Mobile PV-Testcenter

User Guide 2.4

2014/02/28

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1. Preface

The Mobile PV-Testcenter is designed for use in the field at installation sites for an in-depth quality analysis of solar panel. The mobile inspection system is providing Electroluminescence inspection, IV-curve measuring using an innovative LED flasher, and Infrared Imaging. Accuracy of testing and measurement is designed and optimized for the requirements which are needed to qualify PV modules on site.

1.1. Obligation and Liability

1.1.1. Warranty

The scope and timeframe of the warranty is specified in the seller's sale and delivery terms and conditions. In addition, MBJ Services does not assume any liability for damage due to ignorance or non-observance of this user manual.

1.1.2. Copyrights and Trademark Rights

All information used in this user manual, such as images, technical data and drawings are the property of MBJ Services and may not be copied or distributed.

1.1.3. Further Limitations

The system operator is responsible for ensuring that the safety instructions (section 3) are observed, that improper operation is precluded and that proper operation of the system is ensured.

2. Contact Information

MBJ Services GmbH
Merkurring 82
22143 Hamburg
Germany

phone: +49 (0)40 606 870 32
email: info@mbj-services.com
Website: www.mbj-services.com

3. Safety Instruction

Note: Please read the safety instructions before operating the system.

- Operation of the system is only allowed for personnel trained by MBJ Services.

- Warning of dangerous electrical voltage. The module connector can hold a hazardous voltage up to 30 seconds after turning off the main power switch.

- Always use certified, touch-safe PV module connectors. Never operate the system without a connector cable.

- The rear hatch of the trailer may only be opened if the trailer has been stabilized in a horizontal position with the rear supports and the front wheel.

- Never open the rear hatch in high winds or storm!
- The rear hatch must always be backed up after opening with the wind prop!

- In bad weather and rain the control units must be protected from moisture!

- Operate the system only between 0 ° C and 30 ° C ambient temperature (without additional air condition).

- Entering the trailer is only allowed to authorized personnel (trained by MBJ Services) after releasing the safety chain and when the mains plug is disconnected!

- Operation of the system is only allowed with closed side door!

- The presence of persons in the trailer during operation or driving is strictly prohibited!

- Dangerously high optical intensities of radiation!

- Risk of crushing through pneumatic moving components! (LED-doors)

- During longer standstill periods the trailer must be protected from condensation.

- Adding additional load to the trailer is not allowed!

- Check before driving:
  - PV-Module is unloaded
  - LED – doors are closed
  - All trailer hatches are closed
  - The rear supports are lifted and secured
  - IR-Camera is laid down (out of the holder)
  - Check also the trailer safety instructions

4. System Overview

4.1. Proper Use

- Operation of the system is only allowed for personnel trained by MBJ Services.
- Persons who operate the system must have read and understood the user manual and must be familiar with the technical specification and the safety instruction (See section 3).
- Verify that the processes and operation of the system are being performed according to the user manual.
- Observe the safety instruction (See section 3) during operation or maintenance of the machine.
- Use only 230V~/50Hz (16A fused) AC power supply or use a generator which was approved by MBJ Services.

The generator must meet the following criteria:

- Suitable for inductive loads up to 1500 watts (Compressor)
- Suitable for electronic devices (PC)
- Continuous load > 11A, peak load > 13A

MBJ recommends the following device:

Honda EM 30, EU30i or EG3600

Possible damages resulting from an unsuitable generator:

- Voltage collapse can lead to damage of the PC installation
- Electronic devices (power supplies) or the compressor may be damaged

If you have any questions regarding the proper use of the Mobile PV-Testcenter, please contact MBJ Services.

4.2. Technical Specification

See Appendix

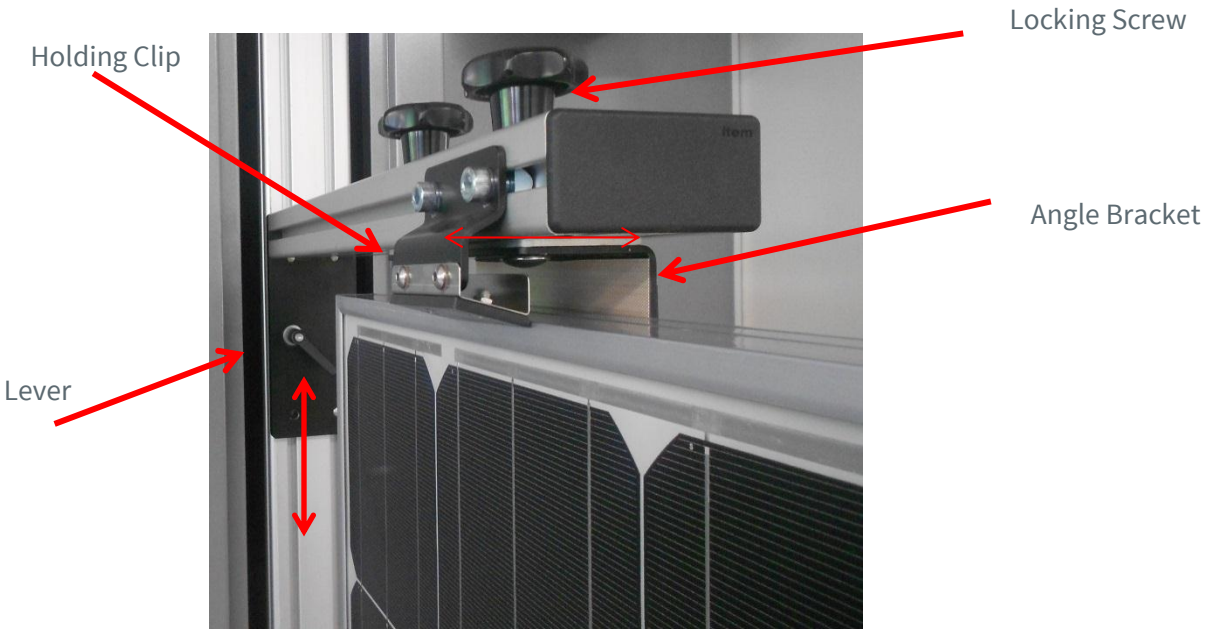
5. Operation

5.1. Turning the Mobile PV-Testcenter on

Before the Mobile PV-Testcenter can be turned on, the trailer must be stabilized in a horizontal position with the rear supports and the front wheel. Open the rear hatch of the trailer, connect the system to a 230V, 50Hz power supply and turn the master switch to power on the inspection system. Then start the PC by pressing the PC Start button and open the Mobile Tester application. Before each measurement, a sample measurement should be performed with a known test module. This test module can be easily fixed in a designated holding device inside the trailer.

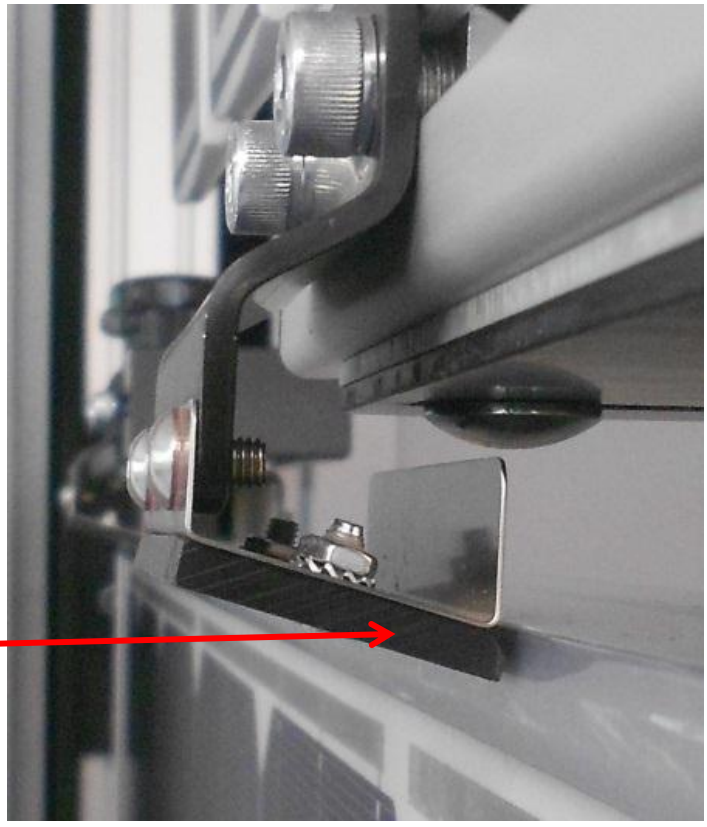
5.2. Adjusting to a Module Size

The support profiles on both sides of the tray must be moved and fixed into the correct position. To adjust the tray to the height of a new solar module type, loosen the black levers, move the support profiles parallel to the tray edge to the target position and tighten down the levers. By loosening the locking screws, the angle brackets can be moved to adjust the tray to the module thickness.

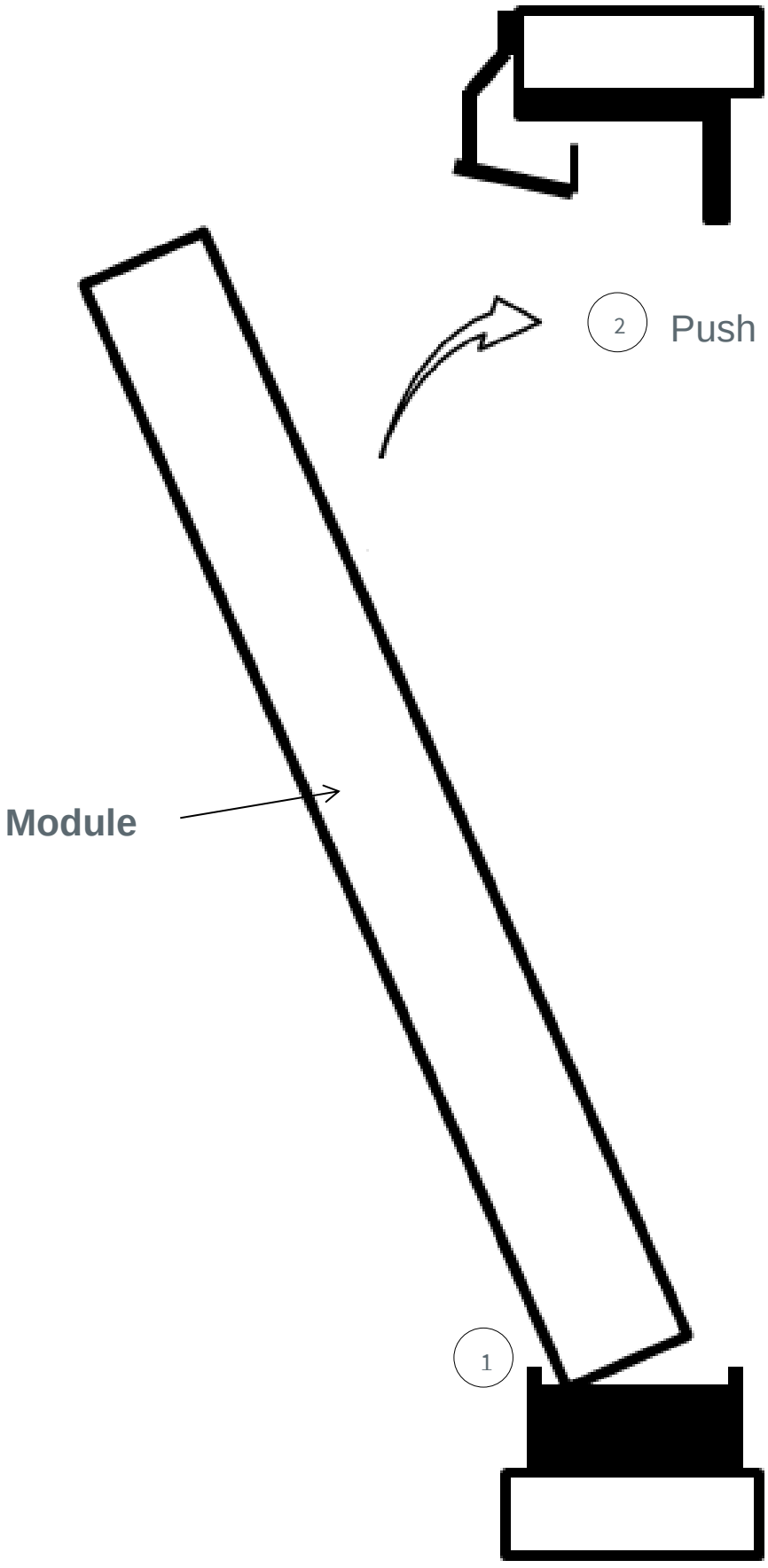


To adjust the tray to frameless Glass-on-Glass modules, loosen the locking screws and rotate the angle brackets by 180°.

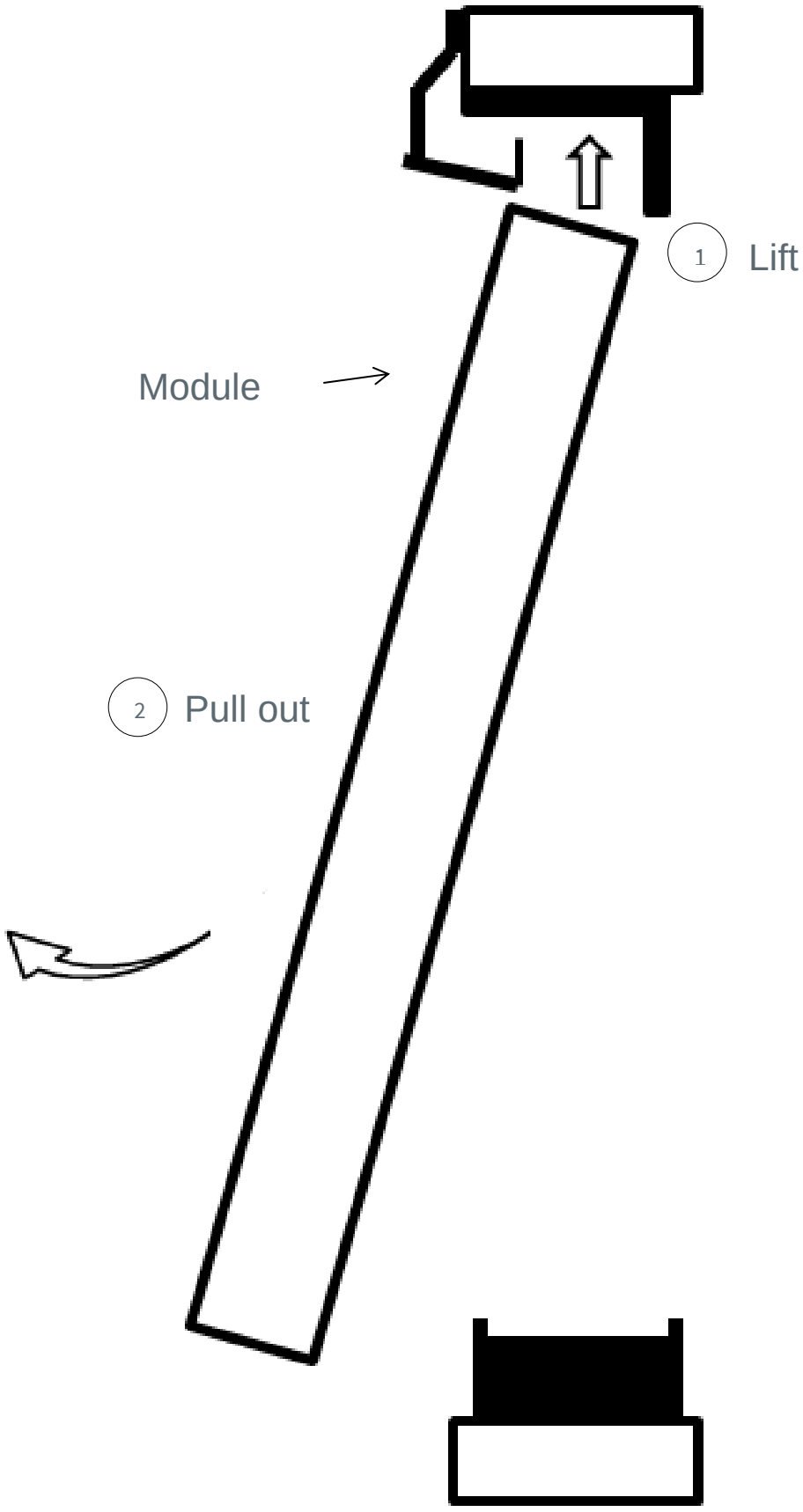
Position the module as shown on the next page. The top edge of the module should be flush with the top edge of the plastic profile of the holding clip.

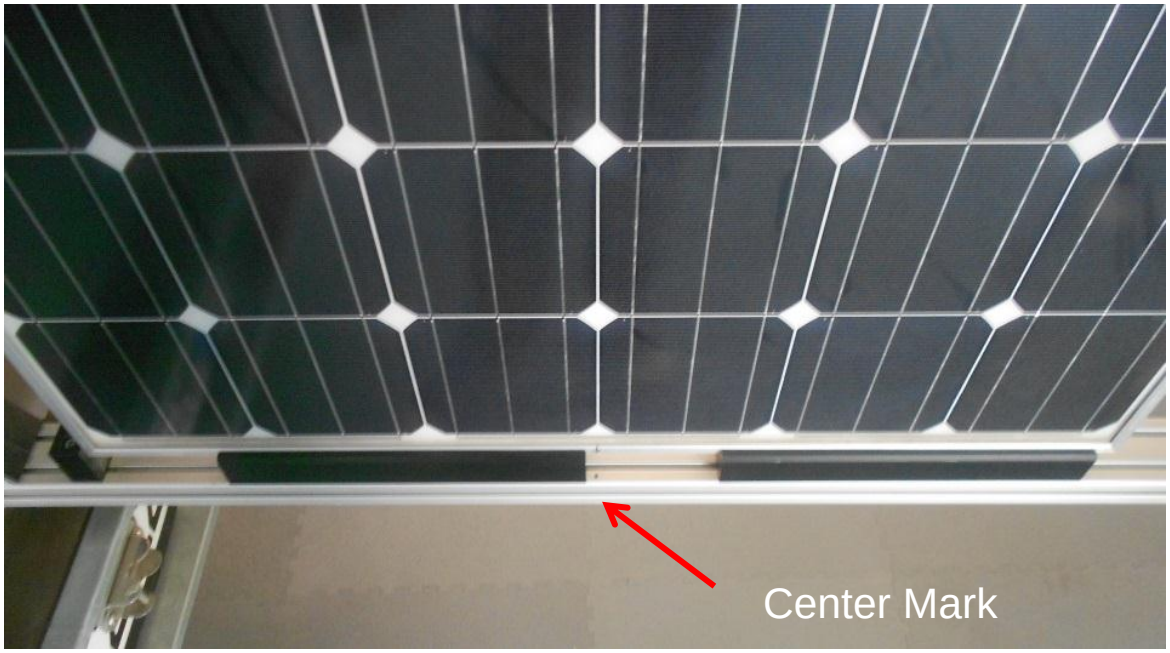


Load module into the tray:

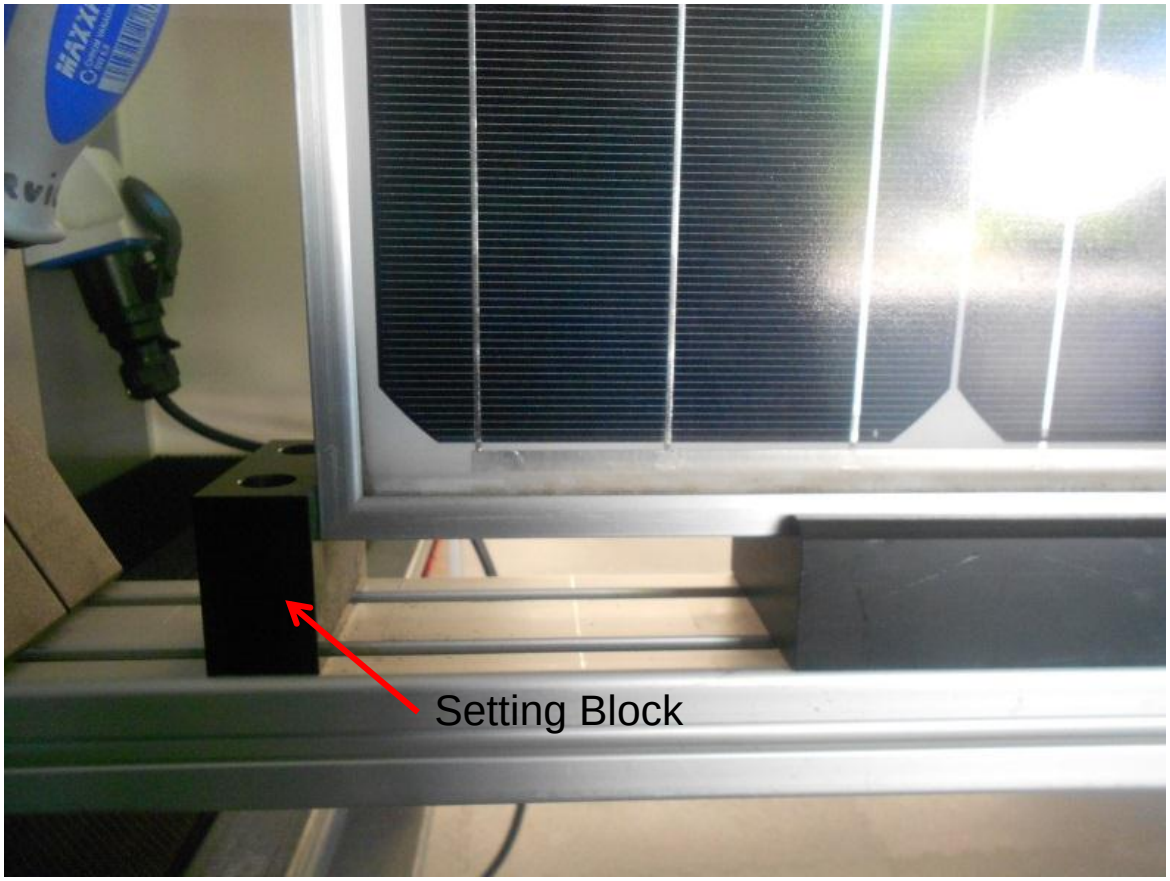


Unload module from the tray:





Position the module so, that its center is on the center mark (hole) of the tray. This position can be fixed with the setting block on the left side of the tray. For this loosen the screws of the setting block, move the block to the target position and tighten down the screws.



