

PVPM 2540X

(250V, 40ADC, 10kW)

Peak Power Measuring Device and IV-Curve Tracer for
Mono- and Bifacial PV Generators

Users Manual

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1 Software End User License Agreement

DEFINITIONS

For the purposes of this Agreement:

Software: Refers to the downloadable applications provided alongside the PVPM hardware.

Files: Includes all digital files that are part of the Software (e.g. PVPM.disp, Curvealyzer®) or distributed with it.

Data files: Refers to files generated by the Software, containing information extracted from the PVPM hardware.

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COMPATIBILITY AND SYSTEM REQUIREMENTS

The Software is designed for use on Windows operating systems. Minimum system requirements are provided in the Software documentation. PV-Engineering GmbH is not responsible for incompatibilities with systems not meeting these requirements.

APPLICABLE LAW AND JURISDICTION

This Agreement is governed by the laws of the Federal Republic of Germany.

The exclusive place of jurisdiction for all disputes arising from this Agreement is the competent court for Iserlohn, Germany.

LANGUAGE

This Agreement is written in English and shall be the legally binding version in the event of discrepancies between translations.

Iserlohn, 18.10.2025

2 Introduction

The PVPM Series is a precision system for measuring I–V characteristics of photovoltaic modules, strings, and arrays in accordance with IEC 60891, IEC 60904-1, and IEC 61829. These standard procedures ensure reliable on-site performance evaluation and quality assurance of PV systems.

In addition, the PVPM incorporates patented diagnostic algorithms developed by Prof. Dr. Klaus Wagner at the University of Applied Sciences Dortmund, enabling direct determination of Peak Power (P_{pk}), Series Resistance (R_s), and Parallel Resistance (R_p) with laboratory-grade precision under real operating conditions.

All results – including numerical data and the full I–V curve – are displayed on the integrated TFT screen and can be transferred to a PC for extended evaluation with the PVe Curvealyzer software. It offers advanced visualization, module comparison, automatic report generation, and statistical analysis according to IEC standards. Custom templates, logo integration, and direct export to PDF or Excel simplify professional documentation.

With optional front- and rear-side irradiance sensors, the PVPM also analyzes bifacial PV systems, determining rear-side gain and albedo effects for comprehensive system characterization.

Combining standard-compliant measurement technology, patented evaluation methods, and powerful analysis software, the PVPM provides a complete and intelligent solution for field testing, research, and long-term quality monitoring of photovoltaic systems.

Key Features and Functionality:

- **Portable Design:** The PVPM is housed in a lightweight, durable plastic casing 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.
- **Continuous Measurement Mode:** The PVPM enables continuous long-term operation with simultaneous charging and measurement, allowing permanent connection to the power supply. Measurements can run automatically or via PC remote control, ensuring flexible integration into laboratories, monitoring setups, and automated test environments.
- **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.

Applications and Benefits:

The PVPM is designed for a wide range of applications – from on-site performance verification and commissioning of PV systems to periodic maintenance, warranty testing, and system diagnostics. Its precision and compliance with international standards make it a trusted instrument for certification bodies, service providers, and quality assurance laboratories.

In research and education, the PVPM provides a powerful platform for studying module behavior, degradation effects, and bifacial performance under real conditions. Combined with the PVe Curvealyzer software, users gain comprehensive insight into system efficiency, loss mechanisms, and optimization potential — ensuring reliable performance throughout the entire lifecycle of a PV installation.

Description of the Measurement Process:

The PVPM analyser automatically records the I–V characteristic curve of the photovoltaic generator using a high-speed capacitive load method. From the acquired data, it accurately determines key electrical parameters

of the solar cells or modules, including Peak Power (Ppk), Series Resistance (Rs), and Parallel Resistance (Rp) [2], [3].

After each measurement, all data are automatically stored in non-volatile memory, ensuring complete traceability and enabling subsequent evaluation and report generation using the PVE Curvealyzer software. The device's internal memory can store thousands of individual measurements, allowing extensive test campaigns or long-term monitoring to be conducted without the need for external data transfer.

The PVPM displays all relevant electrical, calculated, and environmental parameters directly on the integrated TFT display. The following data groups are shown, depending on configuration and measurement mode:

Electrical Measurement Values (directly measured)

- **Open-circuit voltage (Voc):** Voltage at zero current
- **Short-circuit current (Isc):** Current at zero voltage
- **Voltage at MPP (Vpmax):** Voltage at maximum power
- **Current at MPP (Ipmax):** Current at maximum power
- **Maximum power (Pmax):** Product of Vpmax × Ipmax

Calculated Parameters

- **Fill Factor (FF):** $P_{max} / (V_{oc} \times I_{sc})$; indicator of curve shape
- **Series Resistance (Rs):** Internal resistance limiting current flow
- **Parallel Resistance (Rp):** Shunt resistance indicating leakage
- **Peak Power (Ppk):** Highest Pmax within a sequence or time period
- **Measurement duration:** I-V sweep time in milliseconds (ms)

Environmental and Sensor Data

- **Module temperature (Tmod):** Temperature sensor on module rear
- **Effective irradiance (Eeff):** Front-side reference cell irradiance
- **Bifacial Irradiance (optional):** Up to 3 sensors (front / rear 1 / rear 2) for bifacial analysis
- **Reference cell temperatures:** Recorded for thermal correction and diagnostics

Reference Module Comparison (optional)

If a reference module is defined by the operator, the following parameters are displayed for comparison and evaluation:

- **Reference identification:** Name / designation of the reference module
- **Configuration:** Number of cells in series and parallel (Ns / Np)
- **Nominal power (Pnom):** Rated peak power under STC
- **Power deviation (ΔP_{pk}):** Difference between measured and nominal power
- **Series resistance deviation (ΔR_s):** Difference to reference Rs
- **Fill factor deviation (ΔFF):** Difference to reference FF

Graphical Visualization

The measured I-V characteristic curve is displayed directly on the integrated display, providing an immediate graphical representation of the PV generator's performance under current conditions.

[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

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 (e.g. PVPM1540X or PVPM2540X)** and a calibration certificate (factory calibration) from the manufacturer
- **Software license for Curvealyzer®** (analysis and evaluation software)
- **A calibrated irradiance reference sensor** frontside irradiation (monocrystalline with certificate) with digital cell temperature sensor DS18B20; stainless steel clamp holder for tool-free mounting on the module frame; 10-meter cable length
- **(optional) 2x calibrated irradiance reference sensor backside irradiation** (monocrystalline with certificate) digital cell temperature sensor DS18B20; stainless steel universal bracket for mounting on the module frame, 3m cable length
- **One DS18B20 temperature sensor** for measuring module temperature; 3-meter cable length
- **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 Pve backpack** for the cables, sensors and accessories

Optional accessories:

- High-precision reference sensors with different filters; mono-, polycrystalline
- Extension cables
- Transport case for the safe transport of the entire system
- PVe backpack or aluminum suitcase for sensors and cables
- Padlocks for the cases
- **All accessories can be purchased separately**
- **Extended warranty and service agreements are available upon request**

4 Normal use

The PVPM Series Peak Power Measurement and I-V Curve Tracer are designed for the precise characterization of photovoltaic modules, strings, and arrays within their specified current and voltage limits. The instruments provide detailed information on the electrical and performance behavior of PV generators, supporting accurate efficiency evaluation and system diagnostics.

Important Guidelines for Safe Operation

1. Adherence to Device Limits

Before connecting the PV generator to the device, verify that its **maximum voltage and current values do not exceed the specified limits** of the PVPM at any time. Exceeding these values may damage the instrument or pose a safety risk to the user. For detailed safety and current limitation information, see Chapter 6: Warnings.

2. Electrical Safety and System Isolation

Ensure all DC components are safely disconnected before measurement (see Chapter 6 for details).

3. Use of Approved Components

Only use **accessories, cables, sensors, and connectors approved by PVE**. Non-approved parts may affect measurement accuracy, device safety, or calibration validity.

4. Safe Installation Site

Place the device on a **stable, level, and dry surface** protected from vibration and mechanical impact. Prevent tipping or falling, as the unit's weight can cause injury or damage. Avoid shading or direct sunlight on the test object during measurement.

5. Personal Protective Equipment (PPE)

Always use appropriate PPE when connecting or disconnecting cables (see Chapter 5).

6. Verification of Environmental Conditions

Operate only within the specified environmental conditions (see Chapter 5).

7. Battery and Power Supply

Ensure an **adequate state of charge** before use. The integrated battery is long-lasting but should be fully charged before extended operation or fieldwork. Low voltage can interrupt measurements or impair communication with sensors.

8. Inspection of Connections

Always check test leads and connectors for **mechanical damage or wear** before use. Damaged components can cause faulty readings or electrical hazards.

9. Device Calibration

Regularly verify the **device calibration** to maintain measurement accuracy. Follow the manufacturer's calibration instructions or contact PVE for service information (see chapter 21.3).

10. Cleaning and Care

Clean the device only with a soft, slightly damp cloth. Do not use any cleaning agents, solvents, or alcohol, as these may damage the housing, connectors, or display. Ensure that no moisture enters the device openings.

By following these guidelines, the PVPM can be operated safely and effectively, ensuring **reliable, repeatable, and precise measurement results**.

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 Curvealyzer® 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 that the PV generator under test does not exceed the maximum voltage and current limits of the PVPM. Ensure all DC components are safely disconnected before measurement (see Chapter 6 for details). Always treat terminals as potentially live. Overloading or improper handling can lead to equipment 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 I: This device is rated for use in measuring category I environments. Do not use this device in measuring category II, III or 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 (see related datasheet).

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/X $I_{max}=40ADC$
- PVPM1040C/X $I_{max}=40ADC$
- PVPM1500X $I_{max}=20ADC$
- PVPM1540X $I_{max}=40ADC$

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

Safety During Measurement:

Only trained and authorized personnel may connect the photovoltaic generator to the PVPM. The measurement procedure must be carried out or supervised by qualified individuals familiar with electrical safety practices and local regulations. Applicable international or national standards (e.g., IEC 60364, NEC, or equivalent) must be observed at all times, as high DC voltages and currents can present a serious risk of electric shock or injury.

The PVPM and all associated components must only be opened, serviced, or repaired by the manufacturer (PVe) or by personnel expressly authorized by the manufacturer. Before opening any enclosure, ensure that all cable connections are fully disconnected. Note that dangerous high voltages may remain inside the device even after disconnection. Unauthorized opening or repair may lead to electric shock, equipment damage, or loss of warranty.

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 photovoltaic generator and the PVPM while the generator is active or during an ongoing measurement. Very high DC currents may occur during operation, posing a severe risk of electric shock, arcing, or equipment damage.

Always ensure that the inverter and all connected DC components are completely disconnected before handling any cables. A PVe LTSX safety disconnect switch must be used as an additional protective device to safely isolate and reconnect the measurement lines to the PVPM (included in the scope of delivery).

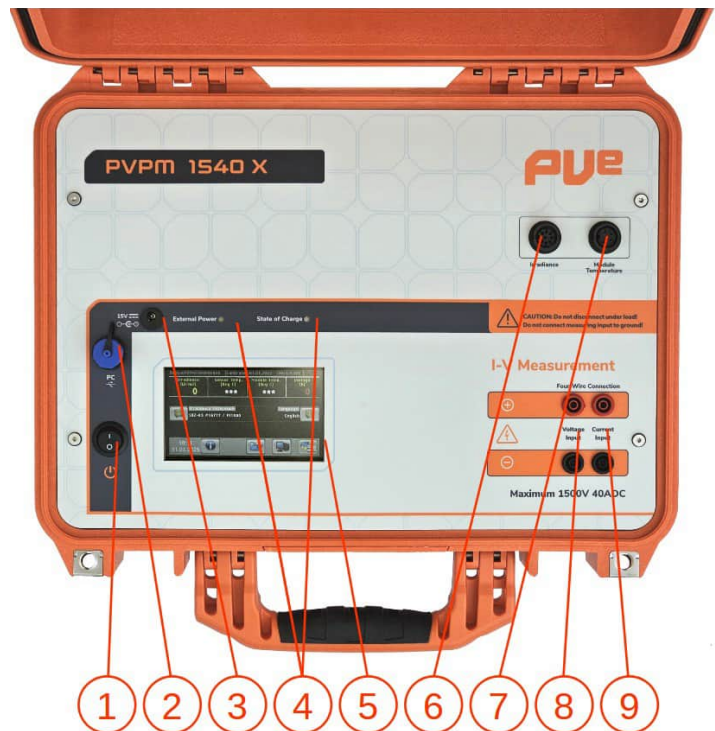
The plugs of the four-wire measurement cables must be inserted fully into their corresponding sockets until they reach the stop. Incomplete connection may cause contact resistance, overheating, or electrical arcing, potentially resulting in fire or permanent damage to the connectors and measuring device.

During measurement, the PVPM intentionally drives the generator into short-circuit conditions. Disconnecting cables under these circumstances can lead to severe electric arcs, posing a high risk to health and safety. Cable connections must only be removed after the PV generator and inverter have been safely isolated.

7 Operation of the PVPM

7.1 Operating and connection elements

1. On/Off push button
2. USB port (mini B) + dust cap
3. Port for external power supply (max. 15VDC, min. 2A)
4. Status lights (state of charge/ power supply)
5. 4.3" TFT colour graphic touch display
6. Combined irradiation and temperature measuring input
7. Module Temperature (not occupied)
8. Four-wire measuring connector (voltage)
9. Four-wire measuring connector (current)



Picture 1: Operating and connection elements

7.2 General information

The PVPM is designed to operate within a specified temperature range (refer to the related datasheet). 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 PVPM casing is waterproof and rated to **IP 67** (closed lid) standards. However, to maintain the device's integrity, avoid direct exposure to water, rain, or similar conditions.

