PVPM 2540C / 1000C / 1040C

Peak Power Measuring Device and IV-Curve Tracer for Photovoltaic Generators

Users Manual

Release © 12 / 2024

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Contents

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Iserlohn, 18.11.2024

2 Introduction

The PVPM Series is a state-of-the-art instrument designed to measure the I-V curve of photovoltaic modules (within current and voltage limits), as well as PV strings or arrays. Utilizing an innovative, patented method developed by Professor Wagner at the University of Applied Sciences Dortmund [2], the PVPM allows for the direct measurement and calculation of Peak Power (Ppk), Series Resistance (Rs), and Parallel Resistance (Rp) at the installation site of a PV system.

Measurement results, including detailed calculations and graphical representations, are displayed on the integrated TFT display. The peak power, a key performance indicator for PV modules under Standard Test Conditions (STC) [1], was historically measurable only in specialized laboratories due to the complexity of the process. The PVPM revolutionizes this process, enabling fast, economical, and highly accurate quality control on-site.

This simple yet effective testing process not only enhances customer and installer confidence but also provides valuable insights into the electrical characteristics of the tested module or string through the measured I-V curves. Consequently, the PVPM is well-suited for both practical field applications and advanced research and development purposes.

Key Features and Functionality:

- **Portable Design:** The PVPM is housed in a in a sturdy 19" aluminum frame with practical carrying handle with an integrated battery supply and charger, ensuring portability and resilience.
- **Standalone Operation:** Equipped with an industrial miniature PC and a high-contrast TFT graphic display, the device operates independently of external systems. A PC can optionally be connected via a standard USB interface for data transfer and advanced analysis.
- **User-Friendly Interface:** Operation is facilitated through a responsive touch screen with an intuitive, self-explanatory on-screen menu. This design minimizes the need for extensive user training, making the device accessible to a wide range of operators.

Additional Sensor Integration:
The PVPM accepts input from standard irradiance reference sensors producing a voltage between 0 mV and 150 mV proportional to the irradiance. For enhanced measurement accuracy, an external temperature sensor (RTD, Pt100) can be connected and attached to the rear of the PV modules under test to account for temperature effects.

Applications and Benefits:
The PVPM enables fast, reliable, and meaningful performance testing of PV systems, promoting efficient quality control and system optimization. Its versatile design also makes it a valuable tool for academic research and the development of photovoltaic technologies.

<u>Description of the Measurement Process: :</u>

The PVPM analyser automatically measures the I-V characteristic curve of the PV generator using a capacitive load. Based on the recorded data, it calculates key parameters of the solar cell, including Peak Power (Ppk), Series Resistance (Rs), and Parallel Resistance (Rp) [2], [3]. Upon completion of the measurement, the data is automatically saved in non-volatile memory, allowing for later analysis, such as in an office setting [4]. The device has the capacity to store data from thousands of individual measurements.

[1] IEC60904-3: STC= Irradiance 1000 W/m2, Spectrum AM=1.5, Cell Temper. 25°C

[2] Wagner A.: Peak Power and Internal Series Resistance Measurement under Natural Ambient Conditions. –EuroSun Copenhagen 2000

[3] Bendel C., Wagner A.: Photovoltaic Measurement relevant to the Energy Yield. - WCPEC3 Osaka 2003

[4] Schulte K.M., Wagner A.: Die Effektive Solarzellenkennlinie. - Anwendung Teillast-Berechnung. Staffelstein. 2002

The following results are displayed (if applicable) on the device:

Permanent Values:

- **Peak Power (Ppk):** Maximum power output of the PV generator.
- **Series Resistance (Rs):** Internal resistance limiting current flow within the PV module.
- **Parallel Resistance (Rp):** Shunt resistance indicating leakage paths in the PV module.

Dynamic Values (varying with irradiation and temperature):

- Voltage and current at maximum power point (**Vpmax**, **Ipmax**)
- Maximum power (**Pmax**)
- Open-circuit voltage (**Voc**)
- Short-circuit current (**Isc**)
- Fill factor (**FF**)
- Module temperature (**Tmod**)
- Effective irradiance (**Eeff**)

Additionally, the measured I-V characteristic curve can be displayed directly on the built-in LCD screen, providing an immediate graphical representation of the PV generator’s performance.

3 Scope of delivery

This section outlines the contents included in the delivery package for the measuring device. The provided components are designed to ensure a seamless setup and operation, offering everything necessary for accurate measurements and analysis.

The delivery package includes the following:

- **Measuring device** and a calibration certificate (factory calibration) from the manufacturer
- **One-year software license for PVPM.disp** (analysis and evaluation software)
- **A calibrated irradiance reference sensor** (monocrystalline with certificate) with temperature sensor Pt1000 for cell temperature; stainless steel clamp holder for tool-free mounting on the module frame; 10-meter cable length
- **One PT100 Class DIN 1/3 B temperature sensor** for measuring module temperature; 10-meter cable length / Additionally, a short circuit connector, which is used if measurement with PT100 is not desired.
- **One set of 4-wire measurement cables** (10 meters) with MC4 adapters
- **2 x Alligator clips** (red/black, max. 1500V DC/20A) with MC4 male/female connectors; 25 cm; for use with the original PVPM measurement cable
- **2 x Test probes** (red/black, max. 1500V DC/40A) with MC4 male/female connectors; 25 cm; for use with the original PVPM measurement cable
- **One MC4 connector release tool**
- **One external safety switch**
- **One external desktop power supply** (Input: 90-264V AC, Output: 15V DC, min. 2ADC), including a CEE power cable (black)
- **One USB cable** for connecting to a PC or laptop
- **One user manual & battery safety data sheet**
- **A durable transport case** for the measurement cables and sensors

Optional accessories:

- High-precision reference sensors with different filters; mono-, polycrystalline
- Extension cables for the PT100 sensor and/or the irradiation reference sensor
- Transport case for the safe transport of the entire system
- Padlocks for the cases
- All accessories can be purchased separately

4 Normal use

The PVPM Series Peak Power measurement and I-V curve tracer are specifically designed for the precise measurement of the I-V characteristics of photovoltaic modules, strings, or arrays with current and voltage limitations. These instruments provide detailed insights into the electrical and performance properties of PV generators, enabling the evaluation of efficiency and operational behavior.

Important Guidelines for Safe Operation:

1. **Adherence to Device Limits:** Before connecting the PV generator under test to the device, it is crucial to ensure that the PV-Generator's maximum current and voltage values will not exceed the device's specified limits at any time. This precaution protects both the instrument and the user from potential damage or malfunctions.

2. **Verification of Environmental Conditions:** Ensure that measurements are conducted under recommended environmental conditions. Extreme temperatures, high humidity, or direct sunlight on the device may affect measurement accuracy or damage the equipment.

3. **Inspection of Connections:** Use suitable test leads and connectors that meet the electrical requirements and inspect them for damage before use. Faulty or worn connections can result in measurement errors or pose safety risks.

4. **Device Calibration:** Regularly verify the calibration of the PVPM device to ensure accurate and reliable results. Follow the manufacturer's specific calibration instructions for optimal performance (see chapter 21.3 or contact the manufacturer → contact details also in chapter 21.3).

By following these guidelines, you can ensure the safe and efficient use of the device while obtaining precise and meaningful measurement data.

5 Safety Requirements

Before using the PVPM for the first time, carefully and thoroughly read this manual. It contains critical safety instructions to prevent harm to users and damage to the device. Safety-related information is highlighted within framed sections for emphasis and must be followed diligently to ensure safe and proper operation. Any damage resulting from neglecting the safety instructions in this manual is excluded from warranty coverage, and no warranty is provided for consequential damages resulting from improper use or failure to follow the safety guidelines.

The PVPM.disp software requires a PC with an operating system such as Windows® 10, Windows® 11, or another current version of Windows supported by Microsoft. The PC should also have a functional hard disk, a mouse or other pointing device, and a USB serial interface to connect to the PVPM. Before installing the software, ensure at least 20 MB of free disk space is available, with additional storage space needed for saving measurement data.

To protect your data and minimize the risk of loss, it is recommended to regularly back up the program's database to an external storage medium, such as a USB drive or cloud service. Data loss can occur due to hardware failure, software corruption, or unforeseen issues, even with modern technology. Always restore the entire database backup instead of individual files to prevent software malfunctions and further data loss. If in doubt, contact the distributor or manufacturer for assistance with backup and restoration.

Additional Safety Precautions

1. **Electrical Safety:** Ensure the PV generator under test does not exceed the maximum voltage and current limits of the PVPM. Overloading the device can lead to damage or hazardous situations.

2. **Environmental Conditions:** Operate the PVPM in a clean, dry, and ventilated area. Avoid exposure to extreme temperatures, high humidity, or direct sunlight. Protect the device from dust, water, and other contaminants that could interfere with its operation.

3. **Handling and Maintenance:** Use only the cables and accessories provided or approved by the manufacturer. Damaged or incompatible components may impair safety and performance. Do not open, modify, or attempt to repair the PVPM. All servicing must be performed by qualified personnel authorized by the manufacturer.

4. **Personal Safety:** When working with photovoltaic modules, be cautious of live circuits and potential high voltages. Use insulated tools and wear appropriate personal protective equipment (PPE), such as gloves and safety glasses. Avoid direct physical contact with connectors or live components during operation. Be aware that PV modules can produce hazardous voltages even in low light conditions. Always disconnect modules safely before handling.

Notice: Failure to comply with the safety instructions outlined in this manual may result in personal injury, device damage, or the voiding of warranty coverage. If you encounter any uncertainties, contact the distributor or manufacturer for clarification. Prioritize safety at all times.

6 Warnings

Failure to follow the instructions below could result in serious injury or even death!

CAUTION:
Before operating the equipment, carefully read this manual in its entirety.

NOTE: Danger of an electrical impact

Electrical Hazard Notice:

Measuring Category III: This device is rated for use in measuring category III environments. Do not use this device in measuring category IV environments.

Danger of Electrical Shock: Always exercise caution when working with electrical equipment to prevent electrical impacts.

Grounding: Do not connect measurement inputs to ground.

General Safety Instructions:

Flammable Gases: Never use this equipment near flammable gases.

Child Safety: Keep children and infants away from the measuring device at all times.

Environmental Conditions: The PVPM is not suitable for use in areas with heavy dust exposure or high humidity. Do not allow any liquids to enter the device.

Unusual Conditions: If you hear unusual sounds, detect smells, or see smoke coming from the device, immediately turn off the device, disconnect the circuit breaker, and disconnect the power source.

Damaged Test Leads: Before each measurement, carefully inspect the power measurement test leads for any visible damage. Do not use damaged test leads! If the wires are damaged, they must be replaced. Do not attempt to repair the test leads.

Current Input Limitations: The current measurement input must only be connected to a limited direct current source, such as a photovoltaic generator, with a maximum current of:

- **PVPM2540C Imax=40ADC**
- **PVPM1040C/X Imax=40ADC**
- **PVPM1500X Imax=20ADC**
- **PVPM1540X Imax=40ADC**

Connecting the device to other sources may cause serious damage to the device and pose a life-threatening risk.

Safety During Measurement:

Qualified Personnel Only: Only qualified personnel should make the cable connections between the photovoltaic generator and the PVPM. The measurement process must be conducted or supervised by qualified personnel. Additionally, relevant qualifications and regulations (e.g., VDE 0100) must be adhered to, as high voltages and currents can pose a severe risk to life.

Authorized Repairs Only: The PVPM and all associated components should only be opened or repaired by authorized, qualified personnel. Before opening any enclosure, ensure that all cable connections are

disconnected. Be aware that dangerous high voltage may still be present inside the unit, even after disconnecting cables.

Handling of High Voltage and Current:
The solar generator can produce very high voltages and currents that can be harmful to your health if not handled with care. Always take appropriate precautions when working with the system.

!! VERY IMPORTANT !!

NEVER connect or disconnect cables between the solar generator and the PVPM while the generator is active. Always ensure that the solar generator is deactivated before handling any cables. A safety switch added to the measurement line should be used to safely disconnect and connect the measurement cables to the PVPM (scope of delivery).

The plugs for the 4-wire power measurement cable must be fully inserted into the corresponding sockets up to the stop. Failure to do so may result in damage to both the meter and the cables, and could lead to an electric arc in the connector, posing a fire risk.

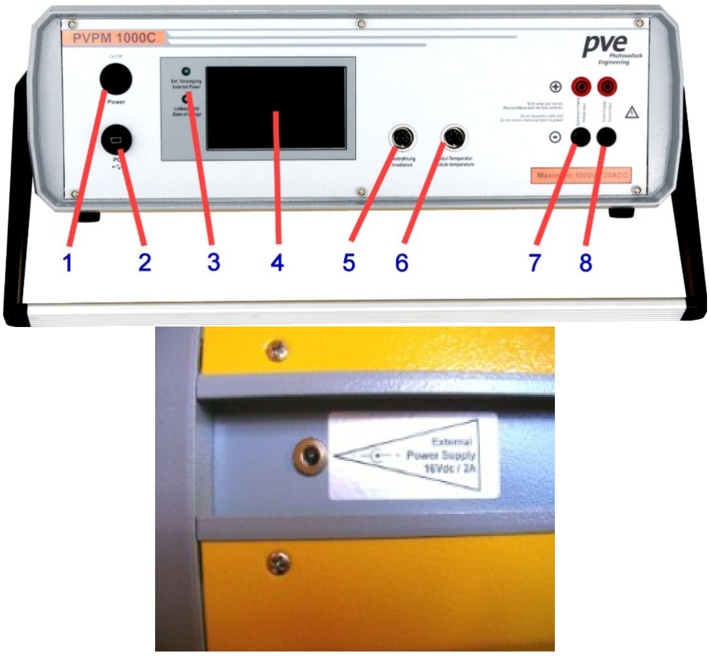
During measurement, the PVPM will create a short circuit. If cables are disconnected under this condition, an electrical arc may form, potentially causing serious health risks and material damage. Only remove the cable connections after the solar generator has been disconnected to avoid harm.

7 Operation of the PVPM

7.1 Operating and connection elements

1. On/Off rocker switch
2. USB port (mini B)
3. Status lights (state of charge/ power supply)
4. TFT colour graphic touch display
5. Combined irradiation and cell temperature measuring input
6. Module temp. measuring input Pt100
7. Four-wire measuring connector (voltage)
8. Four-wire measuring connector (current)

On the left side of the measuring device you will find the connection for plugging in the charger (15V, min. 2Adc)



Picture 1: Operating and connection elements

7.2 General information

The PVPM is designed to operate within a specified temperature range (refer to the appendix for details). To prevent overheating, the PVPM should not be exposed to direct sunlight for extended periods. Always place the device in a shaded area or use a sunshade to protect it from direct sunlight.

The standard version of the PVPM is a standalone device and cannot be integrated into other equipment, such as brackets or enclosures. It is crucial to ensure unrestricted airflow around the device's casing to maintain proper cooling. Stacking is strictly prohibited while the PVPM is in operation or charging. Stacking is permitted only when the device is completely powered off and disconnected from any power source.

Attention: Never disconnect a measurement cable during an active measurement! The significant DC voltages and currents can generate an electric arc, which poses a severe risk of fire, serious injury, or even death. Always refer to the safety instructions in Chapters 4 and 5 for detailed guidance.

Handling and Care of the PVPM Front Panel and Device:

The front panel and the entire PVPM device are designed for durability but must be handled with care to avoid damage. Please adhere to the following guidelines:

- **Avoid Sharp Objects:** Do not touch the front panel with sharp or pointed objects, as this may cause scratches or damage the foil, particularly in areas with underlying switches.
- **Cleaning Instructions:** Clean the front panel and the entire device only with a **soft, damp cloth**. **Do not use cleaning agents or chemicals** of any kind, as they may damage the surface or compromise the functionality of the device. Avoid abrasive materials, especially on the display cover, as scratches can significantly reduce display quality.

Water Resistance:

The case is not water proof. Do not expose the PVPM directly to influence of water, rain or similar.

Optimal Measuring Conditions:
For high-quality measurements, the solar irradiance during operation should exceed **500 W/m²**. Although I-V curve measurements are technically possible below this threshold, the resulting STC values will be less accurate and less meaningful. In such cases, the STC values will be automatically suppressed to ensure data reliability.

Status lights

The front panel of the PVPM is equipped with status lights that provide visual feedback on the device's status and operation. These lights include:

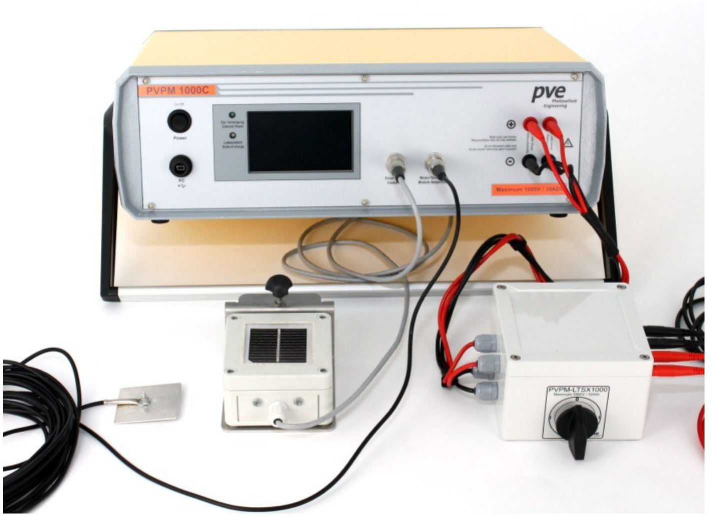
State of charge (3 color LED)	Li-Ion battery	Blinking Red: battery nearly discharged (charge!) Red: battery is charging (Power supply connected) Green: charge is nearly finished (Power sup. con.) Off: charge is finished (Power supply connected)	Operation time left <u>max. 30 minutes</u> Operation is possible Operation is possible Operation is possible
External supply	Lights up, when an external power supply is connected, the internal battery will be charged automatically.		

The PVPM reports several system conditions, functions and errors by speaker signals. A list of signals you will find in the appendix.

7.3 Connecting Peripheral Devices

For an I-V-curve measurement besides the PVPM the following components are required:

1. 4-wire-measurement cable
2. External security switch (see chapter 7) between measurement cable and PVPM
3. Irradiance reference sensor
4. Exernal RTD (Pt100) or short circuit adaptor
5. 2 x Test probes (red/black, max. 1500V DC/40A, **optional**)
6. 2 x Alligator clips (red/black, max. 1500V DC/20A, **optional**)
7. USB connection to operating PC **(optional)**
8. External power supply **(optional)**



Picture 2: Connecting Peripheral Devices

The PVPM is equipped with the following input/output interfaces (you will find all interfaces at the front panel and on the left side of the case, they are all marked accordingly):

Interface	Function
Power supply	Input 15Vdc/ min. 2A, coaxial power connector 5.5x2.1mm
Temperature	(External) temperature sensor: either short circuit connector or Pt100
Irradiance	Combined sensor: irradiance + Pt1000 cell temperature of the ref. cell
Voltage input	Voltage input (modules under test)
Current input	Current input (modules under test)
PC	Serial connection to PC (USB cable)

7.4 Power Supply

The PVPM is equipped with an integrated Li-Ion battery, enabling independent operation without reliance on a mains power supply. The battery is recharged using an external power adapter in combination with an integrated charge controller. Once the external power adapter is connected to the front panel of the PVPM, the battery charging process begins automatically. The charging status is indicated by an LED located on the device's front panel, providing a clear visual display of the battery's condition.

7.5 Connecting a PC

The PVPM can function autonomously without the need for an external PC. However, if you wish to perform an advanced analysis of the measured data or control the PVPM via a PC, you can connect the device to your computer using the included USB cable. Plug one end of the cable into an available USB port on your PC and the other end into the "PC" connector on the PVPM.

To enable PC control of the PVPM, ensure the following steps are completed:

1. Install the **PVPM.disp** software (refer to Chapter 10).
2. Install the USB port device driver (refer to Chapter 11).
3. Activate the "Transfer" function on the PVPM.

Failure to complete these steps will prevent data transfer between the PVPM and your PC.

Important: Before operating the PVPM from a PC using PVPM.disp, you must select the "Transfer" option in the PVPM menu. Without this step, the PVPM will not respond to the serial port, and the PC will be unable to access the device.

7.6 Connecting the Solar Generator

Important: Befor an I-V curve measurement, the solar generator under test must be disconnected from all other devices, such as batteries, inverters, or loads. The PVPM will short-circuit the solar generator for a few seconds during the measurement, and any connected batteries or inverter load capacitances could cause damage to the system.