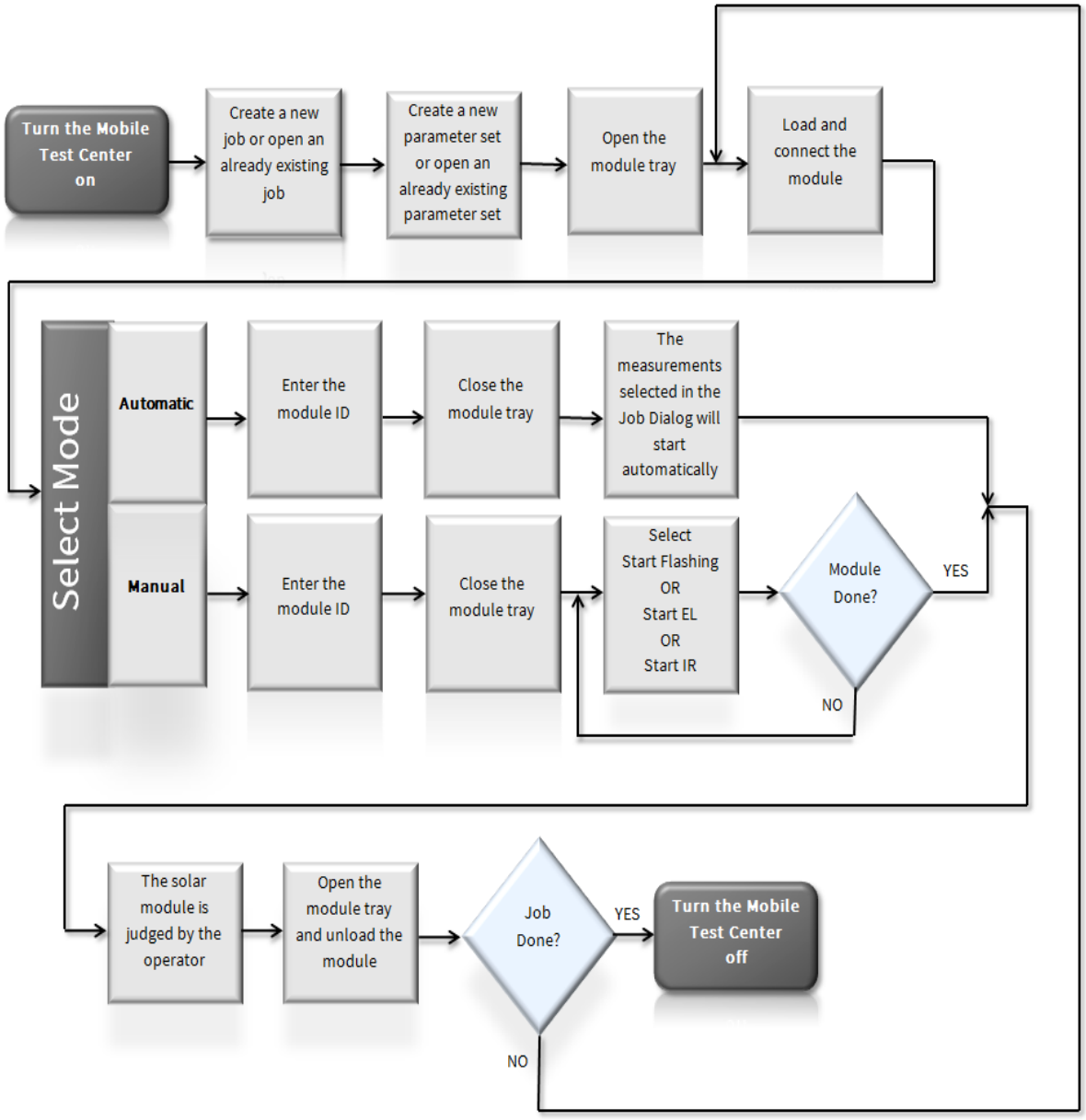
5.3. Inspection process

- ✓ Create a new job or open an already existing job.
- ✓ Create a new parameter set or open an already existing parameter set.
- ✓ Open the module tray.
- ✓ Load and connect a module.
- ✓ Start the measurement by clicking the <Automatic> or the <Manual> button (see section 5.4.1)
- ✓ Enter the module ID
- ✓ Close the module tray. In the manual mode one of the measurements must now be started by pressing the <Start Flashing> button, the <Start EL> button or the <Start IR> button. In the Automatic mode the measurement will start automatically.

  Automatic mode: A new module ID is asked for and the measurements selected in the Job Dialog (see section 5.4.2) are automatically performed when the tray is closed.

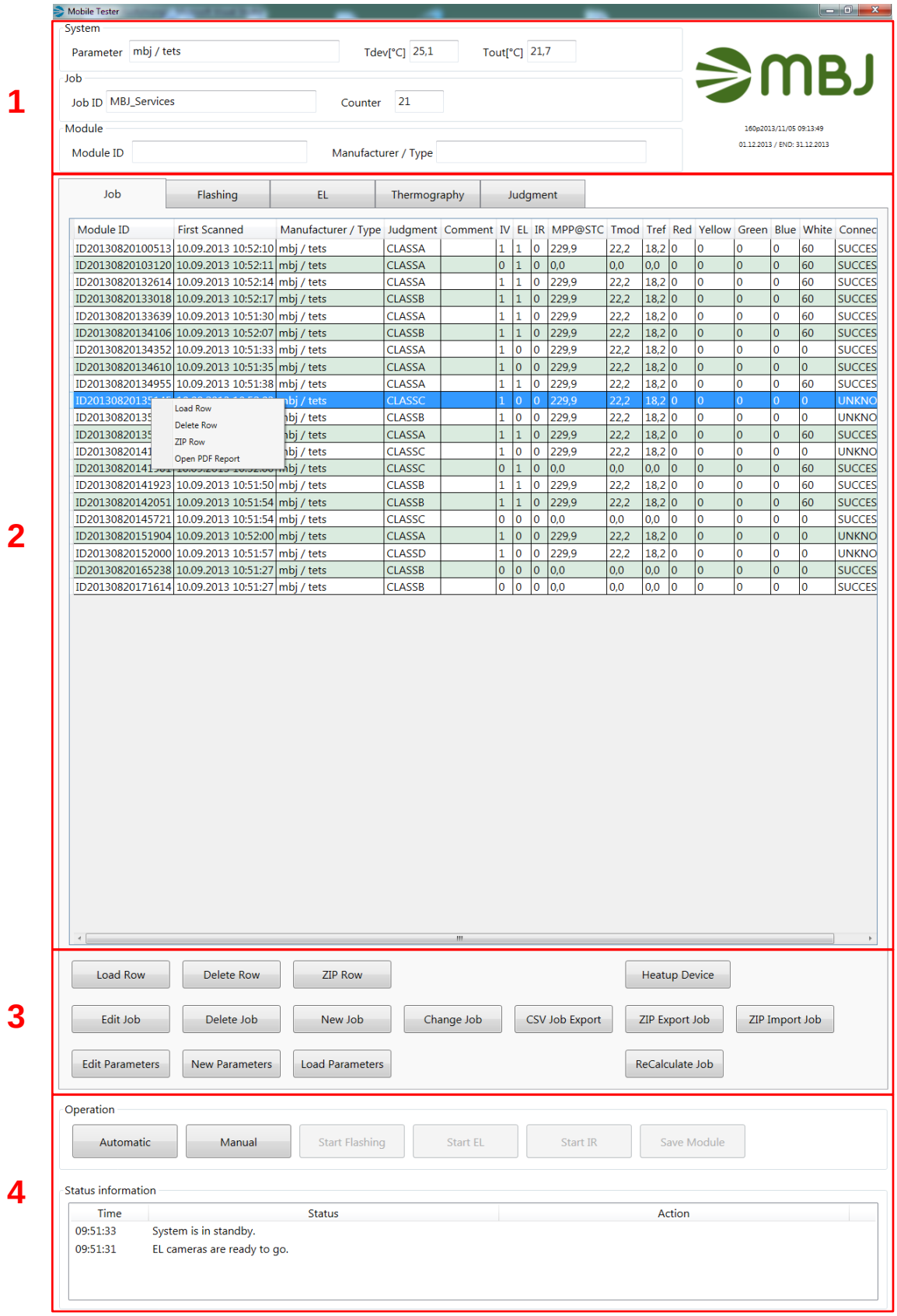
  Manual mode: A new module ID is asked for, but no measurements are automatically triggered.

  Note: Make sure that the safety chain is correctly connected otherwise the LED doors will not move.
- ✓ The PV module is judged by the operator.
- ✓ Open the module tray and unload the module.


Turn the Mobile Test Center on
Create a new job or open an already existing job
Create a new parameter set or open an already existing parameter set
Open the module tray
Load and connect the module
Select Mode
Automatic
Enter the module ID
Close the module tray
The measurements selected in the Job Dialog will start automatically
Manual
Enter the module ID
Close the module tray
Select Start Flashing OR Start EL OR Start IR
Module Done?
YES
NO
The solar module is judged by the operator
Open the module tray and unload the module
Job Done?
YES
Turn the Mobile Test Center off
NO

5.4. Software Interface

5.4.1. Main Window



1 Overview

System:

- **Parameter:** Name of the selected parameter set.
- **Tdev [°C]:** Temperature inside the device. Operate the system only between 5 ° C and 40 ° inside the device.
- **Tout [°C]:** Outside temperature. Operate the system only between 0 ° C and 30 ° C ambient temperature (without additional air condition).

Job:

- **Job ID:** ID of the current job.
- **Counter:** Number of measured modules in a job**.**

Module:

- **Module ID:** Clear allocation of the measurement data to a module. An option is available for reading the module ID using a barcode scanner. If the operator does not enter a module ID, then the software automatically generates a timestamp in this field. Measurements for the same module ID will override itself in the same job.
- **Manufacturer/Type:** Manufacturer name and type of the current module**.**

2 Tab Menu

- **“Job” list view tab**

  This tab shows a list of all measured and saved modules of the current job and various buttons to manage already existing jobs or to create new jobs.

  Load Row: Pressing the <Load Row > button loads the measurement results of the currently selected row. This also can be done by double click on the row or using the right click context menu.

  Delete Row: Deletes the currently selected row. This can be done by pressing the <Delete Row> button or using the right click context menu.

ZIP Row: Saves the currently selected row as a ZIP file. This can be done by pressing the <ZIP file> button or using the right click context menu**.**

Open PDF Report: Opens the PDF Report of the currently selected row. This can be done using the right click context menu.

Heatup Device: Opens a dialog to change the target temperature of the heater inside the device (Temperature must be higher than 5°C). The Heating is only active when dialog is open and switched on.

Note: Make sure that the Heater/Ventilator is not obstructed by any objects

Edit Job: Opens a dialog to edit the current job.

Delete Job: Opens a dialog to delete the current job.

New Job: Opens a dialog to create a new.

Change Job: Opens a dialog to select an already existing job.

CSV Job Export: Saves the current job as a CSV file.

ZIP Export Job: Saves the current job as a ZIP file.

ZIP Import Job: Opens an already existing job from a ZIP file.

Edit Parameters: Opens a dialog to change the parameters (see section 5.4.4.1).

New Parameters: Opens a dialog to create a new parameter set (see section 5.4.4.1).

Load Parameters: Opens a dialog to select an already existing parameter set (see section 5.4.3).

ReCalculate Job: (see section 5.4.9)

- **“Flashing” result tab**

  This tab shows the result of the I-V-curve measurement (see section 5.4.5)

- **“EL” result tab**

  This tab shows the result of the electroluminescence measurement (see section 5.4.6)

- **“Thermography” result tab**

  This tab shows the result of the thermography measurement (see section 5.4.7**)**

- **“Judgment” overview tab**

  This tab shows judgment of the current module (see section 5.4.8)

3 Operation (Buttons)

- **Automatic:** A new module ID is asked for and the measurements are automatically performed when the tray is closed.
- **Manual:** A new module ID is asked for, but no measurements are automatically triggered.
- **Start Flashing:** Starts the IV-curve measuring.
- **Start EL:** Starts the electroluminescence measurement.
- **Start IR:** Starts the Thermography measurement.
- **Save Module:** Saves measurement, triggers report generation.
- **Save & Next:** Saves the currently loaded module and load the next module in this job.

4 Status information

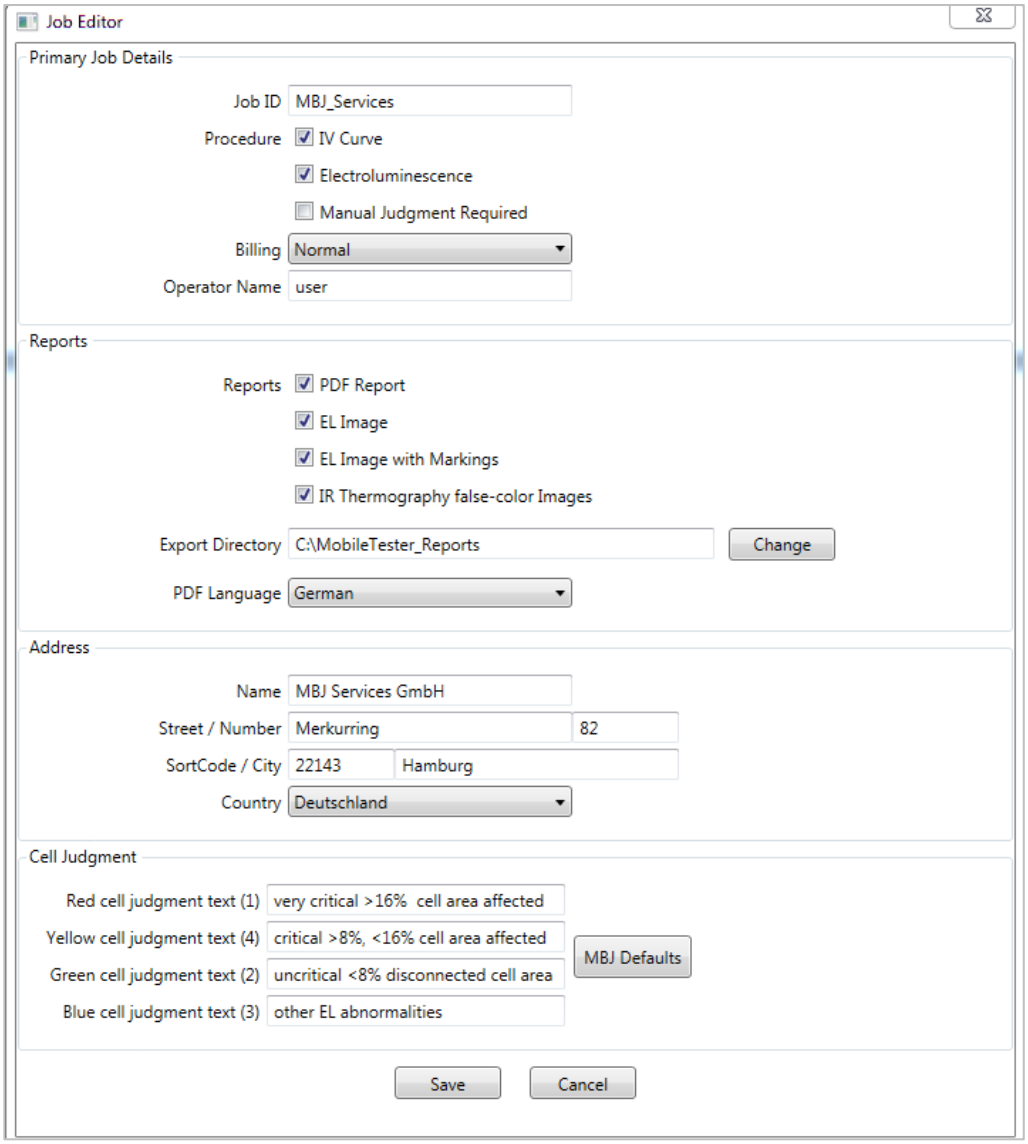
The status information area displays the current status of the machine sorted by timestamp, status and action. Action prompts the user for the next operating step to take. Previous status messages can be displayed using the scroll bar. Errors will be highlighted.

Yellow warnings are important information for measures to be taken in the near future. Please inform MBJ Services in such cases, especially if these warnings are occurring again and again.

Red error messages indicate that a function or functionality or the whole system is not able to work anymore. Please inform MBJ in any case and use the MBJ Sync Tool to create debug information to be attached to an E-Mail with a general written error description. (look at chapter 7 about the MBJ Sync Tool)

5.4.2. Creating a new job

By using the <New Job> button the user opens the Job Editor dialog.



Primary Job Details

- **Job ID:** Name of the job. The name is used as the directory name.
- **Procedures:** Determines the procedure of the measurement at the automatic mode. If no checkboxes are set, the automatic mode is similar to the manual mode.
- **Billing:** Selection between demonstration mode for tests and regular mode.
- **Operator Name**: Name of the operator.

Reports

- **Reports:** Selection of the type of report. Selection options:

- PDF Report
- EL Image
- EL Image with markings
- IR Thermography false-color image

- **Export Directory:** The results file is stored on the hard disk in D:\MobileTester_Reports. This directory can be changed by clicking the <Change > Button.
- PDF Language: Language of the PDF report.

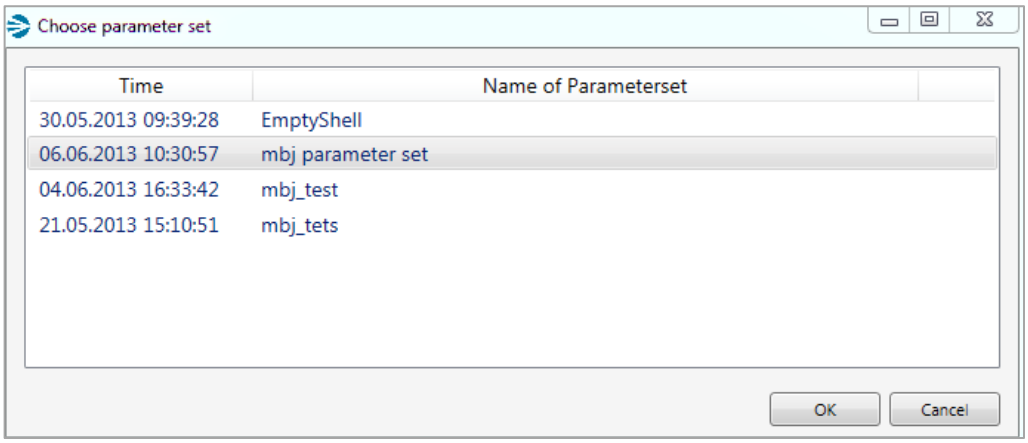
Address

Address of the location where the measurements are carried out.

Cell Judgment

Area to add a description for the cell judgement. By clicking the <MBJ Default> button, the MBJ judgment criterias will be added (see section 5.4.8).

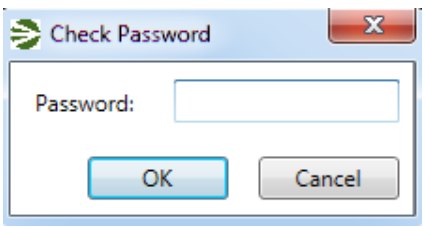
5.4.3. Selecting the Module Type



Before a solar module can be inspected, a parameter set must be chosen for the solar module type to be inspected. By using the <Load Parameters> button the user opens the “Choose parameter set” Dialog to select an already created parameter set.

5.4.4. Setting up a new Module Type

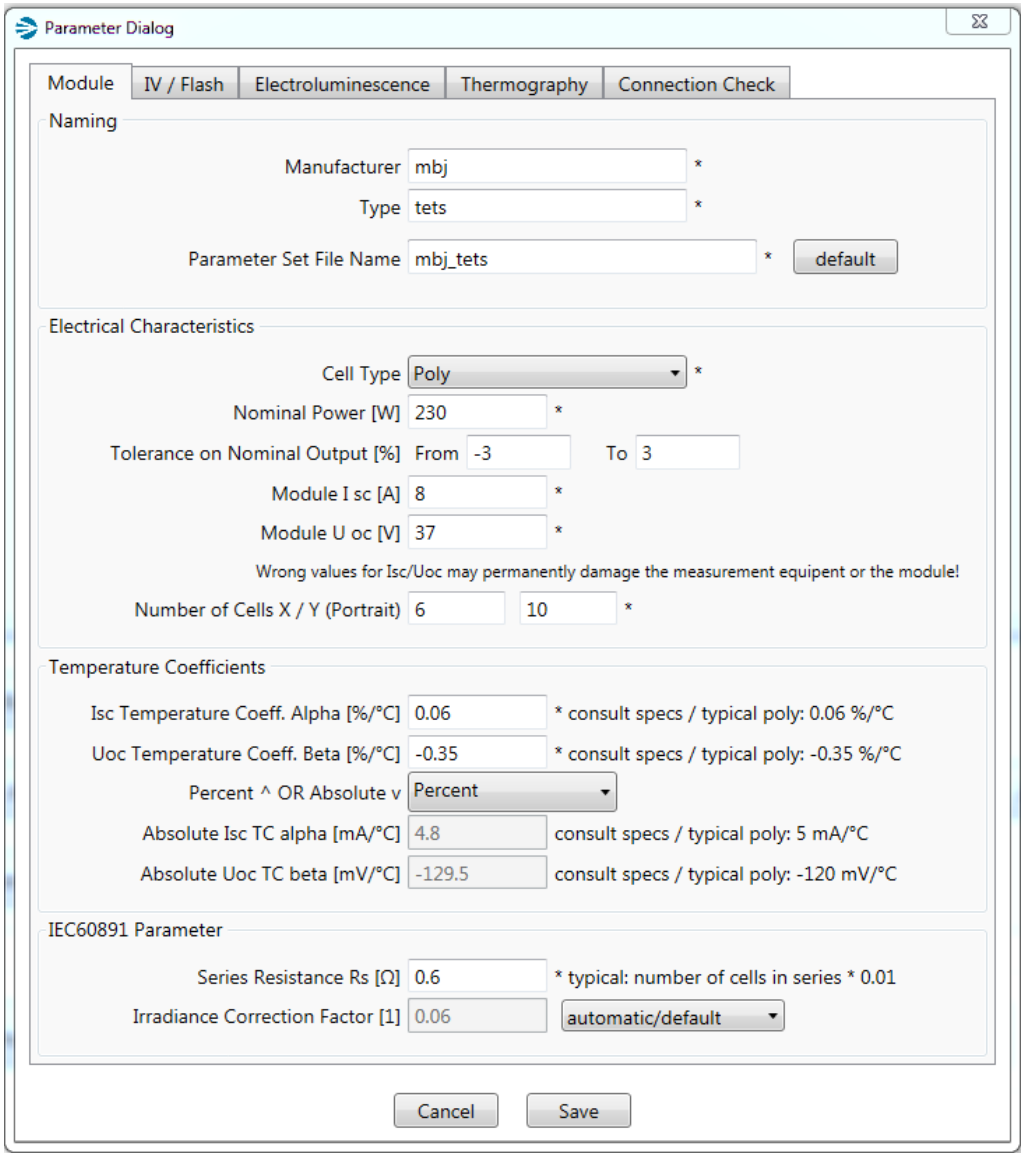
To set up a new module Type, a new parameter set must be created. By using the <New Parameters> button and entering the password assigned by MBJ-Services the user opens the Parameter Dialog.



5.4.5. Parameter dialog

5.4.5.1. “Module” parameters

Information of the solar module being tested can be entered in this form.



Naming

- **Manufacturer:**
  Module Manufacturer name.
- **Type:** Type or product name of the module.
- **Parameter Set File Name:**
  Name of the parameter set. The set file name is a combination of the manufacturer name and the type of the module (Default). The set file name can be changed by the user.

Electrical Characteristics

- **Cell Type:** Cell Type of the current modules. (Mono, Poly, Thinfilm).
- **Nominal Power [W]:** Nominal Power in watts of the current modules.
- **Tolerance on Nominal Output [%]:** Module manufacturers given tolerance on nominal output for this module type. Tolerance from (min) must be less or equal than the to (max) value.
- **Module Isc [A]:** Short cut current in Amps of the current modules.
- **Module Uoc [V]:** Open collector voltage of the current modules.

Note: Wrong values for Isc/Uoc may permanently damage the measurement equipment or the module!

- **Number of Cells X/Y (Portrait):** Number of cells along the short and the long side of the module.