Optimal Measuring Conditions:

For accurate and reliable measurements, solar irradiance should be as close as possible to Standard Test Conditions (STC). According to international standards, measurements should preferably be conducted at irradiance levels of at least 800 W/m². While I–V curve measurements are technically possible above 500 W/m², results below this level may lead to less precise STC normalization and reduced comparability. In such cases, the automatic suppression of STC values ensures data integrity.

For optimal results, the PV module should be oriented orthogonally to the sun's rays, with a maximum deviation of ±10°, and be completely free of shading, dirt, or partial obstructions. Measurements should only be performed under clear-sky conditions, avoiding clouds, fog, or haze, as these factors can cause irradiance fluctuations and measurement instability.

Status lights

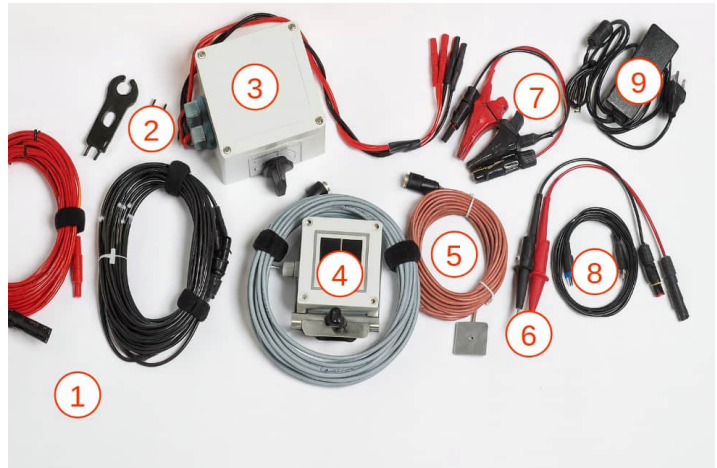
The front panel of the PVPM is equipped with status lights that provide visual feedback on the device's status and operation. These lights include:

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 Accessories & Peripheral Devices

For general operation, the following accessories are required or included in the standard scope of delivery. Not all components are needed simultaneously; their use depends on the specific measurement setup and application.



Picture 2: Peripheral Devices / Accessories

1. 4-wire-measurement cable (10m)
2. MC4 release tool
3. External security switch (see chapter 7) between measurement cable and PVPM
4. Irradiance reference sensor (Front) & Irradiance reference sensors (Back; optional accessory)
5. Modul temperature sensor NES DS18B20
6. Test probes (red/black, max. 1500V DC/40A)
7. Alligator clips (red/black, max. 1500V DC/20A)
8. USB cable
9. External power supply

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

Interface	Function
Power supply	Input 15VDC/ min. 2A, coaxial power connector 5.5x2.1mm
Temperature	not occupied
Irradiance	Combined sensor: irradiance (front and backside optional) + temperature of the module as well as the ref. cells
Voltage input	Voltage input (modules under test; max. 1500VDC)
Current input	Current input (modules under test; max 40ADC)
PC	Serial connection to PC (USB cable)

Power cables, test leads, accessories and power supplies must only be replaced with components that meet the specified ratings and safety requirements. Using unsuitable or non-approved parts can lead to malfunction or safety risks. Replacement parts that are safety-relevant or affect measurement accuracy may only be obtained from and verified by the manufacturer (PV-Engineering GmbH) to ensure proper operation and compliance with all applicable standards.

7.4 Powering On the PVPM

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

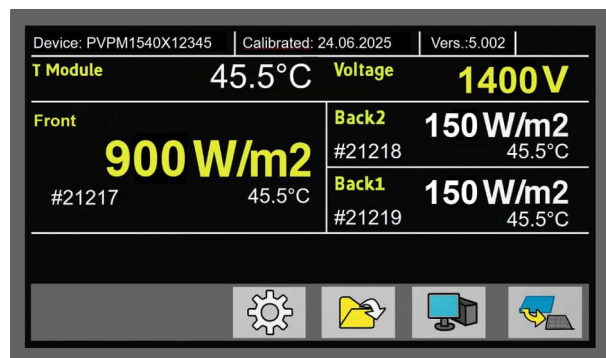
The PVPM will perform a series of self-tests, completing its initialization within approximately 10 seconds.

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 of the frontside and backside sensors (if available), temperature of the irradiance reference cells (Front, Back1, Back2), module back-surface temperature (if available) as well as the voltage at the power measurement input.
- **Sensor & Language Line:** Displays the currently identified irradiance reference sensor / sensors. Once the sensors have been recognized by the system, they identify themselves, which is indicated by the display of the unique serial number (e.g. #21217).
- **Bottom Line:** Displays the current time and date as well as the following menu buttons:
 - **Settings**
 - **Archive**
 - **Data transfer mode**
 - **New Measurement**



Picture 3: Start-up screen PVPM



Picture 4: Main menu

7.5 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“

7.6 Power Supply

The PVPM is equipped with a high-performance lithium-ion battery pack (RRC2020, 10.8 V / 9.22 Ah / 99.6 Wh), enabling fully independent operation without connection to the mains supply. The intelligent smart-battery system communicates via SMBus, providing optimized charging, accurate state-of-charge monitoring, and advanced safety control.

The battery complies with all major international safety and transport regulations, including IEC 62133, UL 2054, CE, UN 38.3, RoHS, and REACH, and is therefore approved for worldwide air and ground transport. Numerous integrated protection circuits safeguard against overvoltage, undervoltage, overcurrent, short circuits, and overheating.

Recharging is managed automatically through the integrated charge controller when the external power adapter is connected to the front panel. An LED indicator shows the current charging and battery status. The battery module is easily replaceable, ensuring long-term serviceability and compliance with PVE's sustainability and maintenance standards.

7.7 Connecting a PC

The PVPM can operate autonomously without the need for an external PC. However, for advanced data analysis, data transfer, or remote control of the device, it can be connected to a 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 download and analyze measurement data on the PC, the PVe Curvealyzer® software is required. This software enables detailed evaluation, visualization, and report generation of all recorded measurements.

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

1. Install the PVe Curvealyzer® software (refer to Chapter 10)
2. Install the USB port device driver (refer to Chapter 11)
3. Activate the "Transfer" function on the PVPM (refer to Chapter 7.10.)

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

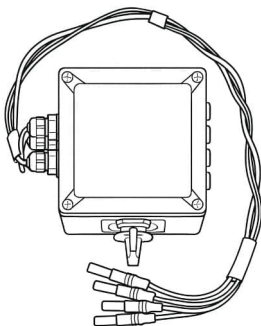
Important: Before operating the PVPM from a PC using Curvealyzer®, you must select the “Transfer” mode on the device. To do this, tap the PC symbol on the main screen. The successful switch to transfer mode is indicated by a screen change on the PVPM display.

If this mode is not activated, the PVPM will not respond to the serial interface, and the PC will be unable to access the device.

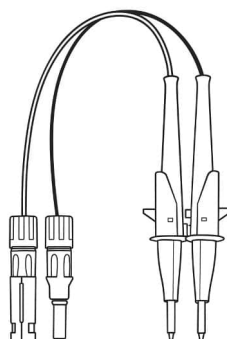
7.8 Connecting the Solar Generator

Important: Before 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 short time during the measurement, and any connected batteries or inverter load capacitances could cause damage to the system.

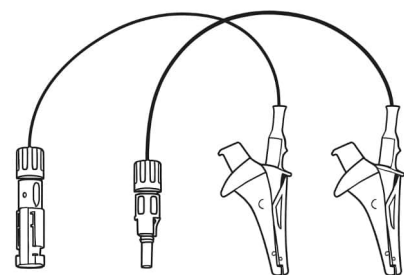
Connect the PVPM using the supplied measurement cables and the external safety switch LTSX1500 (see also chapter “LTSX1500”). The switch must be installed **between the measurement leads and the PVPM** and set to position “0” (OFF) while connecting or disconnecting cables. The PVPM must be **switched on before connection** so that voltage values and possible warnings (e.g. reverse polarity) are displayed.



Picture 5: PVPM LTSX1500 safety switch



Picture 6: PVPM TestTips



Picture 7: PVPM crocodile clips

The **red (positive)** lead has an MC4-compatible **female** connector, and the **black (negative)** lead an MC4-compatible **male** connector as counterparts to the PV module connectors. Their 4 mm safety plugs are inserted

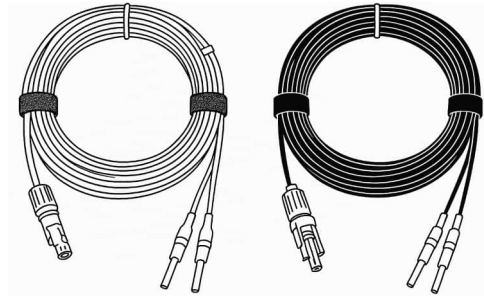
firmly and completely into the color-coded sockets of the LTSX1500. The LTSX1500's 80 cm output cables are then connected to the corresponding red and black sockets on the PVPM. Never reverse polarity.

Measurements can be performed in different ways:

- Directly via the **MC4 connectors of the test lead to the MC4 connectors** of the module or string.
- Using **test tips** attached to the measurement leads (MC4 connectors).
- Using **crocodile clips** attached to the leads for temporary contact (MC4 connectors).

All accessories are **MC4-compatible** and rated to **CAT III 1500 V** (crocodile clips max. 20 A, test tips max. 40 A DC). **Test tips and crocodile clips must never be connected directly to the**

PV generator via their MC4 connectors, as this would be improper use and could make them unintentionally live. Always attach them **to the measurement leads only**, in a **de-energized state**, and ensure all connectors are **fully inserted and securely locked**.



Picture 8: PVPM test leads

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

A reversed polarity connection must be avoided at all costs, even if an IPP-device 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!

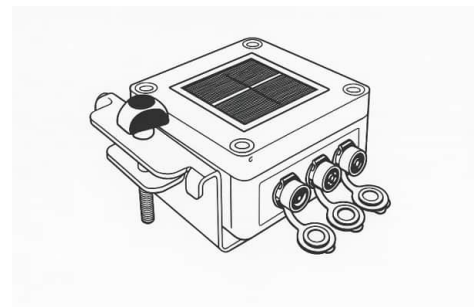
7.9 Connecting the SOZ-03 irradiance reference sensor

Connect the digital irradiance reference sensor to the “Irradiance” port on the PVPM. The front-side sensor communicates via Modbus and is equipped with a coded plug for correct alignment and secure attachment. It is equipped with a snap-in lock.

To disengage the snap-in lock, press the silver locking lever on the connector fully. Then carefully pull the connector straight off. Make sure to pull only on the connector itself—never on the cable.

The front irradiance sensor features a 10 m connection cable and a stainless-steel clamp mount for tool-free installation directly on the PV module frame. It contains an integrated digital temperature sensor for measuring the reference cell temperature, enabling automatic temperature compensation of the measured irradiance values. These parameters can also be verified or adjusted later in the PVe Curvealyzer® software if required.

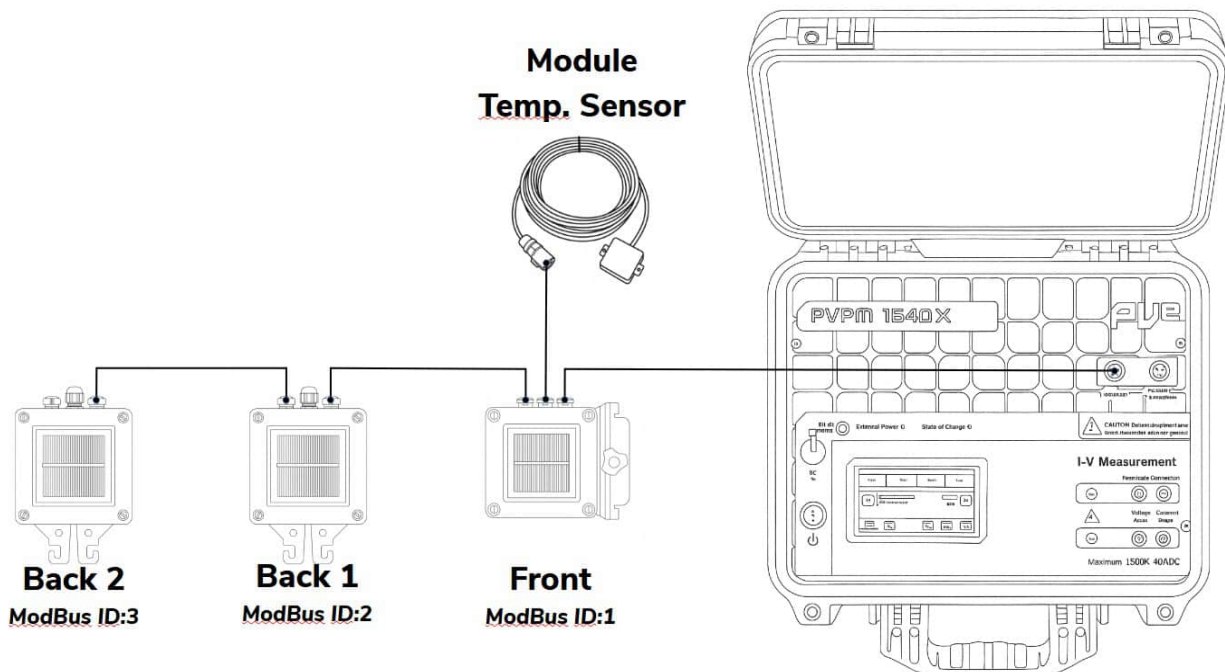
Optionally, up to two additional rear-side irradiance sensors can be connected for the analysis of bifacial PV systems. These sensors are of the same technical design but are supplied with universal stainless-steel mounts, allowing flexible attachment to the rear structure of the PV module or supporting frame components. The rear sensors measure irradiance only (no additional module temperature measurement).



Picture 9: SOZ-03 front irr. sensor

All sensors are connected in a daisy-chain configuration:

- The front sensor is connected directly to the PVPM.
- The module temperature sensor (DS18B20) is connected to the center port on the front sensor.
- The second sensor (rear 1) is connected to the outer free port on the front sensor.
- The third sensor (rear 2) is connected to the free port on the second sensor.