Connect the PVPM properly to the solar generator using the cables as well as the external safety switch delivered with the PVPM. The **plus pole is marked RED**, the **minus pole is marked BLACK**! The measuring cable is plugged into the safety switch and then the safety switch cables are plugged into the PVPM device.

Assure that all connectors of the power measuring cables are pushed in completely (until stop) into the sockets.

It is important, that all 4 plugs of the 4-wire-measurement are connected properly by the delivered 4-wire-cable. Without this connection a measurement is not possible!

A reversed polarity connection must be avoided at all costs, even if an IPP-Diode protects the measuring device from damage caused by reverse polarity.

Caution: Maintain a safe distance from the live parts of the cables connecting the solar generator to the measuring device. These cables may carry high voltage, which can pose a health risk even without direct contact!

7.7 Connecting the irradiance reference sensor

Connect the combined PT1000 temperature and irradiance reference sensor to the designated port on the PVPM. The coded plug ensures correct alignment and can be secured with a simple twist. These sensors are vital for calculating Standard Test Conditions (STC) values, as the integrated temperature sensor in the reference cell enables automatic temperature compensation. Note: these sensors are unnecessary for series resistance (Rs) measurements or I-V curve tests without STC calculations. The plugs are uniquely coded to prevent misconnection with other sensors.

Position the combined sensor near the modules under test, aligning it with the same elevation and azimuth toward the sun. Ideally, attach it directly to the module frame using the supplied stainless steel clamp, which fits various frame heights and requires no tools. Ensure the sensor casts no shadow on the modules and is not placed in a different environment, as this could distort readings due to varying light intensities.

Before taking measurements, allow the sensor to acclimate (up to 15 minutes) so its temperature matches the modules. Use the PT100 module temperature sensor to verify alignment. Alternatively, use the supplied short-circuit bridge on the "temperature" input and manually adjust values in the PVPM.disp software if needed (see Chapter 12.5 for details).

Proper positioning and acclimation ensure accurate and consistent measurements (refer to Chapter 7.10 for additional guidance).

7.8 Connecting the PT100 module temperature sensor

To install the PT100 backside surface temperature sensor, begin by connecting the sensor's 10-meter cable to the designated port on the PVPM measurement device. The connection is facilitated by a coded plug that ensures proper alignment; insert the plug into the port and secure it by rotating it clockwise until firmly in place. The sensor is equipped with an aluminum plate designed to serve two purposes: it simplifies attachment to the module's backside and provides thermal inertia to enable more stable temperature measurements by mitigating the influence of environmental fluctuations.

Attach the aluminum plate, along with the sensor, to the rear surface of the module using standard insulating tape. Ensure the sensor is in full contact with the surface for optimal thermal conduction and accurate temperature readings.

Once the sensors have acclimated (up to 15 minutes after installation), and the measured module temperature matches that of the reference cell, measurements with the PVPM can proceed (see Chapter 7.10 for further details).

7.9 Powering On the PVPM

To turn on the PVPM, activate the "Power" rocker switch located on the front panel. Upon activation, the TFT display will show the start-up screen.

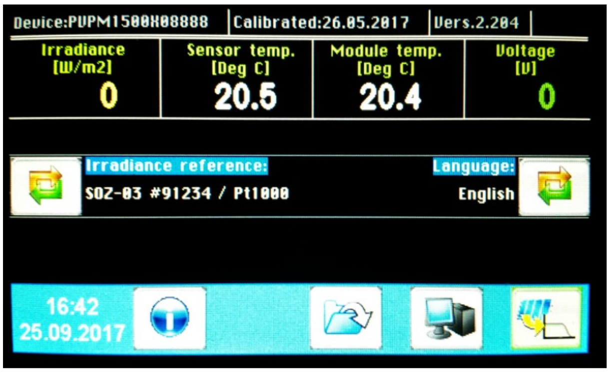
Info: The start up screen as well as the main menu are identical for all versions except for specific information such as type, serial number, calibration date, etc.

The PVPM will perform a series of self-tests, completing its initialization within approximately 10 seconds.

Picture 3: Start-up screen PVPM1540X

Once the initialization is complete, the device is ready for operation, and the main menu will appear on the LCD screen. The following information and options are displayed:

- **Header:** Displays the device serial number, calibration date, and firmware version.
- **Data Line:** Shows real-time values, including current irradiance, temperature of the irradiance reference cell, module back-surface temperature (if available), and voltage at the power measurement input.
- **Sensor & Language Line:** Displays the currently selected irradiance reference sensor, which can be modified as needed. The system language can also be set.
- **Bottom Line:** Displays the current time and date, along with the following menu buttons:
  - **Info**
  - **Archive**
  - **PC**
  - **New Measurement**



Picture 4: Main menu

7.10 Buttons

Possible actions will be displayed as buttons, which show a symbol according to the action, for example a PC for the transfer between PVPM and PC.

 Info: displays an overview about the buttons

 Change: This option allows you to select and modify a different value or entry

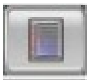
 New I-V-curve measurement, displays submenu

 Retrieve measurement data from archive

 Connection to PC („Transfer“)

 Start I-V-measurement now

 General: abort, cancel function

 Display results

 Display I-V-curve

 Add entry

 Previous page

 Next page

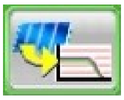
 Confirm, „OK“

7.11 Measurement

Picture 5: Main Menu

Please pay attention to the safety hints in chapters 4, 5 & 6 and factors affecting measurement accuracy in chapter 9.

The measurement can be started from the PVPM or from a connected PC (see chapter 12). The measurement should not be started before the solar generator and the necessary sensors are connected properly. The I-V-curve measurement will take up to 2 seconds, than the calculated results will be displayed immediately on the PVPMs display (or on the PC).



Opens sub-page for measurement

Picture 6: Sub-page for measurement

The parameters for the project can be defined on the corresponding sub-page. This includes specifying the customer, the installation, the respective string number, and the module type to be measured. Changes can be made at any time by clicking the “Change” button.

Each submenu also allows the addition of individual entries. For example, new entries can be added to the internal module database, and all relevant parameters from the corresponding datasheet can be entered.

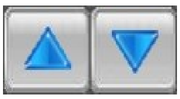
7.11.1 Start measurement

This button activates a single measurement of the I-V-curve. The measurement runs automatically, errors will be reported and the results as Ppk, Rs and I-V-curve are displayed on the screen.If you have previously made entries about the project, these will be adopted and saved in the measurement file. The information will then be available for later evaluation and report creation.

Picture 7: Start measurement

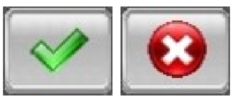
7.11.2 Archive

This button enables you to retrieve data of already made measurements. The data-sets are listed according to the creation date.



Goes to next/previous line in the list.

Selects next/ prior page



Select a file with “OK”, exit dialog with “Abort”

Use the button “Delete” to delete the selected data-set from PVPM memory. Caution: this operation is not reversible!

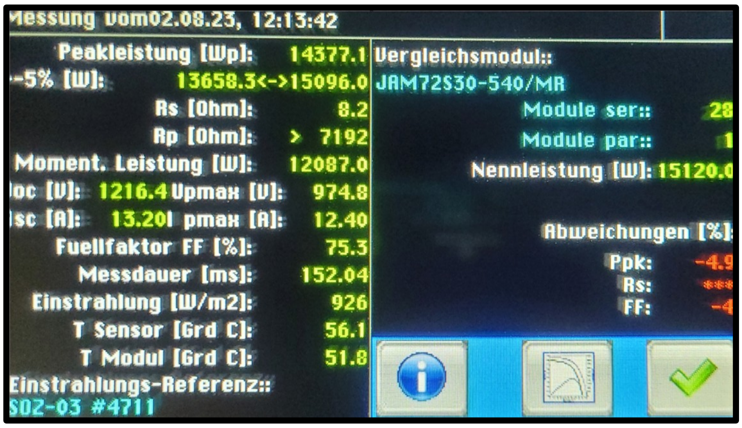
7.11.3 Transfer

The “Transfer”-Button activates the transfer between PVPM and a connected PC. You can cancel this transfer mode by pressing the “Abort” button at the PVPM screen. This function must be activated if, for example, you want to transfer data from the measuring device to the PC or if you want to start measurements and/or continuous measurements from the PC (operating the device via PC).

7.11.4 Results

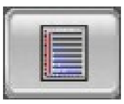
The "Results" page is automatically displayed after a measurement has been successfully carried out. All relevant measurement results and calculation results are displayed, such as:

- Peak power [Wp]
- plus/minus 5% tolerance for the determined peak power [W]
- Rs series internal resistance [Ohm]
- Rp parallel resistance [Ohm]
- Open circuit voltage Voc [V]
- Short-circuit current Isc [A]
- Voltage in MPP Upmax [V]
- Current in MPP Ipmax [A]
- Fill factor FF [%]
- Sweep duration [ms]
- Irradiance [W/m2]
- Temperature Irradiance reference sensor: T Sensor [°C]
- Module Temperature e.g. PT100 sensor: T Module [°C]
- Irradiance reference sensor type and serial number
- Reference Module
- Number of modules in series connection / in parallel connection
- Nominal Power [W] of the reference Module, String or Array
- Deviation in [%] for the Ppk, Rs and Rp (comparison of measurement to nominal values)



Picture 8: Displayed results

Picture 9: I-V-curve



The page “Results” displays the measured (voltages, currents, temperatures etc.) and calculated values (Ppk, Rs, Rp, FF).

The button “Diagram” selects the page with the I-V-curve, the button “Results” displays the results as described above.

7.11.5 Messages

Message:	*Description:*
'Serial error'	An error in the serial connection between PVPM and PC occurred
'No measured data'	No measured data present
'Configuration file not found!'	Internal error, consult manufacturer. PVPM cannot work without its configuration file
'Irradiance varies (ref-cell)!', 'Irradiance too low!', 'Irradiance varies (module)!'	The irradiance is not constant enough for the peak power measurement (e.g. due to moving clouds)
'not available'	This result cannot be calculated
'No room for new data!', 'Delete files from PVPM'	There is no space left on the internal permanent storage, you have to delete stored data from the permanent storage of the PVPM (see chapter 12.3.2)
'Error when writing '	Problems during the writing of a measuring data to the internal permanent memory
Measurement runs', 'Please wait...'	Measurement is in process
'Error writing file '	An error occurred storing the measured data
'Data transfer:', 'Quit transfer with ESC'	Data connection to PC invoked
'Measurement not yet possible'	The security delay between two measurements is not yet elapsed
'Calculation of Rs not possible'	Data is not sufficient for calculation of Rs. Redo the measurement
'Values not evaluablely'	Data is not sufficient for calculation. Redo the measurement
'Voltage too high!'	Immediately switch off the generator with the external security switch! The device could be damaged by the high voltage!
'Repair required immediately!'	The device is damaged internally and requires test and repair through authorised personnel.
'Wrong polarity!'	The measuring cables are mounted in the wrong way! Switch off the generator with the external security switch immediately! The device will short circuit the generator if the polarity is wrong and can take harm. If you disconnect the cables under voltage a light arc can cause serious damage to health and material

8 External Security Switch 1000V / 50A, 1500V / 20A

To prevent damage to the PVPM or risks to personal safety, always use the disconnection switch to isolate the PVPM from the photovoltaic (PV) power before connecting or disconnecting the measuring cables.

Procedure:

1. Turn the knob on the switch to the neutral "0" position (either of the two "0" positions is equivalent).
2. Firmly insert the measuring cables supplied with the PVPM into the sockets on the switch housing. Ensure the red connectors are inserted into the red sockets and the black connectors into the black sockets. The two red connectors can be interchanged without risk, as can the two black ones.
3. Connect the cables from the switch to the PVPM, matching red to red and black to black.

Measurement Operation:

- Before starting a measurement, turn the switch knob to one of the "1" positions.
- After completing the measurement, return the switch to the "0" position.
- Once in the "0" position, the wiring can be safely removed from the PVPM.

By following this process, you ensure safe handling and protect both the equipment and personnel.

Security advice

CAUTION: Always ensure the switch is set to the "0" position before handling the connectors on the PVPM!

Repairs and Replacement: Repairs and replacement of the switch may only be carried out using spare parts approved by PV-Engineering and by authorized professionals, as this is a safety-critical component.

Damaged Components: Switches, housings, or cables that show any signs of damage must not be used under any circumstances. Replace such components immediately to avoid safety hazards.

Cleaning: Clean the switch only with a soft cloth, which may be slightly dampened with water if necessary. Do not use cleaning agents or chemicals.

Usage Note: The switch is designed to disconnect maximum currents only once. During normal operation, when the circuit is interrupted by the switch, no current flows through it. Current is present only during the measurement process or e.g. in the event of a technical fault.

Technical Limitations:

The switch can interrupt currents of up to 40A at 1500VDC a single time.

During normal operation, when the circuit is interrupted by the switch, no current flows through it. Current is present only during the measurement process or e.g. in the event of a technical fault.

If the switch is used to disconnect a load exceeding I= 20A, it must be replaced immediately.

Adhering to these guidelines ensures safe and reliable operation of the switch while protecting both equipment and personnel.

9 Impacts on the accuracy of the measurement

To ensure accurate measurements, follow these guidelines:

1. **Avoid Shadows:**
   Ensure that no shadows, even the smallest ones, fall on the modules under test. This includes shadows from objects such as grass, as even minor shading can cause errors. The same applies to the reference sensor. Additionally, dirt or contamination on the modules also acts as shading and must be avoided.

2. **Irradiance Requirements:**
   Higher irradiance levels yield more accurate results. Ideally, the values are close to the target 1000 W/m². The irradiance measured by the combined sensor should exceed 500 W/m² for reliable results.

3. **Combined Sensor Functionality:**
   The combined sensor measures two parameters:

   - **Irradiance:** The intensity of sunlight.
   - **Cell Temperature:** The temperature on the back of the irradiance reference cell.

   If no external temperature sensor is available for measuring the backside temperature of the test modules, the PVPM assumes that the temperature of the reference cell is approximately the same as that of the test modules. Please insert the supplied short-circuit bridge into the "Temperature" input This assumption is valid if the modules and the reference cell have been exposed to sunlight for the same duration (at least 15 minutes).

4. **Pre-Measurement Exposure:**
   Before starting a measurement, ensure that both the modules and the reference cell are directly aligned with the sun and exposed for more than 15 minutes. For additional accuracy, check the backside temperature of the modules using an infrared thermometer before performing the I-V curve measurement or use the supplied PT100 sensor to measure the temperature on the back of the module.

5. **Module Alignment:**
   The modules should be positioned so that their angle to the sunlight deviates by no more than 10° from a perpendicular alignment. Precise alignment of the reference cell is also critical. The reference cell should receive the same sunlight as the modules under test.

6. **Sensor Placement:**
   The easiest approach is to attach the combined sensor directly to the side or top frame of the module under test. Alternatively, the sensor can be positioned at a distance, provided it is correctly aligned and exposed to the same sunlight as the modules.

7. **Spectral Compatibility:**
   The irradiance reference sensor must have the same spectral response as the modules under test, in accordance with **IEC 60904**.

   - It is possible to use a module identical to those under test as an irradiance reference. In this setup, the module is short-circuited using a precision shunt resistor, operating it near its short-circuit current (**Isc**). The voltage across the shunt resistor is proportional to the **Isc** and, consequently, to the irradiance. This principle is used in most irradiance reference sensors.

Caution: Even a small temperature deviation between the reference cell and the module can result in significant errors in the peak power measurement. Before performing a measurement, ensure that both the reference sensor and the modules have been exposed to the same ambient conditions for an adequate period of time!

To enhance the accuracy of PVPM measurement results, it is recommended to measure the same object multiple times (e.g. five times) and perform a statistical analysis on the obtained data.

Sweep Time Overview

The time required to capture a single I-V curve, referred to as the sweep time, depends on the current and voltage characteristics of the tested PV generator. More specifically, it is determined by the ratio between the current and voltage.

The PVPM device uses a capacitive load. The time required to charge this capacitor, which is influenced by the current-to-voltage ratio, determines the sweep time for an I-V curve.

Sweep Time Considerations

- **Impact of Fast Sweep Times:**
  If the sweep time is too short, the instrument will no longer measure the pure I-V characteristics but will also include the capacitive behavior of the PV generator. This can result in distorted and unreliable I-V curves.

- **Minimum Sweep Time:**
  Sweep times below 7 milliseconds should be avoided, as they may lead to inaccurate results.

- **Adjusting Sweep Time:**
  To increase the sweep time, you can raise the total voltage of the PV system under test. This can be achieved by measuring more modules in series.

9.1 Accuracy of the peak power calculations from I-V characteristics of PV generators with the PVPM

Under following constraints the peak power results of the PVPM have an accuracy of +/- 5% relating to the actual peak power value of the device under test:

- The device under test consists of mono- or polycristalline silicon cells
- The device under test is not (not even slightly) shadowed
- The irradiation reference sensor is not (not even slightly) shadowed
- The irradiation reference sensor must have largely the same spectral sensitivity as the tested device
- The measurement has to be carried out under natural sunlight
- According to IEC60904 the sun has to stand within +/- 10° at right angle to the active surface of the device under test
- According to IEC60904 an irradiation of at least 800W/m² is required. On the basis of comparative measurements we found 600W/m² to be sufficient for the PVPM
- The measurement of the irradiation has to take place immediately before/after that of the I-V characteristic, the time-lag between measurement of characteristic and irradiation should be less than 1ms.
- The measured value of the irradiation reference sensor has to be adjusted with the measured temperature of the reference cell
- The measurement of the cell temperature has to take place immediately before/after the measurement of the characteristic within 1second and an accurateness of 1K
- The active surface of the device under test must lie in-plane with the irradiation reference sensor (within +/- 1-2°)
- Before the measurement of the I-V characteristic the irradiation has to be constant enough (+/- 10 W/m²) for at least 10 seconds , in that way misinterpretations of the temperature of tested device and reference sensor can be avoided
- The irradiation must not vary more than 10 W/m² during the measurement (PVPM will caution the user in this case)
- The temperature of the device under test and the reference sensor has got to be balanced (no alteration of temperature may be indicated)
- Current and voltage of the device under test are measured with distinct measuring lines (four-wire measurement)

10 Installation of the Transfer and Evaluation Software PVPM.disp

Please download the recent software PVPM.disp for MS Windows® from:

https://t1p.de/wkb5p

This executable file contains the setup program for easy installation of the software on to your PC. The setup program will copy all necessary files to your hard disk and initializes the program. The installation can be performed by every person with basic experience of PC and MS Windows®.
For the installation of the software perhaps administrator rights are required.

For the installation the following steps are necessary:

1. Download the setup application to an appropriate drive/folder of your PC.
2. Under Windows® “Start” select menu option “Execute”. Select the downloaded file from the hard disk. Press ENTER now or click the Ok-Button.
3. The setup application will be executed. Follow the messages on the screen.
4. Setup now copies all necessary files to your hard disk and will as well create a new program group for PVPM.disp.
5. After completing the installation please execute PVPM.disp. The program should now work as described in the following text.

The operation of the program will be professed detailed in chapter 12.

For the operation of the program these files are necessary:

{program} \ PVPMdisp	Program file and additionally files required for the operation of the application (eg language files)
{common} appdata \ PV Engineering \ PVPMdisp	Configuration and the database files
{user docs} \ PVPMdisp	Sample and measured data

The program will create data files with the extension .SUI, which contains measured data from one I-V-measurement. When these files are created automatically during the data transfer from the PVPM to the PC the file name will contain the date and time of the measurement.
A typical data file name could be **"24-05-24 14_17_04.SUI",** this file contains data from a measurement made May 24th, 2024 at 02:17:04 pm.

The measuring data are usually stored in files below “My Documents\PVPMdisp\”.

Uninstalling the Software on Windows 11
To remove the software from your Windows 11 system, follow these steps:

1. **Open Settings:**
   - Press the **Windows** key and type *Settings*, then press **Enter**, or click the gear icon in the Start Menu.
   - Alternatively, press **Win + I** to open the Settings window directly.
2. **Navigate to Installed Apps:**
   - In the Settings window, select Apps from the left-hand menu.
   - Click on *Installed apps*.

3. **Locate the Software:**
    - Use the search bar or scroll through the list to find the software you wish to uninstall.
4. **Uninstall the Software:**
    - Click the three-dot menu (⋮) next to the software name.
    - Select *Uninstall* from the dropdown menu.
    - Confirm the uninstallation and follow any on-screen prompts to complete the process.
5. **Verify the Removal:**
    - Once the process is complete, ensure the software is no longer listed under *Installed apps*.