Temperature Coefficients

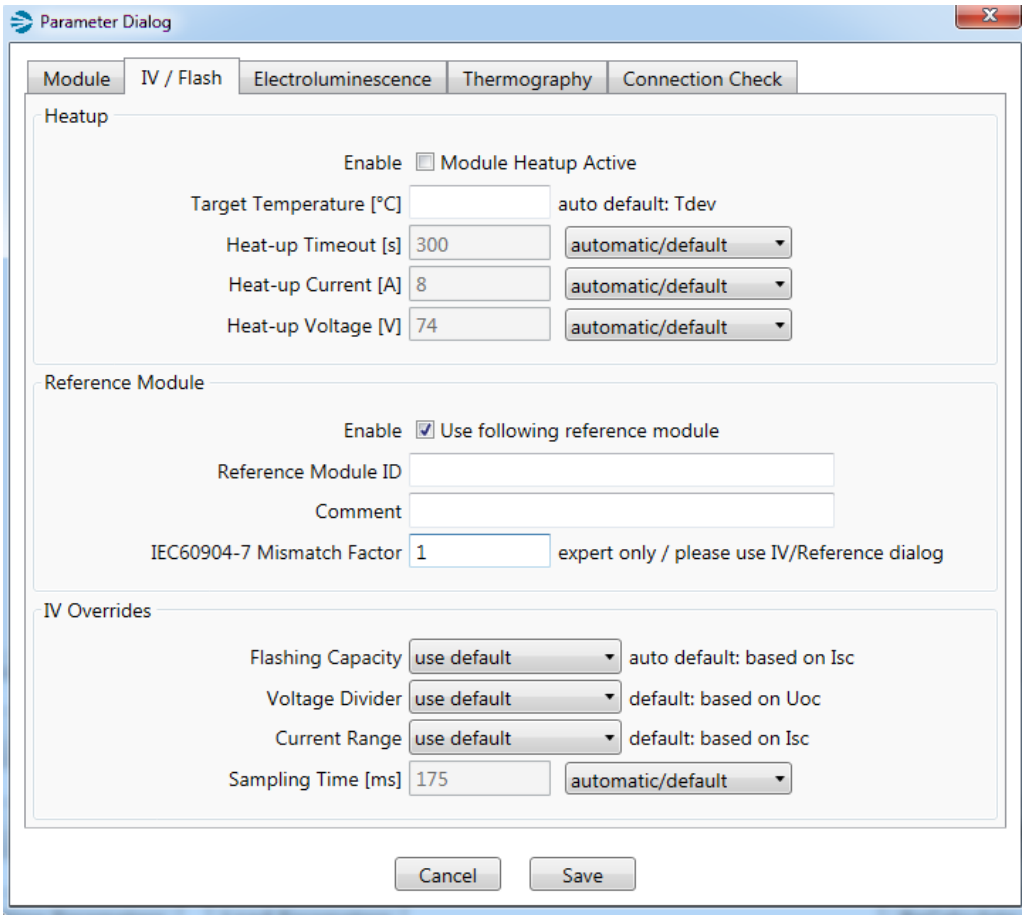
- **Isc Temperature Coeff. Alpha [%/°C)]:** Short cut current temperature coefficient in %/°C. Consult the specification of the module. Typical poly: 0.06%/°C.
- **Uoc Temperature Coeff. Beta [%/°C]:** Open collector voltage temperature coefficient in %/°C. Consult the specification of the module. Typical poly: -0.35%/°C.
- **Absolute Isc TC alpha [mA/°C]:** Short cut current absolute temperature coefficient in mA/°C. Consult the specification of the module. Typical poly: 5mA/°C.
- **Absolute Uoc TC beta [mA/°C]:** Open collector voltage absolute temperature coefficient in mA/°C. Consult the specification of the module. Typical poly: -120mA/°C.

IEC60891 Parameter

- **Series Resistance Rs [Ω]:** Is the internal series resistance of the module. Typical: number of cells in series * 0.01.
- **Irradiance Correction Factor:** Correction of irradiance and temperature to STC conditions is according to IEC 60891 Procedure 2. A typical value for the irradiance correction factor is 0.06.

5.4.5.2. “IV / Flash” parameters

Parameters for the IV-curve measurement can be entered in this form.



Heatup

- **Module Heatup Active:** This check box activates the module heatup process.
- **Target Temperature:** Requested target temperature for heat-up. This temperature might not be reached because the maximum heat-up temperature is limited to Tdev and the heat-up timeout.
- **Heat-up Timeout [s]:** This is the heating time of the module.
- **Heat-up Current [A]:** This is the applied current in amps which flows during the heatup process.
- **Heat-up Voltage [V]:** This is the applied voltage which is applied during the heatup process.

Reference Module

- **Use following reference module:** Checkbox to use a reference module with verified MPP at standard test conditions.

- **Reference Module ID:** ID of the reference module. Referencing to a reference module of the same type can be done prior to the measurement or afterwards at the ReCalculateJob Dialog.

- **Comment:** Option to enter comments regarding the reference module, like Test Report ID from former measurement at test lab.

- **IEC60904-7 Mismatch Factor :** Correction factor calculated by the software on the given values.

IV Overrides

- **Flashing Capacity:** C940 is the smallest capacity C13640 the highest. The capacity to be selected is proportional to the expected current of the module. A high power requires a high capacity.

- **Voltage Divider:** Range of the voltage mesasurement.
  - use default: auto default based on Uoc.
  - HIGH Uoc: 0-100V
  - LOW Uoc: 0-200V

- **Current Range:** Range of the current mesasurement.
  - Use default: auto default based on Isc
  - HIGH Isc:
  - LOW Isc: 0-10[a]

- **Sampling Time [ms]:** Flash pulse duration Long pulse, 175ms at full irradiance.

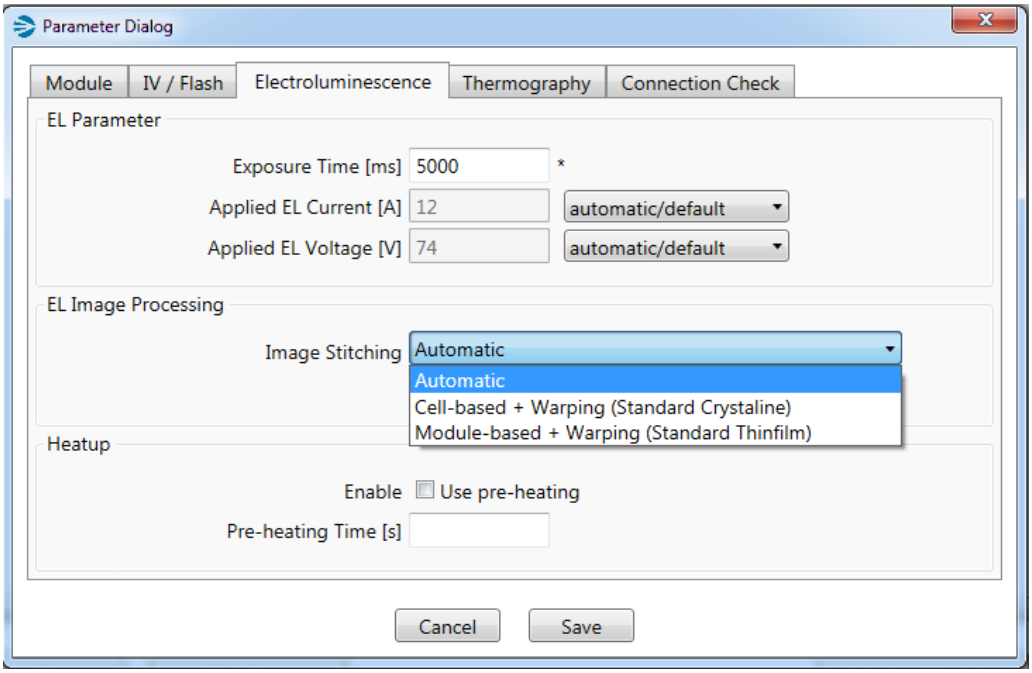
  Note: If you are not sure about the settings, please leave the default settings.

5.4.5.3. “Electroluminescence” parameters

The tab Electroluminescence in the Parameter dialog is used to specify the electrical values for the power supply feeding the module during inspection. It also allows setting the exposure times of the cameras.

The amperage affects the amount of light radiated by the solar cells directly. Higher amperage directly relates to a larger amount of radiated light. The larger amount of radiated light allows a shorter exposure time for the cameras.

Note: First just vary the exposure time and leave the current and voltage on default! If no image quality improvement occurs, vary the current and the voltage.



EL Parameter

- **Exposure time in ms**: The exposure time determines the duration of an inspection cycle. The higher the selected exposure time, the longer an inspection cycle takes.
  Default value: 5000ms
  Maximal value: 30 000ms

- **Applied EL Current [A]:** This is the applied current in amps which flows during the inspection.

- **Applied EL Voltage [V]:** This is the applied voltage which is applied during the inspection.
  Note: This value must be at least as high as the open-circuit voltage of the solar module being tested, or no current will flow.

EL Image Processing

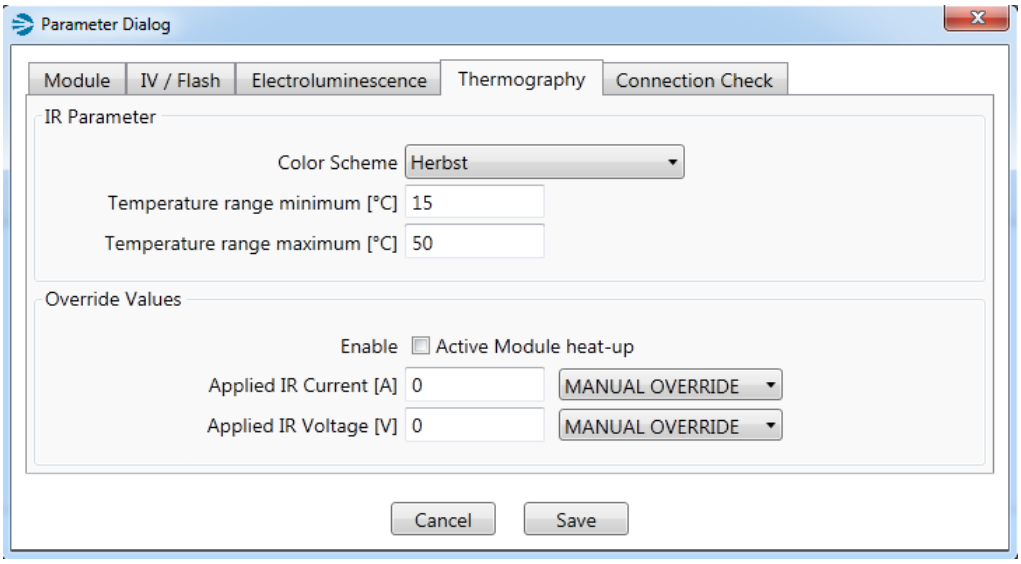
- **Image Stitching:**
  - **Automatic:** Image stitching depending on the cell type (crystalline or thinfilm) currently selected in the module parameter settings (see section 5.4.5.1). Use this as default.
  - **Cell-based + Warping(Standard Crystalline):** Cell based image stitching used for crystalline modules (see section 5.4.7.1).
  - **Module-based + Warping (Standard Thinfilm):** Module based image stitching used for thinfilm. In rare cases it can happen that indivitual crystalline cells can not be covered completely by the cameras. In this case it is possible to use the module based image stitching modules (see section 5.4.7.2).

Heatup

- **Use Pre Heating:** This check box activates the pre heating process for thin film modules, which simulates the light soaking effect.
- **Pre Heating Time [s]:** This is the time for the pre heating process in seconds

5.4.5.4. "Thermography" parameters

Parameters for the thermal imaging can be entered in this form.



IR Parameter

- **Color Scheme:** Color Scheme to display the thermal variations.
- **Temperature range minimum [°C]:** Minimum temprature for the visualisation .

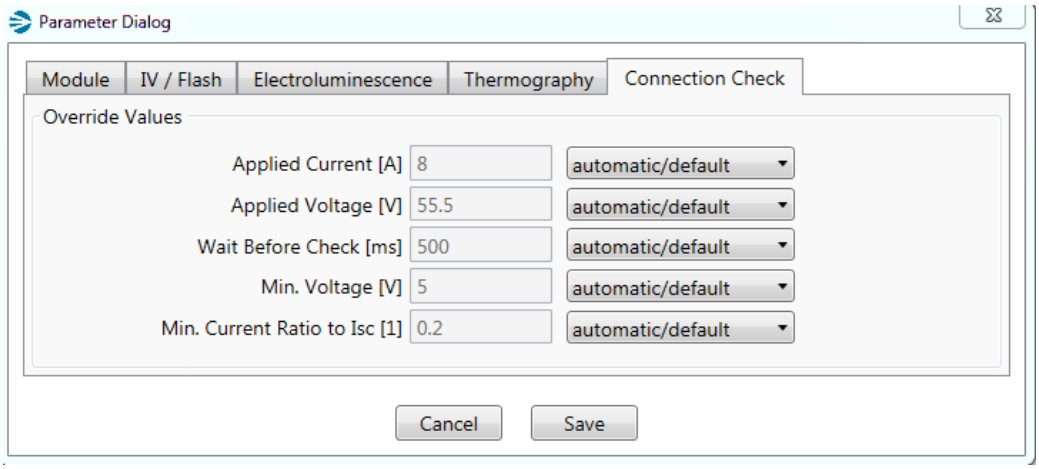
- **Temperature range maximum [°C]:** maximum temperature for the visualisation

Override Values

- **Activate Module heat-up:** This check box activates the module heat-up process.
- **Applied IR Current [A]:** This is the applied current in amps which flows during the inspection.
- **Applied IR Voltage [V]:** This is the applied voltage which is applied during the inspection.

5.4.5.5. "Connection Check" parameters

The settings in this dialog can be left at default except the open collector voltage of the module is higher than 120V



Override Values

Applied Current [A]: This is the applied current in amps which flows during the connection check. Corresponds to the short cut current of the module.

Applied Voltage [V]: This is the applied voltage which is applied during the connection check. Corresponds to the open collector voltage multiplied by the factor 1.5. In the default setting, the voltage is limited to 120V. In modules with an open collector voltage over 120V, the voltage must be entered manually.

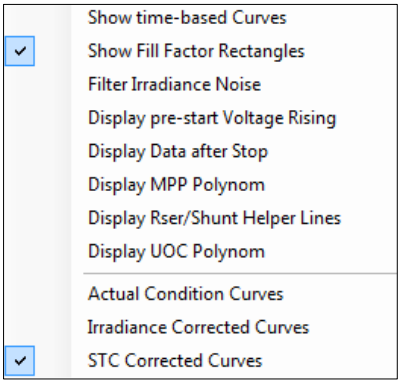
Wait Before Check [ms]: Time until the connection check starts.

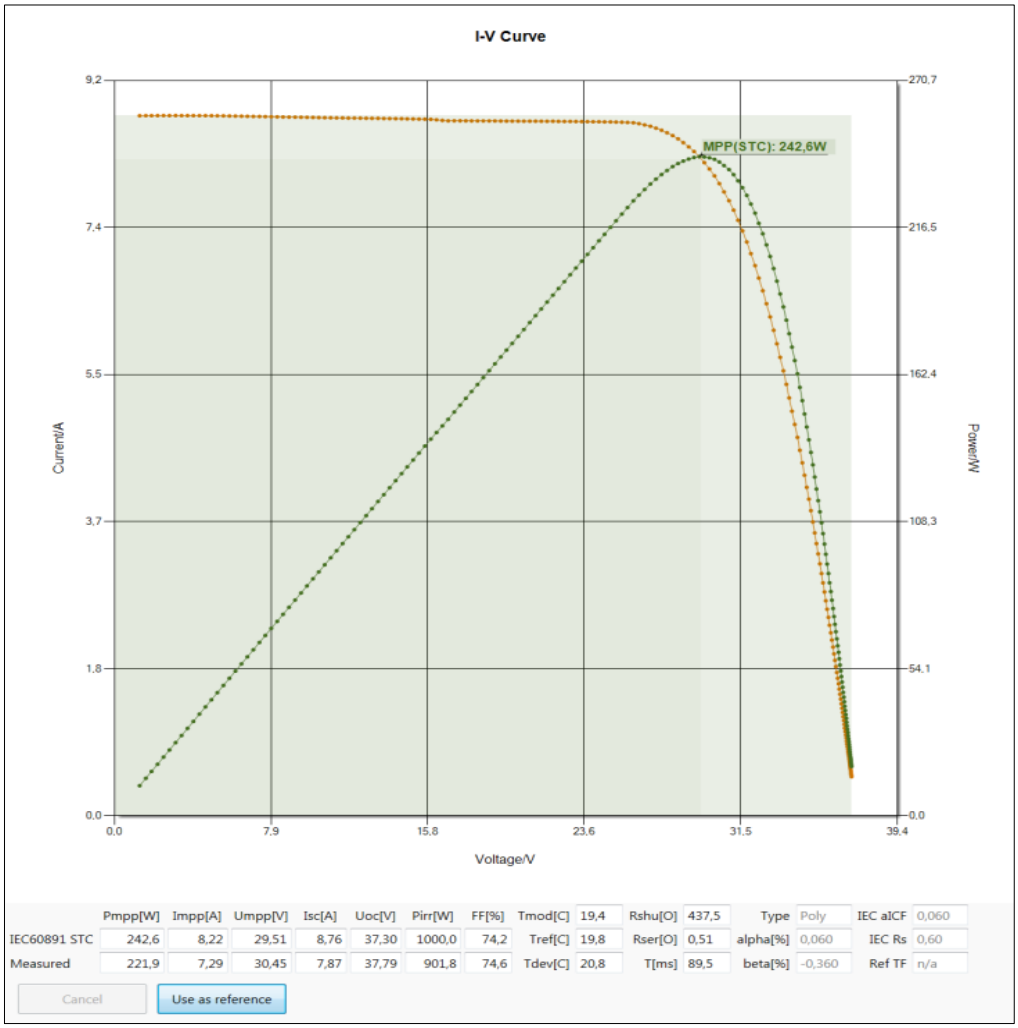
Min. Voltage [V]: Minimum voltage that must be measured to ensure that the connection check was successful.

Min. Current Ratio to Isc [1]: Ratio of the short cut current that must be measured to ensure that the connection check was successful.

5.4.6. “I-V Curve” measurement result tab

After the flashing measurement has been performed, the I-V curve is displayed immediately. By a right mouse button click, the user has the possibility to choose between different graph representations.

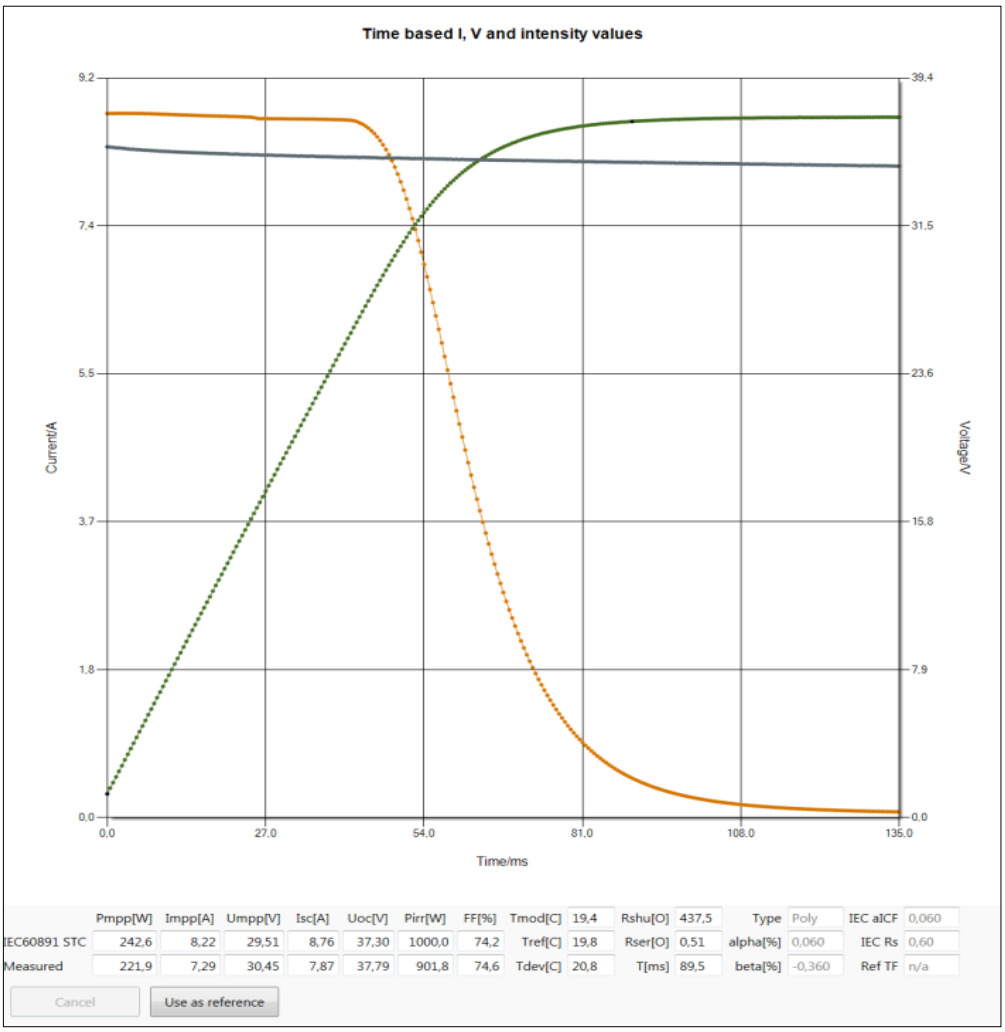




I-V curve ; power

You can change some settings for the displayed time span, you can turn on some options to see the underlaying calculation beeing performed (polynominal calculation).

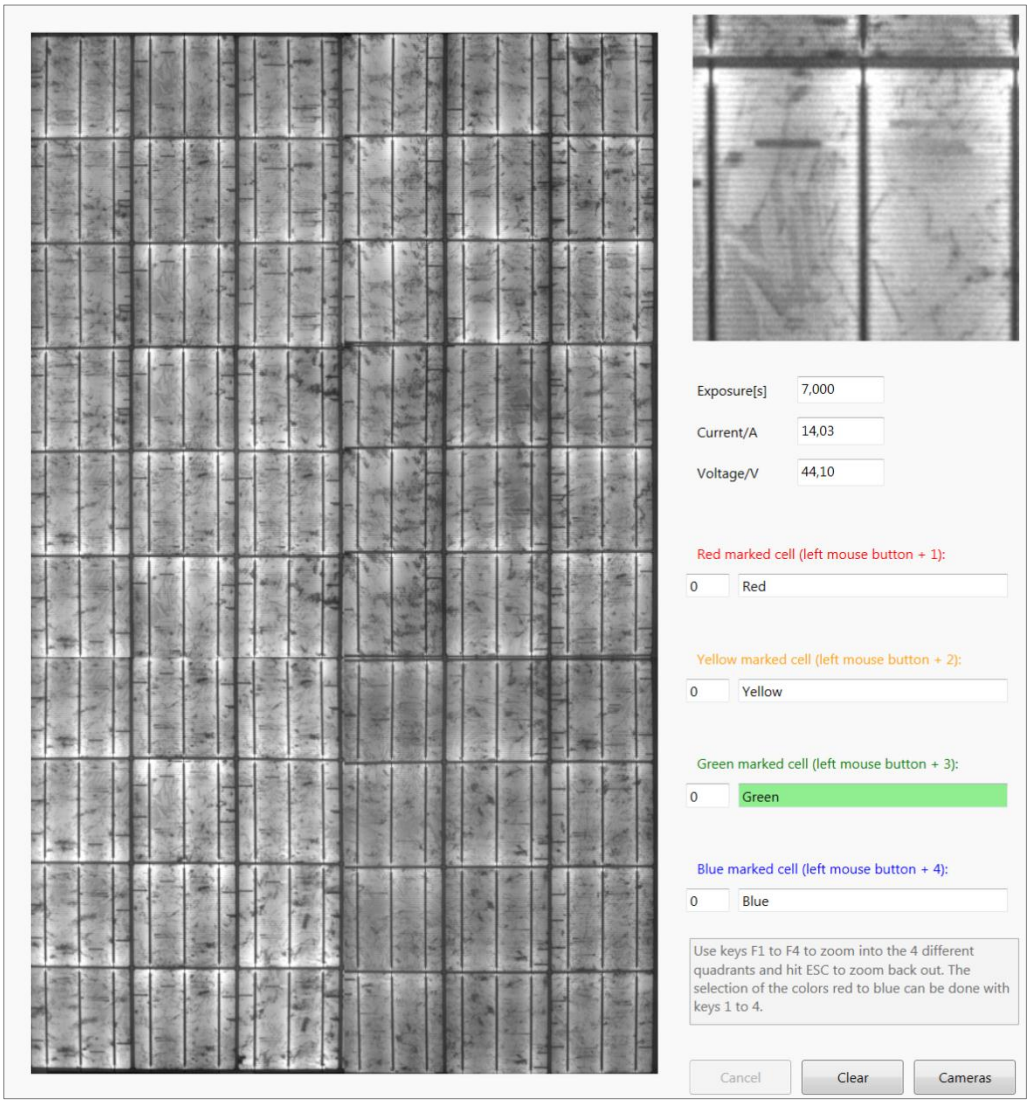
Below you see the time based curve, which is active when the first option is activated (“Show time-based Curves”) This is also the default view, if there are problems to detect the IV-Curve itself within the sampled data.



current ; voltage ; intensity

In generals, to zoom, click and hold the left mouse button and drag the cursor over the area of interest.

