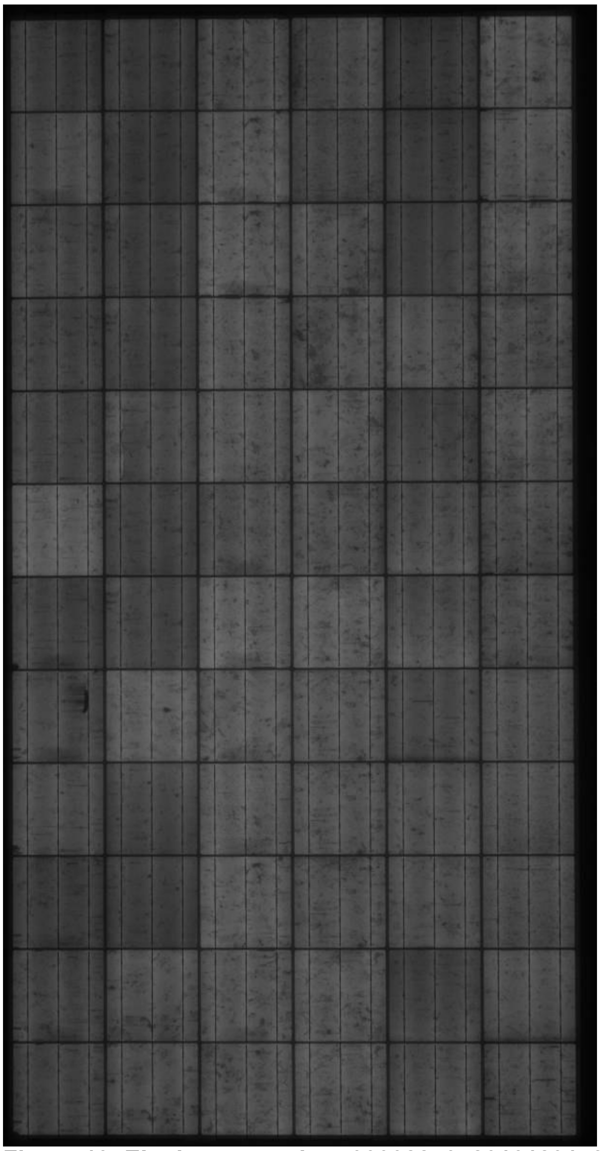


Figure 13: EL picture number: 00008849_2016120153_140403040301691_RX.jpg.

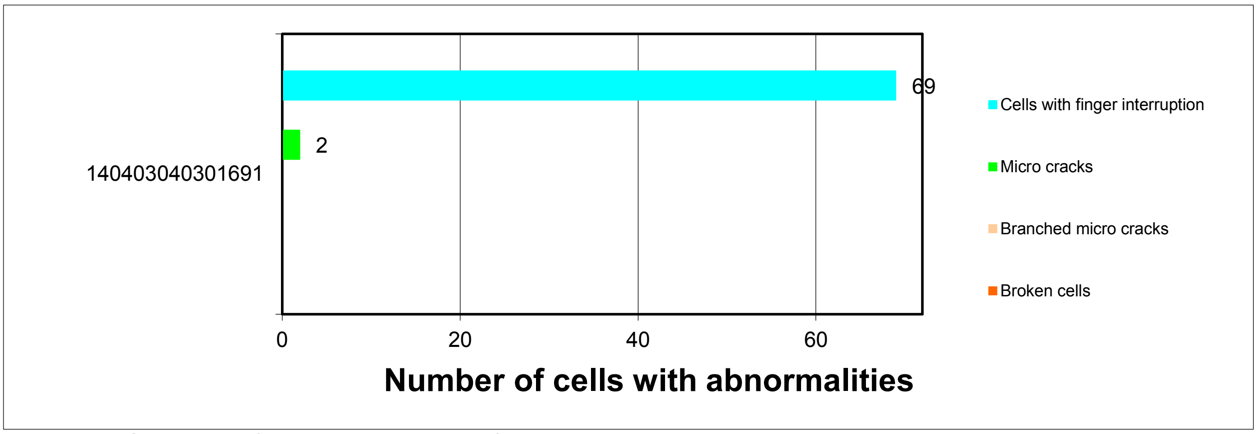


Figure 14: Overview of cell abnormalities of the module: 140403040301691.