Picture 10: Connection diagram of the irradiance ref. sensors and the module temp. sensor via ModBus to the PVPM

This chain allows simultaneous acquisition of front and rear irradiance values and front-side temperature data with a single digital bus connection.

For optimal accuracy, position the front sensor in the same plane and orientation as the module under test, without shading or obstruction, and allow 10–15 minutes of acclimation to match module temperature before measurement. Proper sensor alignment and stable environmental conditions are essential for accurate and repeatable results (see Chapter 7.10).

The irradiance reference sensor should be cleaned regularly using a soft, lint-free cloth and distilled water or mild detergent. Scratches, residues, or harsh cleaners can damage the optical surface and alter its spectral sensitivity.

7.9.1 Scan for new sensors / Changing the ModBus ID

Each PVPM measurement system is delivered fully configured, calibrated, and ready for operation. Therefore, no additional setup is required during initial commissioning—apart from possibly adjusting the system clock to the local time at your location.

However, if it ever becomes necessary to replace one or more sensors, or to compare sensors with different types, these sensors must first be configured for use with the PVPM. Each sensor communicates via Modbus and has a unique Modbus ID, typically in the range of 1...3. It is essential to ensure that **no two sensors within the same system share the same Modbus ID**, as this would cause communication conflicts.

To check which sensors are currently connected (and which Modbus IDs are active), make sure that all intended sensors are properly connected—either individually or via daisy chain—and then proceed as follows:

1. On the **main screen**, tap the **gear icon** to open the Settings menu.
2. In this menu, you can adjust the system language, initiate a **Modbus rescan**, or assign a **new Modbus ID**.
3. Press the **“Modbus Rescan”** button to start a scan. The PVPM will detect all connected sensors and display their corresponding Modbus IDs.

If you need to change a sensor’s Modbus ID, follow these steps:

1. Ensure that only the sensor to be reconfigured is connected directly to the PVPM (no other sensors attached).
2. Press **“Change Modbus ID”**.
3. The device will display the detected sensor along with its serial number for confirmation. Confirm to proceed.
4. In the following dialog, enter the new Modbus ID and confirm the input.
5. Please note that this procedure only works when a single sensor is connected.
6. For bifacial module measurements, make sure that only one sensor in the system carries the corresponding ID.
7. The factory default ID is printed on the label of each sensor.

After changing the ID, restart the PVPM (power on/off).

Then, return to the Settings menu via the gear icon to verify that the updated Modbus ID has been applied correctly.

Repeat this procedure for all additional sensors as required.

7.10 Connecting the module temperature sensor (NES DS18B20)

The module temperature sensor (type NES DS18B20) is used to measure the rear-side surface temperature of the PV module under test. It features a 3-meter connection cable and a coded plug, which must be inserted into the center port of the front irradiance sensor. The plug ensures proper alignment and is secured with a snap-in lock.

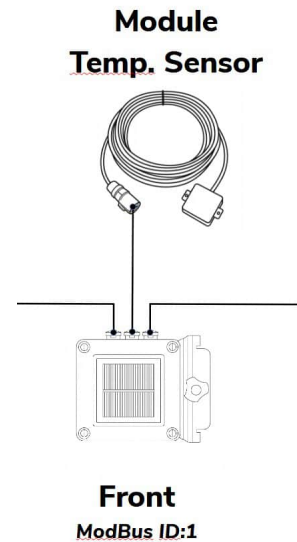
To disengage the snap-in lock, press the silver locking lever on the connector fully. Then carefully pull the connector straight off. Make sure to pull only on the connector itself—never on the cable.

The DS18B20 sensor includes an aluminum mounting plate that serves two functions: it simplifies installation on the back of the PV module and provides thermal inertia, ensuring stable and accurate temperature readings by minimizing short-term environmental fluctuations.

Attach the aluminum plate and sensor firmly to the rear surface of the module using standard insulating adhesive tape, ensuring full contact with the module surface for optimal heat transfer.

If necessary, clean the affected area of the module as specified by the DUT manufacturer.

Before starting measurements, allow approximately 10–15 minutes of acclimation so that the measured module temperature aligns closely with the reference cell temperature. Once stable, the PVPM measurement can be initiated (see Chapter 7.10 for further guidance).



Picture 11: NES DS18B20 temp. sensor

Importance of Module Temperature Measurement

Accurate module temperature measurement is essential for reliable I–V curve analysis. The temperature of a photovoltaic module has a direct influence on its electrical characteristics—particularly on the open-circuit voltage (V_{oc}) and, to a lesser extent, on the short-circuit current (I_{sc}). Even small temperature fluctuations during measurement can lead to significant deviations in the resulting curve and, consequently, in the calculated STC values.

Since ambient conditions such as solar irradiance, wind speed, and module mounting can change rapidly in the field, the actual module temperature often differs from the ambient air temperature. By measuring the module's back-side temperature directly, these influences can be quantified and properly compensated during data evaluation.

In addition, the temperature measurement enables a precise comparison between the module and the reference cell, ensuring that the temperature correction in accordance with IEC 60891 is applied correctly. This is particularly important when comparing different modules, evaluating degradation effects, or verifying manufacturer data under varying environmental conditions.

7.11 Placement of Irradiance Sensors on Bifacial Modules

Bifacial PV modules generate power from both front and rear illumination. Correct sensor placement is essential for accurate and norm-compliant I-V measurements. The PVPM system supports this with up to three PV-based reference sensors (front and two rear sensors), which continuously record irradiance and temperature values in accordance with IEC 60904-1:2020, IEC TS 60904-1-2:2024, and IEC 60891.

Required Sensors and Function

Sensor	Function	Typical Mounting
Front sensor	Front-side irradiance G_{front} [W/m ²], cell temperature [°C] (Article no.: NES-SOZ-03-ModBus1)	Clamped tool-free to module frame (front)
Rear sensor A	Rear irradiance $G_{\text{rear A}}$ [W/m ²], cell temperature [°C] (Article no.: NES-SOZ-03-ModBus2/3)	Stainless-steel multi-holder, rear side
Rear sensor B	Rear irradiance $G_{\text{rear B}}$ [W/m ²], cell temperature [°C] (Article no.: NES-SOZ-03-ModBus2/3)	Stainless-steel multi-holder, rear side
Temp-Sensor	Module temperature of the DUT [°C] (Article no.: NES-DS18B20)	Adhesive tape

All sensors measure irradiance and cell-temperature and transmit live values to the PVPM for automatic plausibility checks and warning functions.

Preparation

- Verify that the module has **bifacial characteristics** and that the rear side receives sufficient illumination.
- Rear irradiance must be $\geq 50 \text{ W/m}^2$ on both sensor positions.
- The difference between both rear sensors (**inhomogeneity**) must not exceed **10 %**. The PVPM automatically checks this and issues a warning if exceeded.
- Sensors must be clean, undamaged, and within calibration (< 12 months).

Correct Sensor Placement

- The **front sensor** is mounted flat and parallel to the module surface using the supplied clamp.
- The **rear sensors** are attached using stainless multi-holders:
 - Sensor A on the *brightest* (highest irradiance) rear area
 - Sensor B on the *darkest* rear area

In this way, the inhomogeneity of the rear radiation can be recorded and evaluated.

- Surfaces must be flat, parallel to the module ($\pm 2^\circ$), and free from shadows or obstructions.
- Route all sensor cables neatly along the frame to avoid partial shading.

Measurement Conditions

Measurement under natural sunlight is only valid when:

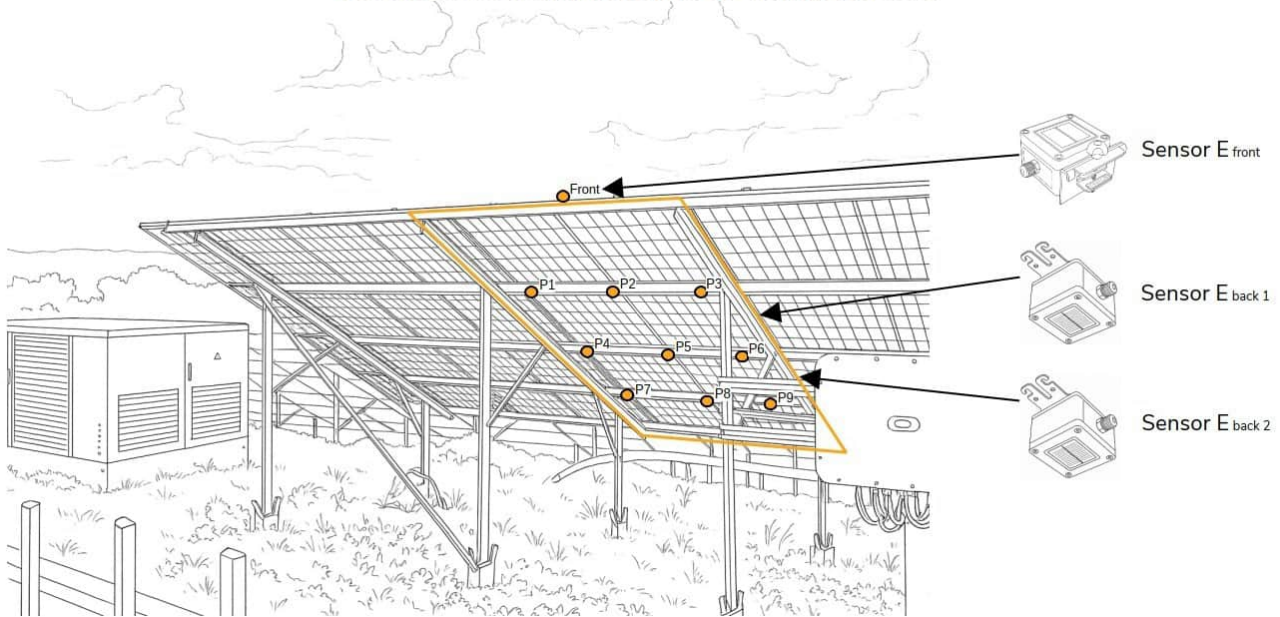
- $G_{\text{front}} \geq 900 \text{ W/m}^2$ ($\pm 10 \%$ of 1000 W/m^2 STC),
- $G_{\text{rear A/B}} \geq 50 \text{ W/m}^2$, Rear inhomogeneity $\leq 10 \%$,
- Temperatures are stable for $\geq 30 \text{ s}$,
- The sun angle is roughly perpendicular to the module surface (10 – 14 h).

If these conditions are not met, postpone the measurement and document the situation in the test report.

Typical Errors and Prevention

No.	Typical Issue	Possible Effect	Recommended Action	Why It Matters
1	Only one rear sensor connected	Rear-side inhomogeneity cannot be detected	Always use both rear sensors (Gear A + B) according to IEC TS 60904-1-2	Ensures valid STC correction and realistic bifacial performance
2	Sensors not parallel to the module surface	Measured irradiance too low or too high	Re-align sensors flat and parallel to the module surface	Inclined sensors distort the cosine response and create up to $\pm 5\%$ error
3	Partial shading by frame, holder, or cable	False irradiance drop; invalid I-V curve	Reposition sensors and route cables along frame edges	Even a small shadow (1 cm^2) can cause $> 2\%$ deviation
4	Rear irradiance difference $> 10\%$	Measurement not norm-compliant	Repeat under diffuse light or reposition rear sensors	IEC TS 60904-1-2 prohibits STC correction above 10% inhomogeneity
5	Unstable irradiance (clouds, reflection)	Fluctuating curve and wrong STC result	Measure only with stable values ($\pm 5\%$ for $\geq 30\text{ s}$)	Prevents inconsistent short-circuit current readings
6	Unstable temperature or rapid heating	STC correction unreliable	Wait until temperature drift $< 1^\circ\text{C}$ for $\geq 30\text{ s}$	Ensures thermal equilibrium for precise correction factors
7	Wrong sensor mounting position	Rear sensors not at irradiance extremes	Place one sensor on brightest and one on darkest rear area	PVPM uses difference for homogeneity check and averaging
8	Dirt or residue on sensor surface	Lower irradiance reading	Clean sensors with a soft, dry cloth before each use	Dust reduces light transmission and affects calibration accuracy
9	Reflections from bright ground (water, foil, snow)	Overestimated rear irradiance	Inspect environment visually and, if needed, relocate sensors	Prevents false STC overestimation due to local reflections

Possible Sensor Mounting Positions on Bifacial PV Modules

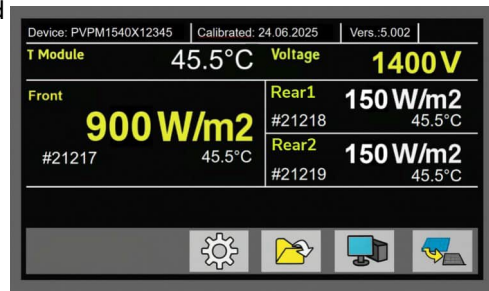


Picture 12: Schematic illustration of a bifacial photovoltaic system. Indicated are potential mounting positions (P1–P9) for rear-side irradiance sensors as well as a mounting point for a front-side irradiance sensor for measuring global and albedo irradiance.

7.12 Measurement

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).



Picture 13: Main Menu



Opens 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.

7.12.1 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.

7.12.2 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 P_{pk} [W_p] / ± 5% tolerance
- Open circuit voltage V_{oc} [V]
- Short-circuit current I_{sc} [A]
- Voltage in MPP U_{pmax} [V]
- Current in MPP I_{pmax} [A]
- Fill factor FF [%]
- R_s series internal resistance [Ohm]
- R_p parallel resistance [Ohm]
- Irradiance E_{eff} (Sensor 1,2,3) [W/m²]
- Cell-Temperature of the ref. Sensor (Sensor 1,2,3) : T_{ref} [°C]
- Module Temperature e.g. DS18B20:
T Module [°C]
- Irradiance reference sensor type and serial number (Sensor 1,2,3)

	Meas	@STC	Nom	Diff [%]
P [W]	0.0	n.a.	--	--
+5% [W]	--	--	--	--
Isc [V]	0.0	--	--	--
Isc [A]	-0.0	--	--	--
Vpmax [V]	-0.0	--	--	--
FF [-]	***	--	--	--
Rs [Ohm]	***	--	--	--
Rp [Ohm]	***	--	--	--
	Front [1]	BackT [2]	BaTotal [3]	
Eff [W/m ²]				
Tref [Deg C]				
Tmod [Deg C]				
Ser. No.				