5.4.7. “EL” result tab / Electroluminescence Inspection

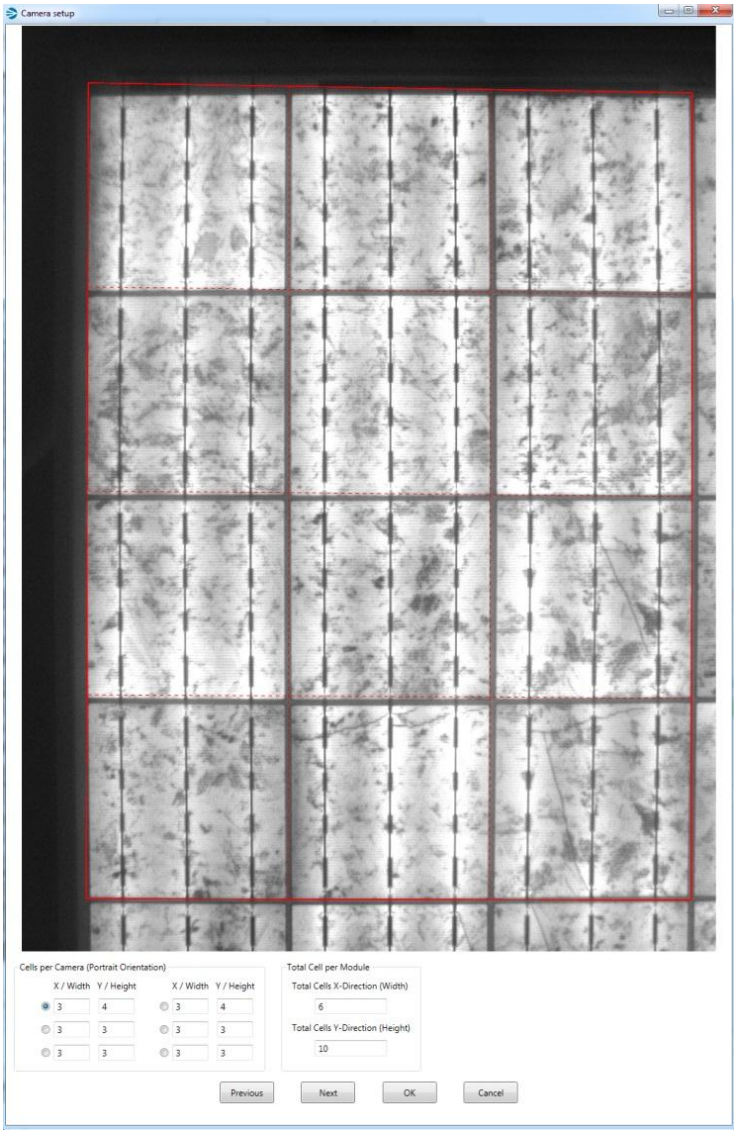


The captured electroluminescence images is shown as one image in the software. The operator can navigate through the image using the arrow keys To zoom into the 4 different quadrants, the operator can use the keys F1 to F4. To zoom back out hit ESC. By pressing and holding the right mouse button, the zoomed image can be moved around. Zooming is also possible using the mouse scroll wheel of an external mouse. The zoom is centered on the mouse location in the image.

To mark the cell for evaluation, click with the left mouse button on the cell of interest. The selection of colors red to blue can be done with the keys 1 to 4.

5.4.7.1. Camera setup / cell based

By using the <Cameras> button the user opens the Camera setup dialog.



Cell-based (Crystalline Cells):

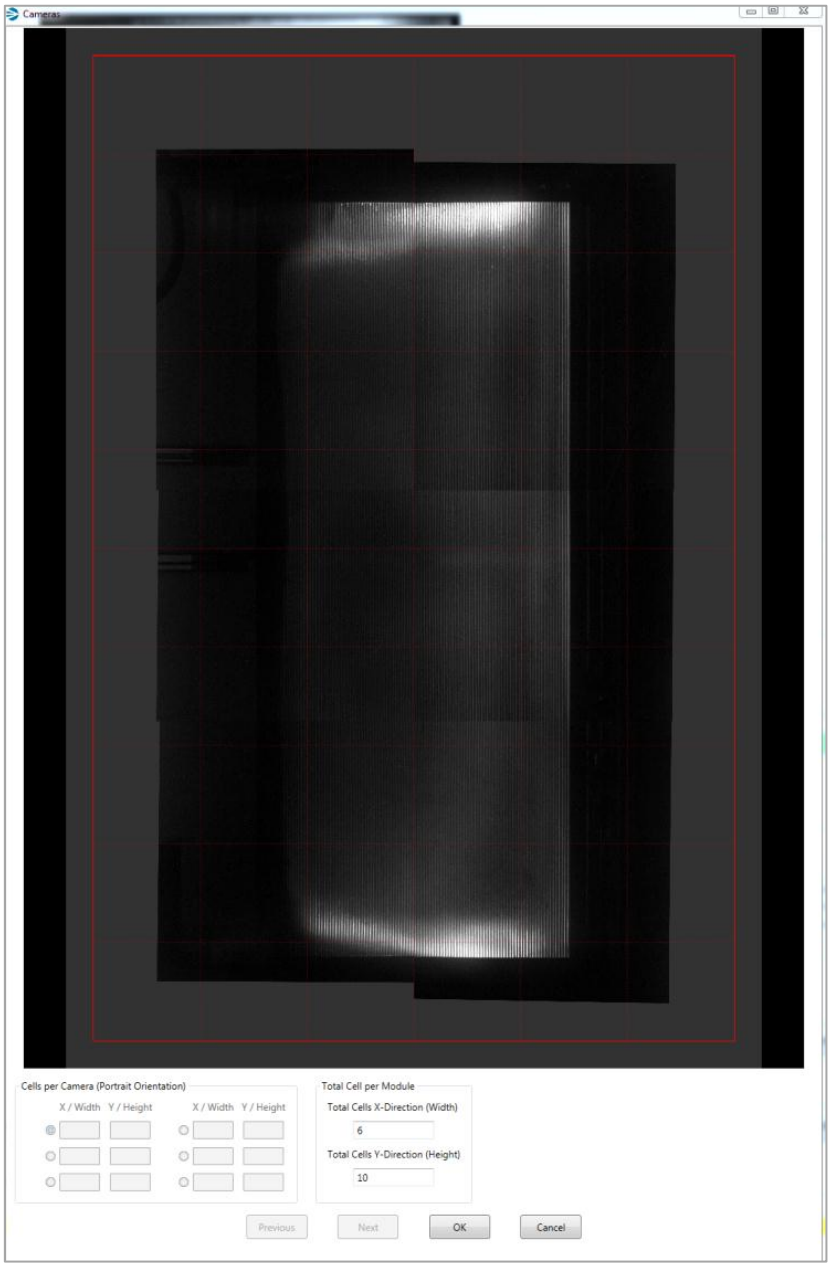
In this dialog, the raw images of each of the six cameras are displayed and can be reached using the <Next> and <Previous> button.

As a first step, the number of cells in X and Y direction for the shown camera must be specified. A red grid is spanned based on the number of cells, which is necessary for a correct display of the cell matrix in the software. In the second step the four corners of the red grid must be drawn on the corresponding corners of the cells by pressing and holding the left mouse button.

Note: Camera Setup works only if password of the Parameter Dialog is entered (see section 5.4.4).

5.4.7.2. Camera setup / module based (Thinfilm)

In this case a composite image of the single images of the six cameras is displayed. A red grid is spanned based on the module. The four corners of the red grid must be drawn on the corresponding corners of the module pressing and holding the left mouse button.



The geometry setup can be saved under the current parameter set using the <OK> button.

This kind of setup is also as option available for crystalline cells.(see section 5.4.7.1)

Note: Camera Setup works only if password of the Parameter Dialog is entered (see section 5.4.4).

5.4.7.3. Electroluminescence cell evaluation / pv-module judgment

Since the test in the Mobile PV Testcenter is carried out with regard to the module's output in future, we initially regard active and inactive cell breaks as being identical. However, active cell breaks often lead to a reduction in power at the time of the test; these are then quantified by the separate power test in the flasher.

Cell breaks are classified into three categories:

- **Uncritical : <8% affected* cell area**
- **Critical : >8%, <16% cell area affected***
- **Very critical : >16% cell area affected***

*to understand how to calculate the affected cell area see appendix “MBJ PV-Module Judgment Criteria”

Based on the result of electroluminescence, power measurement and thermal imaging, the overall module judgment will be done:

Class 1 / A
Best classification, none or hardly any negative findings

Class 2 / B
Only a few negative properties that should lie within the expected degradation

Class 3 / C
Increased negative properties that may lead to a premature drop in power

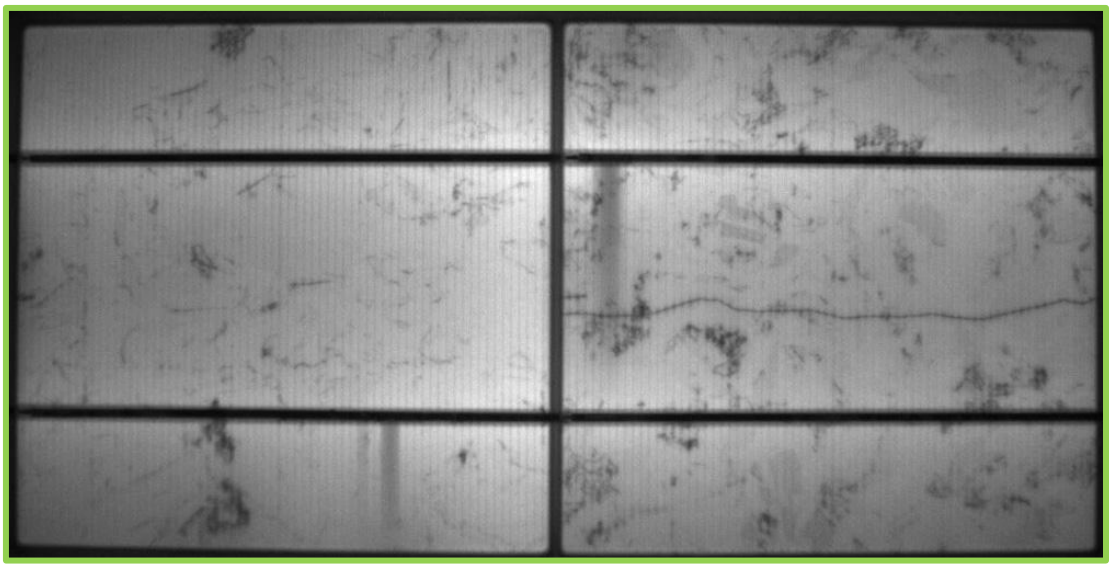
Class 4 / D
Obvious properties that already indicate a lower module output in the power test

For further information on how in detail this should be performed see appendix “MBJ PV-Module Judgment Criteria”.

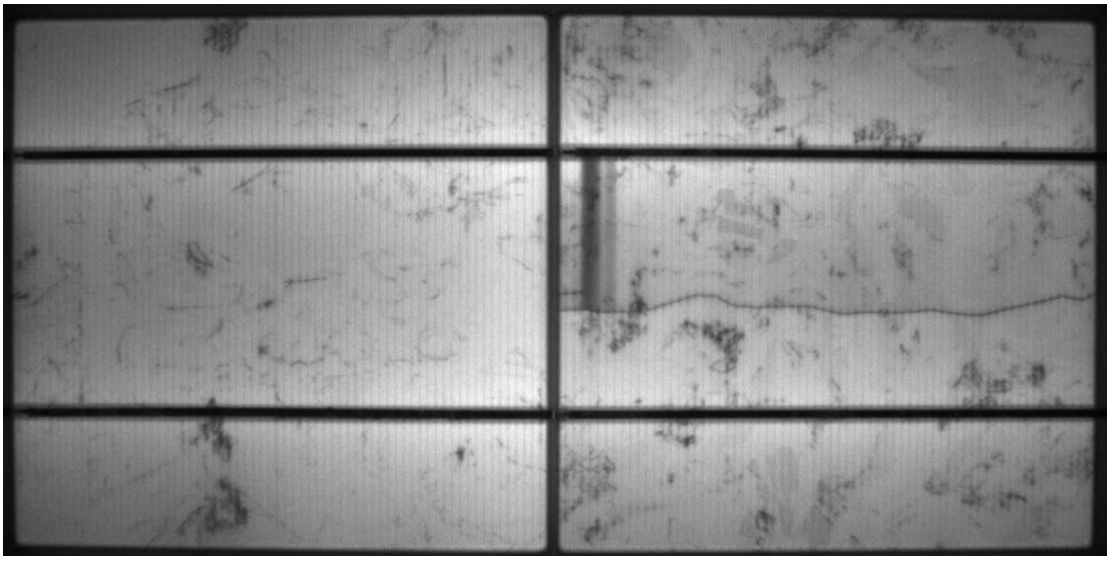
5.4.7.4. Accelerated degradation of cell through cracks and cell breaks

On the next pages you see some examples of how cell breaks can influence the degradtion of pv modules. Especially the thermo cycles from day to night and during the winter season are helping cracks to become cell breaks, seperating cell areas from the active / connected cell area.

Example for non-critical cell break



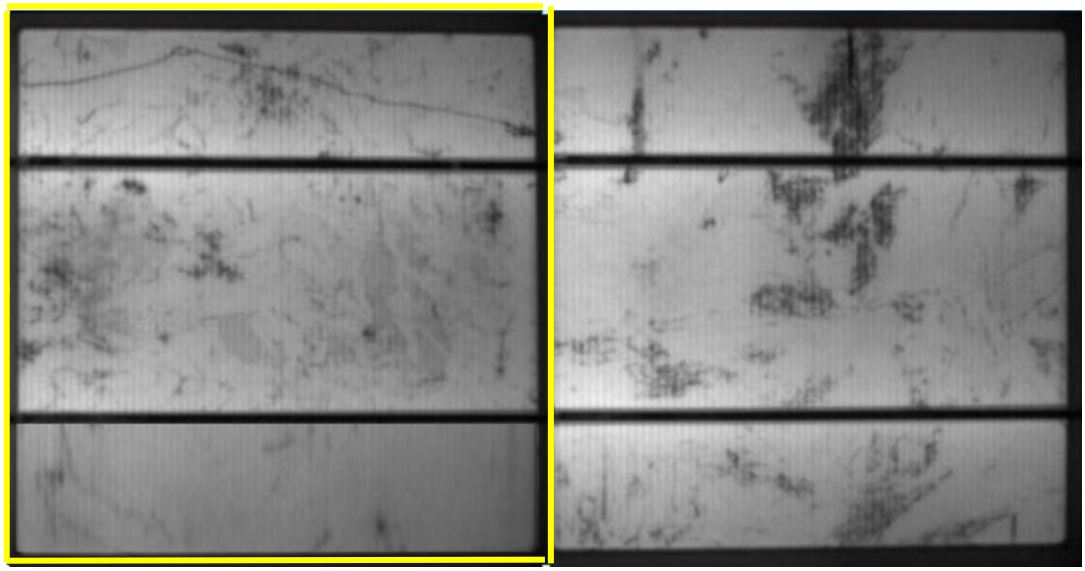
Non critical micro crack parallel between two bus bars (before aging)



Non critical micro crack parallel between two bus bars (after aging)

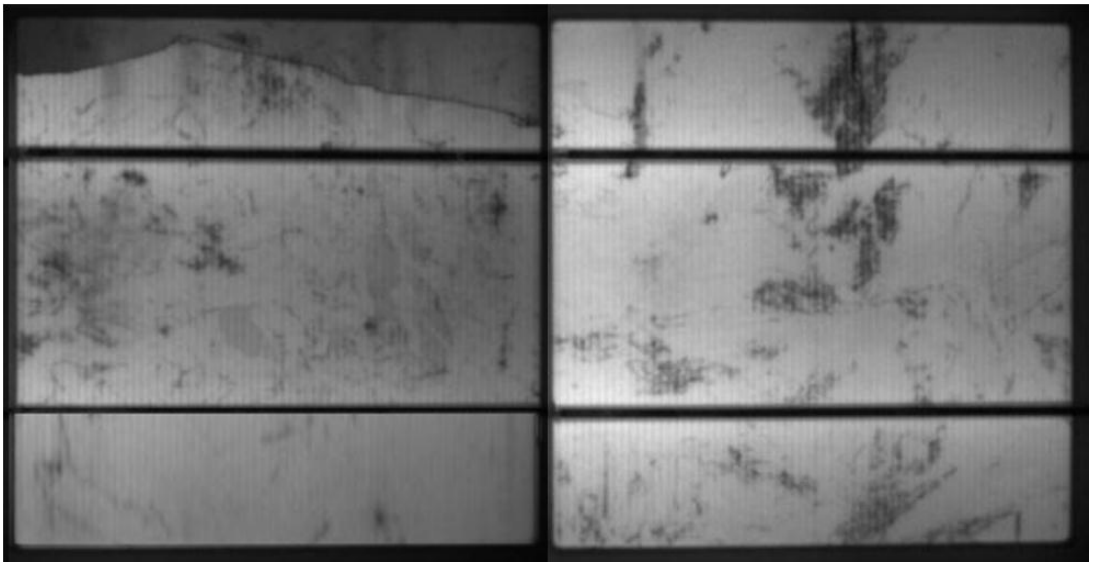
Example for critical cell break

All cell areas that can potentially disconnect the power supply (>8%, <16% disconnected cell area), or which already do so, should be classified 'conspicuous' or yellow.



Critical micro crack (before aging)

The cell on the left has a cell break between the bus bar and the cell edge. This break can potentially reduce the active area of the cell more than approx. 8%, so that they are classified as yellow



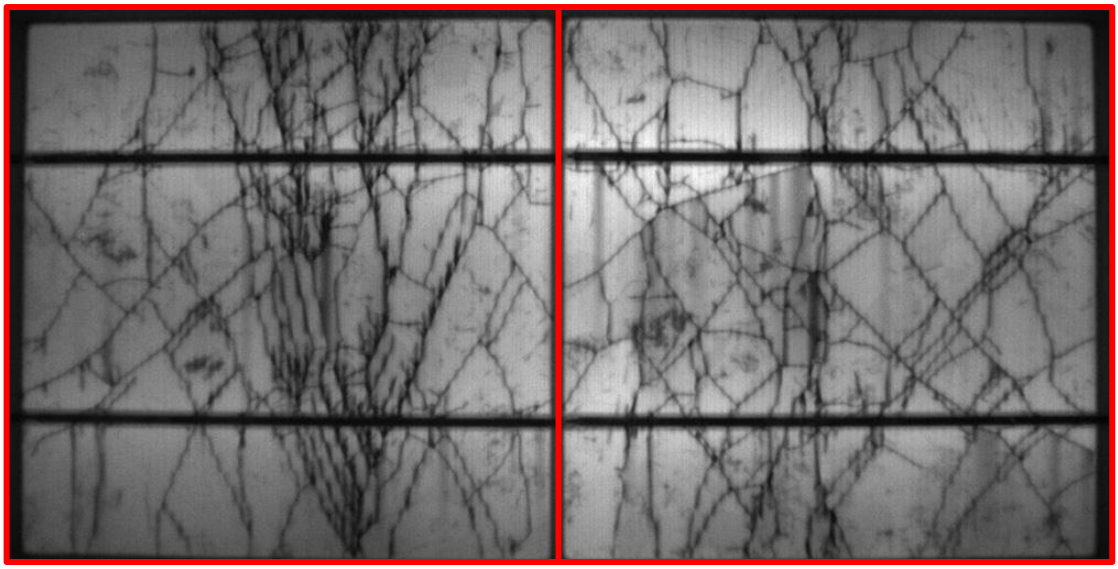
Critical micro crack (after aging)

Example for very critical cell breaks

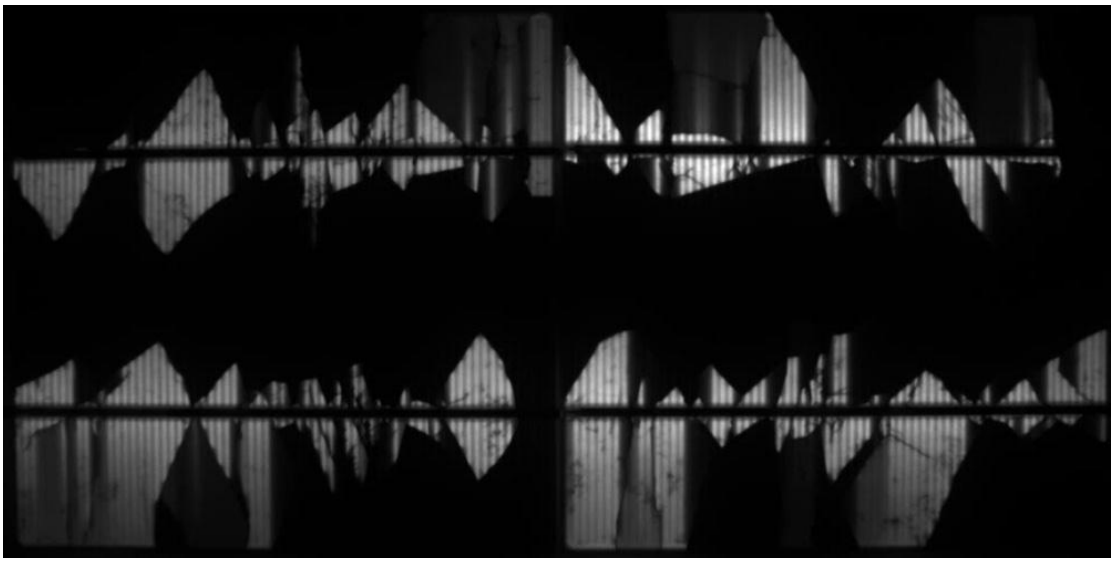
Cell breaks that can potentially disconnect more than approx. 16% of the cell area from the power supply are classified in the 'critical' category and marked red.

This category includes above all comminuted or fan-like breaks. Red cells lead directly to the classification of a PV module in the class 3/C.

(See appendix: MBJ PV-Module Judgment Criteria).



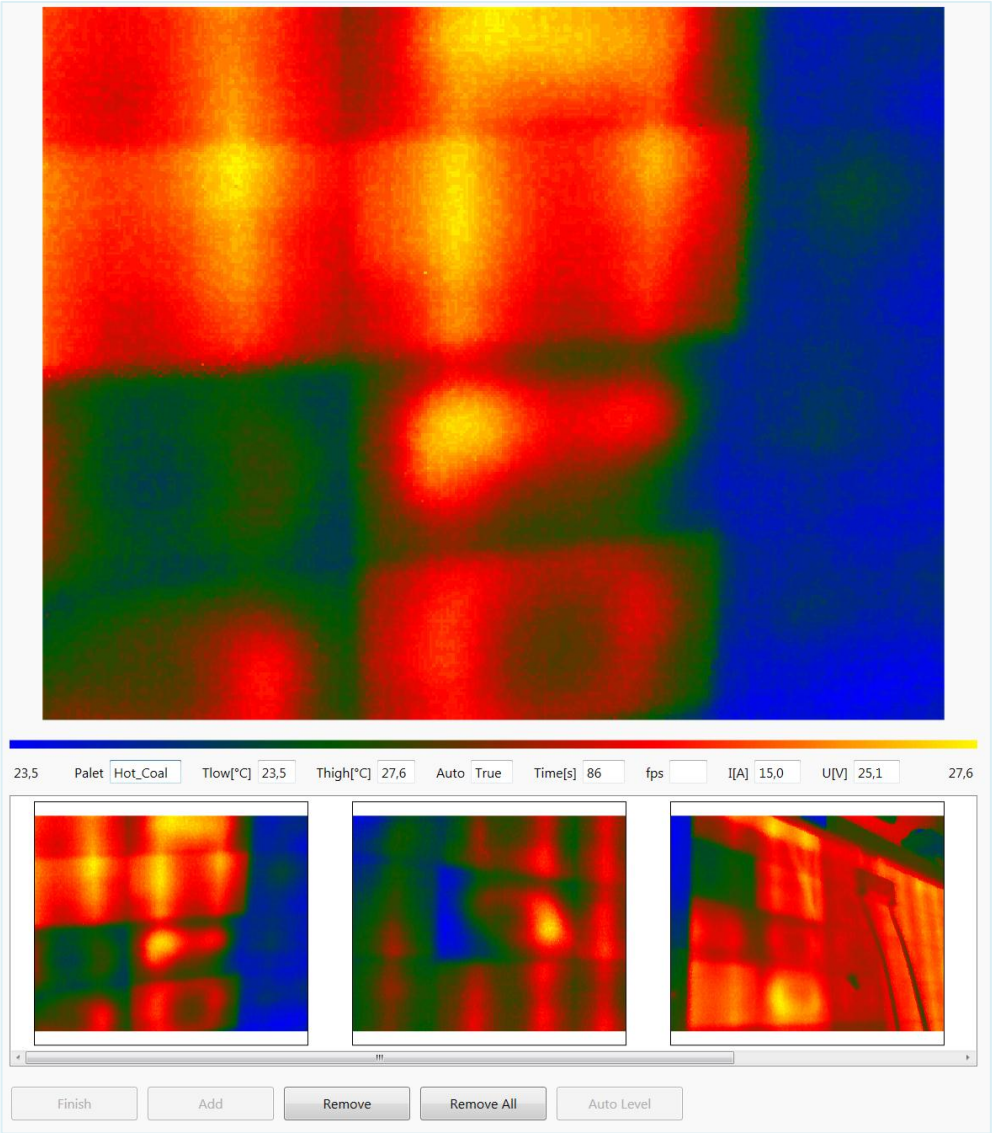
Critical fan-like breaks (before aging)



Critical fan-like breaks (after aging)

Note: Cells with other abnormal areas are marked blue, they have not influence on accelerated degradation of cells (See appendix: MBJ PV-Module Judgment Criteria).

