Höcherl & Hackl
The electronic load

Application Note #24

Best Practices for PV Module Measurements: I-V Curve Tracing and MPP Tracking

Safety Instructions

Before commissioning, read the operating manual of your device, especially:

- General safety instructions
- Safety instructions regarding connection of the device under test (DUT)
- Information about the maximum permissible input power
- Information regarding the use of sense leads

Ensure that the voltage, current, and power ratings of the PV module are within the specifications of the electronic load.

Electronic loads from Höcherl & Hackl with integrated MPPT functionality enable automatic acquisition of I-V characteristics as well as continuous Maximum Power Point (MPP) tracking of photovoltaic modules.

Typical applications include:

- Characterization of PV modules
- Comparison of different module types
- Long-term monitoring of solar modules
- Investigation of shading effects
- Determination of energy yield under real operating conditions
- Photovoltaic research and development

The MPPT function combines automatic I-V curve acquisition with subsequent Maximum Power Point tracking, enabling both detailed analysis and efficient operation of PV modules.

Scope

This application note applies to the HES, TRL, SCL, PMLA, PLA und PLI(B) series.
The ZS and PLI(A) series also support MPPT functionality but differ in terms of user interface, SCPI command set, and software support. Therefore, the procedures and examples described in this document are not applicable to these series.

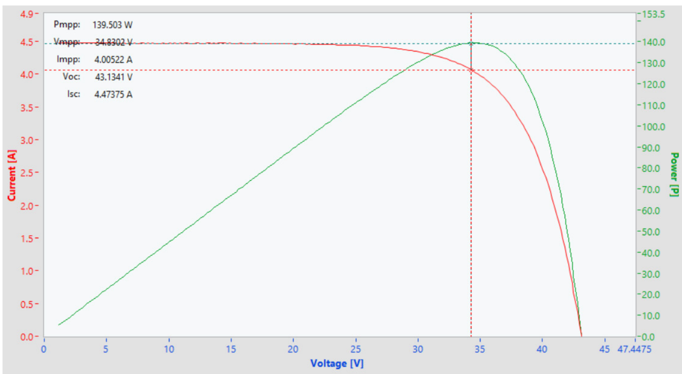
Fundamentals of the Maximum Power Point Tracking

The current-voltage characteristic of a photovoltaic module is non-linear.

The operating point at which the module delivers the highest output power is called the Maximum Power Point (MPP).

Important parameters:

- Voc – Open-circuit voltage
- Isc – Short-circuit current
- Vmpp – Voltage at MPP
- Impp – Current at MPP
- Pmpp – Maximum power



U/I and U/P Characteristics at MPP

MPPT Function Operation

The MPPT function consists of two sub-functions:

1. Sweeping

During each sweep, the complete I-V characteristic of the PV module is measured.

The electronic load:

- Measures voltage and current
- Records the I-V curve
- Determines the current MPP

The following parameters can be configured:

- Sweep duration
- Sweep period
- Sweep direction

The sweep direction can be selected either from Voc to 0 V or from 0 V to Voc.
The data from the most recent sweep can be retrieved using the following SCPI query:
FUNC:MPPT:SWE:DATA?
The response is an array of voltage-current tuples:
<Volt_0>,<Curr_0>,<Volt_1>,<Curr_1>...<Volt_n>,<Curr_n>

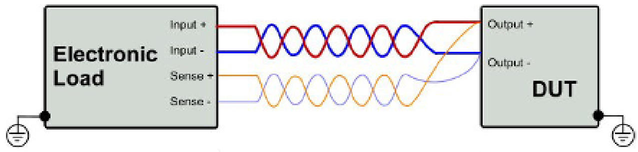
2. Tracking

After completion of a sweep, the function automatically switches to Tracking mode.
The electronic load continuously regulates to the previously determined Maximum Power Point and draws the maximum available power from the PV module.
Current MPP data can be queried using SCPI command:
FUNC:MPPT:MPP?
The following values are returned:

- Vmpp
- Impp
- Pmpp

Connecting the PV Module

For highest measurement accuracy, the sense terminals should always be used.