Note: If the software does not uninstall correctly or you encounter issues, ensure you have administrative privileges. For further assistance, contact the software's technical support.

11 Installing the USB device driver

1. Please download the USB driver installation file from:

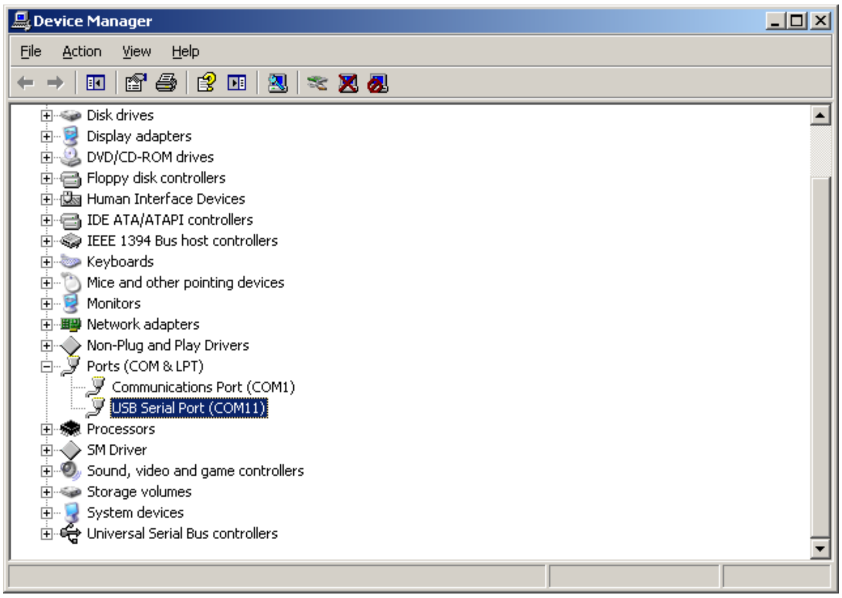
   https://t1p.de/8wx3f

   The newest driver will as well be available on the website of FTDI (www.ftdichip.com).

2. Execute the installation file you have downloaded.

3. The application will guide you through the installation of the USB driver files.

4. After the successful installation the new COM port appears in the device manager.



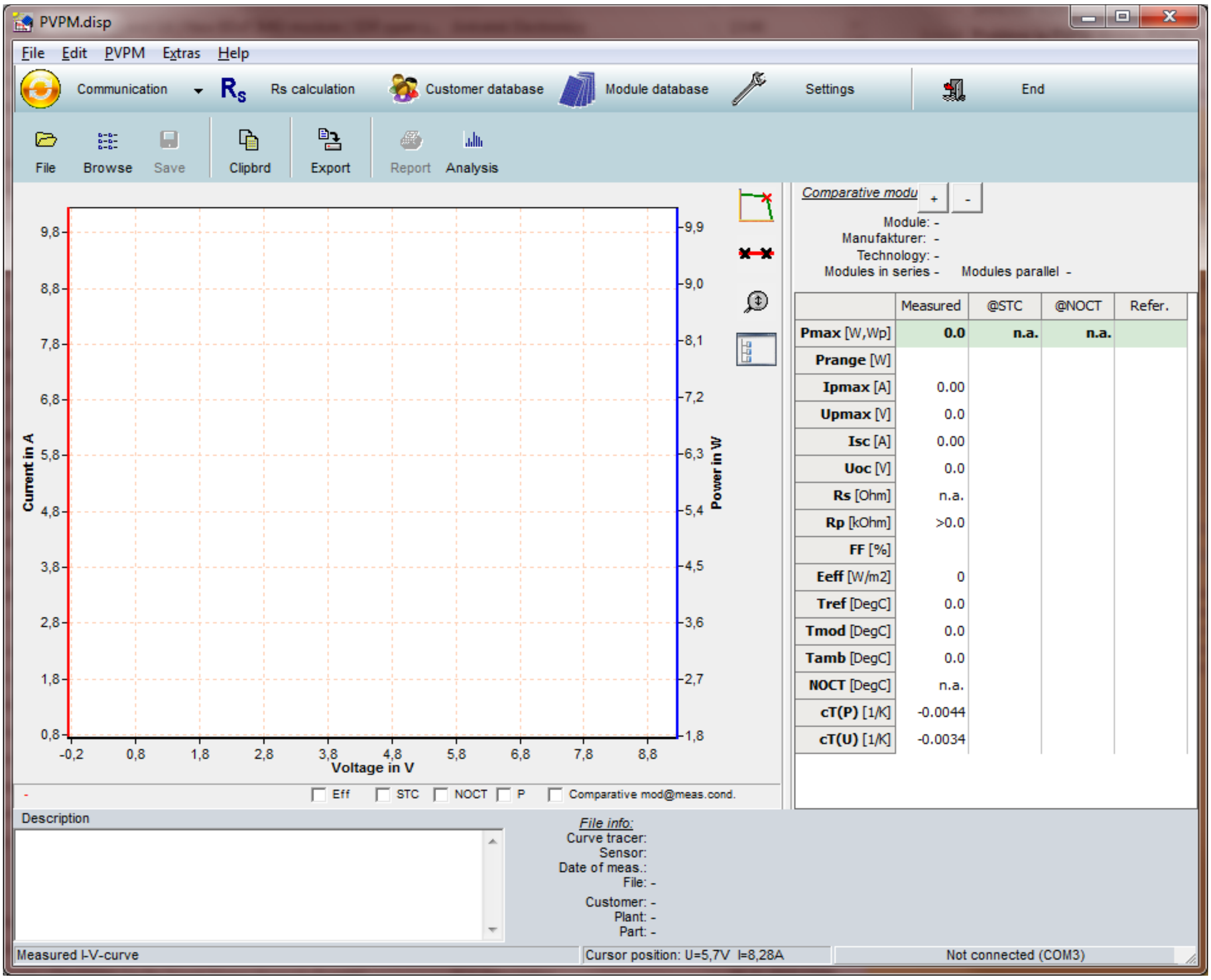
Picture 10: Device Manager

11.1 Uninstalling the USB driver

The driver can be removed using the Windows device manager: select the device in the list of devices with the right mouse key and select "Uninstall". This will delete the entries for this device from registry.

12 Operation of the Software PVPM.disp

For the installation of the software please refer to chapter 10 & 11. After starting the software the following window appears:



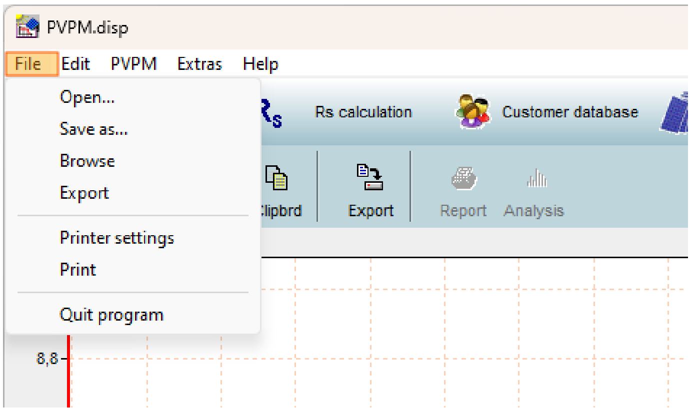
Picture 11: Main screen software after start

The displayed document is currently empty, with all values set to zero. At this point, you can either open an existing data file, conduct a new measurement, or retrieve previously recorded data from the PVPM. Any newly created or imported data will be saved to this document, allowing you to continue analyzing the data or save it to a file on your hard drive.

For analysis, you can utilize the diagram of the measured data and the displayed results. Additionally, the “Export” function enables you to export the data into various file formats for further processing in other software applications.

Inactive buttons are grayed out to indicate their non-availability. They become active and clickable when their respective functions are applicable.

12.1 Main Menu: File

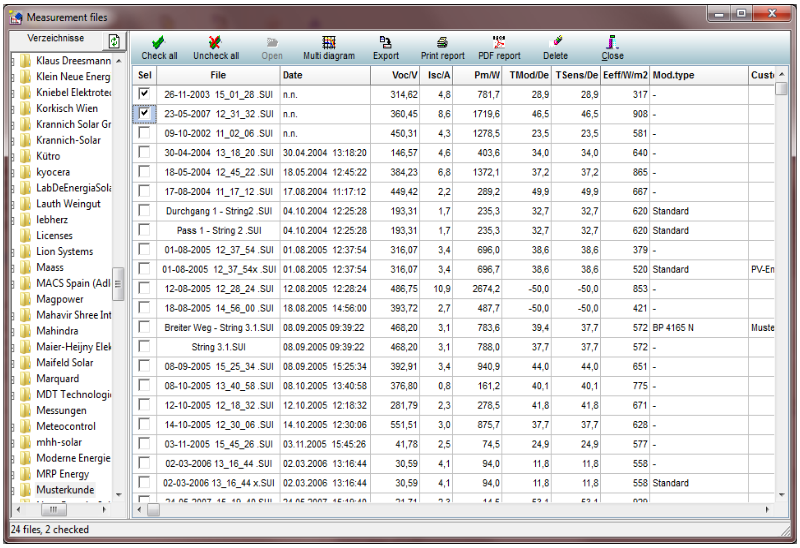


Picture 12: Menu items in the "File" tab

12.1.1 Open

Previously saved I-V curves can be reloaded using the “Open” button. Please note that loading new data will overwrite the data currently in memory of the PV software. To preserve the current data for future use, save it to a file before loading different data. The default file extension for saved files is `.SUI`.

By clicking the folder icon next to the displayed directory in the dialog window, you can navigate to and select a directory containing measurement data to be shown in the list.



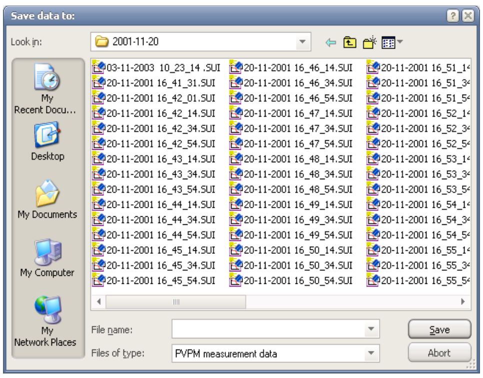
Picture 13: Display of saved measurements

Within this list, you can either double-click an entry to load and display the data directly in the working window, or select one or more entries for additional actions. Selected entries can be deleted, exported, or printed as test reports.

12.1.2 Save as...

This function allows you to save the current data to a file on your disk. All information, including any text entered in the “Remarks” field, will be stored as part of the file. This ensures that any additional notes or context related to the measurement are preserved for future reference.

The default file extension for saved files is `.SUI`, which is specifically used for this system to ensure compatibility and easy identification. When saving, you can choose the directory and file name according to your preference, making it convenient to organize and retrieve your data later.



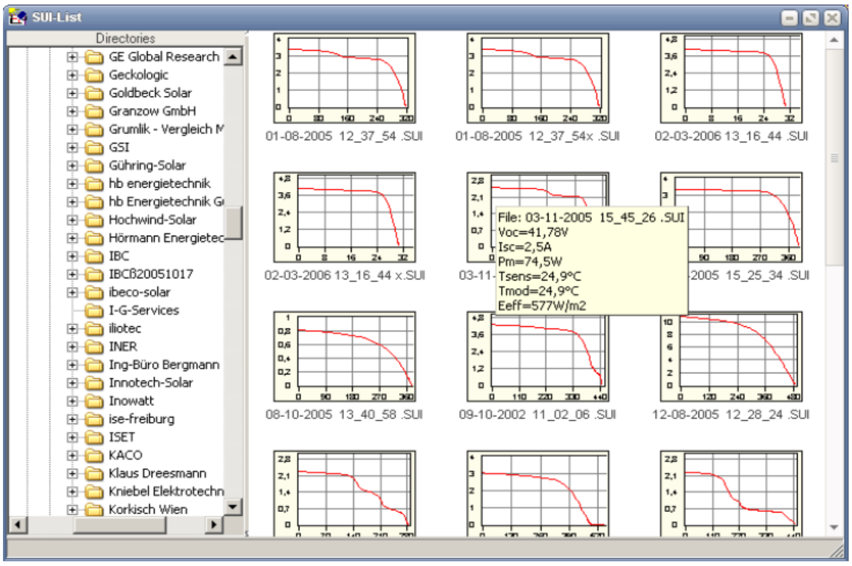
Picture 14: Saving measurements

By maintaining this structure, you can build a clear archive of your measurements, complete with metadata and annotations, facilitating efficient data management and subsequent analysis.

12.1.3 Browse

The "Browse" window provides a visual overview of the measured curves saved in the selected directory, displayed as thumbnail images. This feature allows for a quick and intuitive review of existing measurements, making it easier to identify a specific curve of interest.

When you hover the mouse cursor over a diagram, a tooltip will appear, displaying key values associated with that curve. This functionality offers additional insight without requiring the file to be opened.



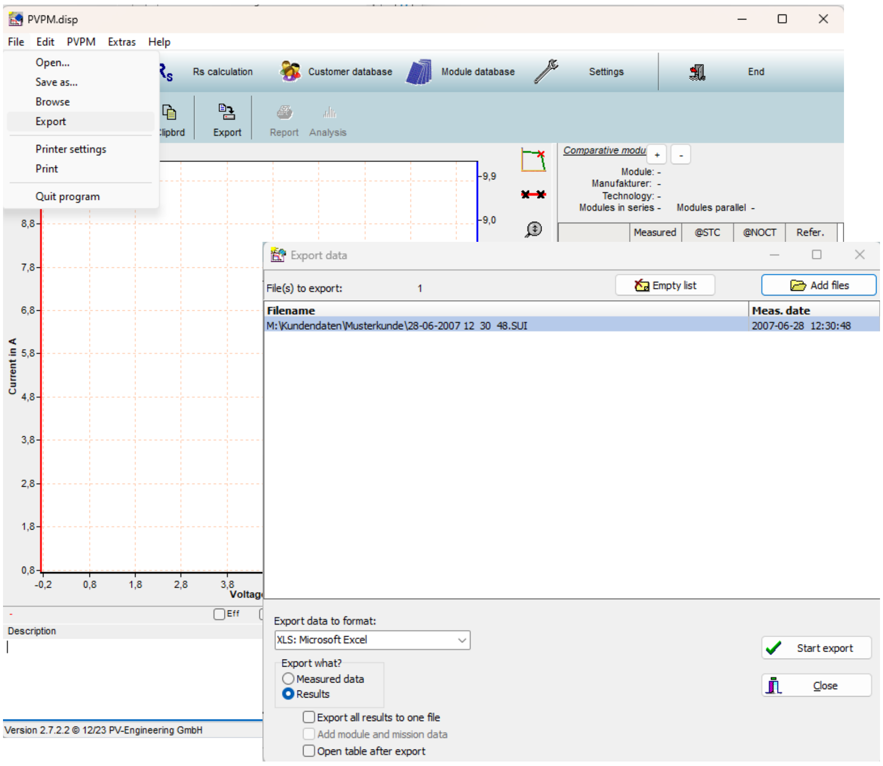
Picture 15: Browsing of measurement data with preview of the characteristic curves

To analyze a curve in detail, simply double-click on its thumbnail. This action will open the corresponding file in the evaluation window, allowing you to work with the data immediately.

12.1.4 Export

The current data can be exported to disk in various file formats compatible with other software applications, such as spreadsheet programs. Supported formats include **.XLS** (Microsoft Excel), **.DBF** (dBase III+), and three different ASCII formats. To select the appropriate format, refer to the documentation of the destination program to ensure compatibility.

The export files can contain either raw measurement data (e.g., I-V measurement points, temperature, and irradiation) or computed results. When exporting computed results, it is even possible to include data from multiple measurements in a single table. In the target table, the data is organized row by row for clear representation.



Picture 16: Export of data

To export data, select the desired file format from the drop-down menu. Then, specify a valid file name for the export file or choose an existing file using the “Search” button. Once ready, click “OK” to proceed.

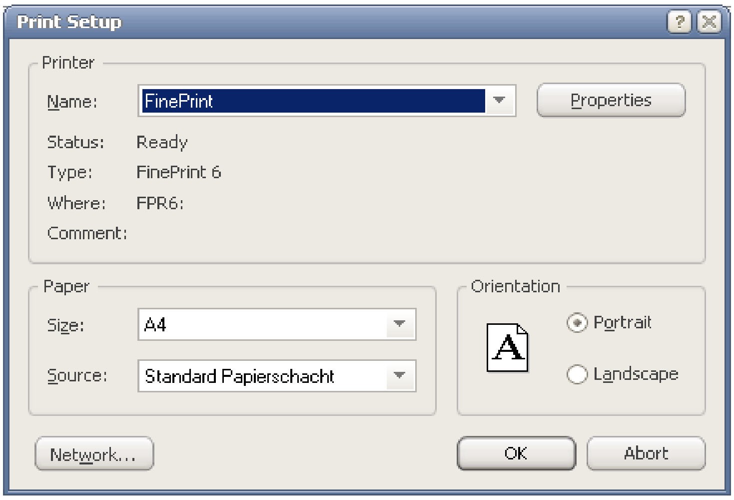
The exported files will be created in the same directory as the original data but with the specified file extension (e.g., `.XLS` instead of `.SUI`). These files can then be processed using any compatible software. Note that any modifications made to the exported files will not affect the original data stored in the application.

12.1.5 Printer Settings

This function opens the standard Windows dialog for “Printer Settings,” allowing you to configure your desired printing preferences. Through this dialog, you can select the appropriate printer from your available devices and customize various settings to ensure optimal printing results.

Key options available in the “Printer Settings” dialog include:

- **Printer Selection:** Choose the printer you want to use from the list of installed devices.
- **Page Orientation:** Specify whether the document should be printed in portrait or landscape mode.
- **Paper Size:** Select the paper dimensions, such as A4, Letter, or any custom size supported by your printer.
- **Print Quality:** Adjust settings like resolution or color options to match your desired output quality.
- **Properties:** Access additional printer-specific settings, such as duplex printing, scaling, or tray selection.



Picture 17: Printer settings

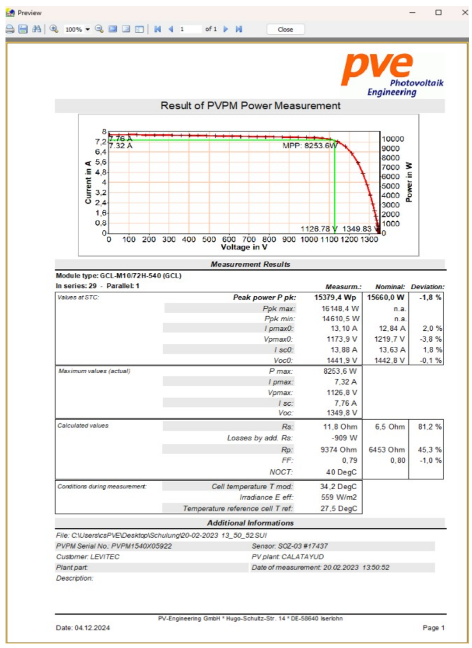
Once you have configured the settings to your preference, confirm your choices by clicking “OK.” These settings will be applied to your current print task, ensuring that the output aligns with your requirements. For more detailed information on specific options, consult the documentation provided with your printer.

12.1.6 Print

The **Print** button creates a comprehensive measurement report that includes the I-V diagram, along with both measured and calculated values of the currently loaded data. The report can be printed directly or saved as a PDF document for digital use.

Important: Before printing, verify that your printer's page orientation is correctly configured, as some reports may require adjustments to prevent truncation. The print function automatically optimizes the use of the full available printing area for enhanced clarity.

At the top of the report preview window, a toolbar provides access to the following features (listed from left to right):



Picture 18: Preview of I-V-curve measurement report

- **Print:** Sends the report directly to the printer.
- **Save:** Allows saving the document in its current format.
- **Export to PDF:** Saves the report as a PDF file for digital storage or sharing.
- **Zoom Factor:** Adjusts the zoom level of the preview for improved readability.
- **Full Page:** Fits the entire page within the preview window for an overall view.
- **Page Settings:** Enables customization of layout options, including margins and orientation.
- **Page Backward/Forward:** Navigates between pages in multi-page reports.
- **Close Preview:** Exits the preview mode and returns to the main interface.