Picture 14: Displayed results

The following information is also displayed in the header:

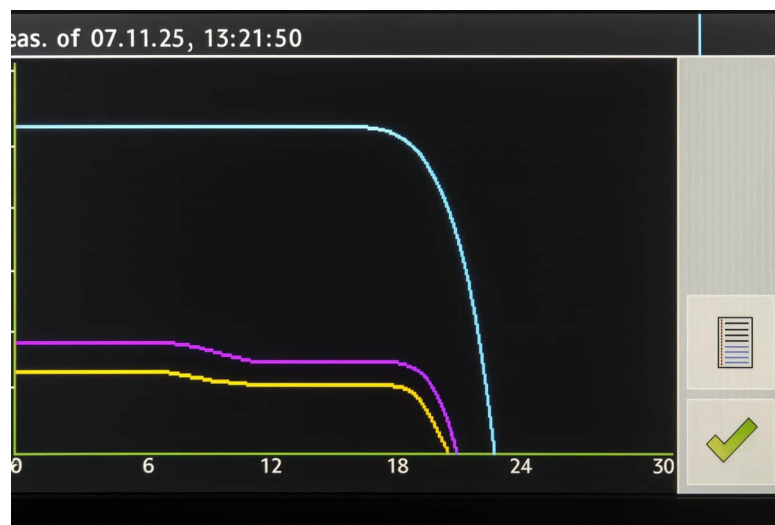
- Date and Time
- Duration of the Measurement [ms]
- Number of modules in series connection / in parallel connection



The page “Results” displays the measured (voltages, currents, temperatures etc.) and calculated values (P_{pk} , R_s , R_p , FF).



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

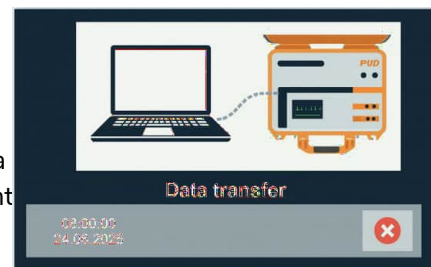


Picture 15: I-V-curve

7.13 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).



Picture 16: Transfer Mode

7.14 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!

7.15 Messages

<i>Message:</i>	<i>Description:</i>
'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 evaluably'	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 Safety Switch LTSX1500

To prevent damage to the PVPM or risks to personal safety, always use the disconnection switch to isolate the PVPM from the DUT 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. You can turn the knob both clockwise and counterclockwise
3. 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.
4. 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 LTSX1500 and e.g. test leads 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, test leads 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. Do not expose to moisture or operate in humid environments.

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

If the switch has been used to interrupt an active current flow exceeding 20 A, 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:

For standard-compliant measurements according to IEC specifications, the irradiance should be at least 800 W/m². Measurements are technically possible at lower levels; however, if the irradiance drops below 500 W/m², a warning message will appear, and STC calculations will be automatically disabled to maintain measurement accuracy and data integrity.

Attention should also be given to environmental and optical influences that may affect measurement accuracy. These include albedo effects, uneven or highly reflective backgrounds, and variations in diffuse and direct irradiance caused by surrounding structures, vegetation, or changing sky conditions. Partial shading, tall grass, or obstructions can lead to non-uniform irradiance on the module surface.

Additionally, soiling, scratches, or improper mounting of the reference sensor or PV modules can distort measurement results. Ensure that all optical surfaces are clean, undamaged, and properly aligned with the test modules to guarantee reliable and reproducible data.

3. SOZ-03 Irradiance Reference Sensor Functionality:

The SOZ-03 combined sensor system measures two key parameters:

- Irradiance: The intensity of sunlight incident on the reference surface.
- Cell Temperature: The temperature on the rear side of the irradiance reference cell, used for automatic temperature compensation during measurement.

In the standard configuration, the PVPM uses one front-side combined sensor and up to two optional rear-side irradiance sensors.

- The front sensor measures both irradiance and cell temperature via an integrated digital temperature sensor and is connected directly to the "Irradiance" input on the PVPM.
- The rear sensors measure irradiance only and are connected in a daisy-chain configuration to the front sensor. They enable the detection of rear-side irradiance for bifacial module analysis.

If no external temperature sensor is available to measure the backside temperature of the test modules, the PVPM assumes that the module temperature approximately corresponds to the reference cell temperature. This assumption is valid if both the test modules and the reference cell have been exposed to sunlight for the same duration (at least 15 minutes) and have reached thermal equilibrium.

All measured sensor values can later be reviewed, corrected, or manually edited in the PVe Curvealyzer® software, allowing precise post-processing and data verification.

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 NES temperature sensor (DS18B20) 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 (**I_{sc}**). The voltage across the shunt resistor is proportional to the **I_{sc}** 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 polycrystalline 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 1s.
- The measured irradiance value of the reference sensor must be temperature-compensated according to DIN EN IEC 60891, using the measured reference cell temperature to ensure accurate determination of irradiance under Standard Test Conditions (STC).
- The measurement of the cell temperature has to take place immediately before/after the measurement of the characteristic within 1 second and an accurateness of 1 K
- 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 temperatures of the device under test and the reference sensor must be in thermal equilibrium; no temperature variation should be observed during the measurement period.
- Current and voltage of the device under test are measured with distinct test leads (four-wire measurement)

10 Installation of the Transfer and Evaluation Software Curvealyzer®

Please download the recent software Curvealyzer® for MS Windows® from:

<https://t1p.de/yllb3>

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 Curvealyzer®.
5. After completing the installation please execute Curvealyzer®. 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} \ Curvealyzer	Program file and additionally files required for the operation of the application (eg language files)
{common} appdata \ PV Engineering \ Curvealyzer	Configuration and the database files
{user docs} \ Curvealyzer	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\Curvealyzer\".

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.

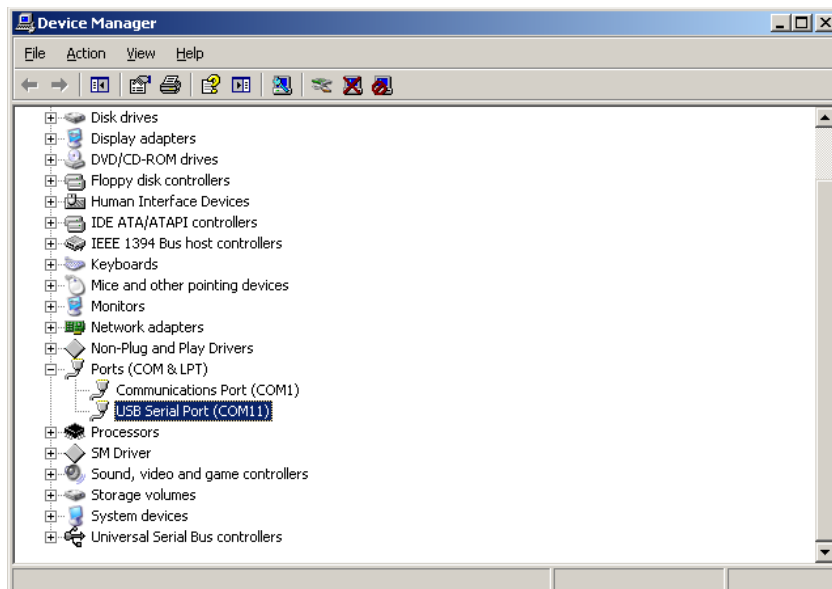
11 Installing the USB device driver

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.



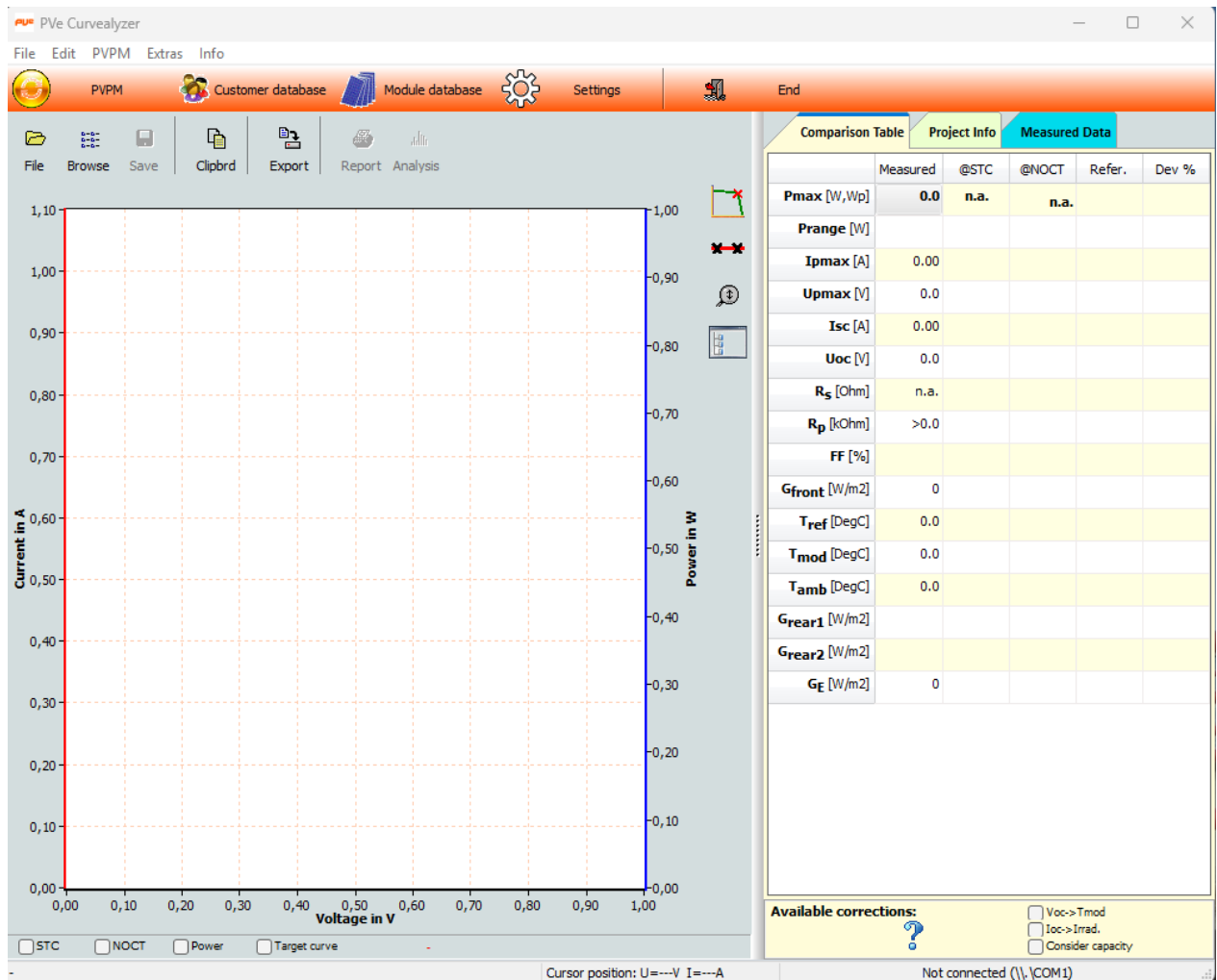
Picture 17: Device Manager

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 Curvealyzer®

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



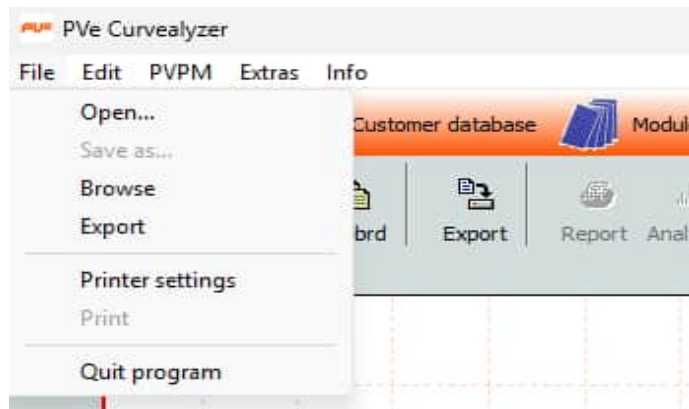
Picture 18: Main screen software after start

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 19: 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.

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.