5.4.8. Thermography



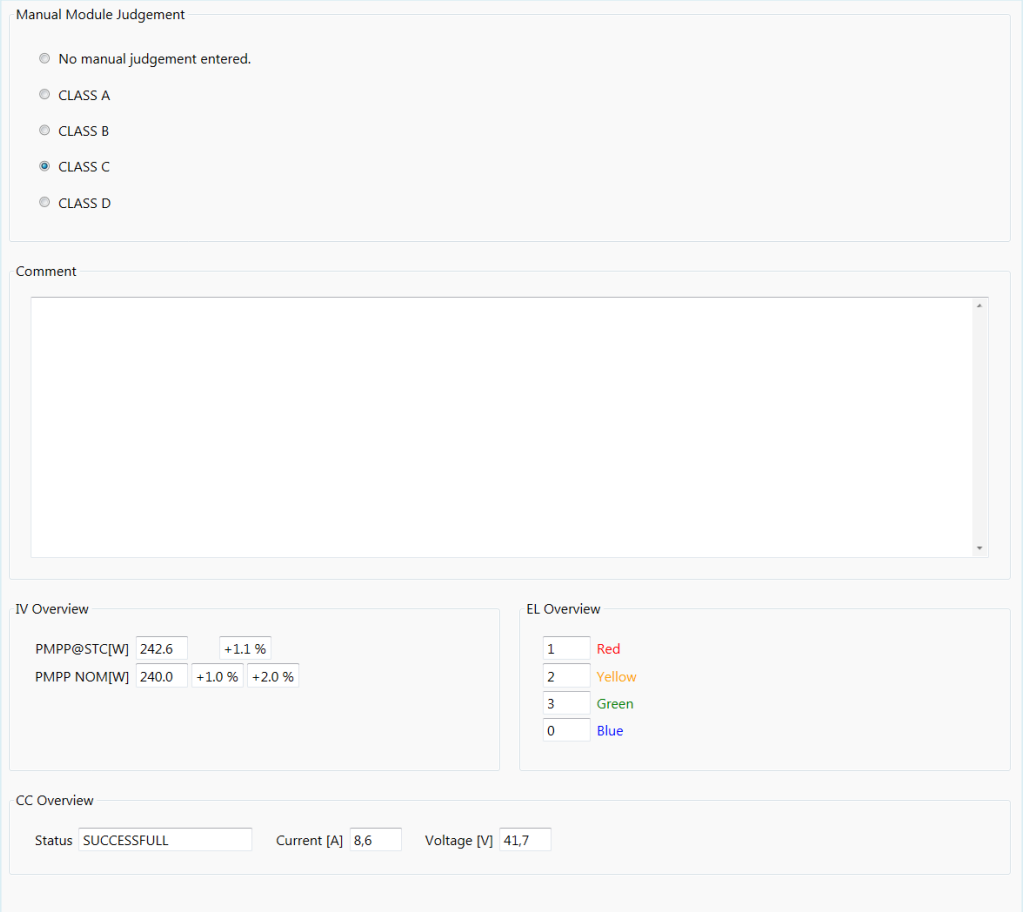
The thermography measurement is as followed:

- ✓ Connect the IR camera to the system.
- ✓ Scan the back side of the module with the IR camera.
- ✓ To enable/disable the automatic contrast adjustment, click on the <Auto Level> button.
- ✓ Take a picture of the area of interest by clicking the <Add> button.
- ✓ Take more pictures if necessary.
- ✓ Complet the measurement by clicking the <Finish> button.

By using the <Remove> button, the currently selected picture can be deleted. To Remove all pictures recorded in this inspection process, click on the <Remove All> button.

5.4.9. Judgment

Proposal for a uniform evaluation throughout the MBJ partner network.



Manual Module Judgment

Modules are divided up into 4 classes on the basis of the test results:

Class 1 / A

Best classification, none or hardly any negative findings

Class 2 / B

Only a few negative properties that should lie within the expected degradation

Class 3 / C

Increased negative properties that may lead to a premature drop in power

Class 4 / D

Obvious properties that already indicate a lower module output in the power test

For details see appendix: MBJ PV-Module Judgment Criteria

Comment

Option to enter comments regarding a measurement.

IV Overview

This area shows an overview of the IV measurement.

The following is displayed:

- PMPP@STC [W]: Power in watts at maximum power point at standard test conditions.
- PMPP NOM [W]: Nominal Power in watts at maximum power point.
- The deviation of the PMPP@STC from the PMPP NOM.
- Module manufacturers given tolerance on nominal output.

EL Overview

Overview of the marked cells of the electroluminescence inspection.

CC Overview

This area shows the connection check result.

The following is displayed:

- Status:

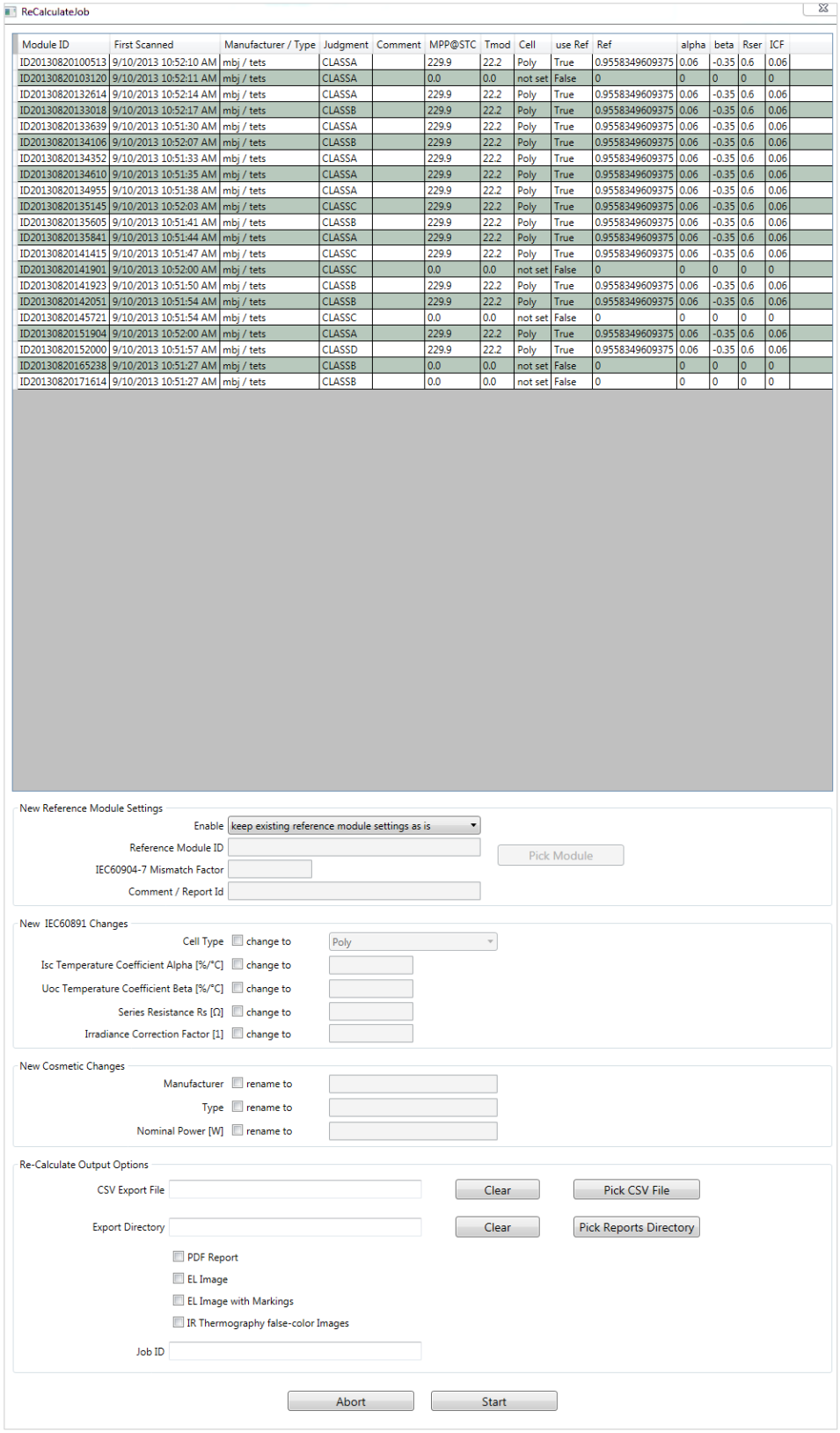
  SUCCESSFUL: connection check was successful.

  MINVOLTAGEFAILED: measured voltage too low.

  MICURRENTFAILED: measured current too low.

- Current [A]: Current in amps during the connection check.
- Voltage [V]: Voltage in volts during the connection check.

5.4.10. ReCalculateJob Dialog



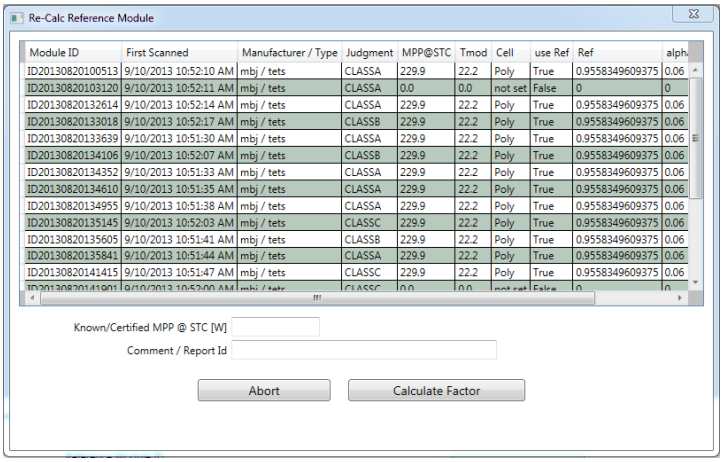
In this dialog the user has the possibility to do the following:

- Change the characteristics of the modules in the current job and recalculate the measurement results. For this purpose the modules to be changed must be selected from the job list at the top of the dialog box. The recalculated modules can be saved in a new job.
- Generate reports (PDF, EL images, IR images) of each measurement if they have not previously been generated.
- Sort the measured modules.
  Example: Sort the modules according to their classification (A,B,C,D). For this purpose the modules with the classification A, B,C or D must be selected from the job list at the top of the dialog box. Now the selected modules can be saved in a new job. It is also possible to generate only the reports.

New Reference Module Settings

Enable: (choose from one below)

- Keep existing reference module settings as is.
- Disable existing reference settings
- Define a new reference module



Pick a Module: Selecting the "Define a new reference module" option enables the <Pick a Module> button that opens the Re-Calc Reference Module dialog. Here the user can select the module which will serve as a reference module.

Reference Module ID: ID of the selected reference module.

IEC60904-7 Mismatch Factor: Recalculated mismatch factor of the reference module.

Comment/Report Id: Comments regarding the reference module.

New IEC60891 Changes

Area to change the parameter settings of the selected modules.

Following settings can be changed:

- Cell Type

- Isc Temperature Coefficient Alpha [%/°C]
- Uoc Temperature Coefficient Beta [%/°C]
- Series Resistance Rs [Ω]
- Irradiance Correction Factor [1]

New Cosmetic Changes

Area to change the naming of the selected modules.

Following settings can be changed:

- Manufacturer
- Type
- Nominal Power [W]

Re-Calculate Output Options

Area to set the output options of the recalculated modules.

Following output options can be set:

- CSV Export File
- Export Directory
- Type of Report (PDF Report, EL Image, EL Image with markings, IR Thermography false-color image)
- Job ID (Name of the new Job. If this textbox is empty, no job will be generated)

6. Troubleshooting

6.1. Error Messages

Error messages from the machine are displayed in two different areas, either in the status information area of the main window (see section 5.4.1) or as an independent popup message window.

Time	Status	Action
16:14:08	**Failed to init analog IO (ET7026).**	**Please contact the service.**

Initializing of the Analog I/O is not possible. Please shutdown the PC and turn the inspection system off using the master switch. Restart the system. If the error message occurs again, please contact the service.

Time	Status	Action
14:17:16	**Failed to init digital IO (ET7052).**	**Please contact the service.**

Initializing of the Digital I/O is not possible. Please shutdown the PC and turn the inspection system off using the master switch. Restart the system. If the error message occurs again, please contact the service.

Time	Status	Action
17:05:22	**ZAT power supply does not deliver enough voltage**	**Check ZAT switch (electric cabinet)**

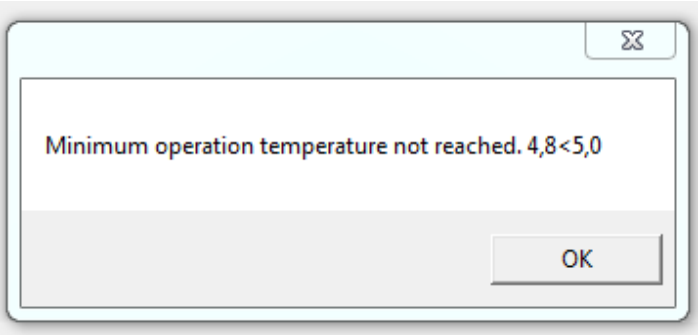
The ZAT power supply does not deliver enough voltage. Check the ZAT switch in the electric cabinet. If the error message occurs again, please contact the service.

Time	Status	Action
10:05:46	LED door signals have a problem. open=close=true	Please contact the service.

The LED door signals have a problem. Restart the system. If the error message occurs again, please contact the service.

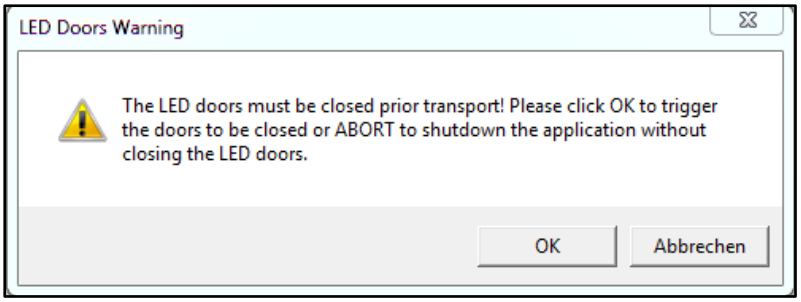
Time	Status	Action
09:36:24	**Machine is in error state.**	**System needs to be restarted.**

Acknowledge any other error message, solve the problems indicated by the error messages, make sure the system is empty. Restart the SW. If the error message occurs again, please contact the service.



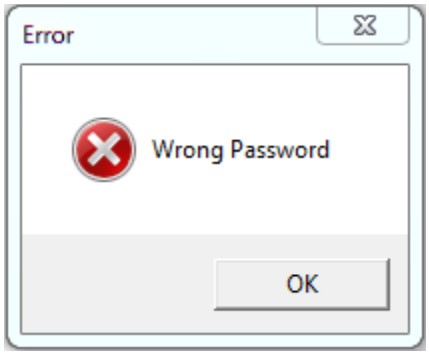
The temperature inside the device must be higher than 5°C. Use the HeatupDevice dialog to increase the temperature (see section 5.4.1).

6.2. Warning Messages



The LED doors must be closed prior transport! Please click OK to trigger the doors to be closed or ABORT to shut down the application without closing the LED doors.

6.3. Other Messages

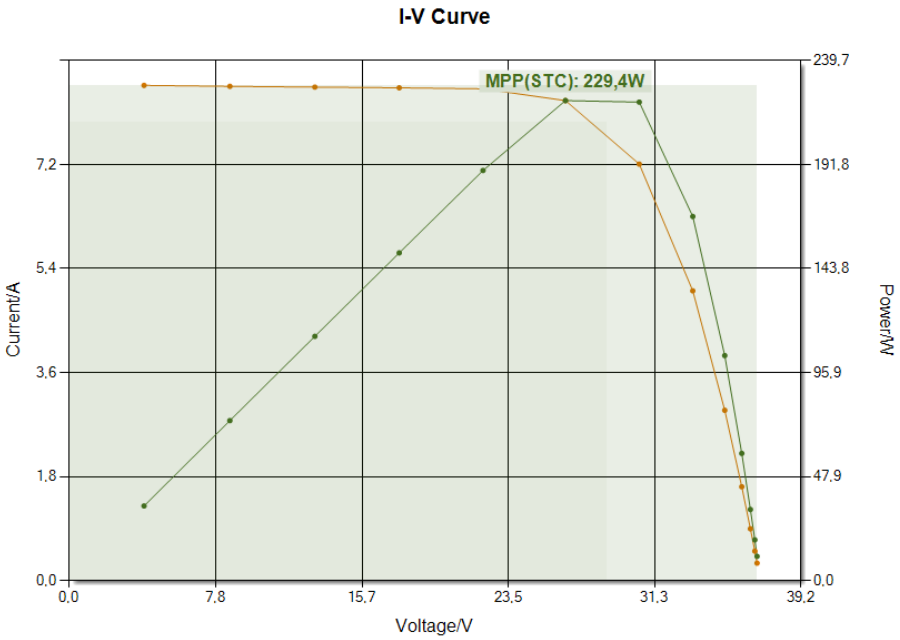


The used password is not correct. Enter the correct password for the chosen user level.

6.4. IV-Curve abnormalities

6.4.1. IV-Curve with few measurement points:

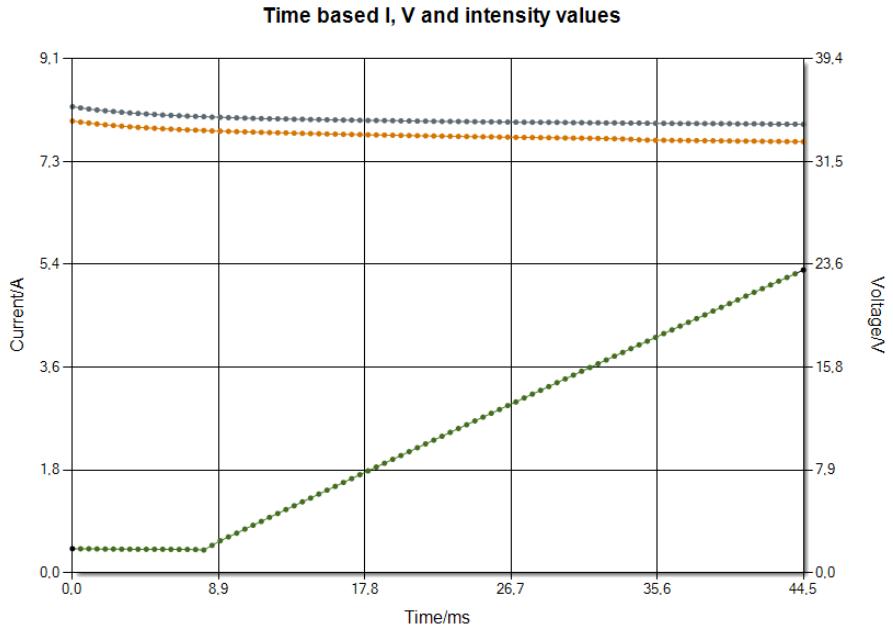
Reason: Flashing capacity is too low.



The capacity to be selected is proportional to the expected current of the module. A high power requires a high capacity (See section 5.4.5.2).

6.4.2. Only the time based IV-Curve appears:

Reason: Sampling time too small.



The capacitors on the LED boards hold their power for about 180ms before the light output of the LEDs starts to fall. The sampling time should always make full use of the maximum flash duration. The maximum sampling time in the IV/Flash parameters is 175ms (see section 5.4.5.2).

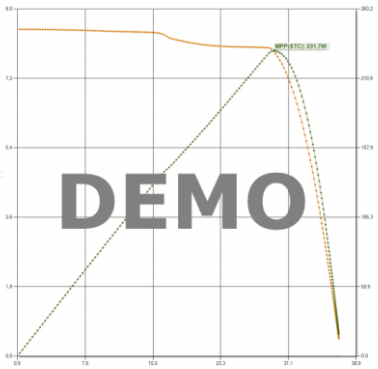
6.4.3. Kink at the IV-Curve:

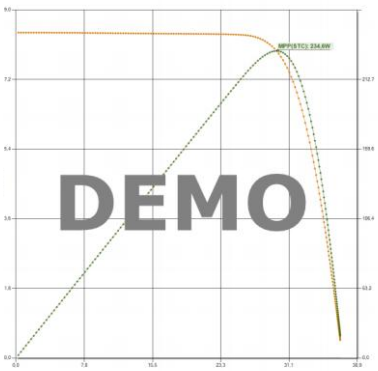
A kink at the curve can be for several reasons:

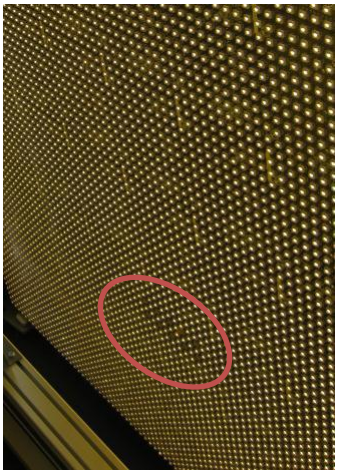
- One or more damaged cells of the module
- Impurities on the module
- One or more LEDs (Flasher) may be defective

Example (defective LEDs):

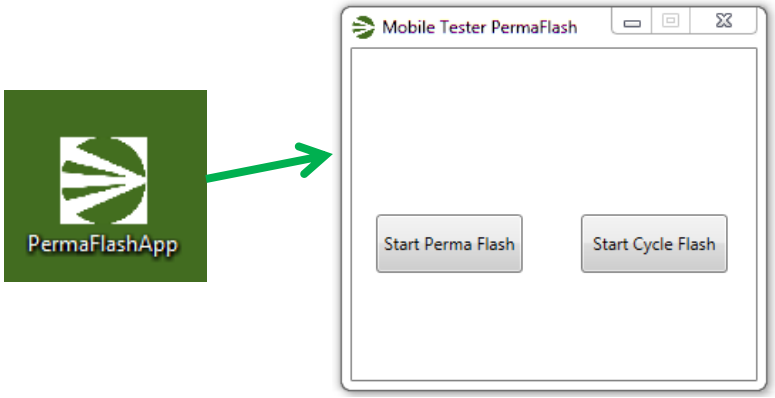
Comparative curves of the same module







The function of the LEDs should be checked regularly. This can be done with the Perma Flash Application.



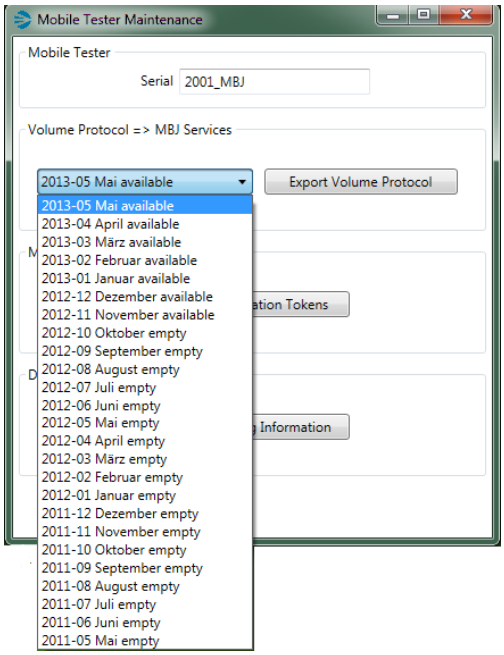
By pressing the <Start Perma Flash> button, 10 consecutive flashes are triggered. Then the LED-boards light up for 15 seconds so that the LEDS can be checked.