This intuitive functionality streamlines the process of reviewing, customizing, and sharing measurement protocols, ensuring accuracy and efficiency in documentation workflows.

12.1.7 Quit Program

This option allows you to exit the PVPM.disp program. It is important to note that any unsaved data will not be saved automatically when you close the program. To prevent accidental data loss, the system will display a warning prompting you to save your current work before exiting.

When you choose to close the program, a dialog box will appear with the following options:

- **Save:** This option lets you save the current data to a file on your disk. You will be guided to select a file name and location if the data hasn't already been saved.
- **Don't Save:** This option discards any changes or unsaved data, allowing you to exit immediately. Be cautious with this choice as the data cannot be recovered once the program is closed.
- **Cancel:** If you decide not to exit at this time, this option will return you to the program, where you can continue working or save your data manually.

This safeguard ensures that you have the opportunity to secure your data, whether it is newly entered measurements, imported files, or computed results. Always verify that your data has been saved before confirming the exit to avoid unintended loss.

Make sure to close the "Transfer" process on the PVPM before exiting to return the device to its normal operation mode. This step is essential to ensure that the PVPM resumes its standard functionality and avoids any potential disruptions.

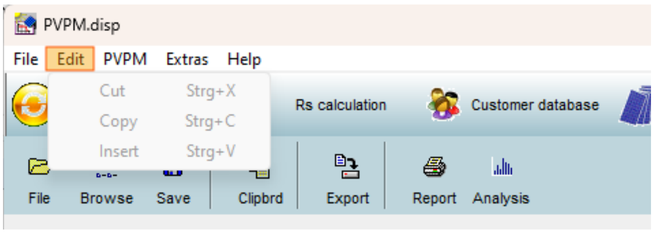
Always exit PVPM.disp using one of the following methods:

- The **"Quit Program"** function
- The **"End"** button
- The key combination **<ALT> + <F4>**

It is also crucial to properly shut down your operating system after closing the program. Failing to do so may result in data loss due to write-back caching or other system processes that have not been completed. Proper system shutdown ensures that all data is safely saved and avoids any potential corruption or loss.

12.2 Edit

This function becomes active only when the cursor is positioned within a text edit field.



Picture 19: Menu items in the "Edit" tab

12.2.1 Cut

Cuts the marked text and moves it to the clipboard.

12.2.2Copy

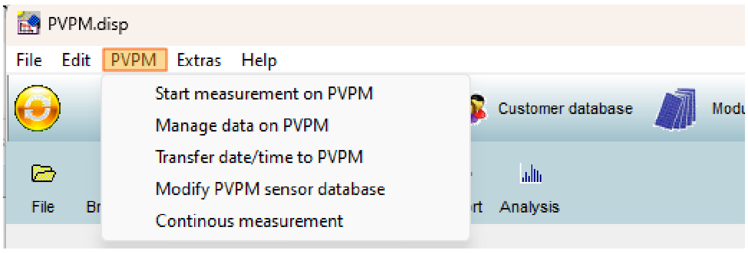
Copies the marked text and moves it to the clipboard.

12.2.3Insert

Inserts the contents of the clipboard at the cursor position.

12.3 PVPM

Before using the “Measurement” function, first switch the PVPM to **“Transfer”** mode. Ensure that the solar generator under test and the sensors are properly connected, if necessary, before proceeding with the measurement.



Picture 20: Menu items in the "PVPM" tab

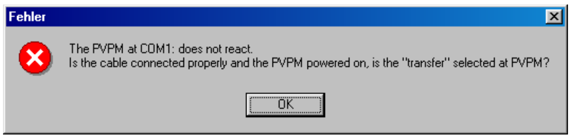
12.3.1 Start Measurement on PVPM

After starting the function the status line will display the message “Measurement processing– Please wait”.

The measurement will take up to 2 seconds. Directly after the measurement the measured values will be transferred to the PC (process will be displayed in the status line) and the main window will display the values and results. Now you can display the data in a diagram (chap. 12.5) or a list (chap. 12.1.4), export (chap. 12.1.4) or save to file (chap. 12.1.2).

Important: When the measurement is initialized from the PC the data will **not** be stored in the PVPM!

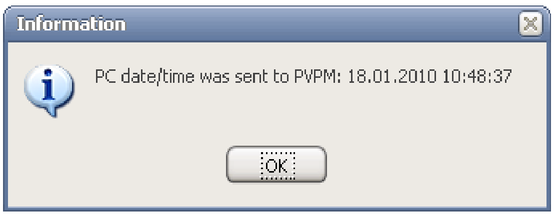
If this message appears (see right), the cable to the PVPM is not mounted properly or the function “Transfer” on the PVPM is not activated.



Picture 21: Error message

12.3.2 Manage data on PVPM

First, the time settings of the PC and PVPM will be compared. If the time difference exceeds 5 minutes, the application will prompt you to decide whether to correct the PVPM time based on the PC's time settings.
Once this is done, the measurement data stored on the PVPM will be displayed in a list (note that the PVPM must be connected and online for this function to work). You can then select one or more data sets from the list and either transfer them to the PC for further processing (using the “Get Data” button) or delete them from the PVPM (using the “Delete Data” button). The destination directory can be set via a directory selection dialog, which appears when you click on the directory symbol next to the displayed directory.



Picture 22: Info about the sending of date and time to the PVPM

Caution: The “Delete” function cannot be undone!

When selecting data transfer, the data sets will be transferred one by one, and the files will be automatically saved to disk with a file name containing the measurement date and time.

If the checkbox "Delete data after transfer" is checked, a dialog will appear after the transfer asking if the transferred data should now be deleted from the PVPM's memory. Only if you are absolutely sure that the data will no longer be needed on the PVPM should you answer "Yes." This will permanently delete the selected data sets from the PVPM's memory.

12.3.3 Transfer date/time to PVPM

With this function the internal real time clock of the PVPM is set to the PCs date/time.

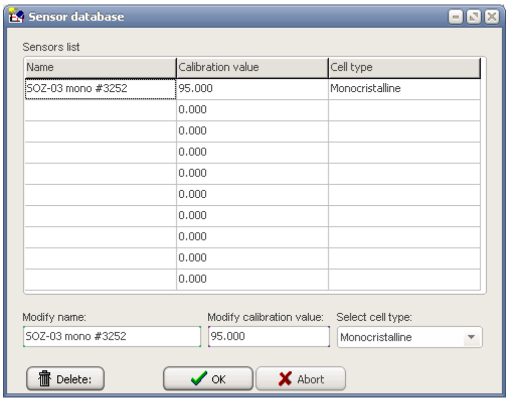
12.3.4 Modify PVPM sensor database

You can connect various irradiance sensors to the PVPM, each with its own calibration value. The PVPM requires this calibration value for accurate operation. To simplify the sensor selection during measurements, you can define a table with up to ten different sensors, including their names and calibration values, which will be stored in the PVPM's permanent memory. Later, you can easily select the appropriate sensor on the PVPM.

The name you assign to each sensor is flexible but should be brief and descriptive, as it will appear on the PVPM display to inform you about the currently selected sensor. You can select the sensor on the PVPM by clicking on the related sensor name on the main screen

To modify the sensors database, the PVPM must be connected and ready for data transfer. When you start this function, the database is loaded from the PVPM and will be saved back to the PVPM when you close the form.

To enter a new sensor, simply select an empty row in the list and input the values in the edit fields below the table. After completing the entries, click OK. You will then be prompted to confirm whether the changes should be transferred to the PVPM. Select “Yes” to save your changes, or they will be discarded.

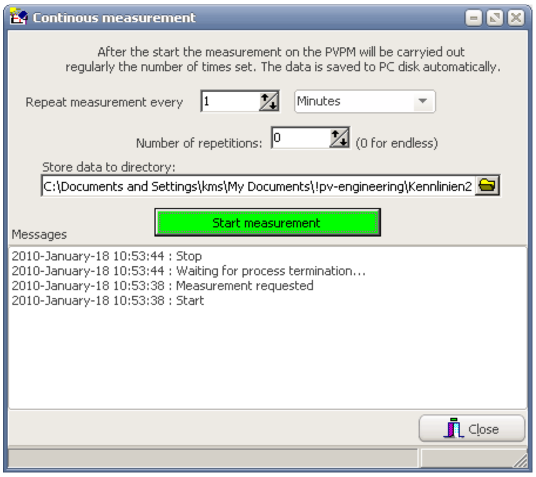


Picture 23: Entries in the PVPM sensor database

12.3.5 Continous measurement

This function enables automatic, timed measurements controlled from the PC.
Set the desired time interval and the time unit (seconds, minutes, or hours) for the measurements, as well as the number of repetitions (set to 0 if the measurements should repeat indefinitely).

After clicking the “Start Measurement” button, the measurements will run automatically and can be stopped at any time by pressing the “Stop” button. The measured data will be automatically saved to files in the predefined directory, with file names containing the date and time of the measurement.



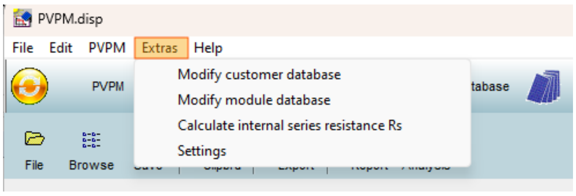
Picture 24: Continous measurement control panel

The automatic measurement will stop once the specified number of repetitions is completed, or if the PVPM does not respond, or if the user cancels the measurements.

12.4 Extra

Under the "Extras" tab, additional functions can be accessed that do not require a data connection to the PVPM. The following functions are available, and are described in more detail below:

- Modify Customer Database
- Modify Module Database
- Calculate Internal Series Resistance (Rc)
- Settings



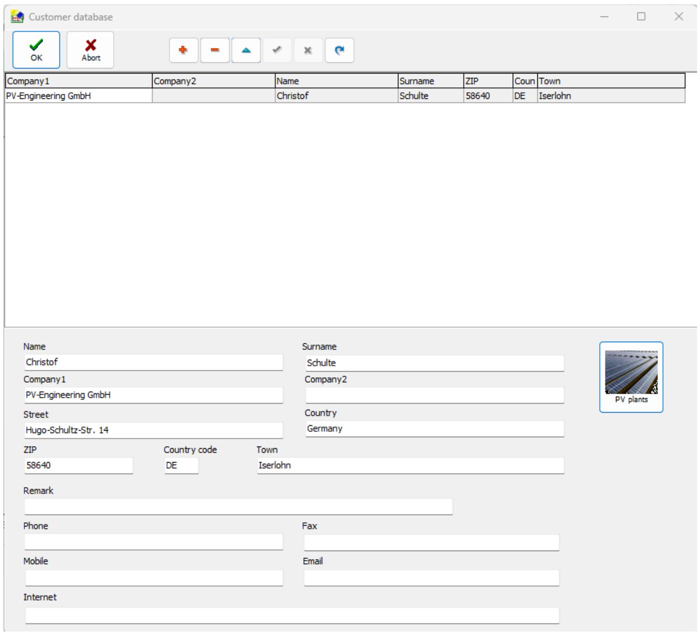
Picture 25: Menu items in the "Extras" tab

12.4.1 Modify Customer Database

Under the "Modify Customer Database" command, you can manage your customers and projects. This allows you to store important information such as names, addresses, and general contact details. To add a new entry, simply click the "+" symbol, and to remove an entry, click the "-" symbol.
To activate editing of an entry, click the "Up Arrow" symbol. This prevents unwanted changes by ensuring the entry is in edit mode. Once you have finished editing, you can close the active window by clicking the checkmark ("✓") symbol. The fields will then be locked to prevent further editing.

Additionally, to apply all changes made to the entries, confirm by clicking the green "OK" symbol. If you wish to discard the changes, press the red "Abort" symbol.

You can also cancel the process by clicking the "X" symbol or undo changes using the "Back" symbol.

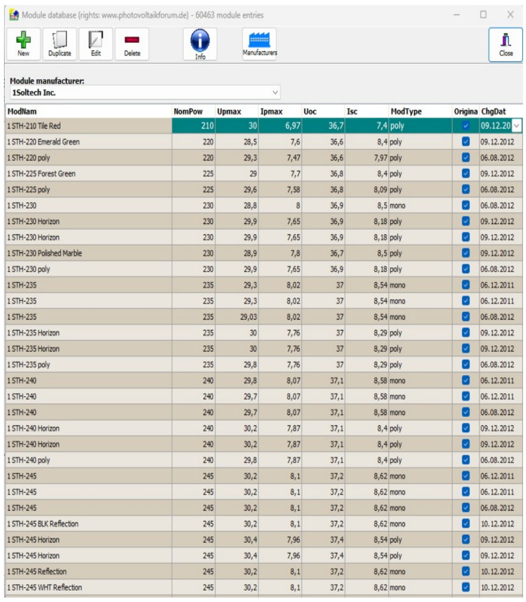


Picture 26: Modify customer database

12.4.2 Modify Module Database

Under the "Modify Module Database" command, you have access to an extensive database of PV modules from various manufacturers. The database is regularly updated and currently includes approximately 60,000 modules. Key parameters and datasheet values of the modules are clearly listed, such as:

- **Nominal Power**: The rated electrical power output of the module under standard test conditions (STC).
- **Maximum Voltage at MPP (Vpmax)**: The maximum voltage the module can achieve at the Maximum Power Point (MPP).
- **Maximum Current at MPP (Ipmax)**: The maximum current the module can provide at the Maximum Power Point (MPP).
- **Open-Circuit Voltage (Voc)**: The voltage across the module when it is not connected to any load (i.e., no current is flowing).



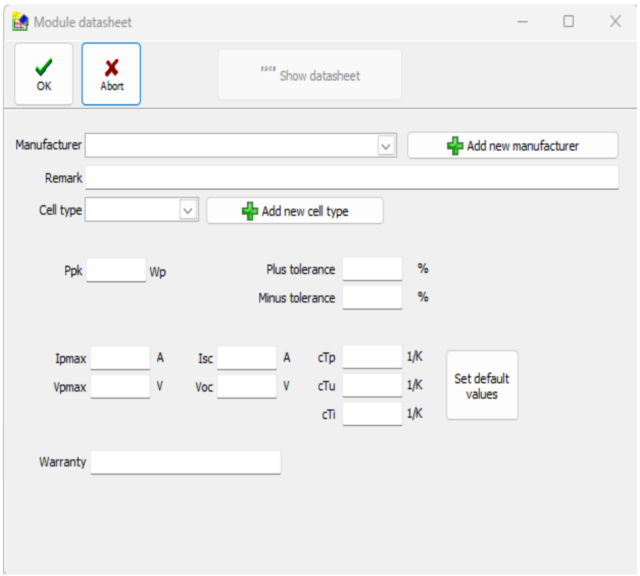
Picture 27: Modify module database

- **Short-Circuit Current (Isc)**: The current that flows when the module's output is shorted, with no load connected.

Additional information, such as module type, may also be available.

You can easily create a personalized module by clicking the green "plus" symbol or duplicate an existing entry. A new row will be added, allowing you to input all the necessary parameters. Existing entries can be edited by selecting the "Edit" button, which will put the entry into editing mode.

When adding a new entry, you will first be asked to confirm the input to avoid unwanted entries. After confirmation, the "Module Datasheet" will open, where you will need to enter the following key values:



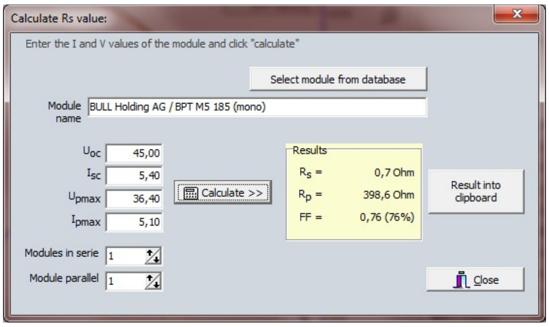
Picture 28: Add a new entry to the module database

- **Manufacturer**: The name of the manufacturer of the PV module.
- **Remarks**: Any additional comments or notes regarding the module.
- **Cell Type**: The type of solar cells used in the module (e.g., monocrystalline, polycrystalline).
- **Ppk [W]**: The peak power output of the module at standard test conditions (STC).
- **Plus Tolerance [%]**: The positive tolerance range of the module's power output.
- **Minus Tolerance [%]**: The negative tolerance range of the module's power output.
- **Ipmax [A]**: The maximum current output of the module at the Maximum Power Point (MPP).
- **Vpmax [V]**: The maximum voltage output of the module at the Maximum Power Point (MPP).
- **Isc [A]**: The short-circuit current, the maximum current the module can generate in an open circuit.
- **Voc [V]**: The open-circuit voltage, the voltage across the module when not under load.
- **Ctp [1/K]**: The temperature coefficient for power, indicating the percentage change in power output per degree Celsius of temperature change.
  Note: The device, and the evaluation software, expect the temperature coefficients in a normalized form as [1/K]. This is simply the datasheet value (usually in %/°C or %/K), divided by 100. For example, a temperature coefficient of power (Ctp) of -0.35 %/°C from the datasheet is used as -0.0035 1/K in the software.
- **Ctu [1/K]**: The temperature coefficient for voltage, indicating the percentage change in voltage with temperature. **Note**: Like **Ctp**, the value for **Ctu** should be divided by 100 to convert from %/°C or %/K to 1/K.
- **Cti [1/K]**: The temperature coefficient for current, indicating the percentage change in current with temperature. **Note**: The value for **Cti** also needs to be divided by 100 to convert from %/°C or %/K to 1/K.
- **Warranty Period**: The length of time for which the manufacturer guarantees the module's performance.

You also have the option to use the "Set Default Values" button to automatically populate standard entries.

12.4.3 Calculate internal series resistance

Based on the nominal values of short-circuit current, open-circuit voltage, and the I-V values at the Maximum Power Point (MPP), the PVPM can calculate the effective solar cell curve and determine the expected internal series resistance (Rs). This theoretical value can then be compared to the actual measured value, providing insight into potential issues, such as faults in the cabling.



Picture 29: Calculation of the Rs value

12.4.4 Settings

All changes made here will be saved automatically and are valid until the next change:

12.4.4.1 Serial Port

You can select the serial USB port (COMx:) used for PVPM communication from the drop-down menu.
If the application is able to read the list of available serial interfaces from the Windows registry, the identifiers of the interfaces defined there will be displayed in the combo box, along with an indication of whether the interface is currently available. If an interface is unavailable, it means it is already in use by another application. In cases where the registry cannot be accessed (due to insufficient user rights), the application will only display basic interface identifiers, such as “COMx.” Nevertheless, it is still possible to select an interface manually.

Picture 30: Settings menu

If you are unsure which interface the PVPM is connected to, you can use the “Search PVPM” button. This feature allows the application to automatically attempt to communicate with all available interfaces until a valid connection is established. The PVPM must be connected to the PC and set to "transfer." Once the application receives a valid response from the PVPM, the search will stop, and the identified interface will be used for communication with the PVPM.

Picture 31: Search PVPM on COM port

12.4.4.2 Working directory

The working directory is used in file open and save dialogs, as well as for the automatic saving of files. Here, you can select the directory that contains your measured data, or the directory where you want the measured data to be saved. This directory is also used during automatic data storage (such as during PVPM data transfer or continuous measurement). The entry field has a button on its right side—click this button to open a directory selection dialog.

12.4.4.3 Dialogue language

PVPM.disp supports the dialog languages English, German and Italian. The language can be changed during program execution. Just select your desired language from the combo box “dialog language”. After you close the dialog box the labels of PVPM.disp will be displayed in the selected language. PVPM.disp will remember the language setting.Please note, that the standard and system dialogs will always be displayed in the language of the current windows version!

12.4.4.4 Temperature correction

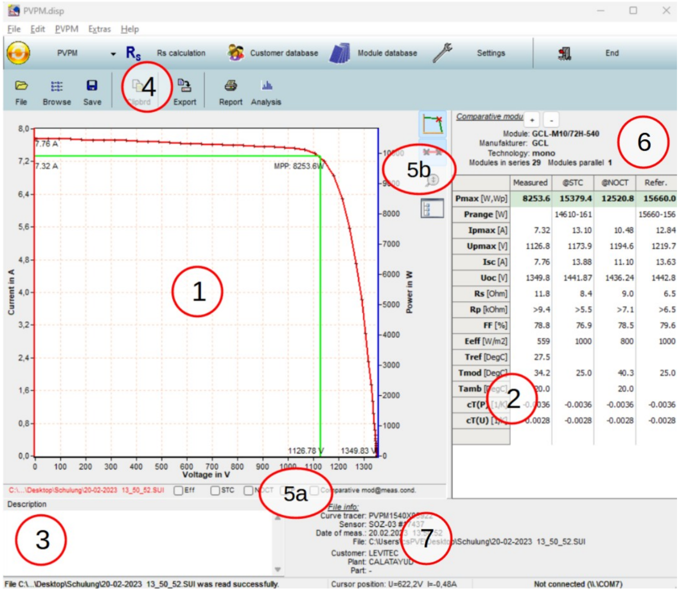
In some cases (e.g. if there is a known deviation between the module rear temperature and the actual cell temperature), it may be useful to apply a correction factor to the measured temperature values. You can enter the correction factor here. The factor will be added to the measured temperatures: enter a negative value if you want to decrease the temperature. If the factor is not zero, the displayed temperatures will be shown as "xx.x°C korr." to indicate that this value has been adjusted and is not the original measured temperature. Please note that the altered value will not be saved.