Sel	File	Date / Time	Voc/V	Isc/A	Pm/W	Mod/DegC	ens/DegC	Eeff/Wm2	Mod.type	Cust
<input checked="" type="checkbox"/>	22-07-2025 13_27_26.SUI	2025-07-22 13:27:26	1364.50	14.7	15219.1	53.2	53.2	902	JAM72042 LB 620	
<input type="checkbox"/>	22-07-2025 13_30_10.SUI	2025-07-22 13:30:10	1352.21	14.9	15135.5	54.5	54.5	902	Default	
<input type="checkbox"/>	22-07-2025 13_31_58.SUI	2025-07-22 13:31:58	1364.66	13.8	14503.0	54.0	54.0	880	Default	
<input type="checkbox"/>	22-07-2025 13_34_06.SUI	2025-07-22 13:34:06	1361.24	14.5	15108.7	54.7	54.7	880	Default	
<input type="checkbox"/>	22-07-2025 13_35_22.SUI	2025-07-22 13:35:22	1351.48	14.5	14918.8	54.1	54.1	880	Default	
<input type="checkbox"/>	22-07-2025 13_36_28.SUI	2025-07-22 13:36:28	1360.43	14.7	15275.7	54.5	54.5	904	Default	
<input type="checkbox"/>	22-07-2025 13_38_06.SUI	2025-07-22 13:38:06	1356.36	14.7	15186.8	54.7	54.7	905	Default	
<input type="checkbox"/>	22-07-2025 13_39_40.SUI	2025-07-22 13:39:40	1355.55	14.9	15351.0	51.5	51.5	904	Default	
<input type="checkbox"/>	22-07-2025 13_40_52.SUI	2025-07-22 13:40:52	1366.94	14.7	15320.1	51.3	51.3	904	Default	
<input type="checkbox"/>	22-07-2025 13_41_48.SUI	2025-07-22 13:41:48	1368.08	14.7	15417.9	50.1	50.1	904	Default	
<input type="checkbox"/>	22-07-2025 13_43_00.SUI	2025-07-22 13:43:00	1366.94	15.0	15691.9	50.0	50.0	904	Default	
<input type="checkbox"/>	22-07-2025 13_43_44.SUI	2025-07-22 13:43:44	1375.89	14.9	15783.2	49.3	49.3	906	Default	
<input type="checkbox"/>	22-07-2025 13_45_00.SUI	2025-07-22 13:45:00	1372.23	14.9	15633.6	49.3	49.3	906	Default	
<input type="checkbox"/>	22-07-2025 13_45_54.SUI	2025-07-22 13:45:54	1365.98	15.0	15651.4	50.1	50.1	903	Default	
<input type="checkbox"/>	22-07-2025 13_47_32.SUI	2025-07-22 13:47:32	1363.68	15.0	15617.5	51.6	51.6	904	Default	
<input type="checkbox"/>	22-07-2025 13_48_22.SUI	2025-07-22 13:48:22	1369.21	14.9	15634.7	51.3	51.3	905	Default	
<input type="checkbox"/>	22-07-2025 13_49_56.SUI	2025-07-22 13:49:56	1374.26	15.1	15827.2	50.4	50.4	903	Default	
<input type="checkbox"/>	22-07-2025 13_50_46.SUI	2025-07-22 13:50:46	1369.70	15.0	15720.0	49.2	49.2	904	Default	
<input type="checkbox"/>	22-07-2025 13_51_46.SUI	2025-07-22 13:51:46	1374.83	15.0	15697.6	48.8	48.8	907	Default	
<input type="checkbox"/>	22-07-2025 13_52_40.SUI	2025-07-22 13:52:40	1370.84	15.2	15872.0	49.0	49.0	906	Default	
<input type="checkbox"/>	22-07-2025 13_53_40.SUI	2025-07-22 13:53:40	1375.48	15.0	15751.2	49.2	49.2	907	Default	
<input type="checkbox"/>	22-07-2025 14_07_59.SUI	2025-07-22 14:07:59	1357.04	14.4	14666.0	56.7	56.7	917	JAM72042 LB 620	

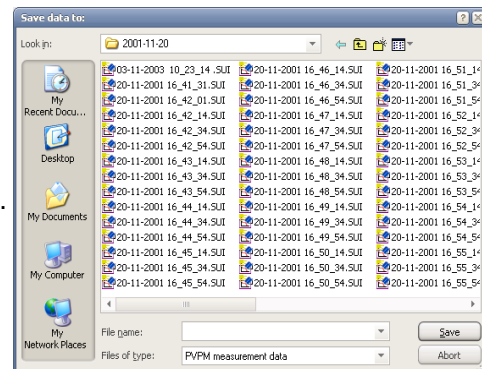
Picture 20: Display of saved measurements

Info: By clicking on "Multi Diagram" you can open several files at the same time and compare the characteristic curves.

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.



Picture 21: Saving measurements

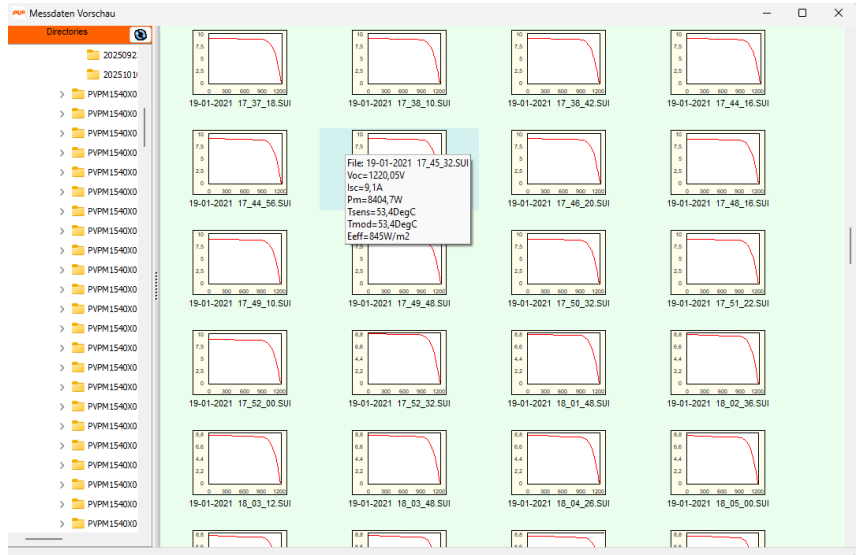
When saving, you can choose the directory and file name according to your preference, making it convenient to organize and retrieve your data later.

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.



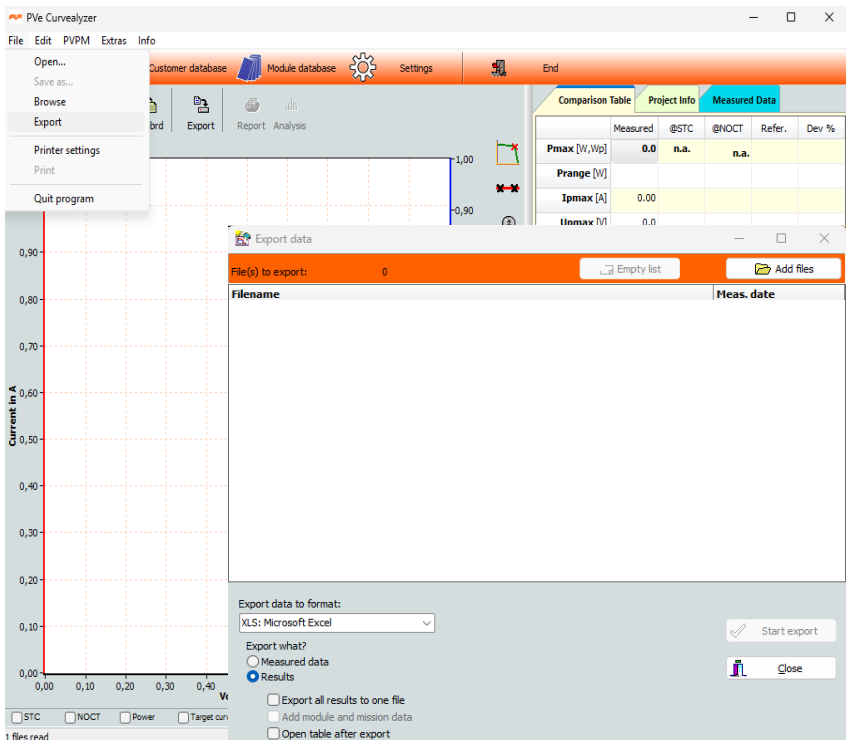
Picture 22: Browsing of measurement data with preview of the characteristic curves

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 23: 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.

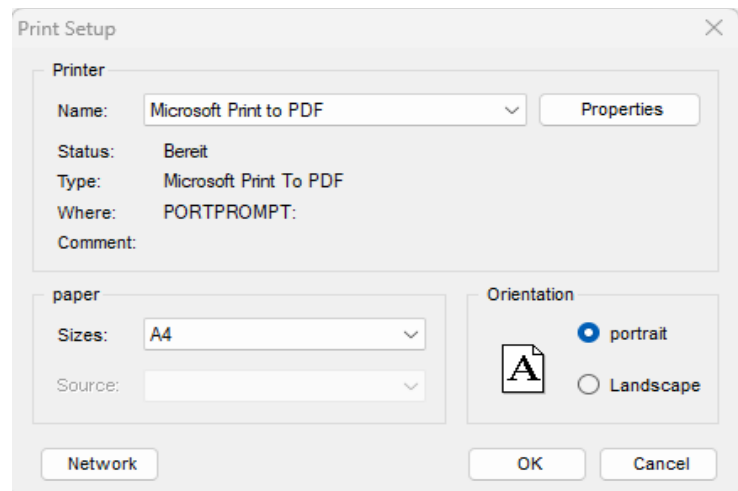
The exported files will be created in the same directory as the original data but with the specified file extension (e.g., .XLS instead of .SUI). These files can then be processed using any compatible software. Note that any modifications made to the exported files will not affect the original data stored 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 24: Printer settings

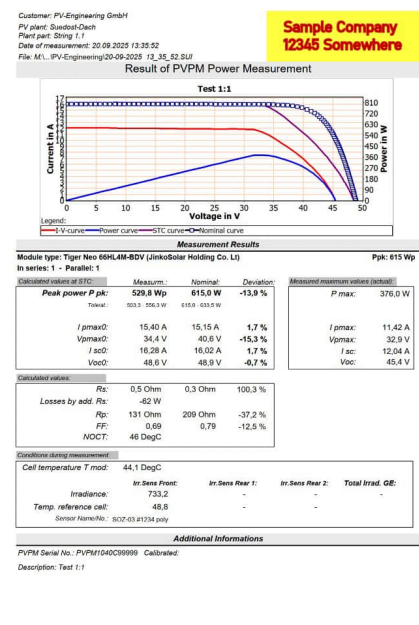
Once you have configured the settings to your preference, confirm your choices by clicking “OK.” These settings will be applied to your current print task, ensuring that the output aligns with your requirements. For more detailed information on specific options, consult the documentation provided with 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 25: 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 Curvealyzer® 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 Curvealyzer® 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.

12.2.1 Cut

Cuts the marked text and moves it to the clipboard.

12.2.2 Copy

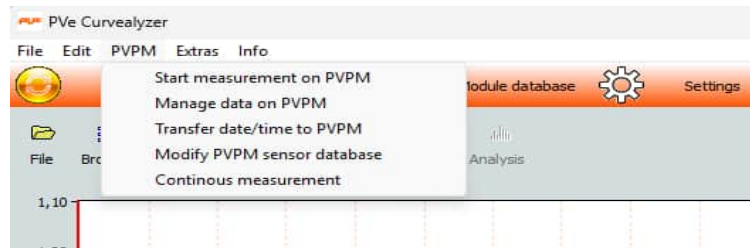
Copies the marked text and moves it to the clipboard.

12.2.3 Insert

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 27: Menu items in the "PVPM" tab

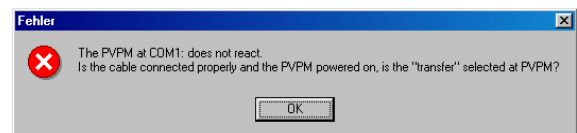
12.3.1 Start Measurement on PVPM

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.

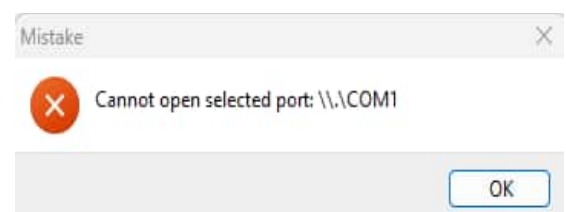


Picture 28: Error message

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 29: 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 PC's date/time.

12.3.4 Modify PVPM sensor database

Info: Applicable only to PVPM devices equipped with analog sensors.

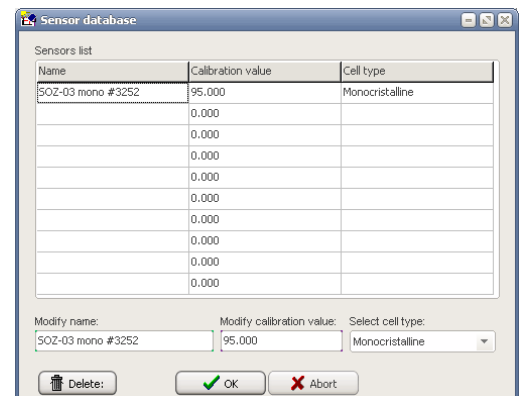
The digital sensors used with the PVPM for measurements on bifacial and monofacial modules are automatically identified by the device and transmit their calibration data and serial numbers to the PVPM without manual input.

You can connect various irradiance sensors to the PVPM (with analog sensor input), 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 30: Entries in the PVPM sensor database

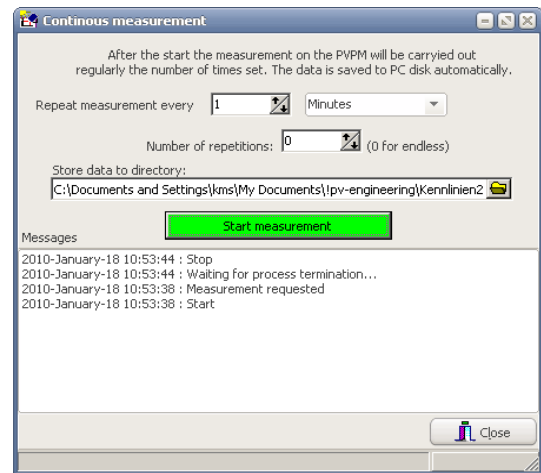
12.3.5 Continuous measurement

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.

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.