3.5.2 Electroluminescence Analysis – SN: 140403040303174

Initial EL Analysis:

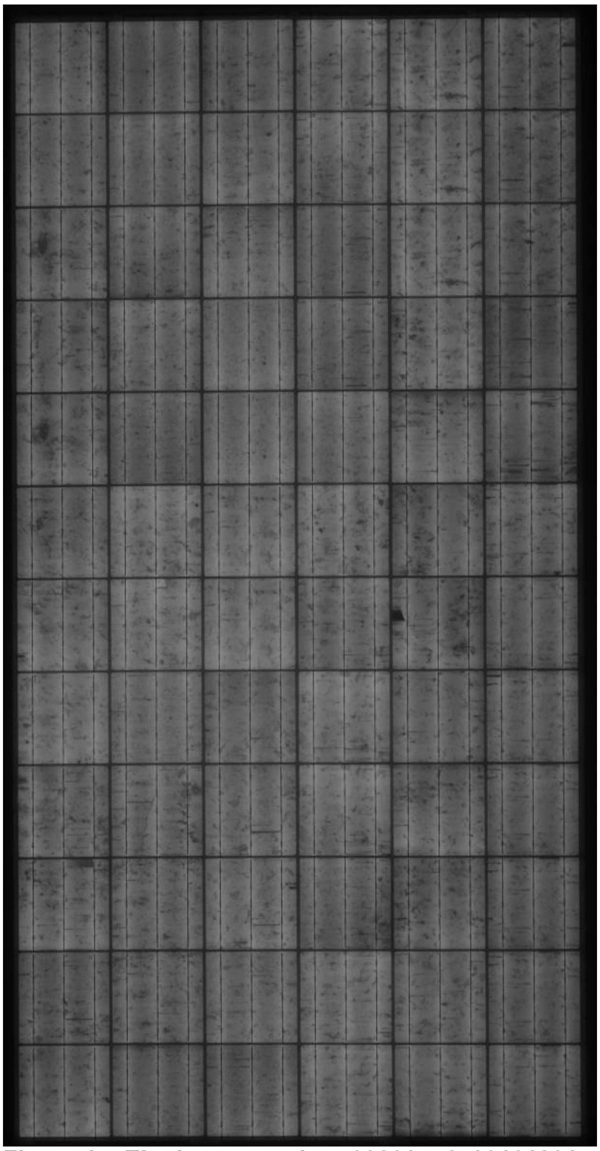


Figure 15: EL picture number: 00008746_2016120155_140403040303174_Initial.jpg.

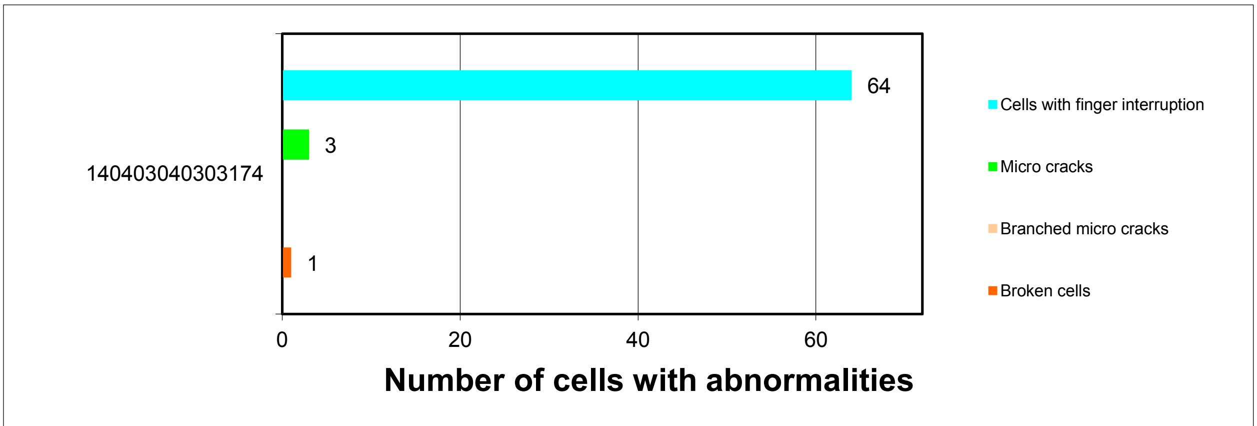


Figure 16: Overview of cell abnormalities of the module: 140403040303174.