12.4.4.5 Report Company and Logo

Here, you can enter your personal address information and company logos, which will later be included in the reports you generate.

12.5 I-V curve / Diagram

The graphic to the right illustrates the PVPM.disp software, which displays an open measurement file. The software presents all relevant information, labeled with the following numbering:



Picture 32: I-V-curve and measured data displayed in the software

1. **Graph Area**
   Displays the graphical representation of the measurement data.

2. **Measured and Calculated Values**
   Shows the actual measured data alongside any calculated values based on the measurements.

3. **Description**
   Provides detailed information or notes related to the open file or measurement.

4. **Clipboard**
   Area where copied items, such as data or files, are temporarily stored.

5. **Toolbar Functions**
   Displays the available functions in the toolbar for quick access to common tasks.

6. **Reference Module**
   Indicates the selected reference module for the measurement.

7. **File Info**
   Displays metadata related to the open file, such as file name, date, and other details. By right-clicking in this field, you can add the displayed customer to your customer database.

12.5.1 Zooming:

You can zoom into a specific region of the diagram by drawing a rectangle with the mouse cursor (click and drag from the top-left to the bottom-right corner while holding the left mouse button). The selected region will be displayed in a zoomed view. To return to the default view, simply click anywhere within the diagram area.

12.5.2 Panning:

To pan the diagram, hold down the **Ctrl key** and the left mouse button simultaneously, then move the mouse in any direction. This allows you to adjust the view within the diagram area.

12.5.3 Editing Data:

Currently, modifications are possible in the following fields „2“:

- **Irradiation**
- **Temperature**
- **Temperature Coefficients (cTP and cTU)**

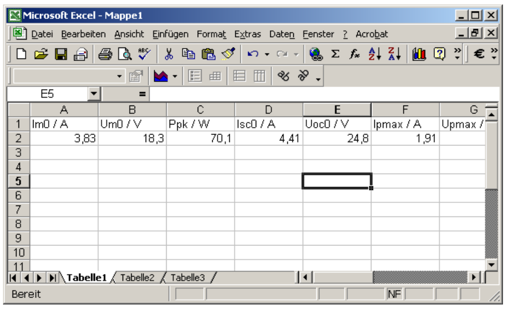
To modify these values, double-click on the displayed value to open a dialog box where you can input the new value. Changes to these fields will persist if the file is saved again.

12.5.4 Adding Notes:

The **Description** field „3“ allows you to include personal notes, which are saved along with the measurement data. The first line of your notes is used as the diagram’s title.

12.5.5 Copying Data:

The **Clipbrd** button „4“ enables you to copy key data in a tabular format to the clipboard. This data can then be pasted into external programs like Microsoft Excel for further analysis. This feature allows you to easily create and compare tables of different measurements without exporting files.

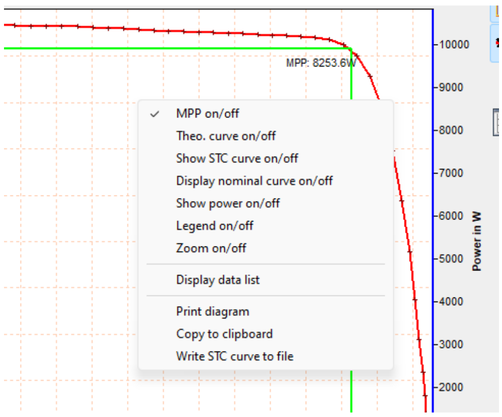


Picture 33: Copying and pasting measurement data

12.5.6 Context Menu and Toolbar Functions:

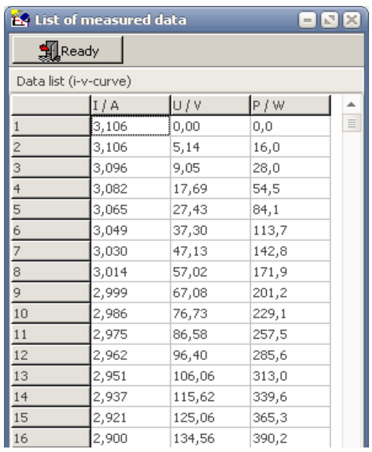
Right-clicking within the viewing area opens a context menu offering additional options. The same functionality is accessible via the buttons located e.g below „5a“ and on the right side „5b“ of the diagram area. Available options include:

- **MPP On/Off:** Toggles the display of the Maximum Power Point (MPP) in the diagram. Note that the displayed MPP is interpolated for higher precision and may not match an exact measured data point.



Picture 34: Context Menu and Toolbar Functions

- **Theoretical Curve On/Off:** Toggles the calculation and display of the effective solar curve derived from the data. Note: The calculation may not be possible depending on the quality of the measured data (see Chapter 12.6).
- **Show STC Curve On/Off:** If an effective solar curve is calculated, it can also be converted to Standard Test Conditions (STC) and displayed. This option toggles the STC curve on or off. The axis scaling adjusts automatically if necessary.
- **Display Nominal Curve On/Off:** Toggles the display of the nominal curve in the diagram, providing additional reference for analysis.
- **Show Power On/Off:** Toggles the display of the power graph in the diagram.
- **Legend On/Off:** Toggles the display of the legend for the plotted graphs.
- **Zoom On/Off:** Adjusts the Y-axis scaling so that the diagram fully utilizes the available Y-axis range.
- **Display Data List:** Opens a tabular view of the data points used in the diagram for detailed inspection.
- **Print Diagram:** Sends the current diagram directly to the printer for hardcopy output.
- **Copy to Clipboard:** Copies the current diagram to the clipboard for pasting into external applications, such as a Word document.
- **Write STC Curve to File:** Exports the calculated STC curve to a file for external use or archiving.



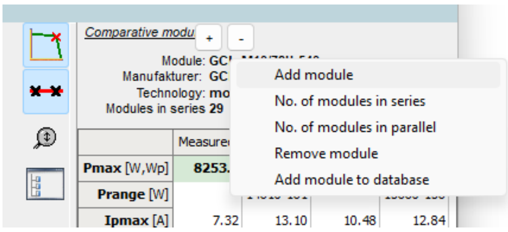
	I / A	U / V	P / W
1	3,106	0,00	0,0
2	3,106	5,14	16,0
3	3,096	9,05	28,0
4	3,082	17,69	54,5
5	3,065	27,43	84,1
6	3,049	37,30	113,7
7	3,030	47,13	142,8
8	3,014	57,02	171,9
9	2,999	67,08	201,2
10	2,986	76,73	229,1
11	2,975	86,58	257,5
12	2,962	96,40	285,6
13	2,951	106,06	313,0
14	2,937	115,62	339,6
15	2,921	125,06	365,3
16	2,900	134,56	390,2

Picture 35: Display data list

These features provide robust tools for diagram interaction, enabling detailed analysis, customization, and seamless integration with external software.

12.5.7 Reference Module Management in Measurements

When you select or create a new reference module as part of a measurement, the associated information is saved in the measurement file. This information is displayed in the upper-right area above the measured values. Right-clicking in this area with the mouse opens a context menu, allowing you to perform the following actions:



Picture 36: Context menu for reference module

1. **Add a New Module**
   Create and configure a new reference module to be included in the measurement setup.

2. **Set Number of Modules in Series**
   Specify how many modules are connected in a series configuration within the measurement.

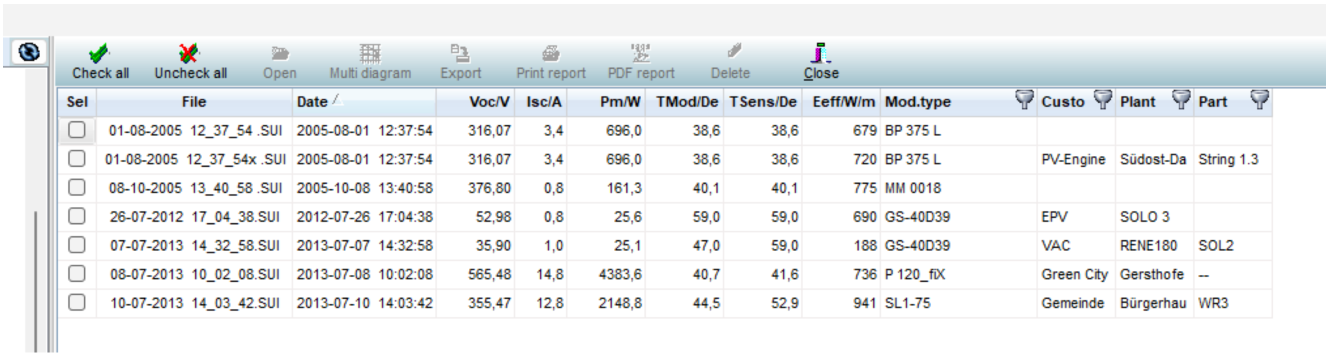
3. **Set Number of Modules in Parallel**
   Define the number of modules arranged in parallel within the measurement setup.

4. **Remove Module**
   Delete a selected module from the measurement configuration.

5. **Add Module to Database**
   Save the selected module's configuration to the database for future use or reference.

12.5.8 Changing information in measurement data

The graphic below illustrates an example of the "Measurements" overview page, which appears when you click on the "File" tab or access the “File - Open” submenu.



Sel	File	Date	Voc/V	Isc/A	Pm/W	TMod/De	TSens/De	Eeff/W/m	Mod.type	Custo	Plant	Part
☐	01-08-2005 12_37_54 .SUI	2005-08-01 12:37:54	316,07	3,4	696,0	38,6	38,6	679	BP 375 L			
☐	01-08-2005 12_37_54x .SUI	2005-08-01 12:37:54	316,07	3,4	696,0	38,6	38,6	720	BP 375 L	PV-Engine	Südost-Da	String 1.3
☐	08-10-2005 13_40_58 .SUI	2005-10-08 13:40:58	376,80	0,8	161,3	40,1	40,1	775	MM 0018			
☐	26-07-2012 17_04_38.SUI	2012-07-26 17:04:38	52,98	0,8	25,6	59,0	59,0	690	GS-40D39	EPV	SOLO 3	
☐	07-07-2013 14_32_58.SUI	2013-07-07 14:32:58	35,90	1,0	25,1	47,0	59,0	188	GS-40D39	VAC	RENE180	SOL2
☐	08-07-2013 10_02_08.SUI	2013-07-08 10:02:08	565,48	14,8	4383,6	40,7	41,6	736	P 120_fiX	Green City	Gersthofe	--
☐	10-07-2013 14_03_42.SUI	2013-07-10 14:03:42	355,47	12,8	2148,8	44,5	52,9	941	SL1-75	Gemeinde	Bürgerhau	WR3

Picture 37: Menu "Measurements"

This page provides a clear and organized display of all relevant data, including:

- **File Name**: The name of the measurement file.
- **Date and Time**: The timestamp indicating when the measurement was recorded.
- **Parameters**: Key measurement parameters such as:
  - **Voc**: Open-circuit voltage.
  - **Isc**: Short-circuit current.
  - **Pm**: Maximum power.
  - **Tmod**: Module temperature.

    - **Tsens**: Sensor temperature.
    - **Eff**: Efficiency of the module or system.
- **Module Type**: The type of module used in the measurement.
- **Customer**: The associated customer's information.
- **Plant**: The plant where the measurement was conducted.
- **Part**: The specific part being measured or analyzed.

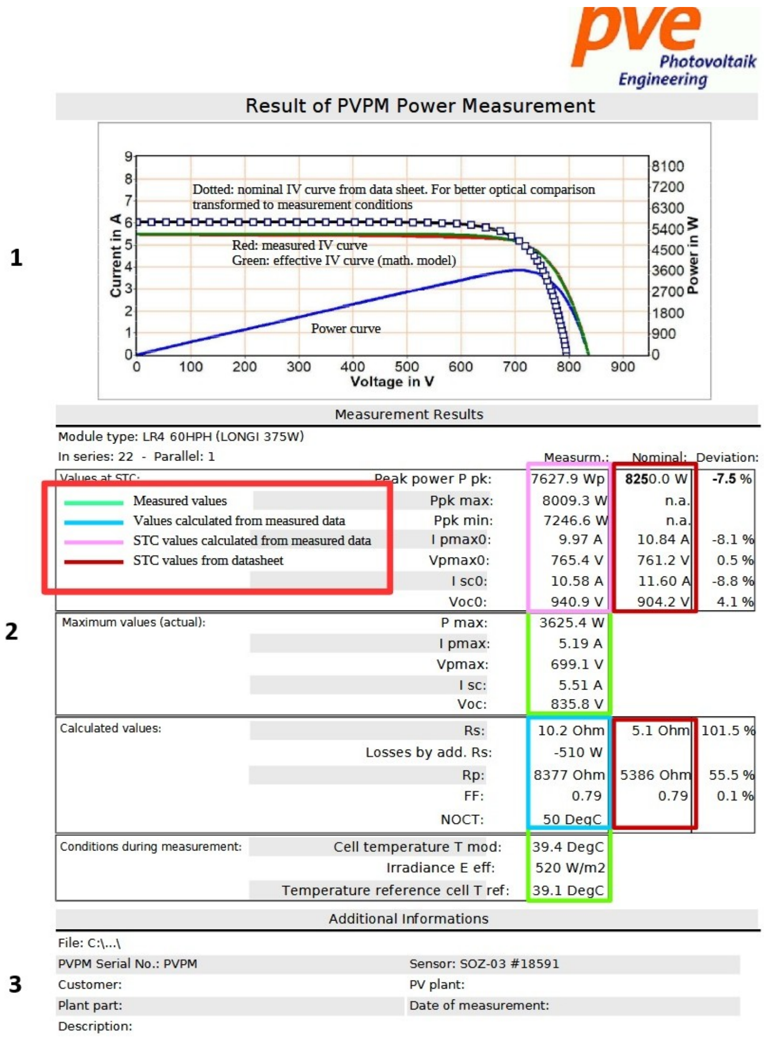
If you wish to make specific changes, such as modifying the module type or updating the customer information, right-click on the entry you want to edit. This will open a context menu that guides you to the corresponding database. Within the database, you can either select an existing entry or create a new one. The change will be applied automatically once completed.

12.6 Report generator / Layout Overview

The software includes an automatic report generator, which allows for the clear and visual presentation of measurement results. The report is divided into three main sections:

Section 1: Measurement Curve
At the top of the report, the **I-V characteristic curve** of the measurement is displayed. Additionally, users can toggle additional curves on or off, such as the **Power Curve** (shown in blue), which illustrates the power output over the measurement range, or the **Nominal Curve** (dotted line), which is derived from the reference module's datasheet values. It is important to note that the **Nominal Curve** has been adjusted for the environmental conditions present at the time of the measurement. Essentially, this adjustment is the reverse of the STC calculation—STC values are recalculated to reflect the current environmental conditions. This feature provides a significant advantage by simplifying the comparison of curves. The measured curve, along with its results, can be directly compared to the calculated curve without needing to first convert the measured curve to STC values. Since this conversion can introduce errors and inaccuracies in non-ideal conditions, this approach offers an interesting alternative for evaluation that adds value.

- The **Measured Curve** is displayed in red in the diagram.
- The **theoretical / effective Curve** (shown in green), which is an idealized model used for calculating Rs and Rp, is also presented. This curve has an informative role.



Picture 38: Report overview

Section 2: Measurement Results
This middle section of the report is labeled "**Measurement Results**." It contains the following information:

- **Green-bordered areas** show the **measured values**, such as Pmax [W], Ipmax [A], Vpmax [V], Isc_0, Voc_0, Tmod, E_eff, and T_ref.
- **Blue-bordered areas** display the **calculated values**, including Rs, losses added by Rs, Rp, FF, and NOCT.
  Please note that it may happen that no values are calculated. This is usually due to reasons such as the irradiance during the measurement being too low (below 500W/m2) or the characteristic curve having an unusual shape, so that a calculation was mathematically impossible. The values are then also displayed directly after the measurement on the PVPM display with *** (no value).
- **Pink-bordered areas** show the **STC values** that were calculated based on the measurement results.
- **Red-bordered areas** show the **STC values** from the reference module's datasheet.

Section 3: Additional Information

The bottom section of the report includes "Additional Information," which provides further details such as:

- The **file path** where the report is saved.
- The **serial number** of the measurement device.
- **Customer** and **Plant section** details.
- A **description** (previously entered in PVPM.disp).
- The **reference sensor used** for irradiation measurements.
- The **PV plant** and the **measurement date**.

This structured layout ensures clarity in presenting measurement results and facilitates easy comparison between actual measurements, calculated values, and reference data.

12.7 Analysis Generator

The **Analysis Generator** creates a document for analyzing the previously selected measurement with a single click. For clarity, the selected characteristic curves are displayed first. The document then includes the following information:

- **File Path**: The path to the measurement file.
- **Device Serial Number**: The serial number of the measuring device.
- **Reference Sensor**: The type and serial number of the reference sensor used.
- **Date of measurement**: The date and time when the measurement was taken.
- **Remark**: Additional notes or comments related to the measurement.

Next, information about the specific reference module is shown, along with the configuration details of the system (number of modules in series and parallel).

The environmental conditions during the measurement are documented, including:

- **Eeff**: Irradiance during measurement.
- **Tamb**: Ambient temperature. Must be defined in advance in the PVPM.dips software, as it is not measured.
- **Tmod**: Module temperature (PT100 measurement).
- **Tmod Expected**: Expected module temperature.
- **T Sensor**: Temperature of the cell of the irradiance reference sensor
- **NOCT**: Calculated nominal Operating Cell Temperature.

Following this, a comparison is made between the target values (based on the reference module and system configuration), the actual measured values , and the divergence between them.

The next section presents an evaluation of the characteristic curve:

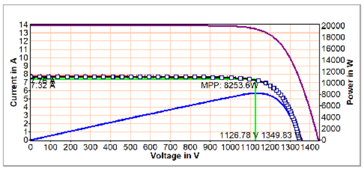
- **Quality of Curve Match**: Compares and evaluates the match between the actual and nominal characteristic curves based on variance and standard deviation. The evaluation proceeds through the following steps:
  - **Well**
  - **Moderate**
  - **Bad**

The evaluation provides the following information:

- A statement on whether the measured peak power matches the expected values.
- The range in which the maximum peak power lies (considering tolerances).
- An assessment of whether the irradiance is sufficient (i.e., at least 500 W/m² required).
- An evaluation of whether the module temperature matches the expected temperature.
- Information on whether the characteristic curve shows any discontinuities, including the location of such discontinuities (indicating the current and voltage values).

Finally, possible causes for the noted deviations are listed, such as fluctuating irradiance or potential inhomogeneity within the generator

Analysis of an I-V-curve measurement



Measurement file: C:\Users\csPVE\Desktop\Schulung\20-02-2023 13_50_52.SUI
Device serial no.:PVPM1540X05922
Reference sensor:SOZ-03 #17437
Date of measurement:20.02.2023 13:50:52
Remark:

Comparison module: GCL-M10/72H-540
Configuration: 29 module(s) in series, 1 module(s) parallel

Conditions during measurement:

	Target values:	Description:
Eeff	559W/m2	Irradiance during measurement
Tamb	20,0DegC	Ambient temperature during measurement
Tmod	34,2DegC	Module temperature during measurement
Tmod exp.	37DegC	Expected module temperature
T Sensor	27,5DegC	Temperature irradiance reference during measurement
NOCT	40DegC	Normal Operating Cell Temperature

	Target values:	Actual values:	Divergence:%	Description:
Ppk:	15660,0Wp	15379,4Wp	-1,8%	Peak power (STC)
Voc:	1442,8V	1441,9V	-0,1%	Open circuit voltage (STC)
Isc:	13,63A	13,88A	1,8%	Short circuit current (STC)
Vpmax:	1219,7V	1173,9V	-3,8%	Voltage at MPP (STC)
Ipmax:	12,84A	13,10A	2,0%	Current at MPP (STC)
Rs:	6,5Ohm	11,8Ohm	81,2%	Internal series resistance
FF:	0,80	0,79	-1,0%	Fill factor
PRs	--	-909W	--	Power loss due to Rs

Quality of curve match:
Well(Variance: 0,01 standard deviation: 0,10)

Evaluation:

Measured peak power equates the expected value!
The measured peak power is between 14610,5WP and 16148,4Wp.