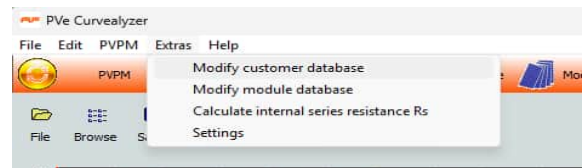


Picture 31: Continuous measurement control panel

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



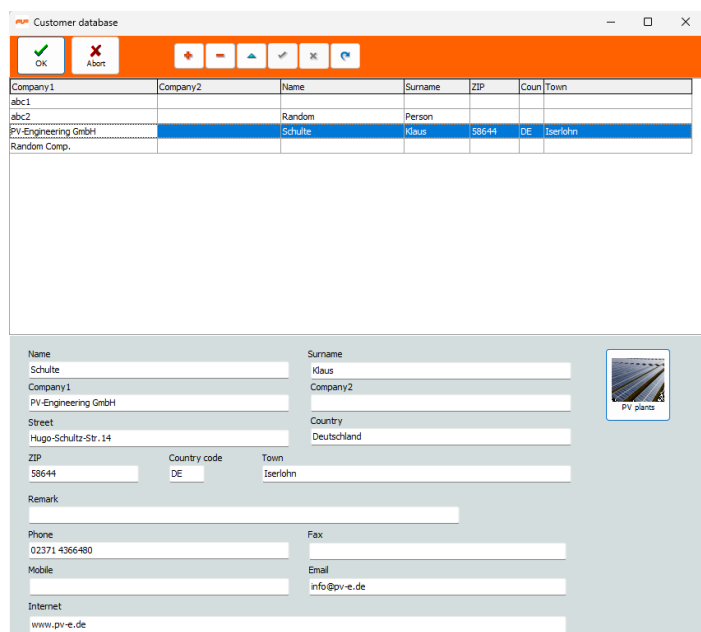
Picture 32: Menu items in the "Extras" tab

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.



Picture 33: Modify customer database

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

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 120,000 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 (V_{pmax}):** The maximum voltage the module can achieve at the Maximum Power Point (MPP).
- **Maximum Current at MPP (I_{pmax}):** The maximum current the module can provide at the Maximum Power Point (MPP).
- **Open-Circuit Voltage (V_{oc}):** The voltage across the module when it is not connected to any load (i.e., no current is flowing).
- **Short-Circuit Current (I_{sc}):** The current that flows when the module's output is shorted, with no load connected.
- **Module Type** (e.g. mono, poly),
- **Bifacial** (Yes/No)

Model	NomPow	Upmax	Ipmax	Voc	Isc	ModType	Bifacial	Origin
15TH-210 Tile Red	210	30,0	7,0	37	07	poly		30
15TH-210 Tile Red	210	30,0	7,0	37	07	poly		30
15TH-220 Emerald Green	220	28,5	7,7	37	08	poly		30
15TH-220 Emerald Green	220	28,5	7,7	37	08	poly		30
15TH-220 poly	220	29,3	7,5	37	08	poly		30
15TH-225 Forest Green	225	29,0	7,8	37	08	poly		30
15TH-225 Forest Green	225	29,0	7,8	37	08	poly		30
15TH-225 poly	225	29,6	7,6	37	08	poly		30
15TH-230	230	28,8	8,0	37	09	mono		30
15TH-230 Horizon	230	29,9	7,7	37	08	poly		30
15TH-230 Horizon	230	29,9	7,7	37	08	poly		30
15TH-230 Horizon	230	29,9	7,7	37	08	poly		30
15TH-230 Polished Marble	230	28,9	8,0	37	09	poly		30
15TH-230 Polished Marble	230	28,9	8,0	37	09	poly		30
15TH-230 poly	230	29,9	7,7	37	08	poly		30
15TH-235	235	29,3	8,0	37	09	mono		30
15TH-235	235	29,3	8,0	37	09	mono		30
15TH-235	235	29,0	8,1	37	09	mono		30
15TH-235 Horizon	235	30,0	7,8	37	08	poly		30
15TH-235 Horizon	235	30,0	7,8	37	08	poly		30
15TH-235 Horizon	235	30,0	7,8	37	08	poly		30
15TH-235 poly	235	29,8	7,9	37	08	poly		30
15TH-240	240	29,8	8,1	37	09	mono		30
15TH-240	240	29,7	8,1	37	09	mono		30
15TH-240	240	29,7	8,1	37	09	mono		30
15TH-240 Horizon	240	30,2	8,0	37	08	poly		30
15TH-240 Horizon	240	30,2	8,0	37	08	poly		30
15TH-240 Horizon	240	30,2	8,0	37	08	poly		30
15TH-240 poly	240	29,8	8,1	37	08	poly		30
15TH-245	245	30,2	8,1	37	09	mono		30

Picture 34: Modify module database

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:

- **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).
- **P_{pk} [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.
- **I_{pmax} [A]:** The maximum current output of the module at the Maximum Power Point (MPP).
- **V_{pmax} [V]:** The maximum voltage output of the module at the Maximum Power Point (MPP).
- **I_{sc} [A]:** The short-circuit current, the maximum current the module can generate in an open circuit.
- **V_{oc} [V]:** The open-circuit voltage, the voltage across the module when not under load.

Picture 35: Add a new entry to the module database

- **C_{tp} [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 (C_{tp}) of -0.35 %/°C from the datasheet is used as -0.0035 1/K in the software.
- **C_{tv} [1/K]:** The temperature coefficient for voltage, indicating the percentage change in voltage with temperature. **Note:** Like C_{tp}, the value for C_{tv} should be divided by 100 to convert from %/°C or %/K to 1/K.
- **C_{ti} [1/K]:** The temperature coefficient for current, indicating the percentage change in current with temperature. **Note:** The value for C_{ti} also needs to be divided by 100 to convert from %/°C or %/K to 1/K.
- **Bifacial:** Is it a module with bifacial properties?
- **Bi-Fac.Factor:** Enter the bifaciality factor from the module here
- **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 Settings

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

12.4.3.1 Serial Port

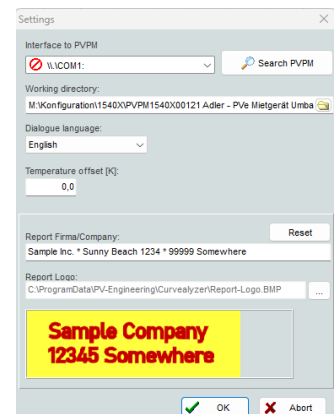
You can select the serial USB port (COMx:) used for PVPM communication from the drop-down menu.

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.

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.

12.4.3.2 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.



Picture 36: Settings menu



Picture 37: Search PVPM on COM port

12.4.3.3 Dialogue language

Curvealyzer® 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 Curvealyzer® will be displayed in the selected language. Curvealyzer® 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!

12.4.3.4 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.

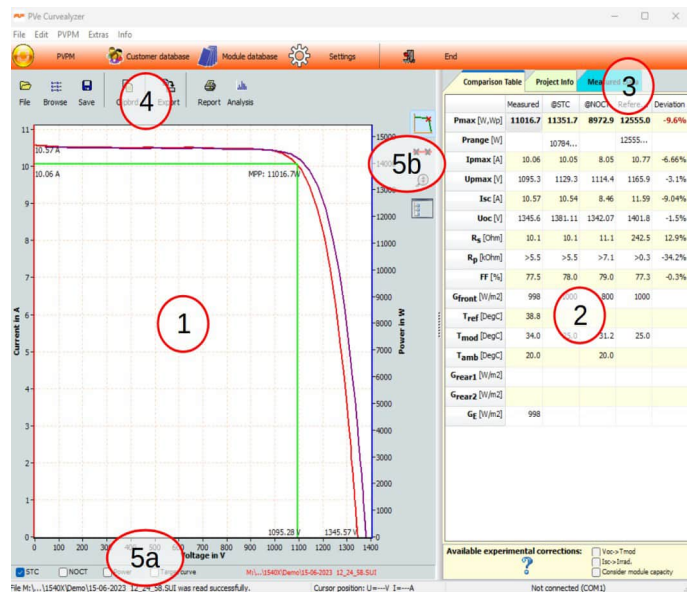
12.4.3.5 Report Company and Logo

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 Curvealyzer software, which displays an open measurement file. The software presents all relevant information, labeled with the following numbering:

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. **Project Info**
Provides detailed information about the comparative module, the setup or notes related to the open file or measurement.



Picture 38: I-V-curve and measured data displayed in the software

Info: By right-clicking in the field “file info”, you can add the displayed customer to your customer database.

4. **Toolbar**
Open, Browse or save files. Copy data to the clipboard or Export the data e.g. in a Excel-sheet. Automatic report generator and analysis function.
5. **Toolbar Functions (5a; 5b)**
Displays the available functions in the toolbar for quick access to common tasks.

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 (c_{TP} and c_{TU})

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.

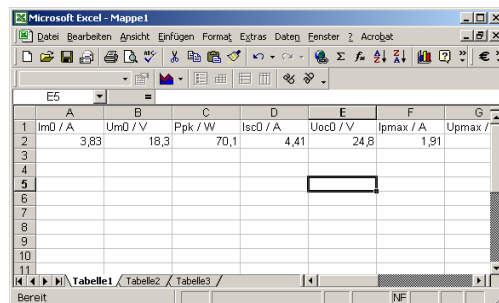
12.5.5 Copying Data:

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.

12.5.6 Context Menu and Toolbar Functions:

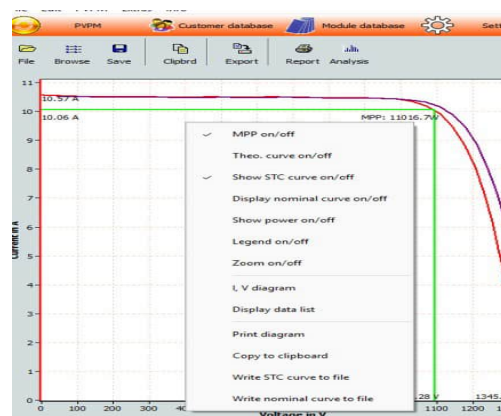
Right-clicking within the viewing area opens a context menu offering additional options. The same functionality is accessible via the buttons located e.g below „5a“ and on the right side „5b“ of the diagram area. Available options include:

- **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.
- **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.
- **IV Diagramm:** Opens a separate window for separate evaluation of the current and voltage characteristics
- **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.
- **Write Nominal Curve to File:** Exports the calculated nominal curve to a file for external use or archiving.

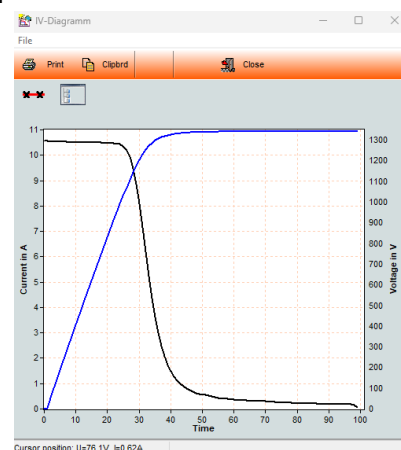


	A	B	C	D	E	F	G
1	Im0 / A	Um0 / V	Ppk / W	Isc0 / A	Uoc0 / V	Igmax / A	Upmax /
2	3,83	18,3	70,1	4,41	24,8	1,91	
3							
4							
5							
6							
7							
8							
9							
10							
11							

Picture 39: Copying and pasting measurement data



Picture 40: Context Menu and Toolbar Functions



Picture 41: Display IV Diagram

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:

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**

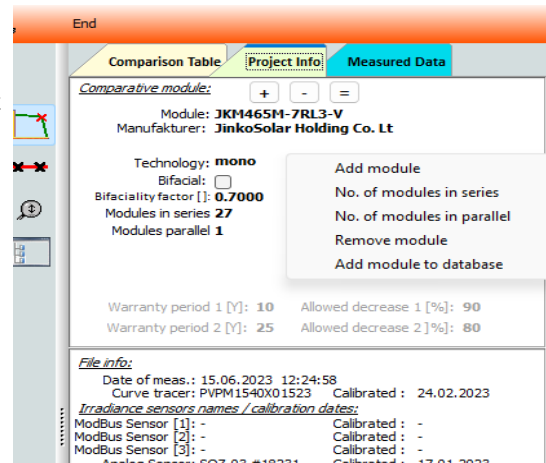
Define the number of modules arranged in parallel within the measurement setup.

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.



Picture 42: Context menu for reference module

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	T Sens/De	Eeff/W/m	Mod.type	Custo	Plant	Part
<input type="checkbox"/>	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			
<input type="checkbox"/>	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
<input type="checkbox"/>	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			
<input type="checkbox"/>	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	
<input type="checkbox"/>	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
<input type="checkbox"/>	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	--
<input type="checkbox"/>	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 43: 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.