Wiring diagram for connecting the electronic load to the device under test

Recommendations:

- Use adequately sized load cables
- Connect the sense leads directly at the PV module
- Route load and sense leads separately
- Keep cables as short as possible
- Twist cable pairs

Influence of Cable Losses

With longer cable runs, significant voltage drops may occur between the PV module and the electronic load.
Example:

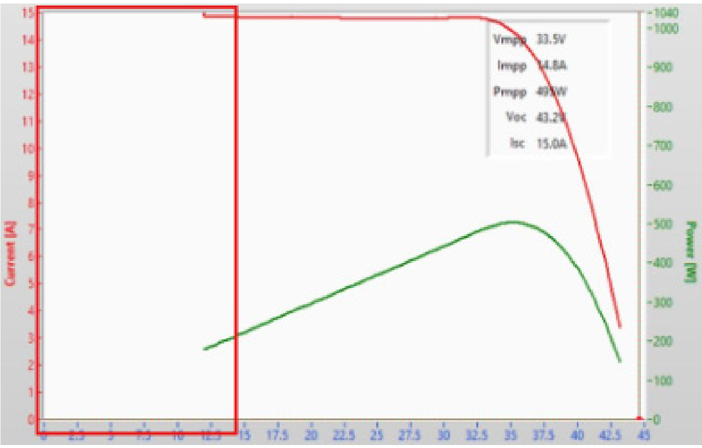
- Module voltage: 40 V
- Load current: 15 A
- Cable length: 90 m
- Conductor cross-sectional area: 4 mm^2

The resulting voltage drop is approximately 12 V.
This corresponds to roughly 30% of the generated module voltage.
Without sense leads, the entire I-V characteristic would be displayed incorrectly.

Special Considerations When Using Sense Leads

The voltage is measured directly at the module via the sense terminals, ensuring that voltage drops in the wires do not distort the voltage measurement.
However, an important physical relationship must be considered:

While the voltage is measured directly at the PV module, the current Impp still flows through the load cables to the electronic load.
As a result, only the voltage reduced by the cable voltage drop is available at the load's „Input +/-“ terminals. As load current increases, the voltage drop across the cables also increases. At high currents, the input voltage of the electronic load may decrease to a point where no further current can be drawn.
This results in a visible gap between 0 V and the beginning of the recorded I-V curve.



U/I and U/P Characteristics at MPP

Important:
This gap is not a measurement error.
The measured voltage and current values of the I-V curve are correct. The gap only represents the voltage drop across the load cables.
The size of this gap depends on:

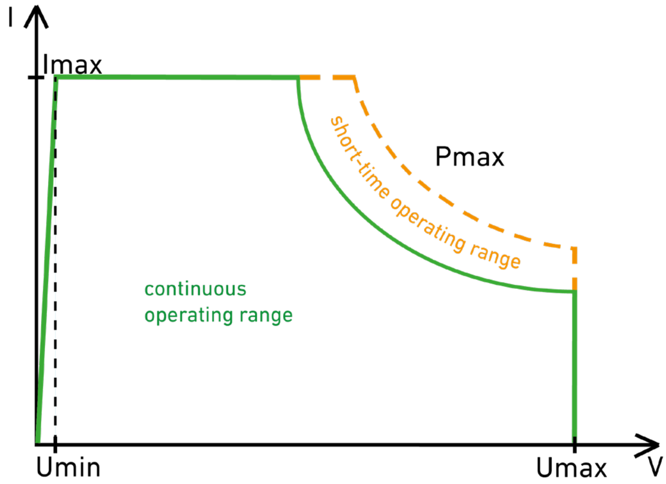
- Cable length
- Conductor cross-sectional area
- Contact resistance
- Load current

To reduce this effect, we recommend:

- Larger conductor cross-sectional area
- Shorter cables
- High-quality connectors
- Low-resistance contact points

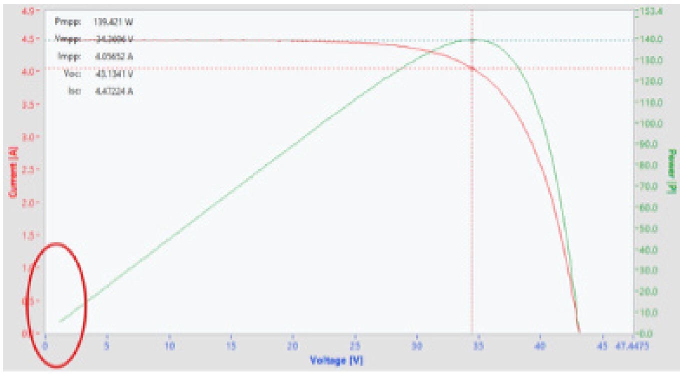
Measurement of Short-Circuit Current Isc

Electronic loads require a minimum input voltage (Umin; typically between 1 and 2 V; see technical specifications) in order to draw the max. current.