Irradiance 559W/m2 sufficient for an estimation!

Measured module temperature largely equates to the expected!

I-V-curve shows discontinuity at
U=1304,66V U=1325,79V
Possible reasons:
> irradiance varies during measurement
> inhomogenoeuos generator (some modules/cells do not work properly)

Picture 39: Example of an analysis report

12.8 Help (not yet implemented)

12.8.1 Content

Displays the content of the online help.

12.8.2 Search

Here you can search within the online help.

12.8.3 Look for program updates

Searching online for updates.

12.8.4 Register file association .SUI

The system outputs measurement data with the extension .SUI

12.8.5 Info

Displays an information window with the version number of the program.

13 Hardware Information

(Subject to change without notice)

Build in a stable metal case with carrying handle and tough front panel.

13.1 Measuring Unit

Sampling rate max. 100kHz
Resolution 0.01V - 0.25V, 0.0005A – 0.005A (depending on sel. range)
Accuracy of the a/d converter 0.08% of FSR±1 LSB
Peak power measurement: ±5%
Reproducement: ±2%
Sweep time string measurement: 20ms up to 2 seconds, avoiding the influence of capacitive properties of the modules under test.
Irradiance reference sensor with integrated Pt100 or Pt1000 temperature sensor measures irradiance and cell temperature. Other commercially available sensors can be connected using a reliable cable connection.

Measuring ranges of the PVPM:

Device / Rating	Voltage [V]	Current [A]	Temperature [°C]	Irradiance [W/m^2]
PVPM2540C	25/50/100/250	5/10/20/40	-100 to +120	0 to 1300 *)
PVPM1000C	25/100/500/1000	2/5/10/20	-100 to +120	0 to 1300 *)
PVPM1040C	25/100/500/1000	2/5/10/40	-100 to +120	0 to 1300 *)

Ranges for current and voltage can be combined in any order
An optimal range is selected by the device automatically.
*) depends on the data of the used irradiance reference sensor

13.2 Pin allocation of the sensor connectors:

Temperature (external): 4 pin female chassis socket Lumberg KFV40
Pin 1 = Current source + (~1 mA)
Pin 2 = Pt100 +
Pin 3 = Pt100 -
Pin 4 = Current source - (~1 mA)

Irradiance: 8 pin female chassis socket Lumberg KFV80 (plug: SV81)
Pin 1 = Irradiance+
Pin 2 = Pt1000 (reference) +
Pin 3 = Irradiance-
Pin 4 = Current source + (~1 mA)
Pin 5 = Current source - (~1 mA)
Pin 6 = do not connect
Pin 7 = do not connect
Pin 8 = Pt1000 (reference) -

13.3 Calculation Unit

Industrial PC with low power consumption, real time clock
No mechanically moved parts like hard disk, fan etc.
Flash disk 512MB (can store several thousand results)
A/D-Sampling Rate max. 100kHz, resolution 12Bit
Accuracy for the I-V-curve better 1%, Peak Power ±5%
The data of several thousand measurements will be stored automatically in the device (flash memory)

13.4 Display

Bright TFT touch display with LED back-light,
resolution 480 x 272 pixels,
RGB 32Bit color, high contrast
sunlight suitable

13.5 Operation

Menu driven with touchscreen on the front panel
Operation and evaluation alternatively by Windows software, connected via USB
USB 2.0 standard cable

13.6 Power Supply

Li-Ion battery: one battery, 11.25V, 8.85Ah, 99.6Wh (continuous operation about 8h),
(tested acc. UN T1-T8 transportation tests, compliant UN 38.3 / PSE / RCM)
External power supply wide range input (90-263Vac, 47-63Hz, min. 30W, Out 15Vdc)
Integrated battery charger with overload protection for battery
Display of battery state with LEDs at the front panel

13.7 Dimensions

Width: 48cm, height: 16cm, depth: 34cm, weight 8.0-8.5kg

13.8 Operation Conditions

	Temperature:	Humidity	Max. height of use:
Operation:	0°C to 40°C	10% to 90% (not condensing)	2000m (6562ft) above sea level
Storage:	-10°C to 60°C	5% to 95%	

13.9 Optionally available accessory

- Irradiance reference sensors with mono- or poly-crystalline cells; very high accuracy
- Extension cables for temperature sensor and/ or irradiation reference sensors
- Measuring accessories such as crocodile clips and/or test probes
- Additional protective cases for transporting the entire system
- Padlocks for the cases

14 List of symbols

AM Air-Mass, relative way length for the sunlight through the atmosphere of the earth
E Irradiance
E_0 1000 W/m^2 (Irradiance at STC)
E_{eff} Irradiation, measured with a crystalline PV cell
FF Fill factor: relationship Isc*Uoc/(Ipmax*Upmax), for crystalline modules about 0.75 = 75%, smaller values can indicate insufficient power
I Current
I_m Short form for Ipmax
I_{ph} Photo current
I_{pmax} Current at Pmax
I_{pmax0} Current at Pmax0 (at STC)
I_{sc} Short circuit current
I_{sc0} Short circuit current (at STC)
MPP Maximum Power Point, other description for P_{max}
NOCT Nominal Operating Cell Temperature, cell operating temperature at T_{ambN} and E_N.
P Power
P_{max} Recent maximum power of a solar cell
P_{pk} Peak Power, maximum power of the solar cell at STC
PV Photovoltaic
R Resistance
R_{pv} Photovoltaic resistance (calculation factor only, no real resistor)
R_s Series internal resistance, apart from resistances in the module e.g. cable/plug resistance, intrinsic resistance of crystalline modules about 0.5 ohms, of thin film cells 2-3 ohms. In strings R_S is determined strongly by the resistances of the cables.
R_p Parallel internal resistance
STC Standard Test Conditions E0=1000W/m^2, AM1.5, T=25°C
T_{mod} Current module temperature (at the back side of the module)
U Voltage
U_m Short form for Upmax
U_{oc} Open circuit voltage
U_{oc0} Open circuit voltage (at STC)
U_{pmax} Maximum power voltage

15 Reasons for decreased Power and Yield of PV Generators

Error	To be detected by:	Possible reason / *workaround*
System configuration chosen inadequately	Measurement of mismatch losses	Design fault / *redesign*
Erroneous match of strings and inverter	Fed power too low for location and in relation to nominal generator power	Design fault / *redesign, replacement of inverters*
Cast shadow	I-V-curve shows "bulge", **peak power** too low, optical check	Barrier near module (e.g. tree, chimney, birds excrements) / *remove barrier*
Diffuse shading (may be hardly visible for bare eye!)	I-V-curve is "impressed", **peak power** too low	Barrier in some distance to module (high portion of diffuse light) / *remove barrier*
Corrosion at plugs and cables	**Serial internal resistance Rs** too high	Material, planning or mounting fault / Clean, *replacement*
De-lamination of cell embedding	see **shading diffuse**	Material / production fault / *Replacement*
Bubbling in resin	see **shading diffuse**	Material defect / *replacement by supplier*
Transparent covering material (glass, plastics, resin) becomes blind	Optical check, **peak power** too low (s. a. **shading diffuse**)	Material defect / *replacement by supplier*
Discoloring of the transparent cover material (plastics, resin)	Optical check, **peak power** too low (s. a. **shading diffuse**)	Material defect / *replacement by supplier*
Intrusion of water into the laminate, leads to other problems (corrosion, discoloring)	Optical check	Material or production fault / *replacement by supplier*
Faults in the crystalline structure of single cells (hot-spot effect)	see **shading diffuse**	Production fault / *reduction of price, replacement by supplier*
Pollution of the module by dust	Optical check, see **shading diffuse**	High dust impact. Check modules periodically / *cleaning*
Moss / algae on module, birds excrements	see **cast shadow**	Normal for several regions / *cleaning*
Broken cover glass, leads to other problems (corrosion, discoloring)	Optical check	Hailstorm, mounting or transportation fault / *replacement by supplier*
Crack of single cells in module	**Peak power** too low, possibly deformation of I-V-curve	material defective / *replacement by supplier*
Improper electrical connections in module	**Peak power** too low, **internal series resistance Rs** higher than calculated	Fault in soldering, material defective, corrosion / *replacement by supplier*
Bypass diode defective (short circuit)	**Peak power of** strings reduced by module power	Overload, material defective / *repair*
Bypass diode mounted the wrong way	**Peak power** of strings reduced by module power	Mounting fault / *repair*
No bypass diode mounted or diode defective (high resistance)	Shading of one module reduces power of the string dramatically	Planning / mounting fault / *repair*
Dimension of cabling too small	**Internal series resistance Rs** too high	Design fault / *replacement of cables*
Cable defective (e.g. break, corrosion)	**Internal series resistance Rs** too high	Mounting fault / *repair*
Insufficient mounting of connectors	**Internal series resistance Rs** too high	Mounting fault / *repair*
Corrosion in screwed or plugged connectors	**Internal series resistance Rs** too high	Mounting fault / *cleaning, repair*
Insufficient preselection of modules regarding peak power	**Peak power** of plant too low	Planning or mounting fault (match losses) / *New preselection of the modules after peak power measurement*

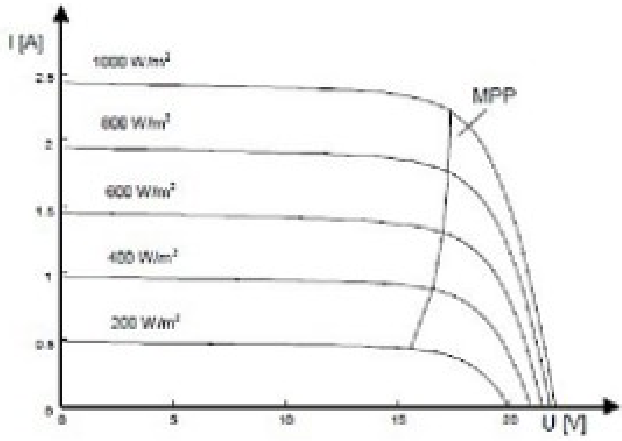
Insufficient preselection of single cells regarding power during module production	**Peak power** of module too low	Production fault / *reduction of price, replacement by supplier*
Short circuit between cells in the module	**Peak power** of plant too low, open circuit voltage U_{oc} too low, shape of curve	Production fault / re*placement by supplier*
Fabrication tolerances in cell production	**Peak power** too low, shape of curve	Production fault / reduction of price, *replacement by supplier*

Please notice: some faults may appear only under special operating states, e.g. high module temperatures.
This compilation does not claim to be complete or free of failures.

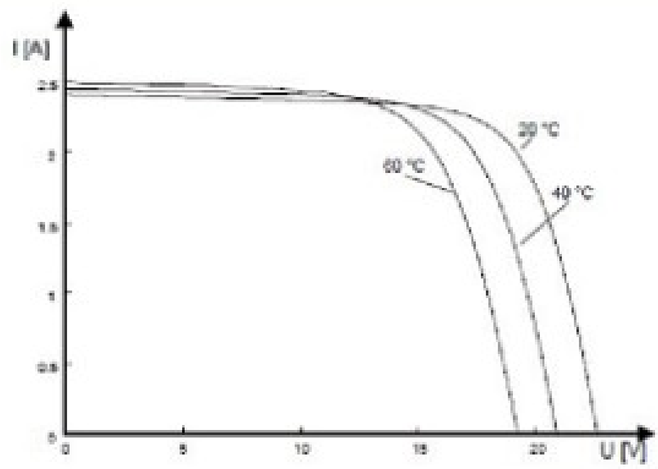
16 I-V-curve: Explanation

The curves represented in the following are from the books (with friendly permission of the authors):

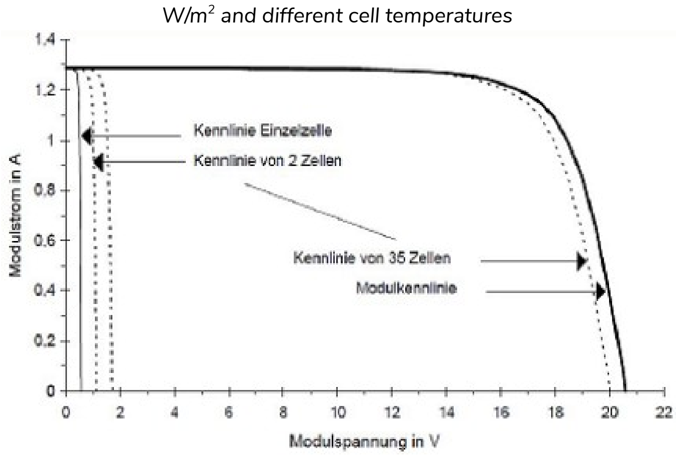
Quaschning, Volker: Simulation der Abschattungsverluste bei solarelektrischen Systemen. Verlag Dr. Köster. Berlin. 1996
Wagner Andreas: Photovoltaik Engineering – Handbuch für Planung, Entwicklung und Anwendung. Springer Verlag. Berlin Heidelberg New York . 2005



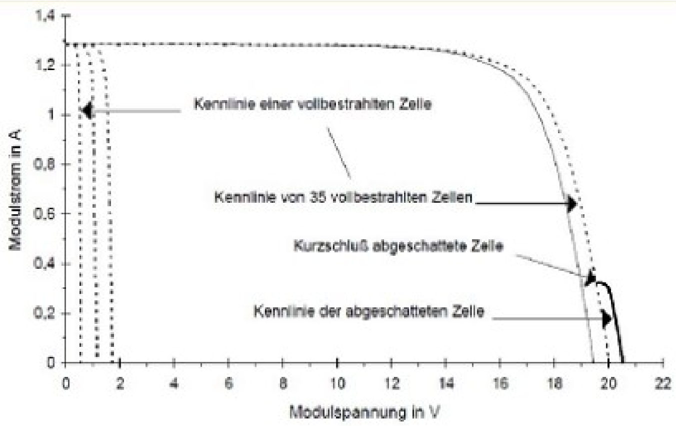
Picture 40: Current voltage characteristics with an irradiation of 1000 W/m² and different irradiations



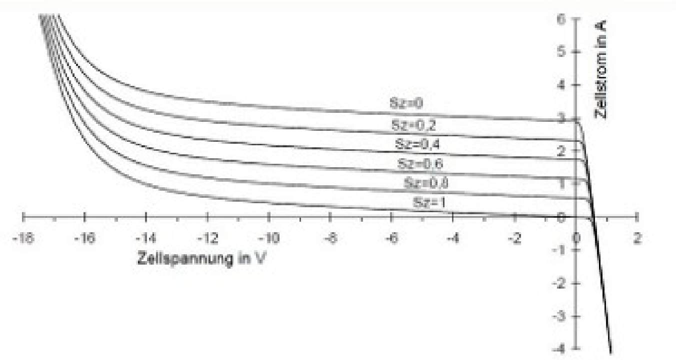
Picture 41: Current voltage characteristics with an irradiation of 1000 W/m² and different cell temperatures



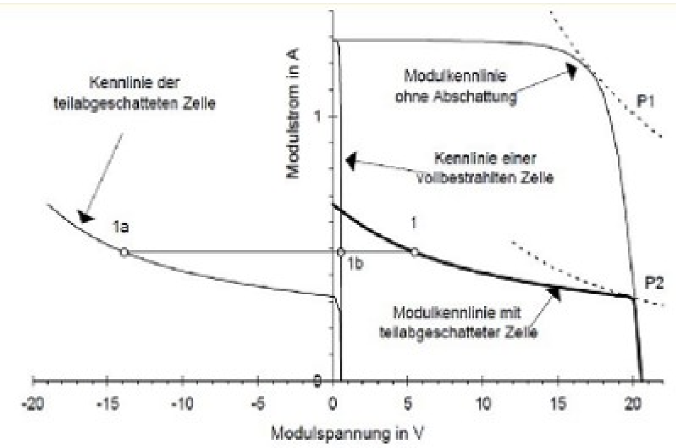
Picture 42: Construction of the module characteristic from the cell characteristics
(irradiance E = 400 W/m², T = 300K)



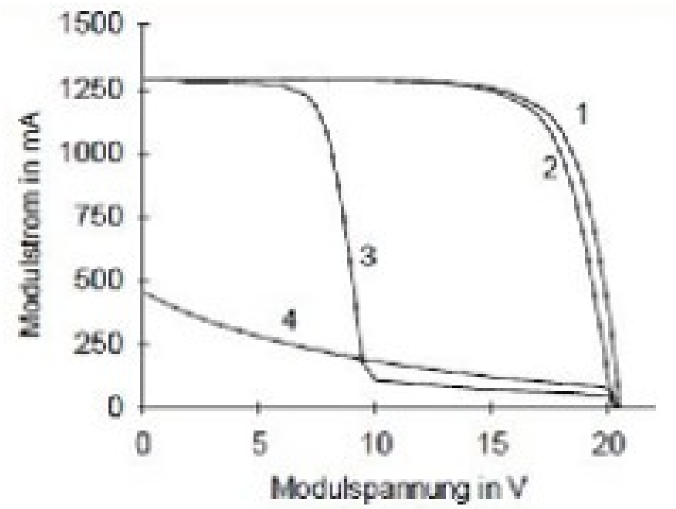
Picture 43: Partial construction of the module characteristic with a part-shaded cell



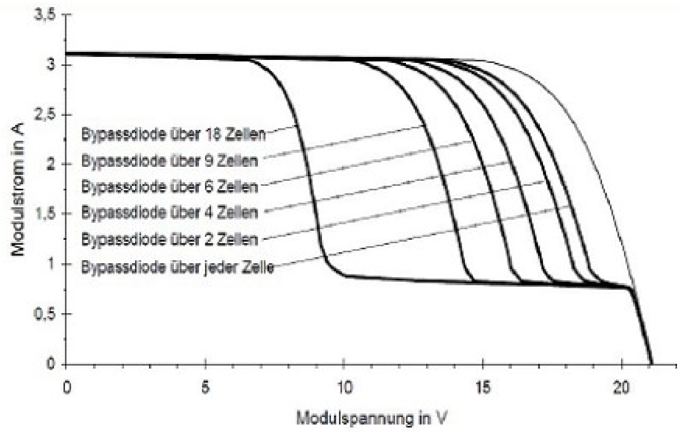
Picture 44: Solar cell characteristic of a polycrystalline cell over the whole voltage range with different shading degrees
(E0 = 1000 W/m^2, T = 300K)



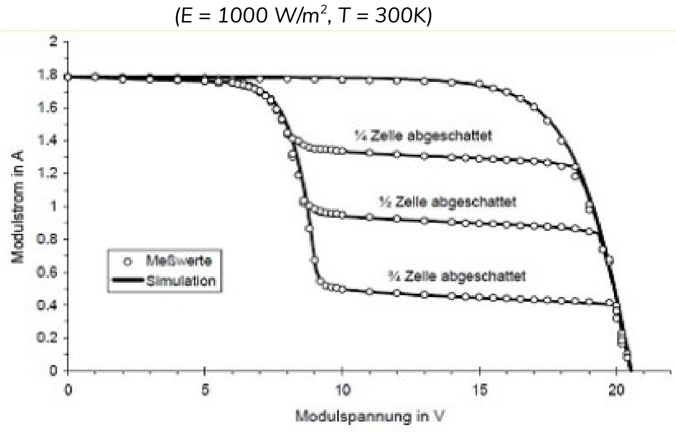
Picture 45: Construction of the module characteristic of the module SM50 with a 75% shaded cell
(E = 407 W/m^2, T = 300k)



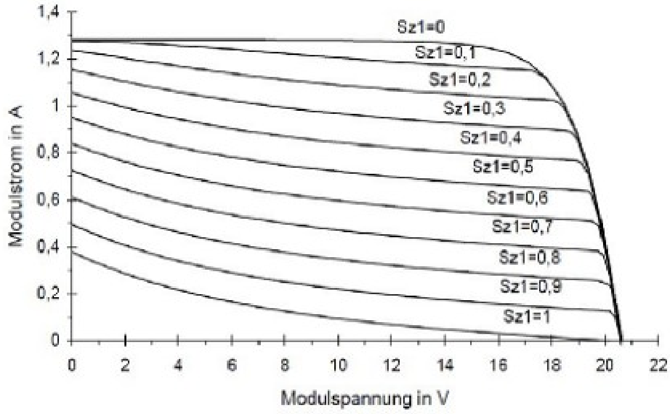
Picture 46: Solar module characteristic: (1) fully illuminated; (2) a cell completely covered, with bypass diode over the cell; (3) with bypass diodes over half cell string; (4) without bypass diode