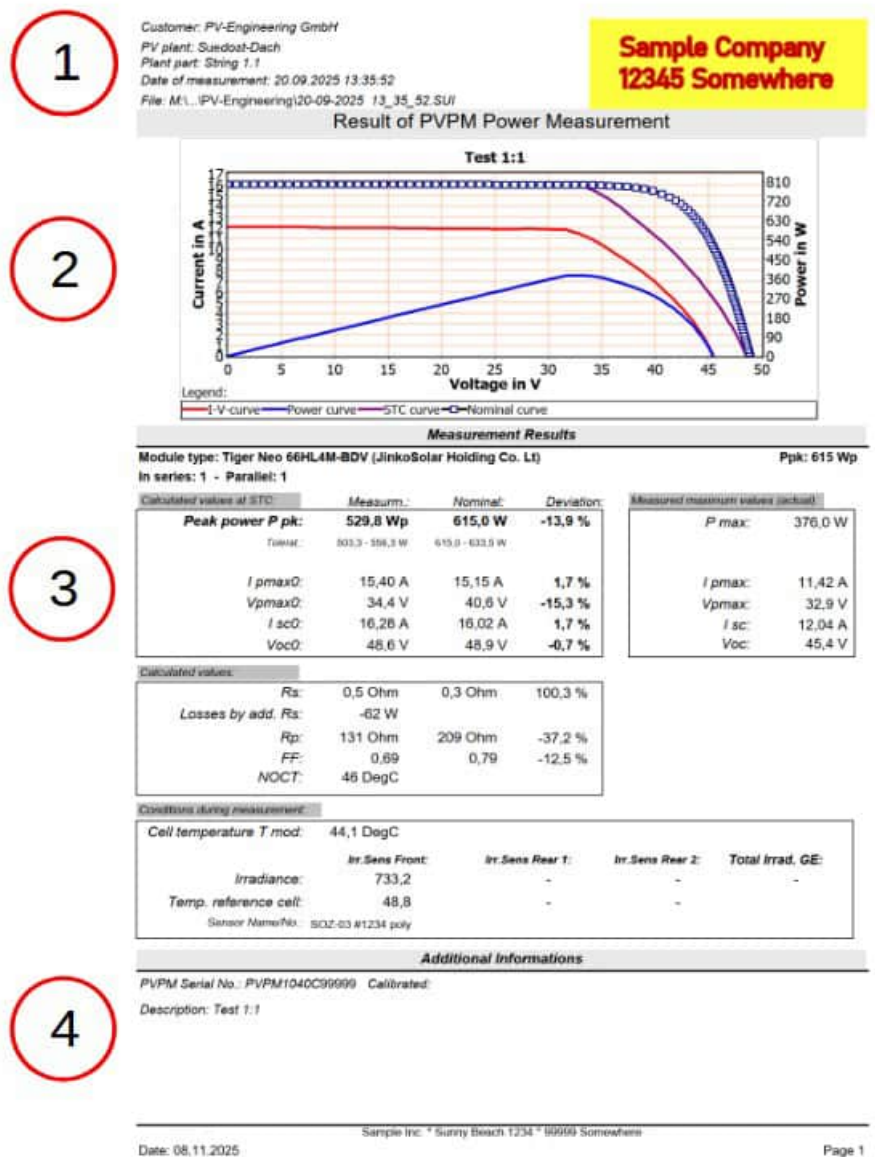
If you wish to make specific changes, such as modifying the module type or updating the customer information, right-click on the entry you want to edit. This will open a context menu that guides you to the corresponding database. Within the database, you can either select an existing entry or create 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 four main sections:

Section 1: General information

The **General Information** section provides all fundamental project details that serve as the basis for the measurement report. It includes information entered directly during the measurement process as well as data added later using the CurveAlyzer software, for example by linking customer entries from an external database. Typical fields are the customer name, PV plant, plant part (string), date and time of the measurement, and the directory in which the report file is stored. In the upper-right corner, the user-defined logo is displayed; this logo can be configured at any time via the application settings.



Picture 44: Report overview

Section 2: I-V Curve Results

The **I-V Curve Results** section displays the measured I-V characteristic of the PV system. The Measured Curve is shown in red, while additional curves can be activated or hidden as needed. These include the Power Curve (blue), illustrating the power output across the measurement range, and the Nominal Curve (dotted line), derived from the reference module's datasheet values. The STC-adjusted curve is shown in purple. In addition, the theoretical or effective curve (green) is presented; this idealized model is used internally for calculating R_s and R_p and serves an informative, diagnostic purpose.

Below the diagram, the measured system configuration is documented. This includes the selected reference module, its P_{pk} value, and the number of series and parallel modules defined for the measurement.

Section 3: Measurement Results

This section of the report provides a structured overview of all key measurement parameters. The content is divided into four logical groups to make interpretation fast and intuitive.

1. Calculated Values at STC (Standard Test Conditions)

This group compares the STC-corrected measurement results with the nominal datasheet values and shows the resulting deviation. Displayed parameters include:

- P_{pk} – nominal peak power
- I_{pmax0} – current at maximum power under STC
- V_{pmax0} – voltage at maximum power under STC
- I_{sc0} – short-circuit current under STC
- V_{oc0} – open-circuit voltage under STC

2. Measured Maximum Values (Actual)

This block contains the directly recorded electrical maximum values obtained during the measurement:

- P_{max} – measured maximum power
- I_{pmax} – current at maximum power
- V_{pmax} – voltage at maximum power
- I_{sc} – short-circuit current
- V_{oc} – open-circuit voltage

3. Calculated Values

These values help assess the electrical condition of the PV module or string. Each parameter is shown with the measured value, the nominal reference, and the deviation. Included are:

- R_s – series resistance
- Power loss caused by increased R_s – theoretical loss resulting from added series resistance
- R_p – parallel resistance
- FF – fill factor
- NOCT – Nominal Operating Cell Temperature

4. Conditions During Measurement

The final block documents all measurement-relevant environmental conditions and sensor details:

- T_{mod} – module temperature during measurement
- Irradiance readings from up to three irradiance sensors
- Temperature of each irradiance sensor
- Serial numbers of all reference sensors used

Section 4: Additional Information

The “Additional Information” section contains all supplementary data that support the interpretation and traceability of the measurement. This includes technical details such as the serial number of the measurement device and the date of its last calibration. In addition, users can enter their own notes through the CurveAlyzer software. These manual entries allow documenting specific environmental conditions, unusual observations during the measurement, or any other relevant information that may help with later analysis or quality assessment.

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:

- **E_{eff}:** Irradiance during measurement (optional front and backside irradiance reference sensors)
- **T_{amb}:** Ambient temperature. Must be defined in advance in the Curvealyzer® software, as it is not measured (Standard set at 25°C).
- **T_{mod}:** Module (DUT) temperature (measured by NES DS18B20).
- **T_{mod Expected}:** Expected module temperature (calculated for reference).
- **T Sensor:** Temperature of the reference cell of the irradiation reference sensor (optional front and backside irradiance reference sensors)
- **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:

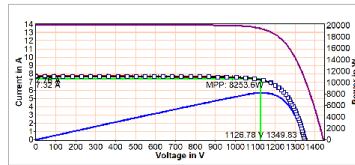
- **Quality of Curve Match:** Compares and evaluates the match between the actual and nominal characteristic curves based on variance and standard deviation. The evaluation proceeds through the following steps:
 - **Well**
 - **Moderate**
 - **Bad**

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\ic\pve\Desktop\Schulung\20-02-2023_13_50_52_SUI
 Device serial no.: PVP1540X05922
 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:
E _{eff}	559W/m ²	Irradiance during measurement
T _{amb}	20,0DegC	Ambient temperature during measurement
T _{mod}	34,2DegC	Module temperature during measurement
T _{mod 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:	15860,0Wp	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)
V _{pmax} :	1219,7V	1173,9V	-3,8%	Voltage at MPP (STC)
I _{pmax} :	12,84A	13,10A	2,0%	Current at MPP (STC)
R _s :	6,5Ohm	11,8Ohm	81,2%	Internal series resistance
FF:	0,80	0,79	-1,0%	Fill factor
PR _s	--	-909W	--	Power loss due to R _s

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
 > inhomogeneous generator (some modules/cells do not work properly)

Picture 45 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 Technical data

Device:	
Device designation	Peak Power and I-V-curve tracer for PV modules and strings
Type	PVPM 2540X-2025
Display	4,3" Color TFT Display 480x272Pixels
Power supply & Current cons.	15VDC; 1,8ADC
IP protection	IP40 (IP67 with closed lid)
Dimensions & Weight	40.6 cm x 17.5 cm x 33.0 cm (W x H x D); about 8,5kg
Operation temperature	0° C to +50°C at 10% to 90% rel. humidity, not condensing
Storage temperature	-10°C to +60°C at 5% to 95% rel. humidity, not condensing
Max. height of use/storage:	2000m (6562ft)
Safety	EN 61010-1:2010 / EN 61010-2-030:2010
EMV	EN 55011:2016 / EN 55032:2015 / EN 61326-1:2013 / EN 61326-2-2:2013 / EN 61000-3-2:2014 / EN 61000-3-3:2013 CFR47 FCC part 15, Class B
Power Supply:	
Voltage input	90 – 264 VAC
Grid frequency	47- 63 Hz
Rated power	about 50VAC at U _e 230VAC
Rated current	220mA at V _e 230VAC
Output voltage; min. current; Power	15VDC; Min. 2ADC; Min. 30W
RRC2020 Lithium-Ion battery pack:	
Nominal voltage	11.25VDC / 8.85Ah / 99.6 Wh (UN 38.3)
Capacity	8.85 Ah / 99.6 Wh
Operating time	Up to 8 hours
Working temperature	0°C to +45°C (charge), -20°C to +60°C (discharge)
Conformity	UN 38.3 / IEC62133
Measurement inputs:	
Measurement category	Measurement category I
Input voltage measurement range	25 / 50 / 100 / 250 VDC
Input current measurement range	2 / 5 / 10 / 40 ADC
Measurement accuracy	$I \leq 1\%$, peak power $\pm 5\%$, $E \leq 3\%$, $T \pm 1K$
Disconnecter switch LTSX1500:	
Max. input voltage	1500VDC
Max. input current	20ADC (40A, Single Action Only!)
IP protection	IP65
Irradiance reference sensor SOZ-03:	
Measuring range	0 to 1500W/m ²
Output signal	RS485 and ModBus RTU protocol
Housing	94x94x57mm, about 0,2kg, IP54
Surface temperature sensor NES DS18B20:	
Type	1-Wire digital Temperature Probe DS18B20
Measurement temperature range	-30°C to +80°C; Accuracy $\pm 0,5K$
Sensor housing:	Plastic with aluminum ground plate; 40x40x12mm; IP68

14 Hardware Information

(Subject to change without notice)

Build in a stable and water proof (IP67) military grade PELI® case with carrying handle, automatic pressure valve and tough front panel.

14.1 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%, reproducibility: ±2%, Accuracy for the I-V-curve better 1%
- Sweep time string measurement: 20ms up to 2 seconds, depending on the applied Voltage and Current of the DUT
- Irradiance reference sensor with integrated digital temperature sensor (DS18B20) measures irradiance and cell temperature
- Additional digital temperature sensor (NES DS18B20) to determine the module temperature

Measuring ranges of the PVPM:

Device / Rating	Voltage [V]	Current [A]	Temperature [°C]	Irradiance [W/m ²]
PVPM2540X	25/50/100/250 min. 2VDC	2/5/10/40	-100 to +120	0 to 1500 *)

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

14.2 Pin allocation of the sensor connectors:

SOZ-03 irradiation reference sensor: 4 pin female Lutronic 2320 04 T12CB100 (plug: 2350 04 T06CB T)

- Pin 1 = RS485 / ModBus +
- Pin 2 = RS485 / ModBus -
- Pin 3 = Supply (12VDC) +
- Pin 4 = Supply (12VDC) -

14.3 Calculation Unit

- Industrial PC with low power consumption, real time clock
- No mechanically moved parts like hard disk, fan etc.
- Flash disk 512MB
- A/D-Sampling Rate max. 100kHz, resolution 12Bit
- The data of several thousand measurements will be stored automatically in the device (flash memory)

14.4 Display

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

14.5 Operation

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

14.6 Optionally available accessory

- Upgrade-Set for the measurement of bifacial systems
- 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
- Pve backpack
- Screenprotector for the TFT touch screen
- Padlocks for the cases

15 List of abbreviations

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 (Front, back1, back2)
FF	Fill factor: relationship $I_{sc} \cdot U_{oc} / (I_{pmax} \cdot U_{pmax})$, for crystalline modules about 0.75 = 75%, smaller values can indicate insufficient power
I	Current
I_m	Short form for I_{pmax}
I_{ph}	Photo current
I_{pmax}	Current at P_{max}
I_{pmax0}	Current at P_{max0} (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 $E_0=1000$ W/m ² , AM1.5, $T=25^\circ\text{C}$
T_{ref}	Temperature, measured at the crystalline PV reference cell (Front, back1, back2)
T_{mod}	Current module temperature (at the back side of the module)
V	Voltage
V_m	Short form for U_{pmax}
V_{oc}	Open circuit voltage
V_{oc0}	Open circuit voltage (at STC)
V_{pmax}	Maximum power voltage

16 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 1 4	Design fault / redesign
Erroneous match of strings and inverter	Fed power too low for location and in relation to nominal generator power 1 4	Design fault / redesign, replacement of inverters
Cast shadow	I-V-curve shows "bulge", peak power too low, optical check 1 2	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 2 6	Barrier in some distance to module (high portion of diffuse light) / remove barrier
Corrosion at plugs and cables	Serial internal resistance R_s too high 5	Material, planning or mounting fault / cleaning, replacement
Delamination of cell embedding	See: diffuse shading 2 6	Material or production fault / replacement
Bubbling in resin	See: diffuse shading 2 6	Material defect / replacement by supplier
Transparent covering material (glass, plastics, resin) becomes blind	Optical check, peak power too low (s. a. diffuse shading) 2 6	Material defect / replacement by supplier
Discolouring of the transparent cover or embedding material (plastics, resin)	Optical check, peak power too low (s. a. diffuse shading) 2 4 6	Material defect / replacement by supplier
Intrusion of water into the laminate, leads to other problems (corrosion, discolouring)	Optical check 4	Material or production fault / replacement by supplier
Faults in the crystalline structure of single cells (hot-spot effect)	See: diffuse shading 2 6	Production fault / reduction of price, replacement by supplier
Pollution of the module by dust	Optical check, see: diffuse shading 2 6	High dust impact / check modules periodically, cleaning
Moss / algae on module, birds excrements	See: cast shadow 1 2	Normal for several regions / cleaning
Broken cover glass, leads to other problems (corrosion, discolouring)	Optical check 4	Hailstorm, mounting or transportation fault / replacement by supplier
Break of single cells in module	Peak power too low, possibly deformation of I-V-curve 1 4	material defective / replacement by supplier
Improper electrical connections in module	Peak power too low, internal series resistance R_s higher than calculated 4 5	Fault in soldering, material defective, corrosion / replacement by supplier
Bypass diode defective (short circuit)	Peak power of strings reduced by module power 3	Overload, material defective / repair
Bypass diode mounted the wrong way	Peak power of strings reduced by module power 3	Mounting fault / repair
No bypass diode mounted or diode defective (high resistance)	Shading of one module reduces power of the string dramatically 1	Planning or mounting fault / repair
Dimension of cabling too small	Internal series resistance R_s too high 5	Design fault / replacement of cables
Cable defective (e.g. break, corrosion)	Internal series resistance R_s too high 5	Mounting fault / repair
Insufficient mounting of connectors	Internal series resistance R_s too high 5	Mounting fault / repair
Corrosion in screwed or plugged connectors	Internal series resistance R_s too high 5	Mounting fault / cleaning, repair
Insufficient pre-selection of modules regarding peak power	Peak power of plant too low 1 4	Mounting fault (match losses) / New preselection after peak power measurement
Insufficient pre-selection of single cells regarding power during module production	Peak power of module too low 1 4	Production fault / reduction of price, replacement by supplier
Short circuit between cells in the module	Peak power of plant too low, open circuit voltage V_{oc} too low, shape of curve 1 3 5	Production fault / replacement by supplier
Fabrication tolerances in cell production	Peak power too low, shape of curve 2 3 5	Production fault / reduction of price, replacement by supplier