By pressing the <Start Cycle Flash> button, 10 consecutive flashes are triggered. Then the LED-boards light up in a specific sequence.

Should one or more of the LEDs may be defective, please contact the service.

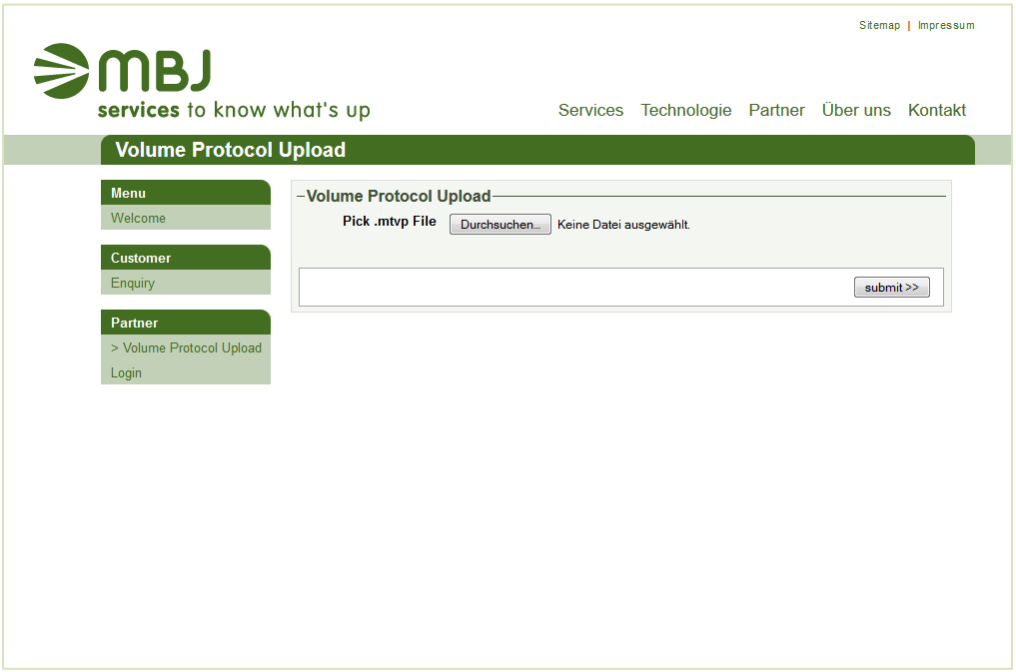
7. Mobile Tester Sync Application

The operators that have signed a licensing agreement with MBJ Services must transmit the volume data (measured modules) for every month to MBJ Services. For this upload the volume data with the mobile tester sync application to:



http://clients.mbj-services.com

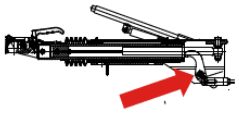
In case of problems with the software, the user can export the debug information by pressing the <Export Debug Information> button.



You will get then the license file, load this one with the mobile tester sync application into the system to assure the proper operation for the next weeks.

8. Maintenance and Cleaning

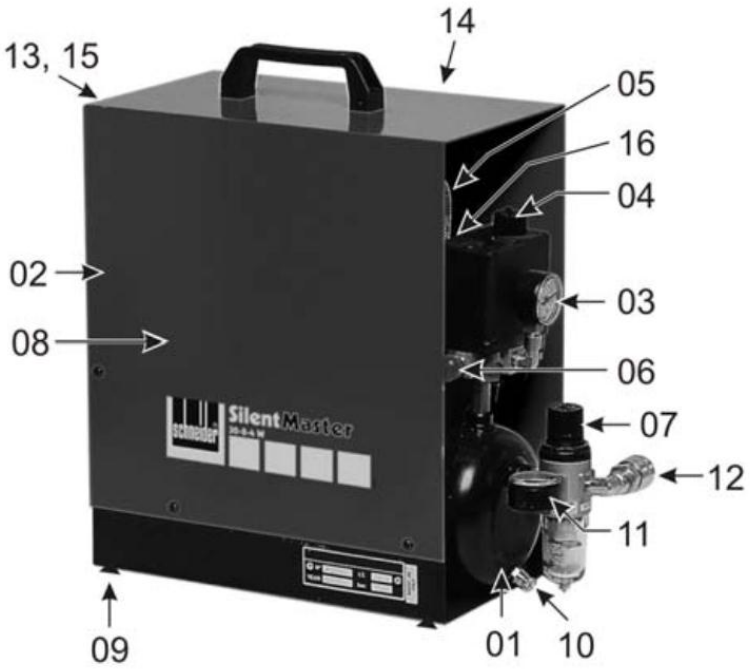
The necessary maintenance and cleaning work is shown below in table form.

Item	Description of maintenance	Frequency
Compressor	Suction Filter: - Inspection - Blow out - Change	 Weekly Every 50 hours of operation At least once a year
	Checking the oil level: (See section 8.2) 	Before each use
	Drain condensate: (See section 8.3) 	At least once a week; better after each use.
LED Doors	Checking that the LED doors open and close correctly	After each use
Trailer	Check wheel nuts for tightness	After 500 km
	Check the tires for damage and wear	Every 5000 km or once a year
	Check the brake cable for damage	Every 5000 km or once a year
	Grease the bell crank 	Every 5000 km or once a year
	Clean ball coupling, grease ball socket, joints and bearings	Every 5000 km or once a year
	Grease the support wheel components	Six-monthly
	Grease the parking brake	Six-monthly
	Check the rear supports	Every 5000 km or once a year

8.1. The Compressor

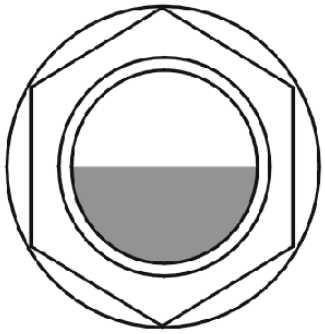
Pos.	Description
01	Tank 4 Liter; 8 bar
02	Compressor power unit
03	Pressure gauge 40 mm (tank pressure)
04	Pressure switch (ON / OFF switch)
05	Connecting hose
06	Safety valve 8 bar, R1/4"a
07	Filter pressure regulator
08	Housing
09	Rubber suction foot
10	Condensate drain valve
11	Pressure gauge 40 mm (working ssure)
12	Quick coupling R1/4" a (NW 7.2)
13	Suction Filter
14*	Oil sight glass
15	Oil plug

* These positions are located on the rear side of the Figure



8.2. Checking the oil level of the compressor

Check the oil level on the oil sight glass (Pos. 14) before each use. If the oil level is between the Minimum and Maximum marks, the compressor aggregate has the optimal oil level.



8.3. Drain condensate of the compressor

Tank (Pos. 01):

The condensate collects at the bottom of the tank. Condensate should be drained periodically, preferably after each use. To do this, open the drain valve (Pos. 10) to one and a half turns and drain the condensate under pressure (up to 2 bars).

Filter pressure regulator (Pos. 07):

Drain the condensate and clean the filter:

The drain valve in center position (Fig. 1) operates semi-automatically. If there is no pressure, the condensate drains off. By pressing the condensate drain valve (Fig. 2), the condensate drains “under pressure”. To lock the valve entirely, turn the condensate drain valve anti-clockwise (Fig. 3). To clean the filter cartridge, dismount the container of the filter pressure regulator in a pressure free condition (Fig. 4). The locking screw of the filter cartridge must be unlocked anti-clockwise manually. Now, the filter cartridge can be removed.

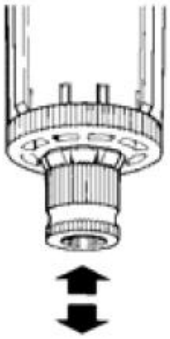


Fig.1

Fig. 2

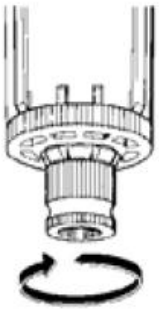


Fig. 3

Fig. 4

9. Appendix

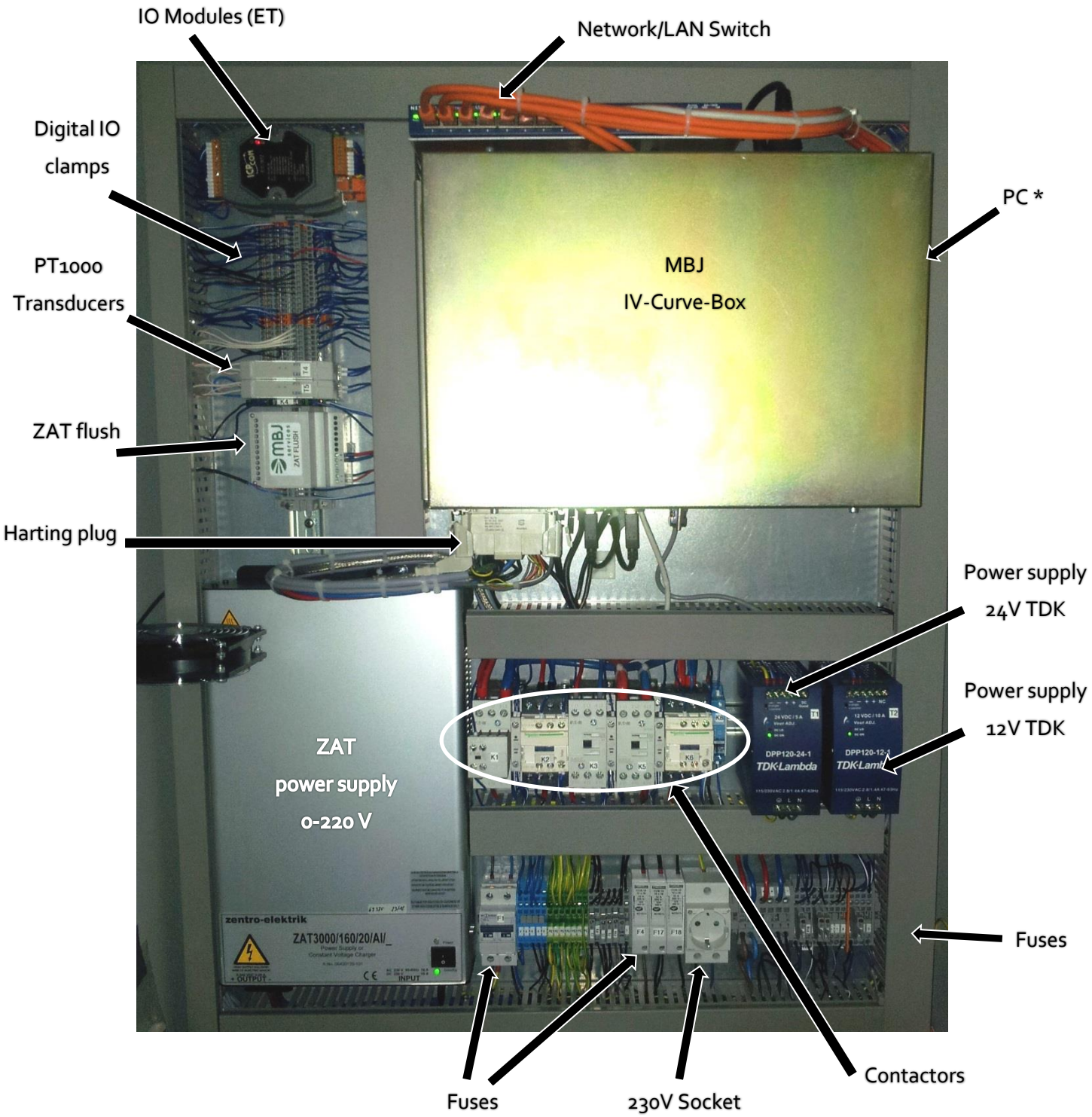
9.1. Control cabinet

9.2. MBJ PV-Module Judgment Criteria

9.3. Power Measurement Optimization Guideline

9.4. Technical Specification

MBJ Mobile Tester control cabinet



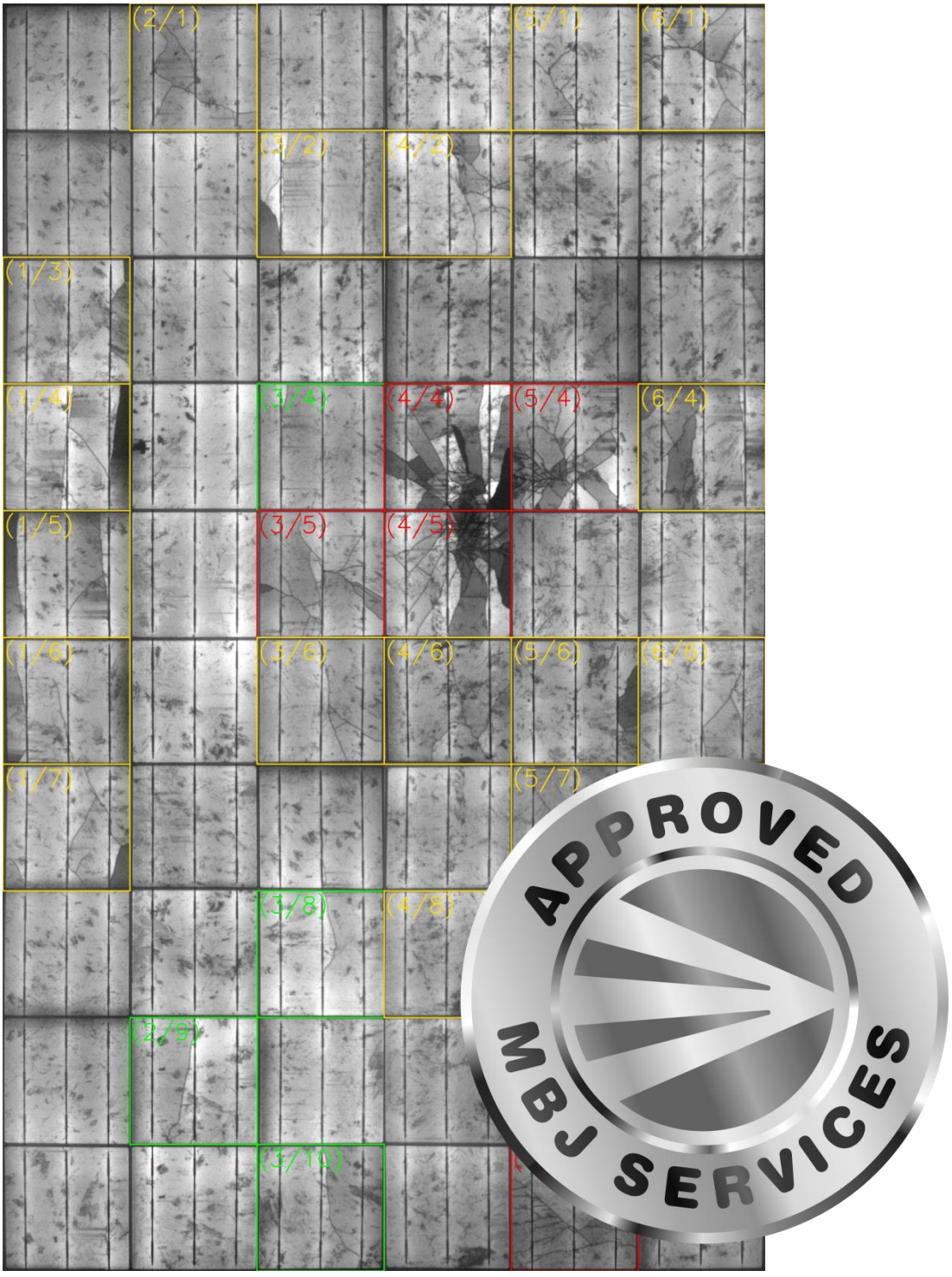
* This position is located behind the MBJ IV-Curve-Box

MBJ PV-Module Judgment Criteria

Analysis criteria for PV module testing in the Mobile PV-Testcenter

Date: 28.02.2014 – Revision 3.1

Compiled by the MBJ affiliate network in cooperation with TÜV SÜD



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Analysis criteria for PV module testing in the Mobile PV-Testcenter

The actual condition and possible preliminary damage to PV modules are tested in the Mobile PV-Testcenter from MBJ Services GmbH by different test methods.

An electroluminescence test is always performed to check for cell breaks in silicon, so-called 'micro-cracks', along with a power test under simulated or approximate STC conditions (ambient temperature or STC temperature). The modules can also be investigated by thermal imaging with a corresponding indication.

In order to guarantee a standard analysis of PV modules with the Mobile PV-Testcenter throughout the affiliate network, this document explains the analysis criteria for the three test methods in more detail using examples.

1 Quality classes for PV modules

Modules are divided up into 4 classes on the basis of the test results:

Class A – No abnormalities that can lead to premature drop in power

Class B – A few abnormalities that do not lead to a premature drop in power

Class C – Increased abnormalities that may lead to a premature drop in power

Class D – Negative properties that can directly lead to a drop in power

In order to rule out a premature degradation we recommend that you do not install modules from class C, or that these are at least grouped separately in strings that should be monitored.

Modules from class D would lead directly to a reduction of the generator's power, so that they should not be installed in any case.

2 Analysis criteria for the electroluminescence test

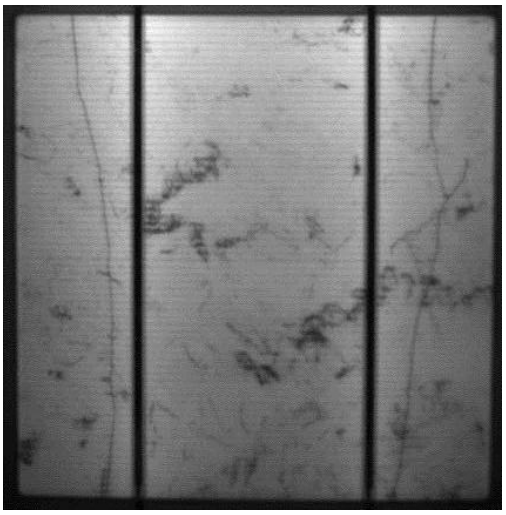
Since the test in the Mobile PV-Testcenter is carried out with regard to the module's output in future, we initially regard active and inactive cell breaks (micro-cracks) as being identical. However, active cell breaks often lead to a reduction in power at the time of the test; these are then quantified by the separate power test in the flasher.

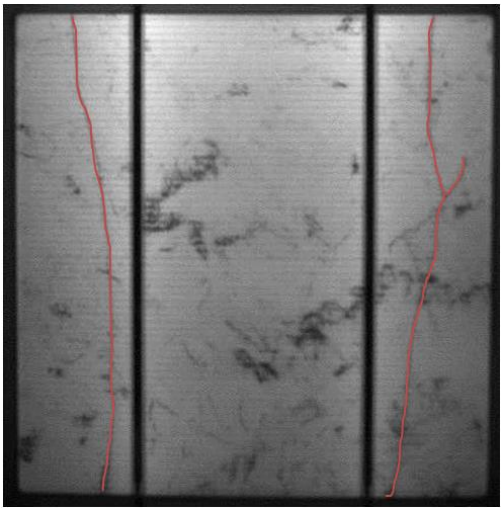
Cell breaks are classified into three categories:

- **Uncritical: no cell area affected**
- **Critical: less than 20% cell area affected**
- **Very critical: 20% or more cell area affected**

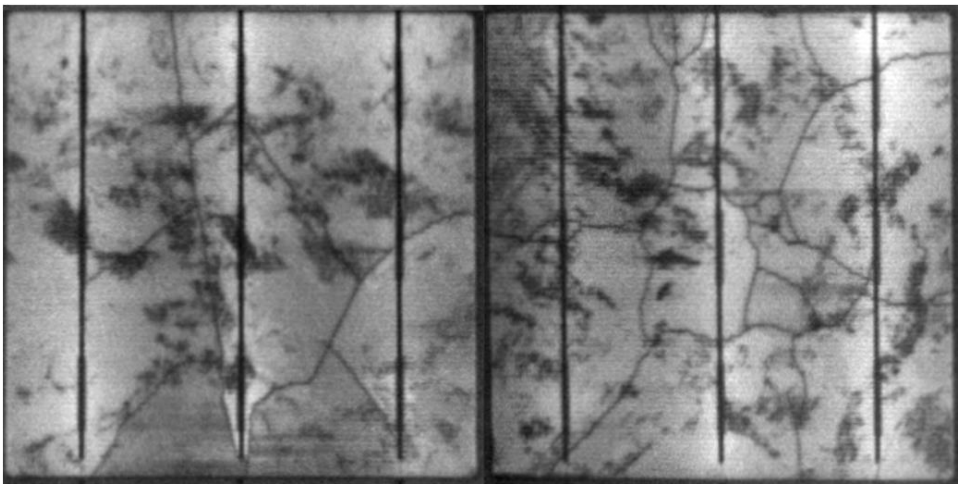
2.1 Cracks and breaks

A micro-crack through a silicon solar cell separates parts from each other which are further connected via the contact fingers to the busbar, and thus remain electrically active. Micro-cracks produce therefore no dark areas in the electroluminescence image. The luminescence remains homogeneous despite the cracks. Micro-cracks alone lead to no or even at a high accumulation only to a slight power loss.