EL Analysis after accelerated test:

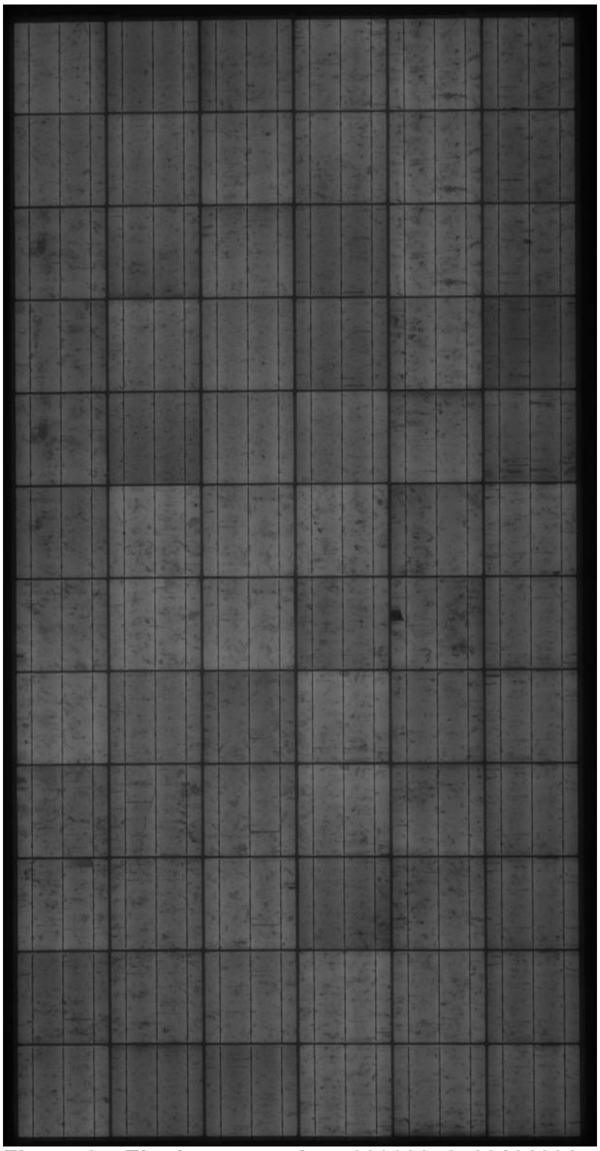


Figure 17: EL picture number: 00008842_2016120155_140403040303174_RX.jpg.

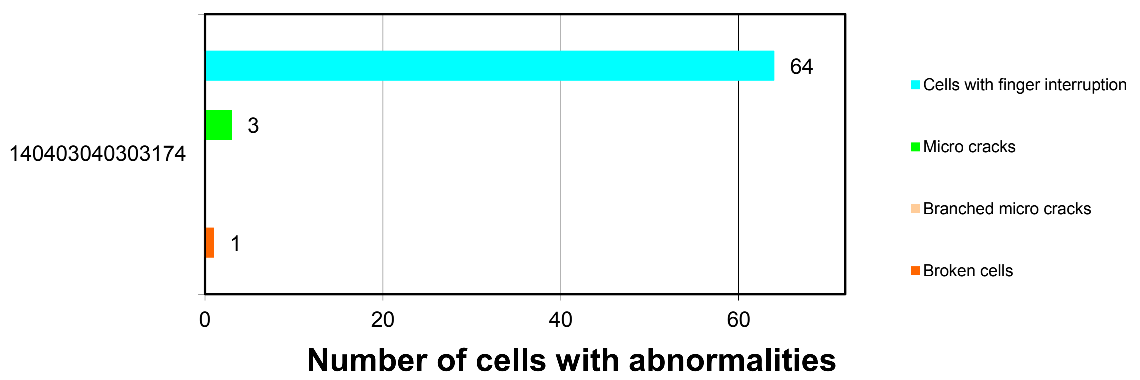


Figure 18: Overview of cell abnormalities of the module: 140403040303174.