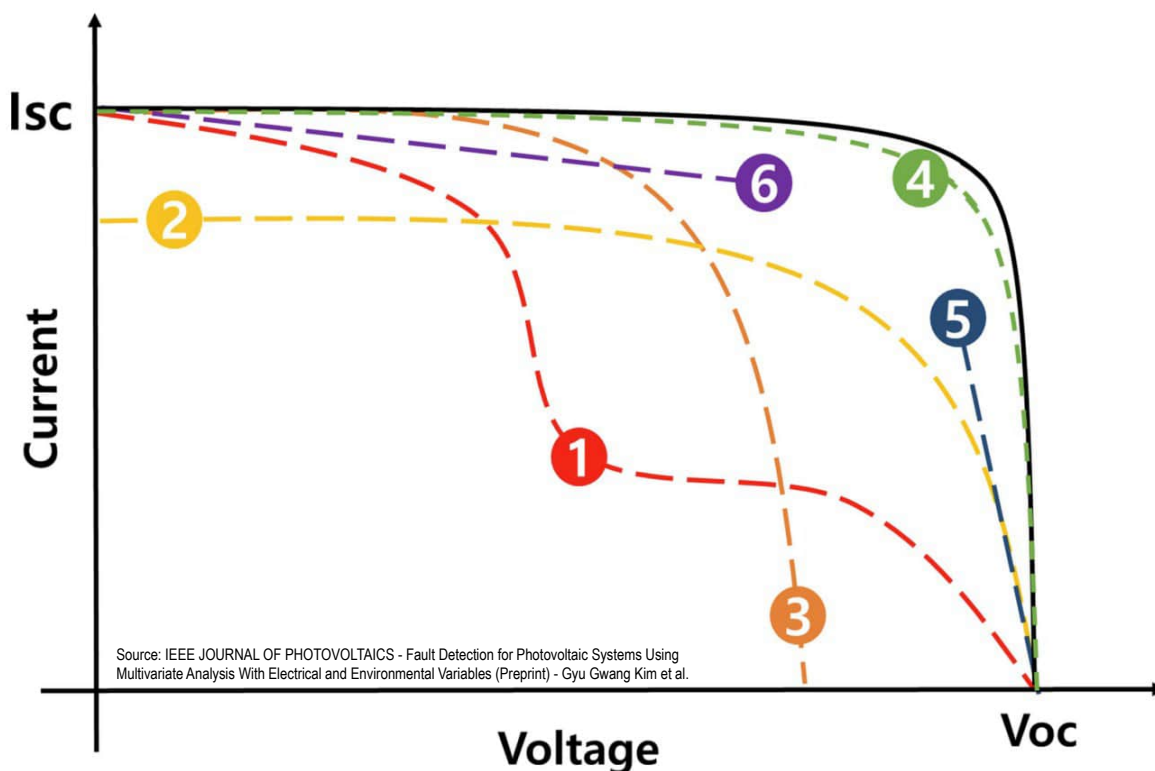
1 2 3 4 5 6: see next page

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.

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PV generator failures are indicated by distorted IV curves



- ① Stepped I-V Curve: not all PV elements produces the same current.
Reasons: faulty modules, partial shading, cracked cells, shorted bypass diode
- ② Low current - Reasons: degradation, soiling
- ③ Low voltage - some modules not operating (shorted bypass diode), incorrect wiring
- ④ Reduced Fill Factor – degradation, high internal series resistance, too fast IV-curve measurement
- ⑤ Decreased slope of vertical leg - high internal series resistance, PID
- ⑥ Increased slope of horizontal leg - low parallel shunt resistance , mismatch of module currents

Each failure may occur in combination with others.

17 Glossary

Albedo

Albedo describes the proportion of sunlight reflected by a surface, expressed as a value between 0 and 1. It indicates how much solar radiation is redirected toward the environment or, in PV systems, toward the rear side of bifacial modules.

Typical albedo values range from about 0.1 for dark soil or asphalt, 0.25–0.35 for concrete or light gravel, and up to 0.8–0.9 for snow or white surfaces. A higher albedo increases the rear-side irradiance and thus the potential energy gain of bifacial modules.

Accurate knowledge of local albedo is therefore essential for realistic yield modeling and performance evaluation of bifacial PV systems. (see also: *Bifaciality*, *Bifaciality Coefficient*)

Azimuth (β) 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.

Bifaciality and Bifaciality Coefficient

Bifaciality describes the ability of a photovoltaic (PV) module to convert light incident on both the front and rear sides of the solar cells into electrical energy. Unlike conventional monofacial modules, bifacial designs utilize the albedo of the surrounding environment — the portion of sunlight reflected from the ground or nearby surfaces — to increase total energy yield.

The bifaciality coefficient (B_f) quantifies the relative performance of the rear side compared to the front side under identical irradiance conditions. It is defined as the ratio of the short-circuit current of the rear side ($I_{sc, rear}$) to that of the front side ($I_{sc, front}$), expressed as:

$$B_f = I_{sc, rear} / I_{sc, front}$$

Typical bifaciality coefficients range between 0.65 and 0.95, depending on the cell technology and encapsulation structure.

PERC-based bifacial modules commonly exhibit coefficients around 0.7–0.8, while n-type TOPCon or

heterojunction (HJT) cells often reach 0.9 or higher due to their symmetric passivation and transparent rear contacts.

A higher bifaciality coefficient indicates more efficient utilization of rear-side irradiance, resulting in improved energy yield in environments with high reflectivity — such as snow-covered surfaces, white membranes, or bright gravel. However, the effective bifacial gain also depends on installation geometry (elevation, tilt, row spacing) and the ground albedo.

IV Curve / 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.

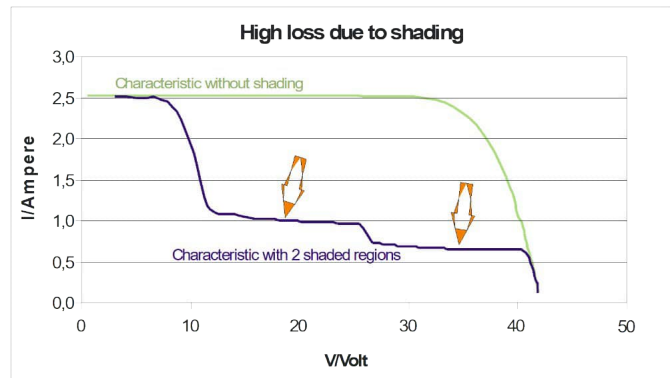
For instance, the I-V characteristic can be affected by **partial or severe shading**, **high internal series resistance**, and issues like **defective or missing bypass diodes**. These factors can significantly alter the I-V curve and thus the generator's performance.

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:

$$FF = (I_{sc} * V_{oc}) / (I_{mp} * V_{mp})$$



Picture 46: I-V-curve with and 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)**.

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.

Degradation characteristic

All solar cells lose part of their efficiency over time. Amorphous solar cells show a rapid initial drop during the first weeks of sunlight exposure, which then stabilizes after about 3 weeks to 5 months. In addition, they exhibit reversible, seasonal efficiency variations — typically performing better in spring and summer than in autumn and winter.

Crystalline cells (mono- and polycrystalline) degrade more slowly and steadily over many years, mainly due to UV exposure, temperature stress, and material fatigue. All cell types show slight seasonal fluctuations in performance, with generally higher efficiency under bright and cool conditions and lower output during heat or aging effects.

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.

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.

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.

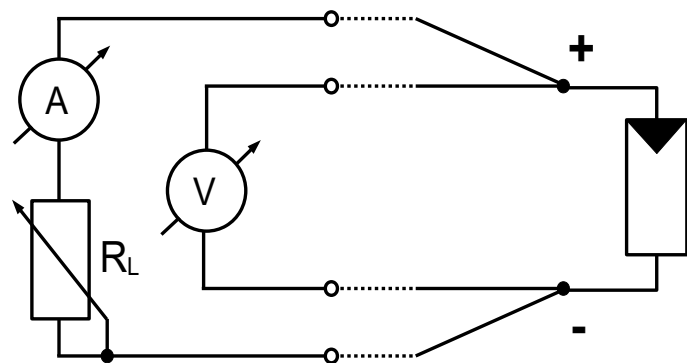
To obtain an accurate measurement of the voltage at the point of interest, the **four-wire measurement** technique is employed. This method uses four separate wires for the measurement process:

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 47: Kelvin measurement

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**.

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).

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.

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.

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.

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 (P_{pk}), internal series resistance (R_s), and parallel resistance (R_p) 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.

Performance Ratio

The Performance Ratio (PR) indicates the overall efficiency of a PV system under real operating conditions. It is defined as the ratio between the actual AC energy output and the theoretical energy yield based on the measured irradiance (IEC 61724-1).

Typical PR values range from **80 to 90 %** for modern, well-designed systems. Losses from temperature, wiring, and inverter conversion prevent values close to 100 %. The PR reflects how effectively the installed capacity converts available sunlight into usable energy and is often seen as a key quality benchmark for PV performance.

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:

- German city of Freiburg is situated at 48° latitude.
- German city of 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.

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.

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.

Solar irradiation

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.

Standard Test Conditions (STC)

To ensure comparability of photovoltaic (PV) modules, performance is evaluated under Standard Test Conditions (STC) defined in IEC 60904-3. These specify an irradiance of 1000 W/m², a solar spectrum with air mass 1.5 (AM 1.5) — typical of clear-sky sunlight at mid-latitudes — and a module temperature of 25 °C.

STC provide a uniform benchmark for comparing nominal power ratings (P_{max}) independent of location or measurement setup. In real operation, however, temperature, irradiance, and incidence angle vary constantly, resulting in different power outputs.

To compare field data with laboratory results, I–V curves measured under natural sunlight are adjusted to STC using the correction procedures defined in IEC 60891. This ensures consistent evaluation of performance and long-term stability under realistic conditions.

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 Appendix A

18.1 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 <u>max. 30 minutes</u> 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	

18.2 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 battery 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

19 Customer support

19.1 Manufacturer's Warranty

In accordance with our General Terms and Conditions, this device is covered by a manufacturer's warranty against material and manufacturing defects. The warranty period is 24 months from the date of delivery, unless otherwise required by national law. During this period, the manufacturer will, at its discretion, repair or replace defective components or the entire device.

This warranty does not cover accessories or batteries, nor defects caused by improper use, modifications, incompatible devices, or inadequate packaging. The manufacturer's liability for personal injury or property damage is limited to cases of intent, gross negligence, or where required by law.

This manufacturer's warranty is provided in addition to the purchaser's statutory rights, which remain unaffected. Statutory warranty claims must be addressed to the seller from whom the product was purchased.

The manufacturer reserves the right to change product specifications or prices without prior notice; this does not affect products already ordered or delivered. Reproduction of this manual or parts thereof requires prior written permission.

For details on how to return a device under warranty, please refer to section 2.2 (Customer Support Procedure).

19.2 Customer support procedure

If the device appears to malfunction, please first check the cables and test leads and replace them if necessary. Ensure that the device is used according to the instructions in this manual.

Before returning any product, please contact customer support or your authorized dealer to obtain return authorization. Returns must include a short description of the issue and should be shipped in the original or equivalent protective packaging.

For justified warranty claims, the manufacturer will bear the reasonable cost of return shipping in accordance with applicable law. For non-warranty repairs or out-of-warranty service, the customer is responsible for the cost of shipping. Any damage caused by inadequate packaging may be charged to the customer.

19.3 Maintenance and calibration of the measuring device

According to the manufacturer's recommendation, measurement equipment and accessories for photovoltaic (PV) systems should be recalibrated annually to maintain accuracy and compliance with applicable standards (e.g. IEC 60904-1 / -2).

PV-Engineering GmbH offers a comprehensive service including maintenance, repair, and calibration to ensure that all measurement devices and related accessories are thoroughly tested and verified.

Our annual inspection service includes recalibration of all measurement inputs and the issuance of a new calibration certificate, ensuring continued accuracy and reliable performance within the specified tolerances.

For more information or to request a personalized quotation, 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

QR-Code: Contact us!

Inspection & Recalibration

Service / Repair / Spare parts

Support



SCAN ME

20 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: /	I-U-Kennlinienmessgerät
Product:	I-V-Curve tracer
Typ: /	PVPM2540X
Typ:	
Baujahr: /	2025
Year of manufact.:	

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 2014/35/EU**
- **EMV-Richtlinie 2014/30/EU**

entspricht.

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

EN 61010-1, EN 61010-2-30, EN 61000-3-2:2014, EN 61000-3-3, EN 61326-1, 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.

A handwritten signature in blue ink, appearing to read 'Klaus M. Schulte', is written over a faint, illegible stamp.

Iserlohn, 01.08.2025
(Ort/Place, Datum/Date)

Dipl.-Ing. Klaus M. Schulte
Geschäftsführer/Managing Director