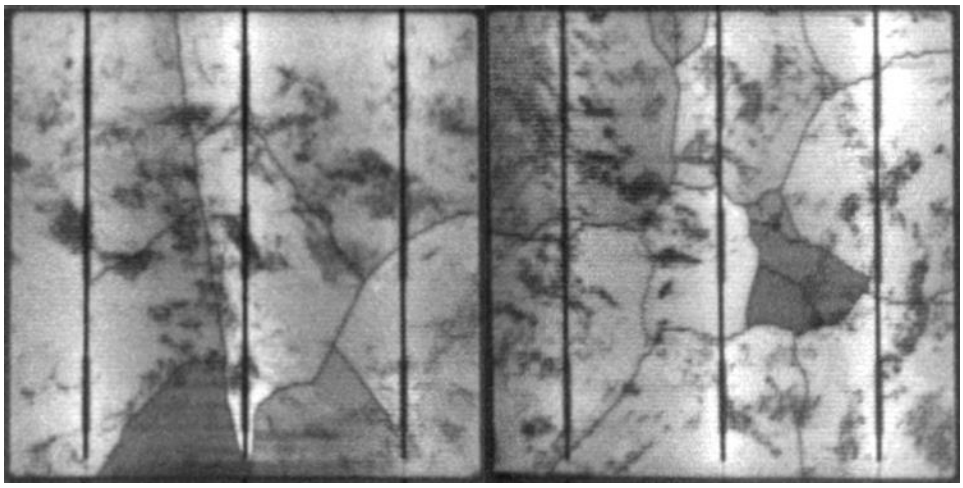




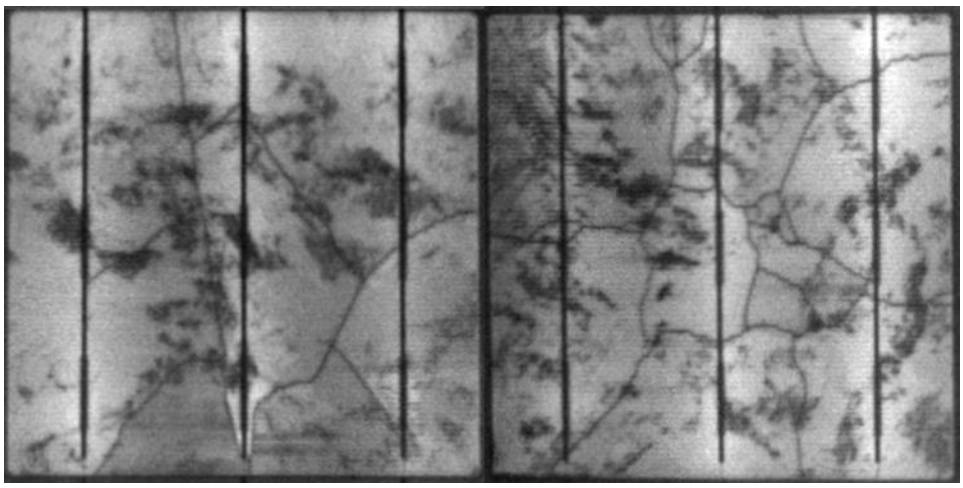
Micro-Cracks can turn into cell breaks by tearing the contact fingers (e.g. by thermal expansion) of two silicon parts, which are separated by a crack. The tearing of the fingers and thus the loss of connection to the busbar leads to inactive cell parts. The breakage may not be immediately complete. It can begin with an increased contact resistance. The electrical connection may be interrupted temporarily, depending on the temperature or mechanical influences. The breaks are apparent through a lower luminescence on one side of the break, homogeneous or with a gradient depending on the location. Breaks lead in the worst case to completely dark (inactive) cell sections. The following images show captures that were made in the course of several hours at slightly different temperatures. This is to illustrate that the transition from crack to break may be smooth, but also reversible:



1st capture, about 16 ° C



2nd capture, about 24 ° C

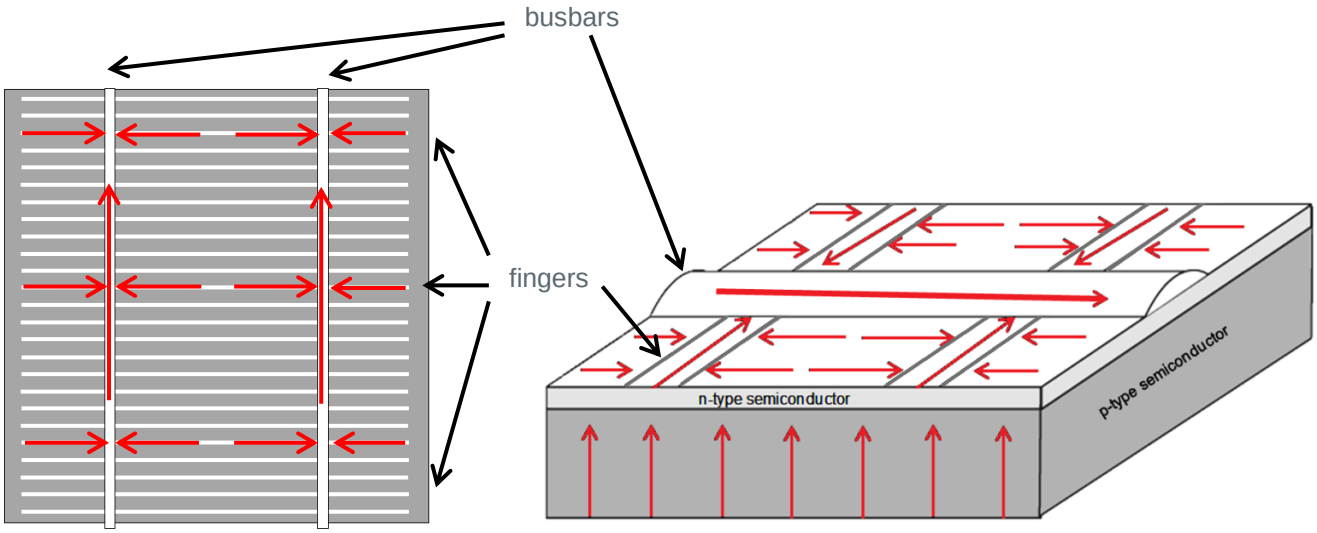


3rd capture, about 15 ° C

The relationship between the orientation of a crack/brake and the power loss associated with the loss of active cell area is considered in more detail in the following pages.

2.2 Cell without any break

The figure below shows the current flow in an intact solar cell.

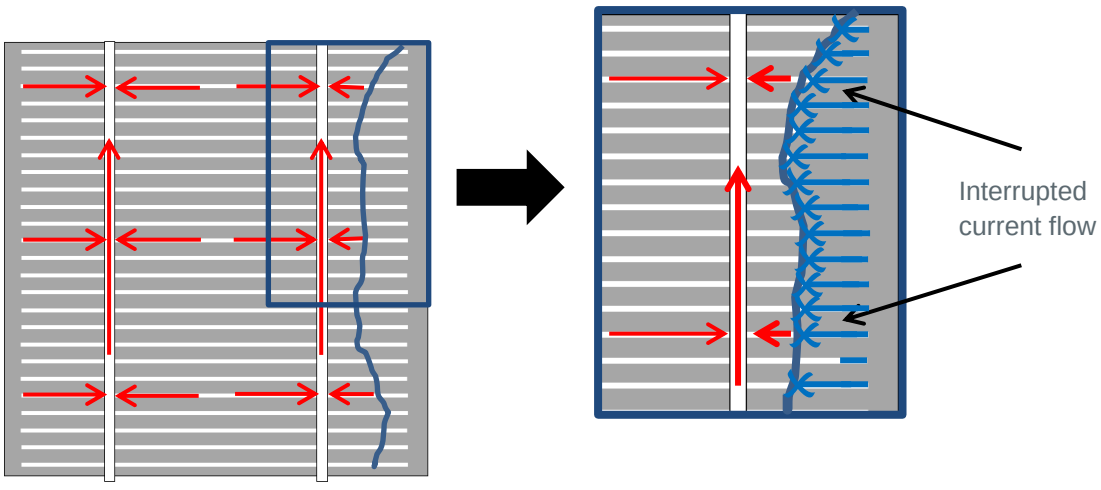


Solar Cell Top Contact

Current flow in a solar cell

2.3 Cell with active break

The following figure shows how the current flow is impaired through a break in the silicon and the resulting interruption of the contact fingers:



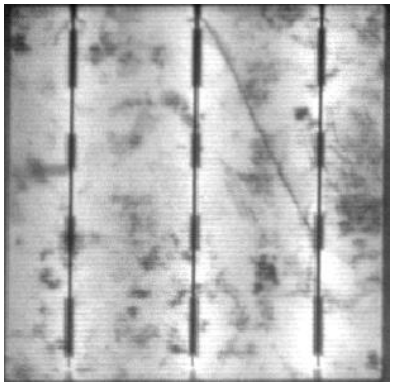
Solar Cell Top Contact

2.4 Uncritical cracks / cell breaks

If a cell break runs in a straight line between the 'busbars' it cannot disconnect areas from the power supply via the 'finger'.

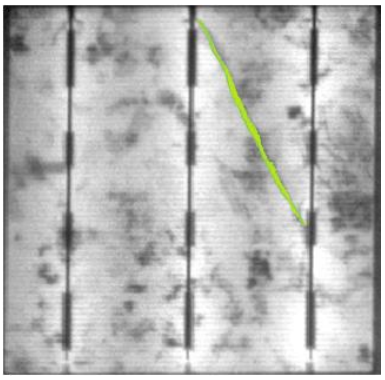
In principle, this is only possible between the busbars or if the break runs absolutely horizontal. Such cell breaks are classified as 'uncritical' or green and do not lead directly to a degradation of the module.

Nevertheless, the development of the cell break should be noted, especially if there is already a tendency to a fanning out of the breaks or to Y-breaks, in which case the cell may have to be classified as 'conspicuous' or yellow. Since this may not be able to be detected with the existing pixel resolution, if more than 10% of cells in a module are marked green, this is also a degradation criterion (see section 2.8).



Description

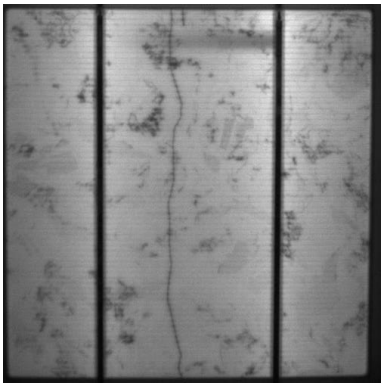
Cell break runs in a straight line between the 'busbars'.



Judgment

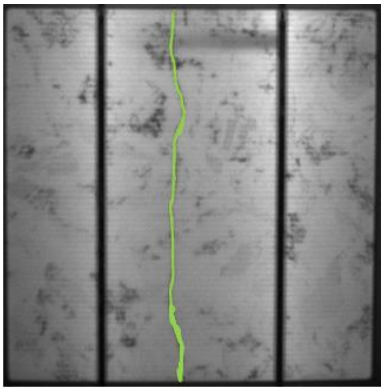
A further expansion of the cell break is not expected.

Possible cell area disconnection 0%.



Description

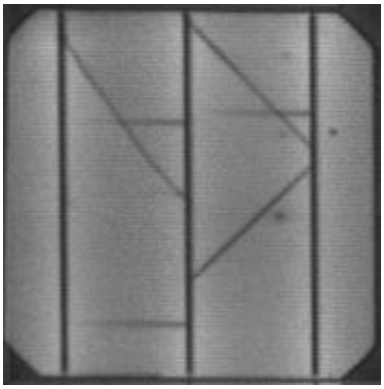
Cell break runs parallel between the 'busbars'.



Judgment

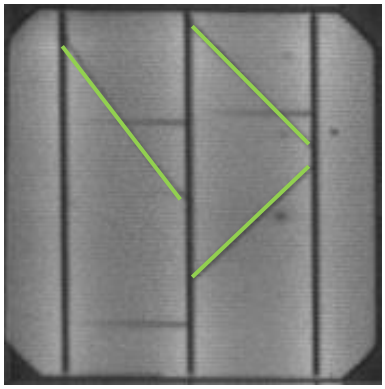
A further expansion of the cell break is not expected.

Possible cell area disconnection 0%.



Description

Various cell break run in a straight line between the 'busbars'.



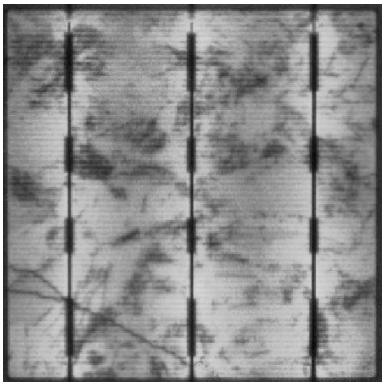
Judgment

A further expansion of the cell breaks is not expected.

Possible cell area disconnection 0%.

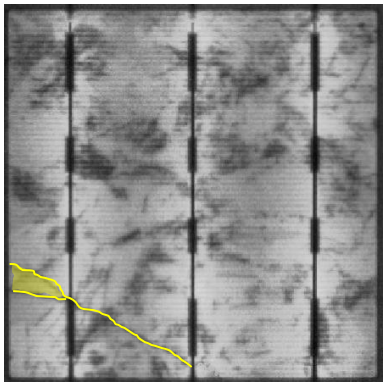
2.5 Critical cracks / cell breaks

All cell areas that can potentially disconnect the power supply or which already do so, should be classified 'conspicuous' or yellow.



Description

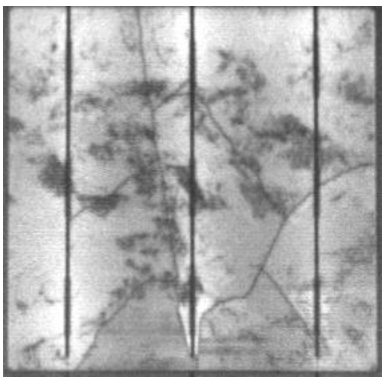
The endpoints of the cell breaks are the 'busbars' and the cell edge.



Judgment

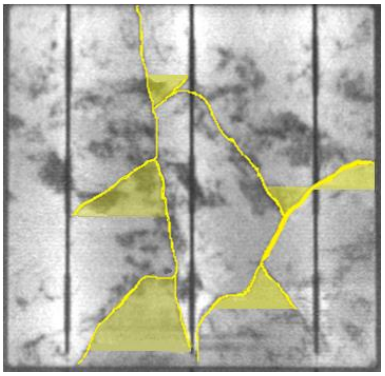
A further expansion of the cell breaks is not expected.

Possible cell area in the single digits.



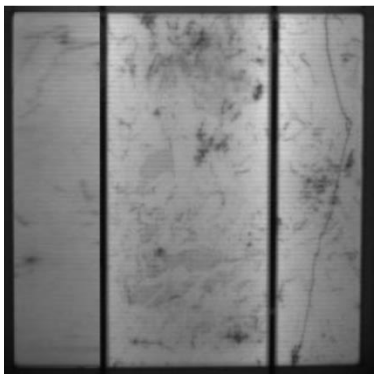
Description

Various Y-breaks between the 'busbars'.



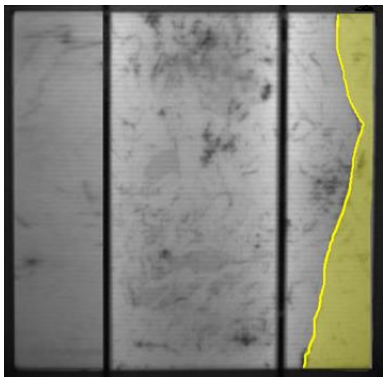
Judgment

Breaks can potentially reduce the active area of the cell approx. 10%.



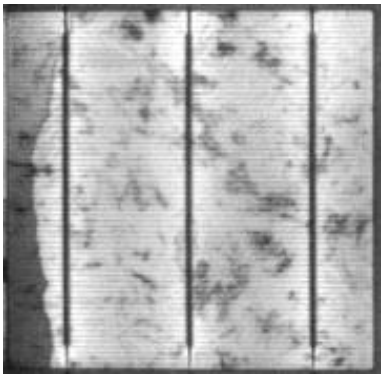
Description

Cell break between 'busbar' and cell edge.



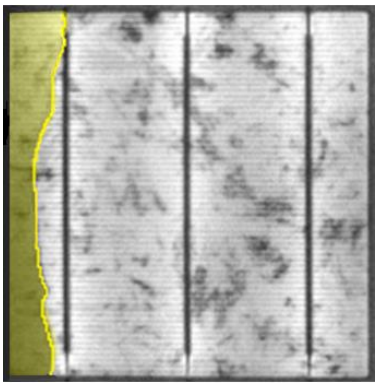
Judgment

Possible cell area disconnection approx. 10%.



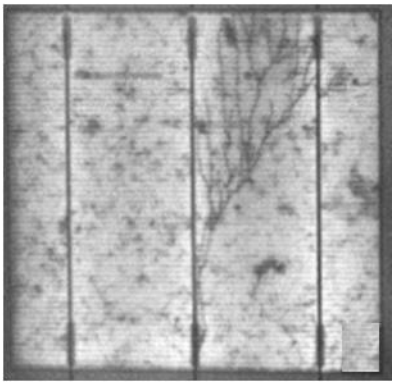
Description

Cell break between 'busbars' and cell edge.



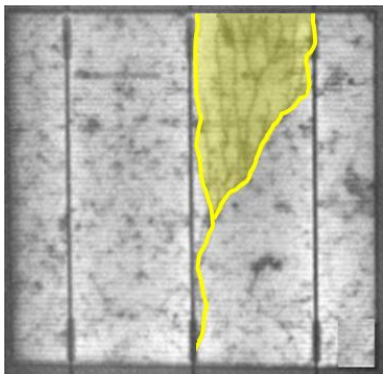
Judgment

Disconnected cell area approx. 10%.



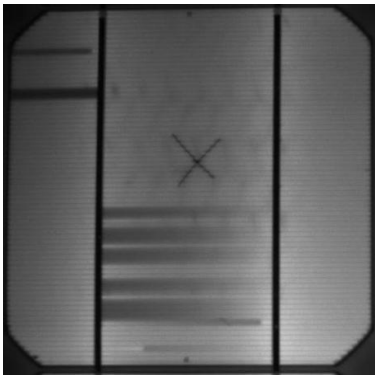
Description

Branched cracks between the 'busbars'



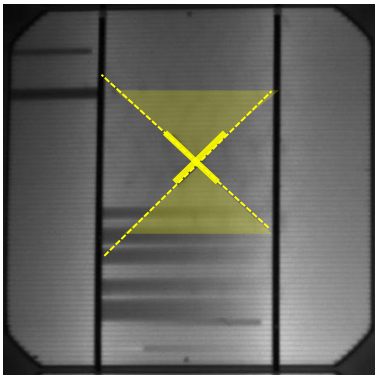
Judgment

Possible cell area disconnection approx. 10%.



Description

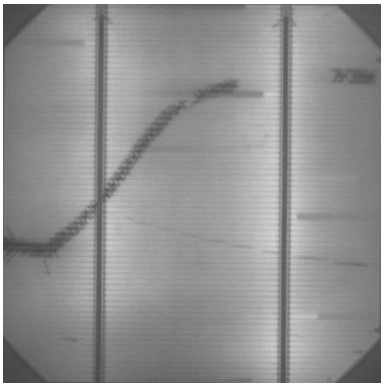
Cross crack caused by punctual stress on the cell, e.g. punctual stress on the back sheet foil of the module.



Judgment

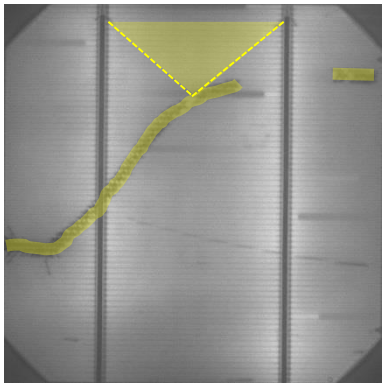
Critical, as it is unclear how the crack will propagate.

Possible cell area disconnection might be more than 10%.



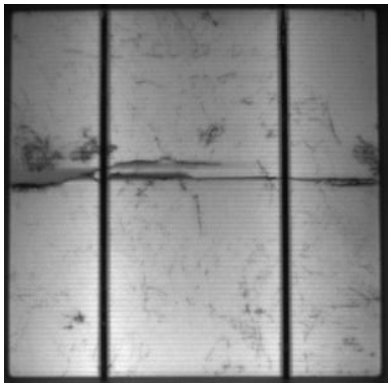
Description

Cross crack lines. Scratch on the back sheet of the module.



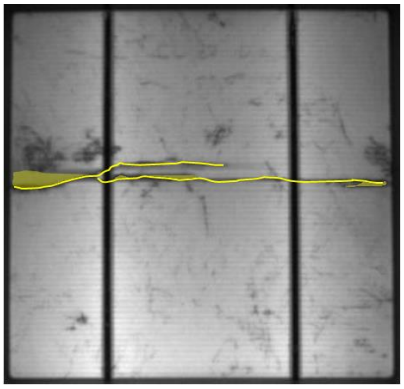
Judgment

Critical, as it is unclear how the cracks will propagate. Cell areas can be disconnected (as indicated in the example)



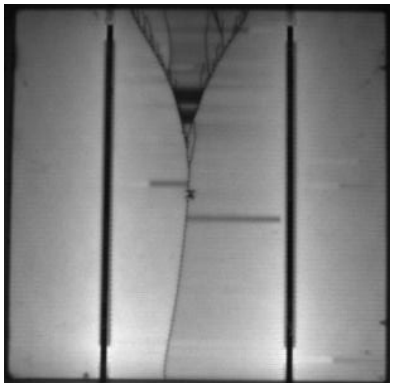
Description

Horizontal main crack with branching.



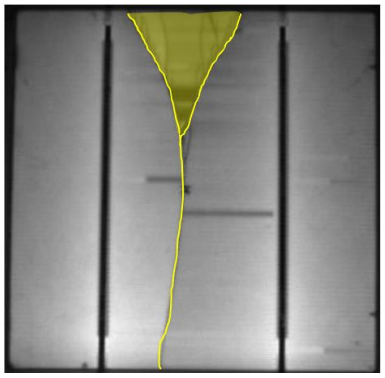
Judgment

A further expansion of the main crack is not expected. Disconnection of smaller cell areas possible.



Description

Y-break between the busbars.



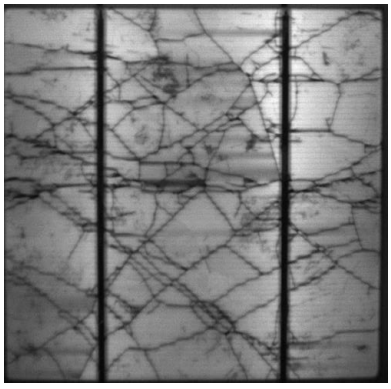
Judgment

Possible cell area disconnection approx. 10%.

2.6 Very critical cracks / cell breaks

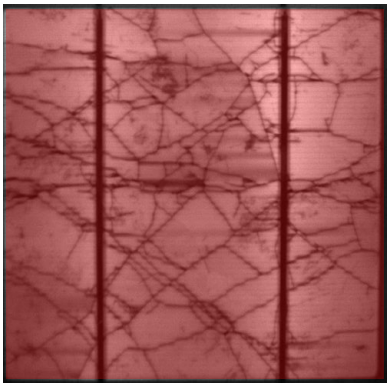
Cell breaks that can potentially disconnect more than 20% of the cell area from the power supply are classified in the 'very critical' category and marked red.

This category includes above all comminuted or fan-like breaks. Red cells lead directly to the classification of a PV module in the class C (see section 2.8).



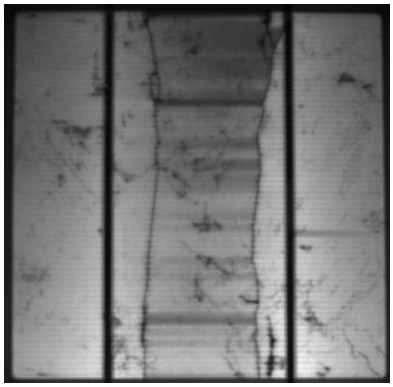
Description

Numerous branched cracks in different size and location.



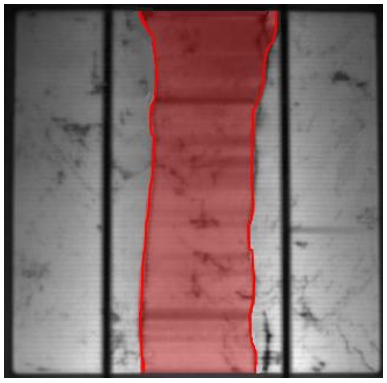
Judgment

These cracks can potentially reduce the active area of the cell far more than 20%.



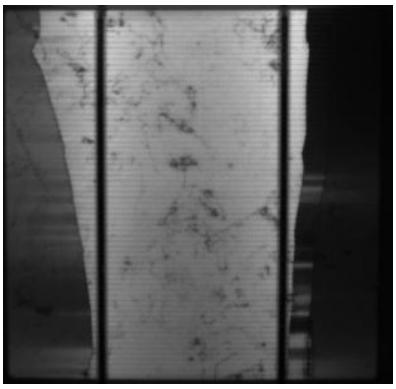
Description

Two cracks run parallel to the 'busbars'.



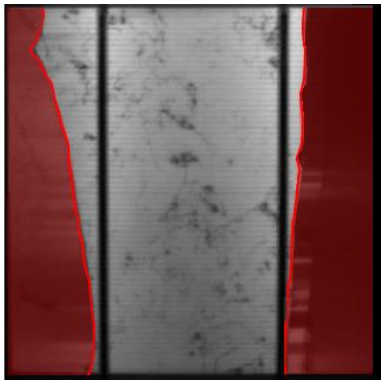
Judgment

Possible cell area more than 20%.



Description

Cell brakeage. Inactive area between 'busbars' and cell edges.



Judgment

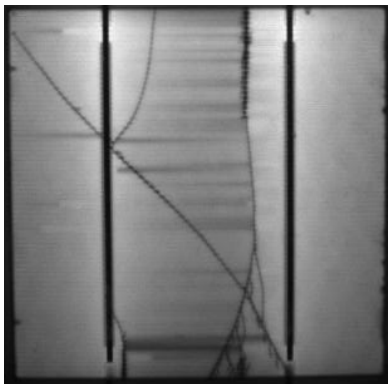
Disconnected cell area far more than 20%.

Description

Various cell brakes caused by mechanical impact e.g. hail.

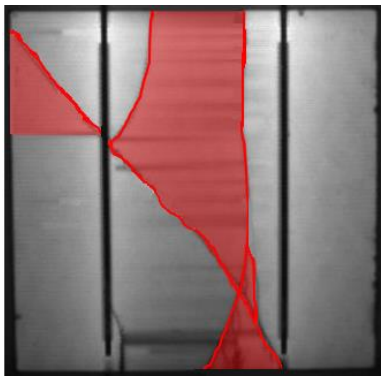
Judgment

These cracks can potentially reduce the active area of the cell far more than 20%.