3.5.3 Electroluminescence Analysis – SN: 140403040304887

Initial EL Analysis:

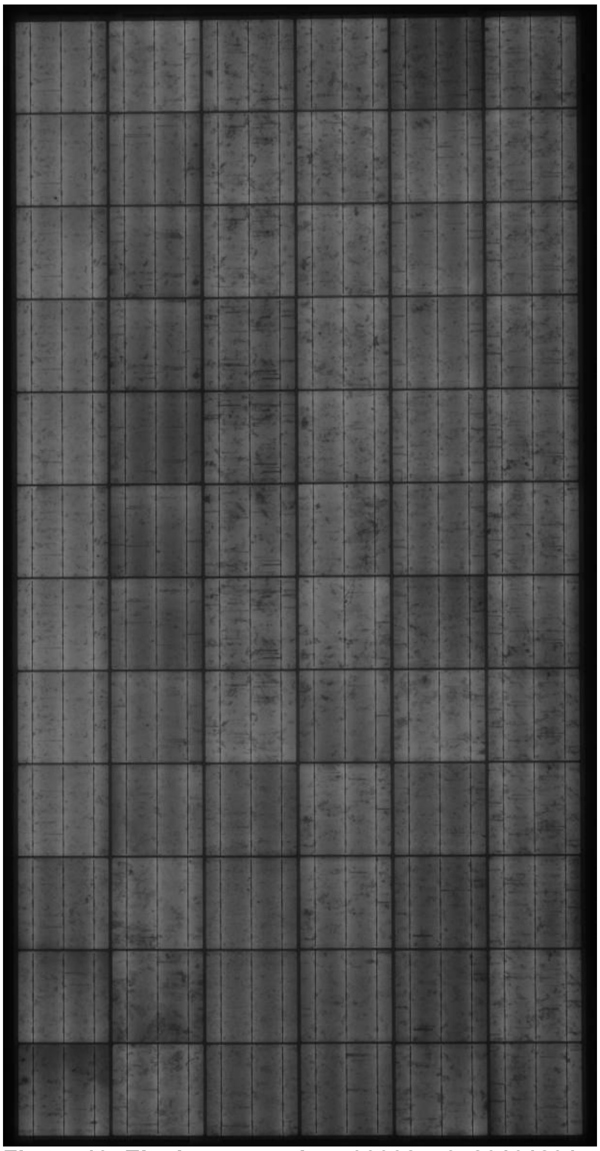


Figure 19: EL picture number: 00008749_2016120154_140403040304887_Initial.jpg.

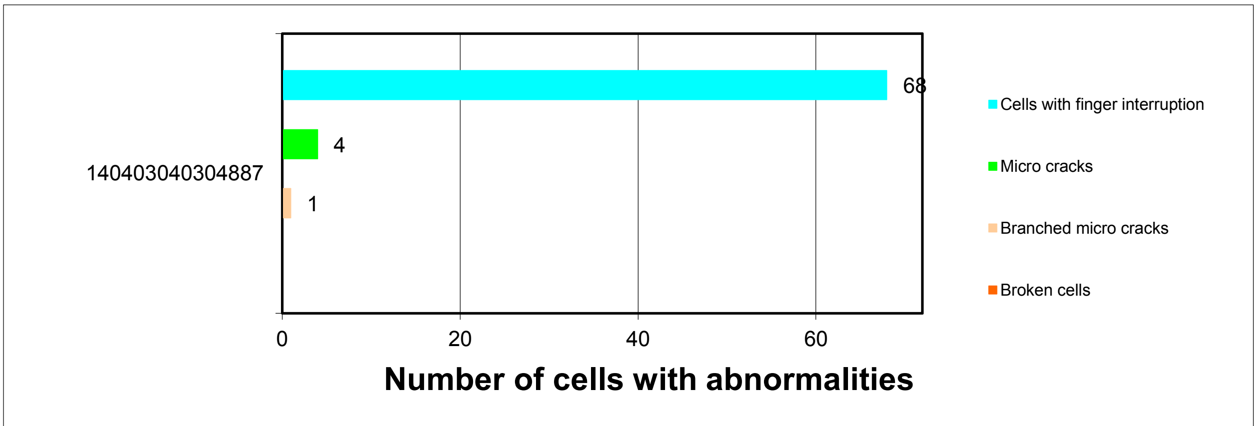


Figure 20: Overview of cell abnormalities of the module: 140403040304887.