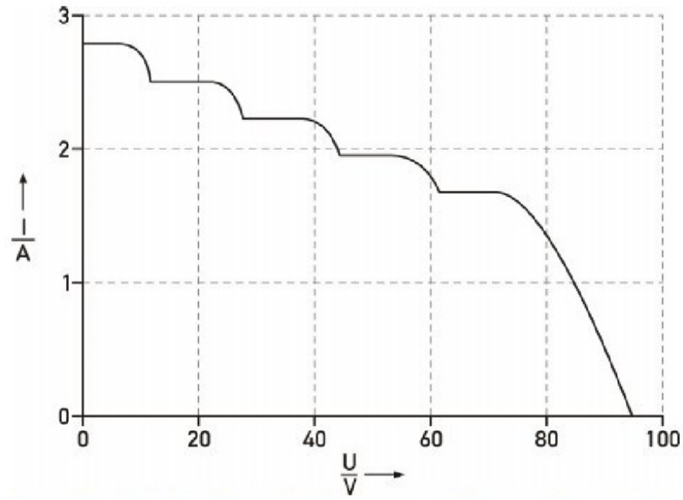
Picture 47: Simulation of different module characteristics with bypass diodes over a different number of cells
(E = 1000 W/m², T = 300K)



Picture 48: Comparison of simulation and measured values by the example of the module SM50, 36 cells with two bypass diodes over in each case 18 cells. A cell was differently shaded, the others was fully illuminated
(E = 574 W/m², T = 300K)

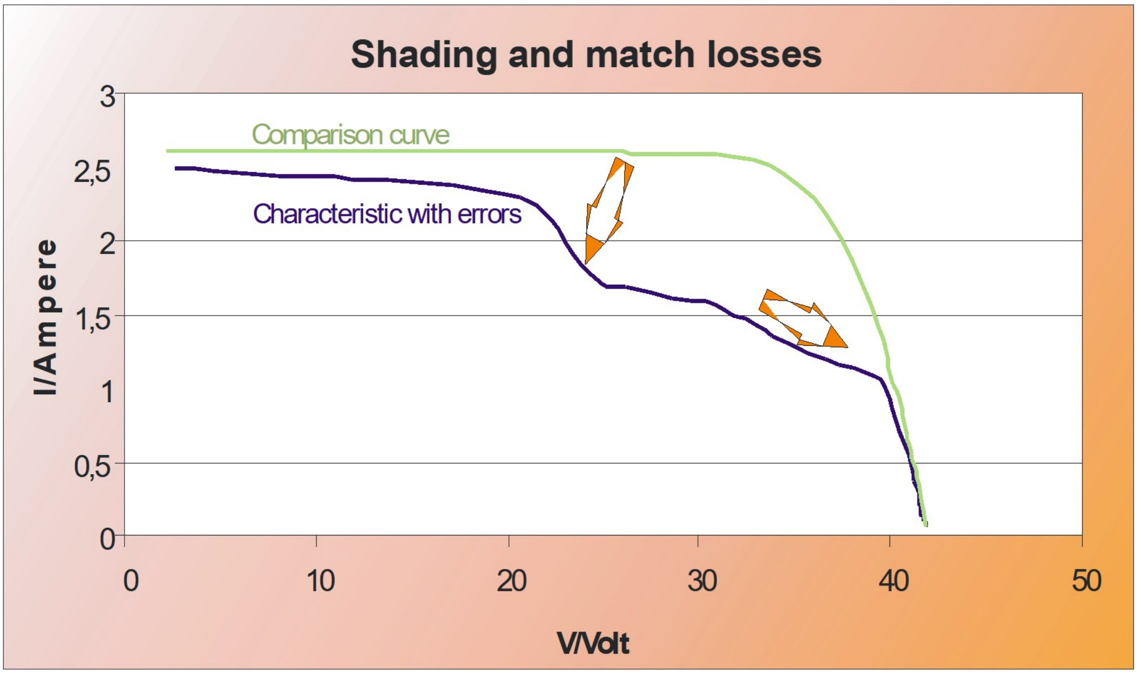


Picture 49: Module characteristics of the module SM50 without bypass diodes, first cell differently shadows (shading degree of SZI = 0..1), E = 407 W/m², T = 300K

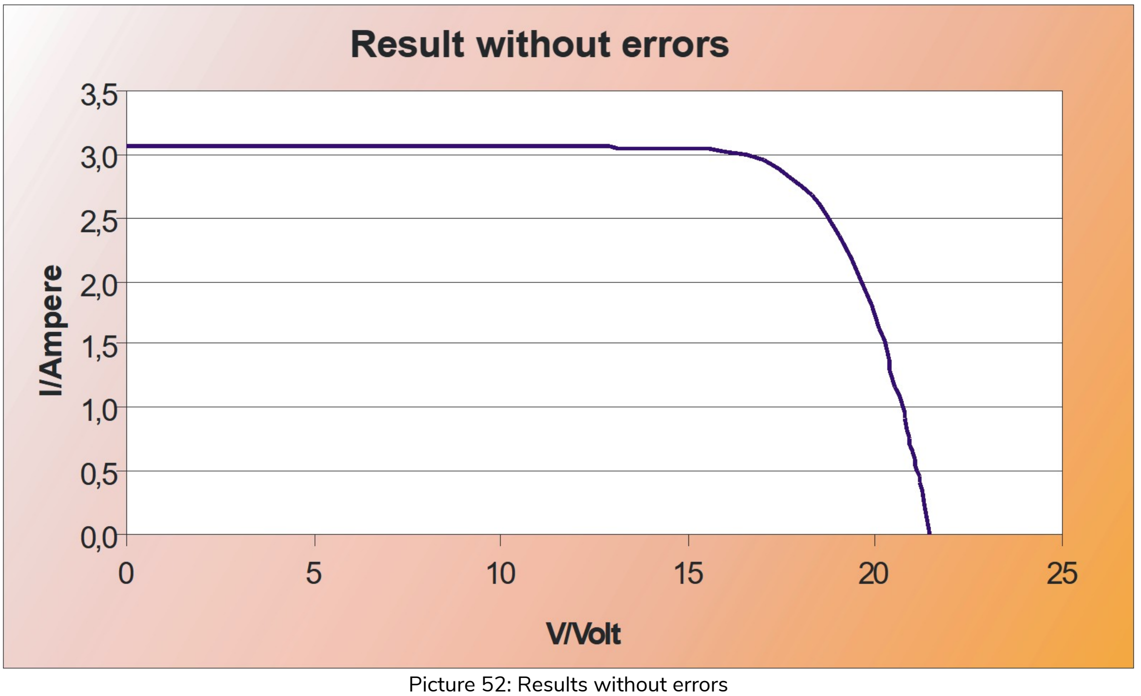


Picture 50: Resulting characteristic during series connection with bypass diode

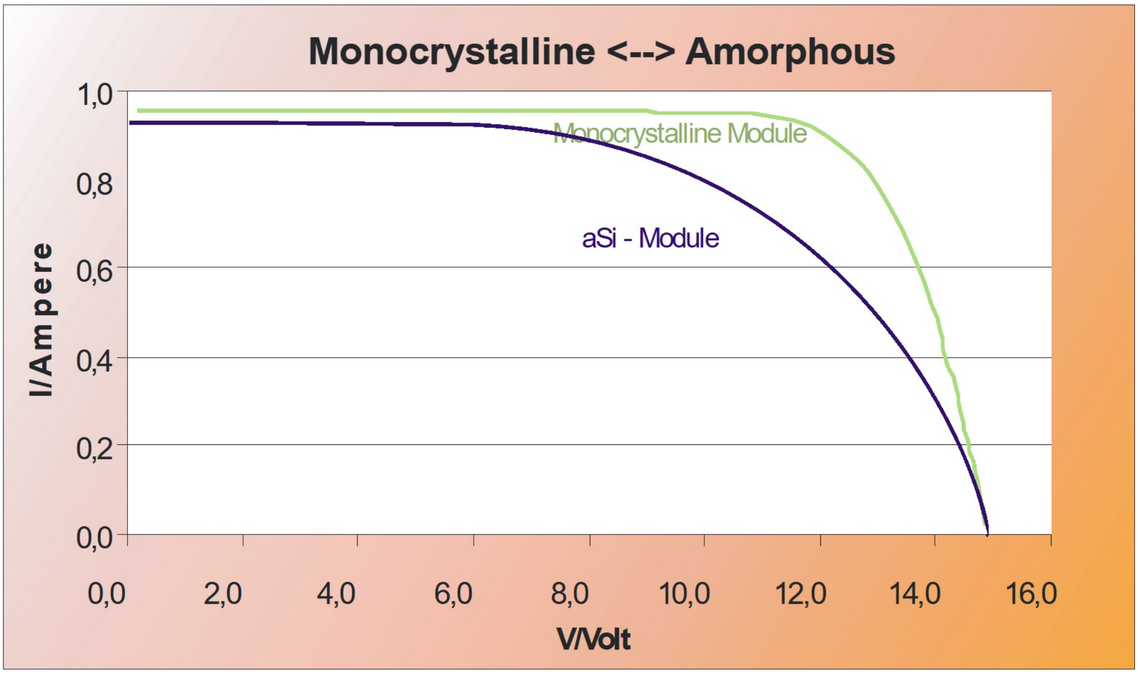
17 Sample Curves



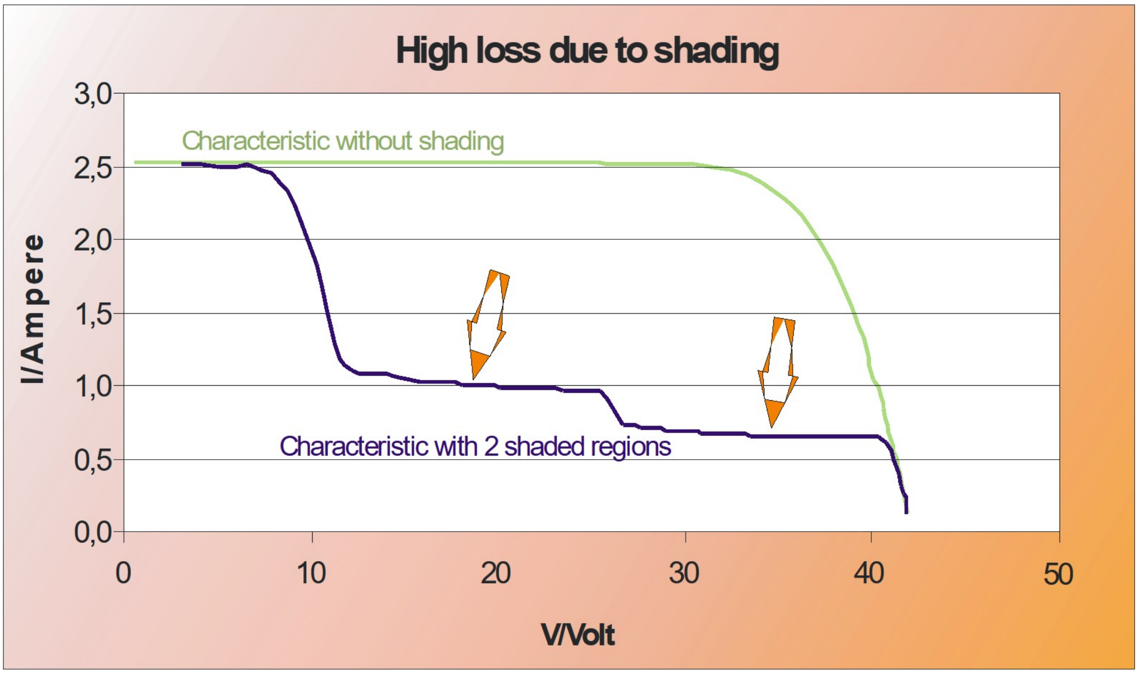
Picture 51: Shading and match losses



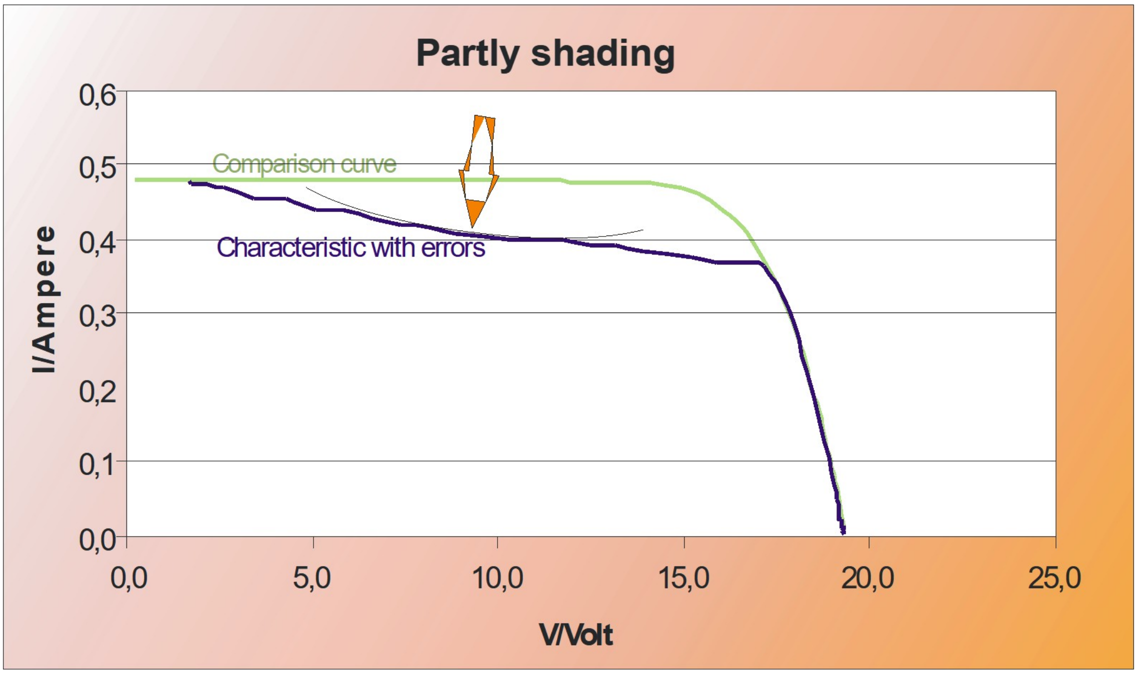
Picture 52: Results without errors



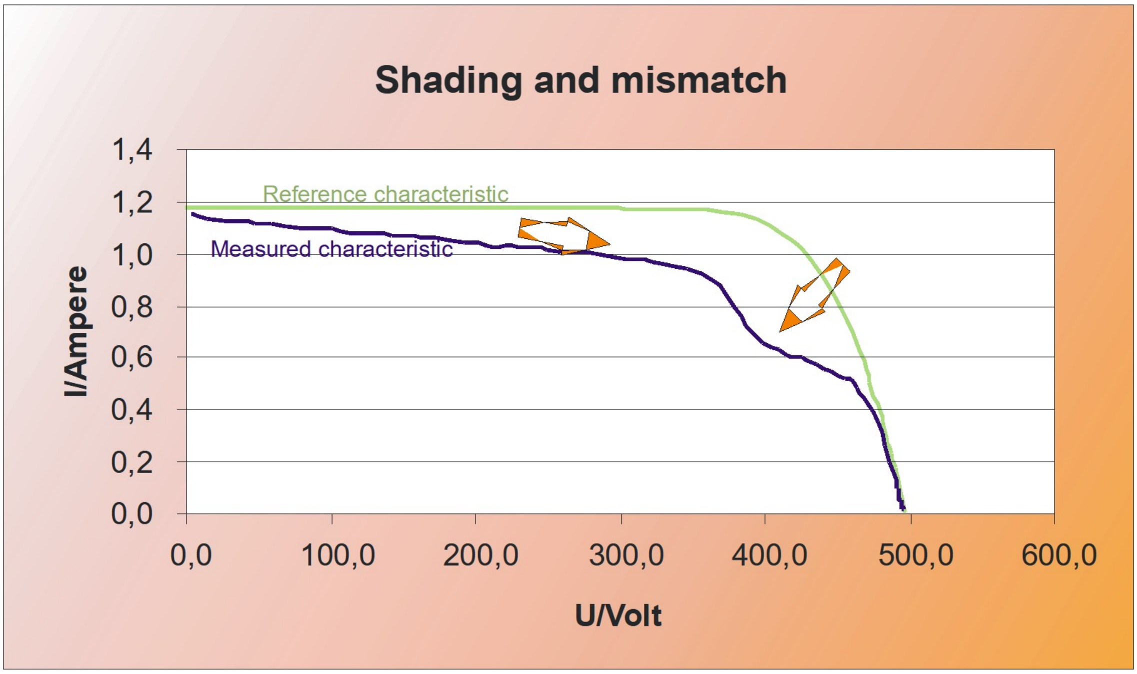
Picture 53: Mono- vs. Polycristalline



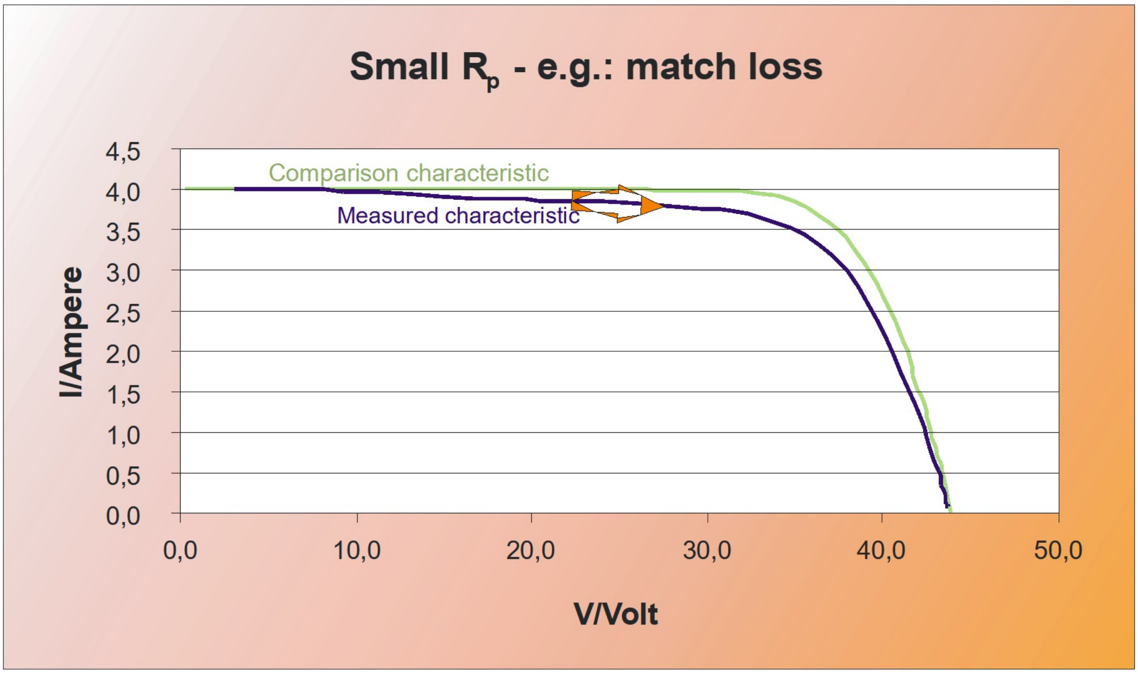
Picture 54: High loss due to shading



Picture 55: Partly shading



Picture 56: Shading and mismatch



Picture 57: Small Rp – match loss

18 Glossary

18.1 Azimuth (ß) and elevation (α)

To maximize the use of solar radiation, modules and collectors are arranged to achieve the highest possible solar yield. Key factors influencing this optimization include the sun's incidence angle, the azimuth, and the elevation of the modules and collectors.

- **Azimuth Angle**: This refers to the angle between the orientation of the modules or collectors and their precise alignment with true south.
- **Elevation Angle**: This denotes the tilt angle of the modules relative to the horizontal plane.