Operating Regions in the I-U Diagram

Therefore, the actual short-circuit current Isc at 0 V cannot be measured directly.
Below the minimum operating voltage, a portion of the I-V curve becomes inaccessible.



U/I and U/P Characteristics at MPP

The following options are available for measurements down to 0 V:

- Devices equipped with an integrated Zero-Volt unit (e.g. HESxxxZV)
- External auxiliary power supply as described in the user manual

Only these solutions allow the load current to be maintained down to the actual short-circuit current.

System Stability

Under certain conditions, the combined PV module and electronic load system may become unstable and exhibit oscillations.

Typical causes include:

- Long load cables
- High cable inductance
- Low irradiance
- Fast control-loop response

Possible remedies:

- Reduce control speed (e.g. with SCPI command FUNC:SPE SLOW)
- Use an external RC damping circuit
- Shorten cable lengths
- Select an appropriate measurement range (multi-range devices only, e.g. PLIxxx**MR** or HESxxx**MR**)

For assistance in dimensioning an RC damping circuit, please contact H&H Support.

support@hoecherl-hackl.com

Selecting the Appropriate Measurement Range

Applicable only to multi-range devices (e.g. HESxxx**MR** or PLIxxx**MR**).

Multi-range devices such as the HESxxx**MR** and PLIxxx**MR** series provide multiple true current and power ranges, allowing the electronic load to be optimally matched to the current operating conditions of the PV module.

In PV applications, module current often varies significantly depending on solar irradiance. During the morning hours, only low currents may be available, while full module output can be reached around midday.

Selecting the smallest current range that still safely covers the expected module current maximizes the available measurement resolution. This improves both I-V curve measurement accuracy and MPP tracking precision.

An excessively large current range can also reduce control-loop stability under low irradiance conditions. In such cases, the electronic load operates only within a small portion of its available measurement and control range, increasing the likelihood of oscillations or unstable tracking behaviour.

As irradiance increases throughout the day, larger ranges can be selected step by step. This ensures optimal accuracy and stability across the entire operating range of the PV module.

Recommendation:

Always select the smallest current range that safely accommodates the expected module current.

Local Operation (Example: HES Series)

Example HES Series menu path:

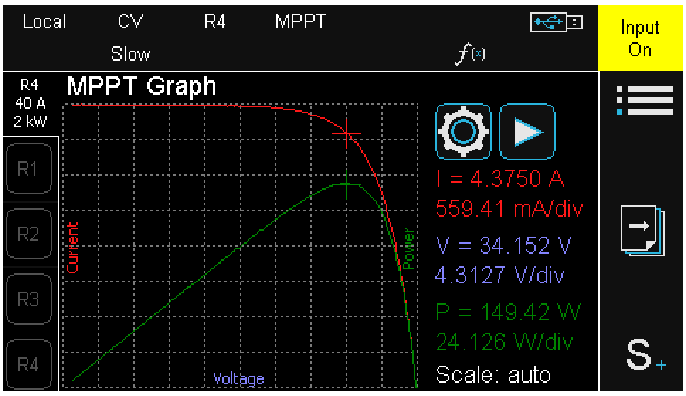
Main Menu – Settings – Functions - MPPT

Configure:

- Sweep time
- Sweep period
- Sweep direction

Start or pause tracking:

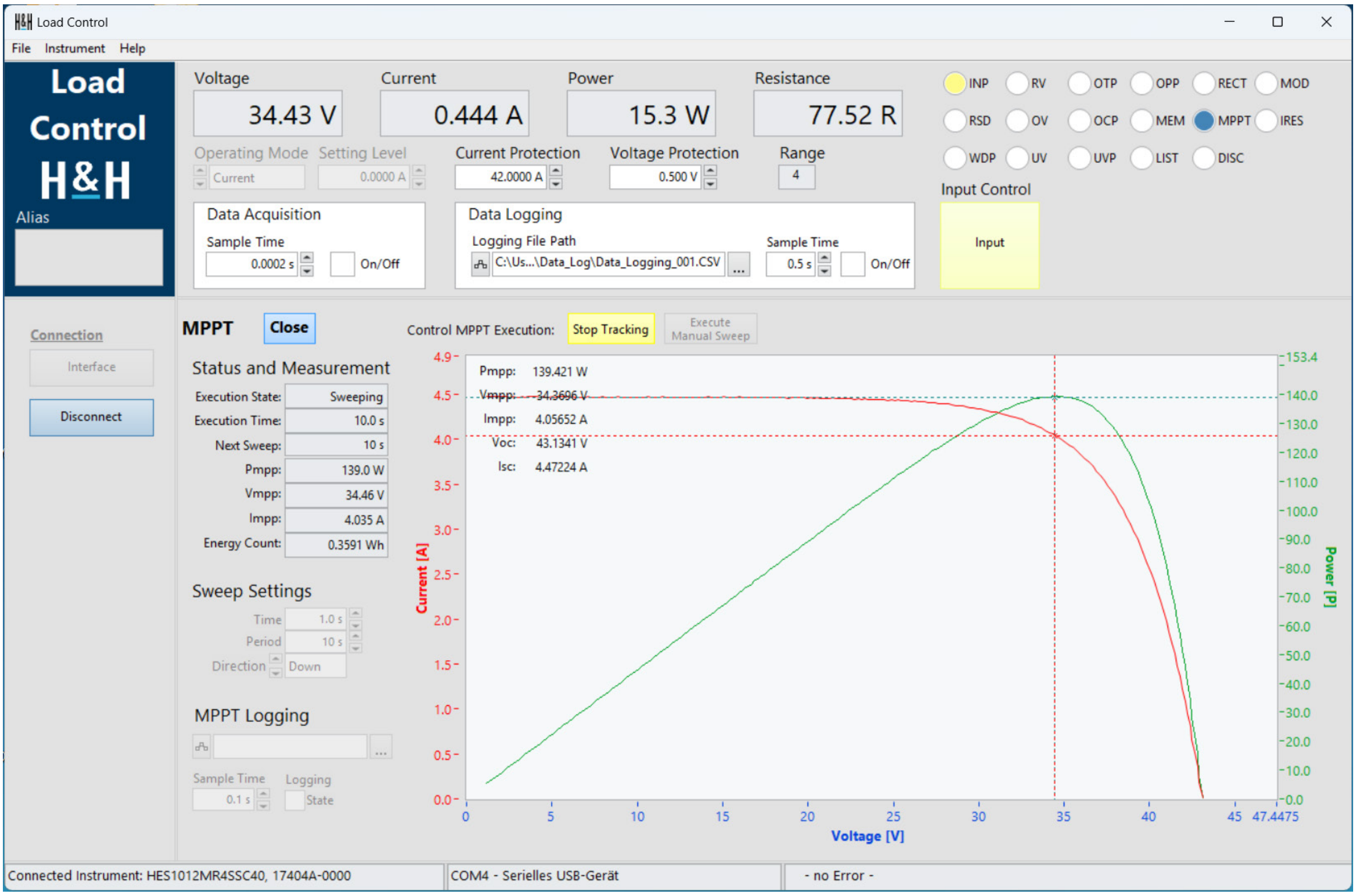
INPUT key



U/I and U/P characteristic curves on the user interface

Operation via H&H Load Control

1. Connect to the electronic load
2. Open the MPPT menu
3. Set sweep duration
4. Set sweep period
5. Select sweep direction
6. Optionally enable data logging
7. Start tracking



Load Control User Interface

SCPI Operation

*RST	Resets the electronic load
RANG 4, 1	Switches to range 4 (multi-range devices only)
CURR:PROT MAX	Sets the current protection to maximum (not required for standard models without MR)
FUNC:MPPT:SWE:TIME 3	Sets the sweep duration to three seconds
FUNC:MPPT:SWE:PER 60	Sets the sweep interval to sixty seconds
FUNC:MPPT:SWE:DIR DOWN	Sets sweep direction from Voc toward 0 V
FUNC:MPPT 1	Activates the MPP tracking function
INP 1	Enables the load input
FUNC:MPPT:SWE	Triggers an immediate sweep if no sweep is currently running
FUNC:MPPT:MPP?	Returns the most recently detected MPP values: Vmpp, Impp, and Pmpp
FUNC:MPPT:ENER?	Returns accumulated energy in Wh
INP 0	Deactivates the load input and pauses the function

Reading Measurement Data

Number of measurement points:

FUNC:MPPT:DATA:POINTS?

Measurement data from the most recent sweep:

FUNC:MPPT:SWE:DATA?

The data can be used to generate:

- I-V characteristic curves
- P-V characteristic curves
- Efficiency analyses
- Long-term performance records

H&H cannot guarantee the correct function of the suggested applications.
H&H assumes no liability for any damage resulting from the use of this application note.

More applications at
www.hoecherl-hackl.com