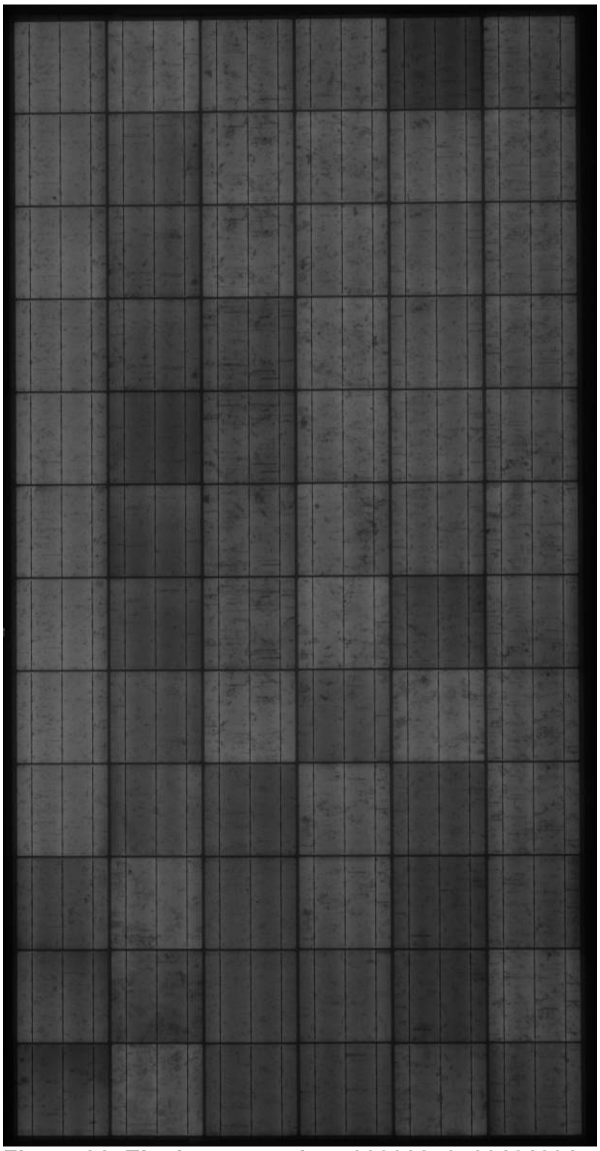


Figure 21: EL picture number: 00008843_2016120154_140403040304887_RX.jpg.

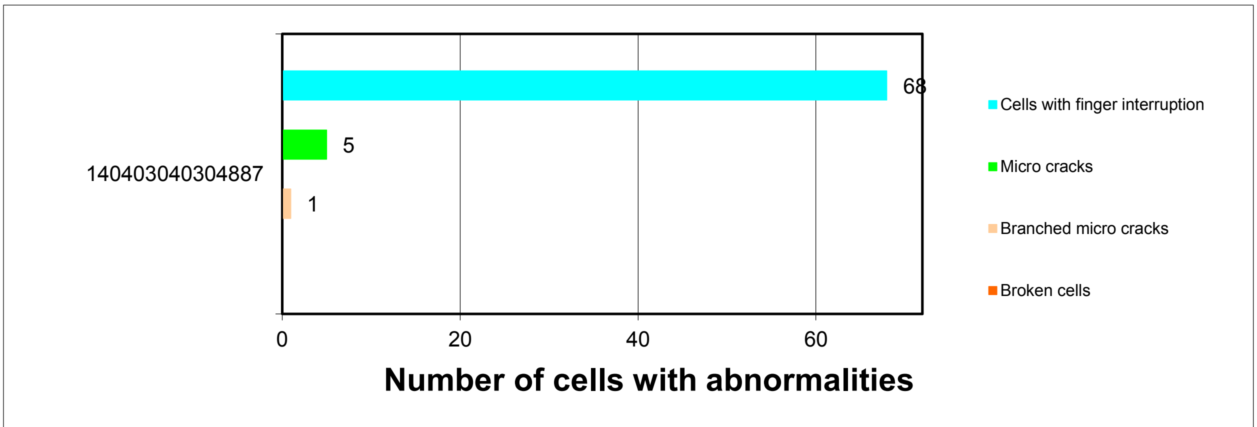


Figure 22: Overview of cell abnormalities of the module: 140403040304887.