Studies have demonstrated that photovoltaic (PV) systems achieve optimal performance when the azimuth angle is 0° and the elevation angle is approximately 30°. However, small deviations from these values are not necessarily problematic. Orientations towards southeast or southwest can still achieve around 95% of the maximum possible yield. For larger installations, tracking systems driven by electric motors are often employed to enhance efficiency by continuously aligning the modules with the sun (see also → **Tracking**).

Alignment Considerations for Measurements with PVPM
When performing measurements with the PVPM device, precise alignment of the irradiation sensor with the modules is critical. The sensor must "observe the same portion of the sky" as the modules. Additionally, environmental factors such as reflections from surrounding surfaces (e.g., walls or other light-reflective areas) can significantly influence the amount of light incident on both the modules and the sensor. These reflections should be carefully considered during the measurement process to ensure accuracy.

18.2 Slope

When planning a solar plant, focusing solely on the roof slope (e.g., as often queried online) can lead to incorrect conclusions. It is not the roof slope that matters but rather the **tilt angle of the collectors**. Even when the roof's slope or orientation is less than ideal, collectors can be adjusted and mounted appropriately to achieve optimal positioning.

Ideal Collector Angles for Solar Radiation Utilization
For maximum efficiency, solar rays should strike the collectors at a right angle. The optimal tilt angle for the collectors generally corresponds to the geographical latitude of the location. For example:

- Freiburg is situated at 48° latitude.
- Lübeck is situated at 54° latitude.

Since the sun's position is higher in the summer and lower in the winter, the ideal tilt angle also depends on the primary period of use for the solar system:

- **Photovoltaic (PV) systems** yield the highest energy output during the long summer days.
- **Thermal solar systems**, which often support heating systems, are more beneficial in winter.

A practical **rule of thumb** for adjusting the tilt angle is:

- Latitude minus 10° for summer optimization.
- Latitude plus 10° for winter optimization.

Roof Orientation and Other Influencing Factors

The roof's **orientation (azimuth angle)**, ideally facing south, is another crucial factor. However, small deviations from the ideal orientation or tilt angle have a negligible impact on overall productivity. In contrast, temporary shading of the collectors has a much greater negative effect on system performance.

By understanding and addressing these factors, solar equipment can be effectively optimized, even in less-than-ideal conditions.

18.3 Direct Current (DC):

A type of electrical current where the flow of electric charge is unidirectional. DC is the form of electricity generated by solar cells and modules and is commonly stored in batteries. When multiple solar cells are connected in series within a module, their individual voltages combine, resulting in a higher total voltage output.

18.4 Degradation characteristic

Amorphous solar cells experience a rapid initial decline in efficiency during the early phase of exposure to sunlight. This irreversible degradation stabilizes after a period ranging from 3 weeks to 5 months. Additionally, these cells undergo **reversible degradation**, resulting in seasonal variations in efficiency. Specifically, amorphous solar cells demonstrate higher efficiency during spring and summer compared to autumn and winter.

18.5 Direct radiation / diffuse radiation

Direct Radiation:
Solar radiation that reaches a surface without scattering through the Earth's atmosphere. This type of radiation creates distinct shadows as it travels in a straight line from the sun to the surface.

Diffuse Radiation:
Solar radiation that is scattered by atmospheric components such as fog, haze, or clouds. Unlike direct radiation, diffuse radiation reaches the surface indirectly and does not cast sharp shadows.

18.6 Generator

Derived from the Latin term "producer", a generator converts other forms of energy into electricity. In photovoltaics, the term refers to the collective assembly of interconnected photovoltaic modules, often referred to as the **solar generator** or **solar power plant**.

18.7 Global/total radiation

Global Horizontal Irradiation (GHI):
The total solar radiation received by a horizontal surface on Earth. It is the sum of **direct irradiation** (sunlight reaching the surface without scattering) and **reflected irradiation** (e.g., sunlight reflected off surfaces like snowfields).

18.8 Short-circuit current (Isc) of solar cells

The current that flows when the positive and negative terminals of a photovoltaic (PV) generator are directly connected, with no resistance or load between them. While this condition is not harmful to the generator itself, disconnecting such a circuit can produce an electric arc. This arc poses potential risks to both health and the environment.

18.9 Mismatching

The practice of connecting solar modules with varying performance levels in the same string. When weaker modules are included alongside more efficient ones, the overall current of the string is limited by the weaker module, thereby reducing the total power output of the system.

18.10 MPP

The point on the current-voltage (I-V) characteristic curve of a solar cell where the product of the usable voltage and the corresponding current reaches its highest value. The MPP is influenced by several factors, including the intensity of irradiation, temperature, and the light spectrum. As these conditions change, the MPP shifts, meaning that the optimal operating voltage and current for maximum power output will vary.

18.11 Tracking

Tracking refers to the ability of solar module surfaces, often mounted on **trackers**, to follow the sun's movement throughout the day. This tracking can be achieved with either a **single-axis** or **dual-axis** system, with dual-axis tracking offering higher efficiency. Compared to a fixed south-oriented system, dual-axis tracking can increase the annual energy yield by up to approximately 30%. Tower-mounted, tracked, and elevated solar plants provide the flexibility to select the optimal positioning. This setup allows for a 180° range of motion, free from shading, regardless of structural constraints.

18.12 Peak Power

To ensure the comparability of power output among photovoltaic (PV) modules, the nominal power of a module is typically measured under standardized conditions. These conditions include a cell temperature of 25°C, an irradiation level of 1000 W/m², and a light spectrum corresponding to AM 1.5. This measurement is referred to as **Peak Power** (often also called the "nominal value" by some manufacturers). The set of conditions under which this measurement is taken is known as **Standard Test Conditions (STC)**.

However, the exact conditions of STC are rarely encountered in natural environments, which is why these measurements were traditionally conducted in laboratories where such conditions could be artificially recreated with significant effort.

With the introduction of new **Peak Power measuring devices** and **curve tracers** (such as the PVPM series), it is now possible to perform these measurements in real-time, under current ambient conditions. The measuring device automatically converts the results to STC, providing a more practical and accurate method of determining peak power. After a single **I-V curve measurement**, the device provides the Peak Power (**Ppk**), **internal series resistance** (**Rs**), and **parallel resistance** (**Rp**) as results. These measurements, when compared to the specified values, can help identify potential issues within the PV generator, simplifying **quality control** and **error detection**.

18.13 Performance Ratio

In the context of photovoltaic systems, the **Performance Ratio** (PR) refers to the ratio between the actual energy output and the expected or nominal output of the system. It is calculated as the quotient of the **alternating current (AC) yield** and the **nominal direct current (DC) output** of the generator. The Performance Ratio indicates the proportion of the energy produced by the generator that is effectively available for use in real-world conditions.

High-capacity PV plants typically achieve a Performance Ratio of over 70%. The Performance Ratio is sometimes referred to as the **quality factor (Q)**. For solar modules based on crystalline cells, the quality factor generally ranges from **0.85 to 0.95**, while grid-connected systems often have an average Performance Ratio between **70% and 75%**.

18.14 Internal series resistance (Rs)

The internal series resistance of a photovoltaic module arises from the material used in the module's construction as well as its cable connections. For crystalline modules, the typical value is approximately **0.5 ohms**, while for thin-film modules, it tends to be higher, often exceeding **2 ohms**.

The internal series resistance can now be measured using the **PVPM series measuring devices**. To perform the measurement, only a single **I-V curve** of the module needs to be taken. Using this data, the device automatically calculates the **Rs**, as well as the **Peak Power (Ppk)** and **parallel resistance (Rp)**.

The **theoretical value** for the internal series resistance can be calculated using the **PVPMdisp software** if the **Standard Test Conditions (STC)** characteristic values for **Voc** (open-circuit voltage), **Isc** (short-circuit current), **Vmp** (voltage at maximum power point), and **Imp** (current at maximum power point) are known.

Once the **calculated Rs** is obtained, it can be compared to the **measured value** displayed by the PVPM device after the I-V curve measurement. If the measured Rs is significantly higher than the calculated value, the module's wiring should be inspected for issues such as **breaks**, **corrosion**, **connection errors**, or **incorrect dimensions**.

18.15 Solar Constant

The **solar constant** refers to the amount of solar radiation that strikes a surface perpendicular to the incoming rays outside the Earth's atmosphere. Its value is approximately **1.37 kW/m²**. In outer space, the solar radiation remains nearly constant. However, on Earth, it fluctuates throughout the day, across seasons, and varies depending on factors such as latitude and weather conditions.

On Earth, the maximum solar radiation typically ranges from about **0.8 kW/m² to 1.2 kW/m²**. The **annual average irradiation** in Germany varies regionally, ranging between **850 and 1100 kWh/m²**.

18.16 Solar irradiation (or Insolation)

Solar irradiation refers to the total amount of solar radiation that reaches a given surface. It consists of **direct radiation** from the sun as well as various **indirect contributions**. These include radiation **reflected by the environment**—for example, snowfields reflect a significant amount of radiation from the blue sky—and other forms of **diffuse radiation**.

To accurately calculate the energy that impacts a surface, the **angle between the sunlight and the surface** is a critical factor. This angle varies depending on the time of year and the time of day. Further information on precise calculations can be found on various online platforms.

Solar radiation is also influenced by several factors, and even under clear blue skies, only about **90%** of the total solar energy actually reaches the Earth's surface.

18.17 Standard Test Conditions (STC)

To ensure the comparability of the power output of photovoltaic (PV) modules, they are always tested under the same standardized conditions. According to **IEC 60904-3**, the **Standard Test Conditions** consist of the following:

- **Irradiation:** 1000 W/m²
- **Light Spectrum:** AM = 1.5 (air mass 1.5), representing the solar radiation spectrum typically encountered at sea level under clear sky conditions in the middle latitudes.
- **Module Temperature:** 25°C

These conditions are used as a reference because they are the basis for comparing the nominal power output of different modules. However, these conditions are rarely found under natural sunlight. Therefore, methods have been developed to estimate the **STC values** of PV modules by measuring their **I-V curves** under actual ambient conditions and adjusting them to match the STC.

It is important to note that while STC provides a standard reference, it does not reflect the real operating conditions of PV modules, where factors such as temperature, irradiation, and angle of incidence may differ significantly.

18.18 Current-Voltage-Characteristic

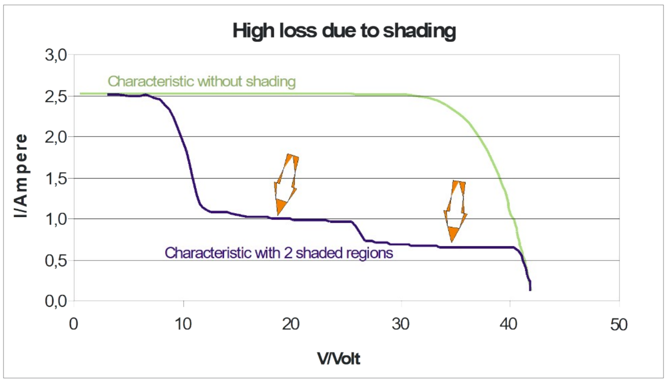
The **Current-Voltage Characteristic** of a photovoltaic (PV) generator displays key performance traits and potential issues within the system. It serves as the foundation for determining several critical parameters and performance indicators of the PV generator.

For instance, the I-V characteristic can be affected by **partial or severe shading**, **high internal series resistance**, and issues like **defective or missing bypass diodes**. These factors can significantly alter the I-V curve and thus the generator's performance.

The I-V characteristic helps determine important values such as:

- **Short-Circuit Current (Isc)**
- **Open-Circuit Voltage (Voc)**
- **Voltage and Current at Maximum Power Point (Vmp and Imp)**

From this, the **Fill Factor (FF)** can be calculated using the following formula:
FF = (Isc * Voc) / (Imp * Vmp)



Picture 58: I-V-curve with an without shaded regions

The I-V curve also serves as the basis for calculating the **effective solar curve**, which in turn allows for the determination of **Peak Power (Ppk)** and **Internal Series Resistance (Rs)**.

18.19 Efficiency

In general terms, **efficiency** refers to the ratio of usable energy output to the total input energy. It is a measure of how effectively a system converts the input energy into useful output.

For example:

- **Conventional light bulbs** convert about **3-4%** of the input energy into light, with the rest lost as heat.
- **Photovoltaic (PV) generators** or solar cells currently achieve an efficiency of **18-22%,** meaning that this percentage of the solar energy they capture is converted into electricity.
- **Thermal solar plants** typically achieve efficiencies between **25-40%**, depending on the system design and the specific conditions, in terms of converting solar radiation into usable thermal energy.

18.20 Four-wire measurement (Kelvin measurement)

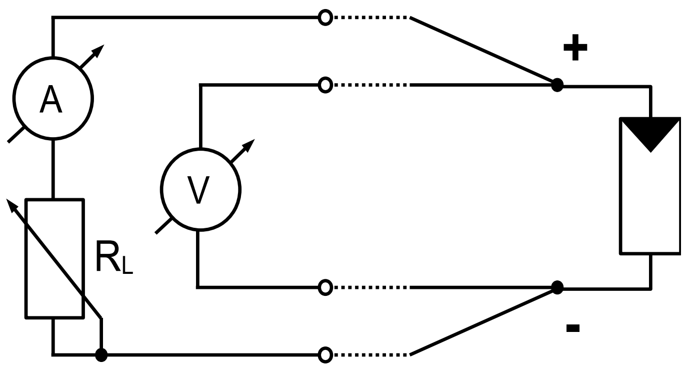
When an electric current flows through a conductor, a voltage drop occurs due to the conductor's specific resistance. This relationship is described by **Ohm's Law** (R = V/I). As a result, the voltage at the end of the wire will be lower than at the beginning (the measurement point), due to the resistance of the conductor itself.
To obtain an accurate measurement of the voltage at the point of interest, the **four-wire measurement** technique is employed. This method uses four separate wires for the measurement process:

1. **Current Measurement Wires:** Two of the wires carry the current, where the input resistance of the measurement device is kept low. Due to the current flow through these wires, a small voltage drop occurs along the wire.

2. **Voltage Measurement Wires:** The other two wires are used to measure the voltage. These wires are connected to a high-resistance input, so very little current flows through them, preventing any significant voltage drop.

This configuration ensures that the voltage measured corresponds accurately to the voltage at the point of measurement, eliminating the errors introduced by the resistance of the wires.

Application in PVPM Measurement Devices:
The **measurement leads of the PVPM devices** are designed according to the four-wire measurement principle, significantly reducing measurement errors. By isolating the current flow from the voltage measurement circuit, the PVPM devices provide highly accurate readings, even in low-resistance scenarios where traditional two-wire measurements might lead to erroneous results. This ensures reliable and precise data for PV module performance assessments.



Picture 59: Kelvin measurement

19 Appendix A

19.1 Indicator lights in the front panel

LED	Function	Remark
State of charge (2 color LED)	Blinking Red: battery nearly discharged (charge!) Red: battery is charged Green: charge is nearly finished Off: charge is finished	Operation time left max. 30 minutes Operation is possible Operation is possible Operation is possible
External Power	Green. On, when an external power supply is connected, the internal battery will be charged automatically	

19.2 Speaker signals:

PVPM reports errors and operating conditions by speaker signals: in the following deep sounds are represented by „da“, higher sounds as „dee“.

audio	*declaration*	*reaction*
click	„Keyboard-click “when pressing the transparency keyboard one simulates	--
dee	During the operation: signals the start or the end of a function	--
da	generally in the case of errors	Consider, which error the device shows on display
dee	If this signal is given with the first appearance of the main menu, the device is ready for operation	Device is ready
da or da-da	Shortly after switching on: CPU Is working	--
da or da-da followed by da-da	Shortly after switching on : probably the lithium buffer batttery of the CPU is empty.	Customer service necessary
dee-dee-da-da	The LC-display cannot be addressed.	Switch the equipment out, after short waiting period on again. If the error arises once more: Customer service necessary
dee dee	After a transfer of a file to the PVPM (only service mode)	File transfer O.K
da-dee-da	After a transfer of a file to the PVPM (only service mode)	File transfer not o.k . destination file is deleted
dee-dee-dee-dee	During measurement: irradiation varies or is too small	Measurement is inaccurate and must be rejected
dee-dee-dee- da-da-da- dee-dee-dee	A/D converter could not be initialized	Customer service necessary

20 Customer support

20.1 Warranty Terms

In accordance with our general terms and conditions, this measuring device is covered by a warranty against material and manufacturing defects. During the warranty period, the manufacturer will, at their discretion, repair or replace any defective components or the entire device.

If the device needs to be returned to customer support or the dealer, the customer is responsible for the cost of return shipping. Shipping arrangements must be made in advance. A letter explaining the reason for the return must be included with the shipment. Only the original packaging should be used for shipping. Any damage caused by the use of non-original packaging will be charged to the customer. The manufacturer will not be liable for any damage to persons or objects.

The warranty does not apply in the following cases:

- Repair and/or replacement of accessories and batteries (not covered under warranty).
- Repairs required due to improper use of the device or its use with incompatible devices.
- Repairs needed because of inadequate packaging.
- Repairs necessitated by unauthorized work.
- Modifications to the device made without the express consent of the manufacturer.
- Usage that deviates from the technical specifications or instructions in the user manual.

The contents of this manual may not be reproduced in any form without the manufacturer's prior approval.

Our products are protected by patents and trademarks. The manufacturer reserves the right to change product specifications and prices due to technical improvements without prior notice.

20.2 Customer support procedure

If the device is malfunctioning, please first check the connections and test leads, and replace them if necessary before contacting customer support. If the device continues to malfunction, ensure that the device is being used according to the instructions in this manual.

If the device needs to be returned to customer support or the dealer, the customer will be responsible for the cost of shipping. Shipping arrangements must be made in advance. A letter explaining the reason for the return must accompany the shipment. Only the original packaging should be used for shipping. Any damage caused by the use of non-original packaging will be charged to the customer.

20.3 Maintenance and calibration of the measuring device

According to the manufacturer's recommendation, it is highly advised that the measurement equipment and accessories for photovoltaic (PV) systems be calibrated annually. PV-Engineering GmbH, as the manufacturer, offers a comprehensive maintenance, repair and calibration service to ensure that the measurement devices and all associated accessories are thoroughly tested. Our annual inspection service includes recalibrating the device's measurement inputs and issuing a new certificate, guaranteeing ongoing accuracy and reliable performance.

For more information or to request a personalized offer, please feel free to contact us.

Contact Details:

PV-Engineering GmbH
Hugo-Schultz-Str. 14
58640 Iserlohn, Germany
Phone: +49 2371 43 66 48-0
WhatsApp: +49 2371 43 66 48-0
Email: info@pv-engineering.de
www.pv-e.de

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QR-Code: Contact us!

Inspection & Recalibration

Service / Repair / Spare parts

Support

SCAN ME

21 Declaration of Conformity

EU-Konformitätserklärung im Sinne der EU-Richtlinien /
EC Declaration **of Conformity** *as defined by the EC Directives*

Der Hersteller /	**PV Engineering GmbH**
The manufacturer	**Hugo-Schultz-Str. 14**
	58640 Iserlohn
	Deutschland/Germany

erklärt hiermit in alleiniger Verantwortung, dass folgende Produkte /
herewith *certifies in sole responsibility that the products*

Produkt: / *Product:*	I-U-Kennlinienmessgerät *I-V-Curve tracer*
Typen: /	PVPM2540C
Types:	PVPM6020C
	PVPM1000C
	PVPM1040C
	PVPM1050C
Baujahr: / *Year of manufact.:*	2009

auf das sich diese Erklärung bezieht, ausschließlich für die Messung der I-U-Kennlinie von Photovoltaikmodulen oder -strings verwendet wird und den Anforderungen der EG-Richtlinien /
to which this declaration refers to are exclusively used for the measurement of the I- V- curve of photovoltaic modules or strings and are in conformity with the directive(s)

- ***Niederspannungsrichtlinie 2006/95/EG***
- ***EMV-Richtlinie 2004/108/EG***

entspricht.

Folgende harmonisierte Normen wurden angewandt: /
The following standards are in use:

EN 61010-1, EN 61000-3-2, EN 61000-3-3, EN 61326-2-2

Eine technische Dokumentation ist vollständig vorhanden. Die zum Messgerät gehörende Betriebsanleitung liegt in der Originalfassung vor. /
A technical documentation is completely available. The operation manual of the device is available in its original version.

Iserlohn, 01.10.2009	*Dipl.-Ing. Klaus M. Schulte*
(Ort/Place, Datum/Date)	*Geschäftsführer/Managing Director*