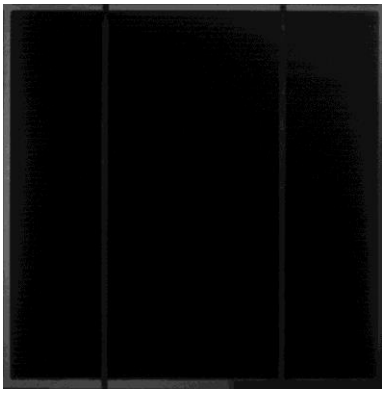
Description

Various cracks in different size and location.



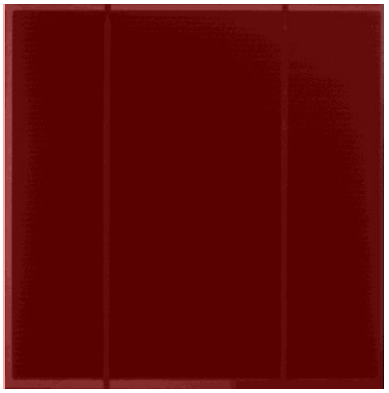
Judgment

These cracks can potentially reduce the active area of the cell more than 20%.



Description

Dark cell.



Judgment

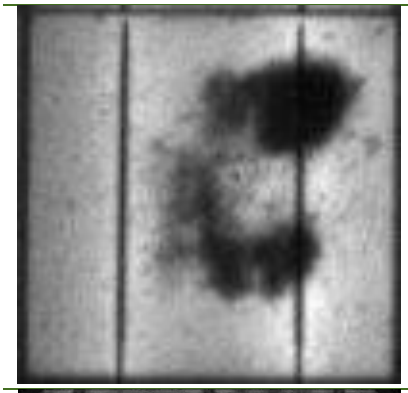
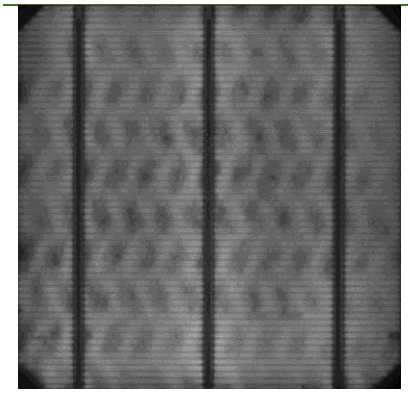
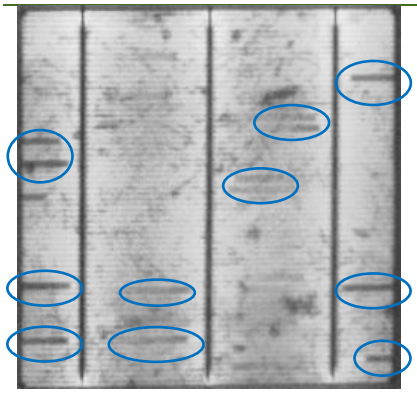
Inactive cell. Should not happen for new modules.

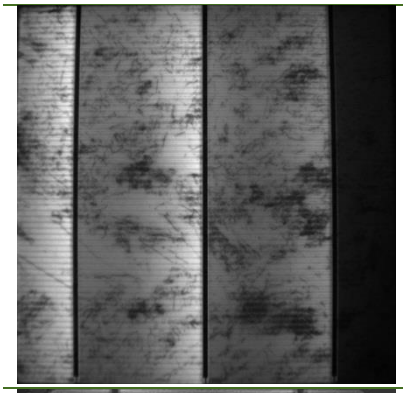
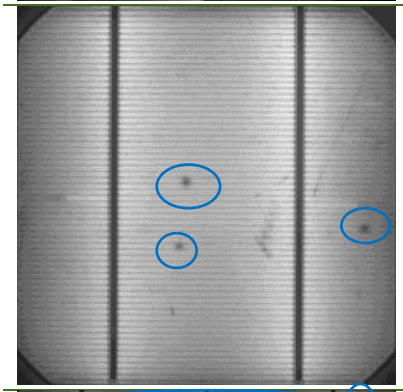
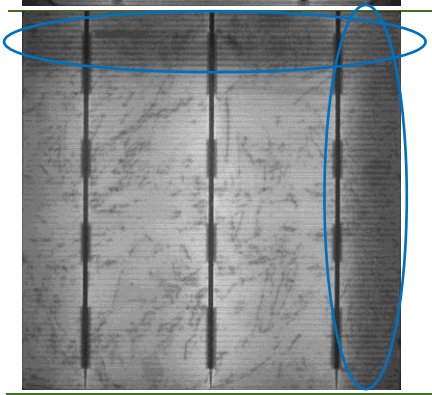
2.7 Other EL abnormalities

This category includes all defects which have occurred in the module manufacturing process and which have no negative impact on performance within the lifetime of the photovoltaic module.

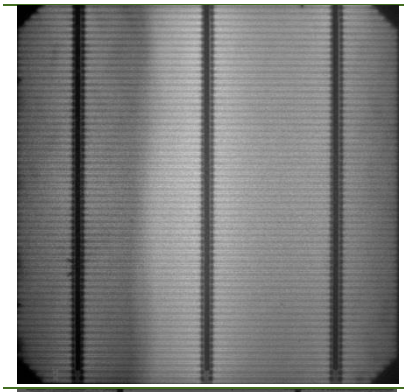
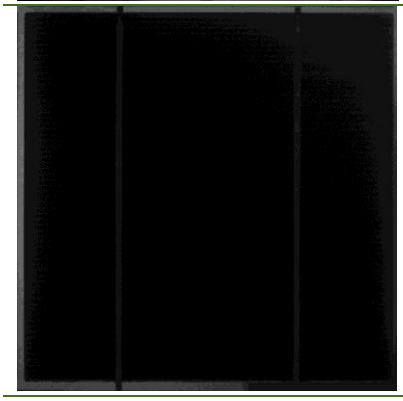
Such defects are normally uncritical and marked blue, since the power loss of the cell is already entered in the performance specified by the manufacturer. Consequential damages are not expected.

Cell process

Defect image	Defect type	Defect description
	Dark areas	Cloudy area with a lower luminescence Firing process Temperature gradient from the cell center to the cell edge
	Chain pattern	Local areas with a lower luminescence Firing process Inhomogeneous temperature distribution caused by the conveyor belt
	Printing failure (Grid finger)	Area of a grid finger with a lower luminescence Interrupted or non-existent grid finger Failure is generated during the screen printing process

	Printing failure (Back contact)	Gradation of the luminescence from one cell edge to the another cell edge The printing of the cell back is shifted Failure is generated during the screen printing process
	Shunts	Points with almost no luminescence E.g. direct contact of the grid finger to the cell base, defect in the pn-junction etc. Verifiable only with the Lock-In thermography or EL under reverse bias
	Ingot edge piece	Lower luminescence on one or two cell edges Contamination of the cell material in the edge area of the ingot Typical for polycrystalline solar cells

Soldering process

Defect image	Defect type	Defect description
	Dark cell	Area with a lower luminescence around the bus bar Not or only partially connected ribbon
		Completely dark cell Inactive cell ➔ E.g. short circuit through a wrong ribbon placement, inverted polarity or a defective cell. Possibly PID (potential-induced degradation, then often with "checkerboard pattern") In any case, such cells must be tested thermographically, heating at the soldering can be expected.

2.8 Module judgment criteria for the electroluminescence test

2.8.1 Class A

Only modules with fewer than 10% uncritical (green) cells. The sum total of the marked cells may not exceed 10% of the cells. Critical cells (yellow, red) are not allowed.

	green	**<10%** of the total amount of cells in the module Example: 60 cell PV-Module: **<6 cells** allowed
NO	**yellow**	**0%** of the total amount of cells in the module Example: 60 cell PV-Module: **0 cells** allowed
NO	**red**	**0%** of the total amount of cells in the module Example: 60 cell PV-Module: **0 cells** allowed
	total	**<10%** of the total amount of cells in the module Example: 60 cell PV-Module: **<6 cells** allowed

2.8.2 Class B

Modules without very critical (red) cells and with no more than 10% critical (yellow) cells and no more than 20% uncritical (green) cells. The sum total of the marked cells may not exceed 20% of the cells.

	green	**<20%** of the total amount of cells in the module Example: 60 cell PV-Module: **<12 cells** allowed
	yellow	**<10%** of the total amount of cells in the module Example: 60 cell PV-Module: **<6 cells** allowed
NO	red	**0%** of the total amount of cells in the module Example: 60 cell PV-Module: **0 cells** allowed
	total	**<20%** of the total amount of cells in the module Example: 60 cell PV-Module: **<12 cells** allowed

2.8.3 Class C

Modules with fewer than 10% very critical (red) cells, more than 10% critical (yellow) cells or more than 20% uncritical (green) cells and in total less than 30% of marked cells.

≥20% of the total amount of cells in the module

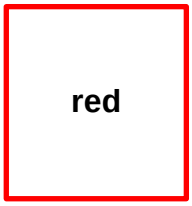
Example: 60 cell PV-Module:

≥12 cells

≥10% of the total amount of cells in the module

Example: 60 cell PV-Module:

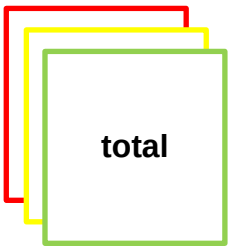
≥6 cells



<10% of the total amount of cells in the module

Example: 60 cell PV-Module:

<6 cells



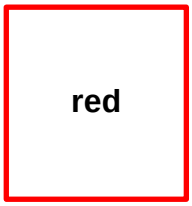
<30% of the total amount of cells in the module

Example: 60 cell PV-Module:

<18 cells

2.8.4 Class D

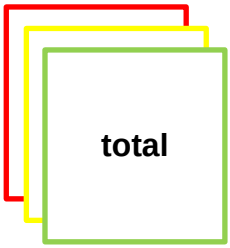
Modules with more than 10% very critical (red) cells or more than 30% marked cells in total.



≥10% of the total amount of cells in the module

Example: 60 cell PV-Module:

≥6 cells



≥30% of the total amount of cells in the module

Example: 60 cell PV-Module:

≥18 cells

3 Module judgment criteria for the power measurement

The judgment criteria below are for new modules, for used modules the expected power degradation like stated by the manufacturer of the modules has to be taken into account.

Class A

Only modules whose measured output is in the upper half of the positive tolerance band of the manufacturer's specification, or above.

Example:

Nominal power = 250W; Manufacturer Tolerances = -0% +3%
Half of the manufacturer's specification =+3% / 2= +1.5%: means +3.75W for 250W

Power MBJ@STC ≥ 253,75 Watts

Class B

Only modules whose measured output is in the lower half of the positive tolerance band of the manufacturer's specification.

Example:

Nominal power = 250W; Manufacturer Tolerances = -0% +3%
Half of the manufacturer's specification =+3% / 2= +1.5%: means +3.75W for 250W

Power MBJ@STC ≥ 250 Watts < 253,75 Watts

Class C

Modules whose output is below the tolerance specified by the manufacturer, but still better than the nominal output minus the uncertainty of the measurement.

Example:

Nominal power 250W Manufacturer Tolerances -0% +3%
MBJ measured Pmpp@STC: 249W
Measurement inaccuracy of MBJ Flasher (example): +/- 5% means 12,5W for 250W

Power MBJ@STC ≥ 237,5 Watts < 250 Watts

Class D

Modules whose output is below the tolerance specified by the manufacturer taking into account the measuring accuracy of the Mobile PV-Testcenter.

Example:

Nominal power 250W Manufacturer Tolerances -0% +3%
Measurement inaccuracy of MBJ Flasher (example): +/- 5% means 12,5W for 250W

Power MBJ@STC < 237,5 Watts

4 Module judgment criteria for the thermal imaging

The focus of the thermal imaging lies especially in the so-called "hot spots". These small regions have a significantly higher temperature than the rest of the module.

Class A

Only modules that have no thermographically conspicuous areas.

Class B

Only modules whose difference between the temperature of conspicuous areas on the module and average temperature of the module is below 5 °C.

Class C

Only modules whose difference between the temperature of conspicuous areas on the module and average temperature of the module is between 5°C and 30°C.

Class D

Only modules whose difference between the temperature of conspicuous areas on the module and the average temperature of the module is more than 30 °C.

5 Overall module judgment

The resulting overall module judgment will be the worst judgment of the three test methods. Means the worst class the module was judged to at electroluminescence, power measurement or thermal imaging.

Example:

Electroluminescence result:	Class B	worst class
Power measurement result:	Class A	wins
Thermal imaging result:	Class A	
Overall module result:	**Class B**	

MBJ Services GmbH - Merkurring 82 – 22143 Hamburg

Mobile PV-Testcenter

Power Measurement Optimization Guideline

Hamburg, August 2013

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1. General rules for optimal results in power measurement

1.1. Module parameters: Temperature coefficients

In order to correct the measured I-V data to STC conditions, all temperatures are measured to be used for temperature compensation according to procedure 2 of IEC 60891.

In order to have an optimal result here, it is necessary to have most accurate and up to date (matching) temperature coefficients (alpha and beta) for the panels to be tested.

Wrong coefficients will lead to wrong correction, so that the basic measurement accuracy of +/- 5% might be not given anymore.

1.2. Temperature of modules to be measured

To get optimal results, temperature of modules to be measured should be as close as possible to STC temperature of 25°C. A range of +/- 5K around the STC temperature gives best results; a range of +/- 15K is acceptable.

For panel temperatures below 10°C and above 40°C the basic measurement accuracy of +/- 5% might be not given anymore, the system will show a yellow warning message!

- **Keep panels to be measured in the shade**
- **Don’t place the system in directed sun, so that panels in the module drawer are exposed to direct sunlight**
- **If possible, store panels to be measured at same temperature conditions**
- **Try to get most accurate and up to date (matching) temperature coefficients (alpha and beta) for the panels to be tested**
- **Avoid everything which will result in inhomogeneous temperature of the panel**

1.3. Reference cell temperature

To get optimal results, temperature of the reference cell should be as close as possible to the module temperature. A range of +/- 5K around the panel temperature gives best results; a range of +/- 10K is acceptable.

For reference cell temperatures differing more than 10K from the module temperature the basic measurement accuracy of +/- 5% might be not given anymore, the system will show a yellow warning message!

- **Try to get the reference cell to the same temperature like the modules to be tested**
- **Don’t place the system in directed sun, so that reference cells in the module drawer are exposed to direct sunlight**
- **If panels to be tested are stored outside in the shade, leave the module drawer as much open as possible to have the reference cells in the shade outside under the same temperature conditions than the modules to be tested.**

1.4. System temperature

A higher system temperature will result in lower irradiance emitted by the LED solar simulator. Even irradiance is corrected to STC irradiance - the lower Led power will result in more intense correction, which can influence the accuracy of the measurement. In addition higher system temperature might result in higher reference cell temperature, far away from the temperature of the modules to be tested.

- **Don’t place the system in directed sun if possible**
- **Keep an eye on the system temperature, values above 40°C are not acceptable and might damage the system**
- **Before using the system in regions of higher temperatures (>30°C) while being exposed to direct sunlight, thing about retrofitting the system with air condition.**

1.5. Series Resistance of module under test

The series resistance of the panel under test is the main value, influencing the irradiance correction of the STC module current.

Using the basic formula (0.01 ohms multiplied with number of cells in series) for calculating the series resistant might be not good enough to get values close to the real resistance, so looking for the measured values of the first modules under test might be the better idea.

2. Measures to increase the accuracy of STC power results for crystalline modules

2.1. Remarks about basic calibration of the built in solar simulator

The MBJ solar simulator is regularly calibrated using an up to date mono- and polycrystalline reference panel, calibrated also regularly at TÜV Rheinland with a measurement accuracy of 2.5%.

Calibration the system is done by recalibrating the irradiance being measured by the internal reference cells in a way, so that the STC Pmpp measured by TÜV for the reference panels is reproduced by the MBJ Testcenter measurement corrected to STC (done at almost STC temperature).

This will also result in a spectral sensitivity correction towards the spectral sensitivity of the reference panels for the built in reference sensors according to IEC 60904-7.

The MBJ Testcenter is using correction procedure 2 of IEC 60891 for correcting the IV-curves to STC according to irradiance and module temperature.

2.2. Power measurement without specific reference panels (basic calibration)

Measuring the power of crystalline panels, without using a reference panel of the same type and same spectral sensitivity will result in the non-optimal accuracy of +/- 5% for the STC corrected values. This accuracy is given for a panel temperature of +/- 15K around STC temperature and a delta of panel temperature to reference cells temperature of less than 10K.

- **This mode of operation is just recommended for small amounts of panels, or where the STC measurement is not critical**
- **Wherever possible, individual reference panels should be used or created, like explained in the following**

2.3. Power measurement using specific reference panels (individual calibration)

Measuring the power of crystalline panels, having upfront or afterwards (after measuring a series of panels) a reference panel of the same type and same spectral sensitivity available will result in a much better accuracy of +/- 1% against the accuracy of the reference. This accuracy is given for a panel temperature of +/- 5K around the reference panel's temperature when being used in the system for individual calibration. The delta of reference cells temperature during measuring the modules under test versus their temperature when calibrating the system by using the reference panels should be also less than 5K.

In order to not exceed this temperature ranges, the reference panel or the panel out of the tested panels selected to become a reference, can be used in a certain interval, to recalibrate the system again and again. This will guarantee to stay within the stated accuracy described above.

- **This mode of operation is recommended for larger amounts of panels, or where the STC measurement is the focus of the measurement**
- **Temperatures have to be monitored**
- **If temperature ranges are close to be exceeded, the calibration for the selected module type should be updated using the available reference panel, or the "chosen" reference panel**
- **"Chosen" reference panels can be calibrated afterwards at a stationary AAA lab flasher under STC, this data can be used to recalibrate the recorded measurement data in one step, or multiple intervals if necessary.**

3. Measurement of STC power for thin film modules

3.1. Remarks for measuring STC power of thin film modules

The MBJ solar simulator is regularly calibrated using an up to date mono- and polycrystalline reference panel, calibrated at TÜV Rheinland with a measurement accuracy of 2.5%.

For thin film panel power measurement this will have no impact.

For measuring thin film modules, an individual calibration per module type has to be done either prior to the measurement, or afterwards by calibration the “chosen” reference panels out of the amount of measured panels at a stationary AAA lab flasher under STC.

The calibration per thin film module type is done by recalibrating the irradiance being measured by the internal reference cells in a way, so that the STC Pmpp measured according to manufactures conditions in a stationary lab for the reference panels is reproduced by the MBJ Testcenter measurement corrected to STC.
This will also result in a spectral sensitivity correction towards the spectral sensitivity of the reference panels for the built in reference sensors according to IEC 60904-7.
(For thin film, the correction is done based on the polycrystalline irradiance sensor)

The MBJ Testcenter is using correction procedure 2 of IEC 60891 for correcting the IV-curves to STC according to irradiance and module temperature.

For best measurement accuracy of around +/- 2% to the reference, the temperature of the panel under test should not exceed +/- 5K to the reference panel’s temperature when being used in the system for individual calibration. The delta of reference cells temperature during measuring the modules under test versus calibrating the system by using the reference panels should be also less than 5K.

In order to not exceed this temperature ranges, the reference panel or the panel out of the tested panels selected to become a reference, can be used in a certain interval, to recalibrate the system again and again. This will guarantee to stay within the stated accuracy described above.

- **When measuring thin-film panels, all of them should be at the same precondition, don’t store them before in different ways (exposed and non-exposed to sun light etc.)**
- **If temperature ranges are close to be exceeded, the calibration for the selected module type should be updated using the available reference panel, or the “chosen” reference panel**
- **“Chosen” reference panels can be calibrated afterwards at a stationary AAA lab flasher under STC, this data can be used to recalibrate the recorded measurement data in one step, or multiple intervals.**

Mobile PV-Testcenter

Technical Specification

Date: 2012.05.03

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General Description

The Mobile PV-Testcenter is designed for use in the field at installation sites for an in-depth quality analysis of solar modules. The mobile inspection system is providing Electroluminescence inspection, IV-curve measuring using an innovative LED flasher, and Infrared Imaging. Accuracy of testing and measurement is designed and optimized for the requirements which are needed to qualify PV modules on site.

General Technical Data

Module sizes (W x L)	Min.: 590mm x 890mm Max.: 1060mm x 1700mm
Module types	Framed modules, mono-crystalline or multi-crystalline and thin film
Frame thickness	6mm to 55mm
Cell formats	5 and 6 inch
Contacting of modules	Manual
User interface	24“ TFT Display with Lenovo keyboard and trackpoint
Configuration	Module type based configuration of all system parameters through SW

Technical Data Electroluminescence

Cameras	6 MBJ NIR-CCD cameras, each 1.3 Megapixel, adaptive and active cooled CCD
Resolution	580 µm/Pixel
Image acquisition time	< 30s
Power supply unit	Power supply up to 220V, 20A for module power supply. Voltage and current controlled by software
Operation mode	Full automatic image acquisition, manual cell/module judgment through operator

Technical Data LED Flasher and I/V Curve Measurement

Illuminated area (W x L)	1200mm x 1900mm
Non uniformity	< +/- 2% (Class A IEC60904 Ed2)
Short term instability (STI)	< +/- 0.5% (Class A IEC60904 Ed2)
Long term instability (LTI)	< +/- 2% (Class A IEC60904 Ed2)
Spectrum	Warm white (400-800nm)
Total irradiance	850-1100 W/m² (depending on the silicon type and ambient temperature)
Repeatability of Pmax (Flash to Flash)	<0.5% (absolute)
Current measurement	0-10A
Current accuracy	+/- 0.2% (FSR)

Voltage measurement	0-200V
Voltage accuracy	+/- 0.2% (FSR)
Sampling	16Bit / 50kHz fully synchronously / configurable IV data recording time
Flash pulse duration	Long pulse, 180ms at full irradiance
Contacting	4 wire
Load element	Adjustable capacitive load
Reference cells	mono-crystalline and multi-crystalline, calibrated at Frauenhofer IWES with +/- 4% accuracy, calibration reference IWE001001IWE0510-V01 ISE CalLab, Shunt voltage is measured with +/- 0.1% (above 2% of measurement range) Recalibrated to reference panels calibrated by TÜV Rheinland.
Accuracy of Pmax	+/- 5% based on in system reference cell usage (assuming to have valid alpha and beta temperature coefficients available and measurement is done between 10°C to 40 °C module temperature) The accuracy of measurement can be increased to up to +/- 1% against calibrated panel of similar type (same technical/spectral parameters) used as reference prior to measurement at the same temperature than the module in test. (accuracy of reference has to be added to calculate overall accuracy) Correction of irradiance and temperature to STC conditions is done according to IEC 60891 Procedure 2
Operation mode	Full automatic measurement, no operator interaction needed

Technical Data Infrared Imaging

Camera	FLIR based MBJ IR camera, attached to the trailer
Resolution	324 x 256 Pixel
Sensor	FLIR-Indigo Microbolometer
Display	Live view on 24” TFT monitor, various color schemes selectable
Operation mode	Manual operation, temperature difference measurement

Software

Operating system	Microsoft Windows 7® 64 Bit
User interface	Windows compliant graphical user interface. Easy to operate. Displays images, stores image data on hard disk drive, and controls the system. User interface facilitates grading the module und test. Several user levels available.
Data Interfaces	File transfer via USB storage device / optional Ethernet
System control	Control of the cameras and the digital I/O signals via one Gigabit Ethernet network

Operation Performance

Tact time	Less than 2-3 Minutes for a combined measurement
Operators	One operator for the system, one person to load/unload (optional)
Daily throughput	With just the operator, including loading and unloading, 100 modules in 8h
	With two persons up to 150 modules in 8h working time

Dimensions of the trailer

Height	3000 mm
Width	2080 mm
Length	4500 mm (trailer body 3150mm plus 1350mm drawbar)
Max driving speed	100 km/h
Weight	approx. 1400 kg, 1600kg total maximum weight

Ambient conditions

Ambient temperature	0°C to 30°C (without additional air condition)
Relative humidity	20% to 90% not condensing

Power requirements

Voltage	230V, 50Hz
Current	16A fused

Documentation and training

User manual	English
Training	On request

Standards

Machinery Directive	2006/42/EG
Low Voltage Directive	2006/95/EG
EMC-Directive	2004/108/EG
ROHS	2003/108/EG