EXAMPLE REPORT

Photovoltaic Power Performance

Version 1.0.

www.neo-messtechnik.com

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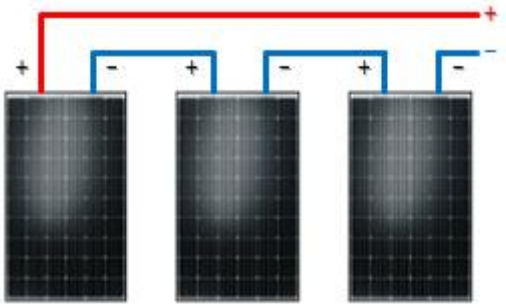
Content

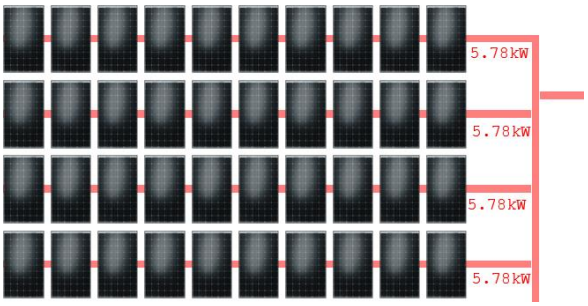
1 General Information (short form)

PV-Park size:	2.4 MW
Number of modules:	6235
Number of Array Combiner boxes:	22

1.1 PV Array Overview



17 panels in series per string



14 to 16 strings parallel per MPP

Module nominal power:	385 Wp
Module information:	anonymous

In the full report more details to the tested PV modules and the PV system configuration will be shown.

1.2 Measurement Instrument

PV-MASTER-70

- 20x String measurement IV Curve
  Voltage up to 1600 V DC – Accuracy 0.05%
  Current up to 40 A – Accuracy 0.1%
- 1x Solar Radiation via Pyranometer
- 2x Temperature Measurement

Features: IV Curve, PV Curve, Mismatch overview, Power Performance, String Voltage, String Current, Earth Leakage Detection, Distance-to-Fault

Related Standards:
IV-Curve: EN 60891, IEC60904, IEC 62446 (VDE 0126-23), DIN EN 61829 (VDE 0126-24)
Thermography: IEC62446-3
Instrument: IEC 61010-1/EN 61010-1/VDE 0411-1, DIN EN 61326-1/VDE 0843-20-1

2 Executive Summary

2.1 Performance Overview

The following table (Table 1) shows an overview of the power performance of the PV park. This example report is based on real measured data, but only four different phenomena are shown as examples using 4 different arrays.

Array	Performance	IV-Curve Result	Affected Strings	Series Losses	Mismatch Losses
Array 1	-2%	OK	0	< 3%	< 3%
Array 2	-27%	Mismatch	1 (all)	-14%	-27%
Array 3	-14%	Defective Module	3	-11%	--14%
Array 4	-15%	Shading	1	-8%	-15%

Table 1: Array performance

Array 1 has a 2% lower power than calculated and is thus almost at the optimum. Array 2 has high power losses of 27%. The power of one string is only about 30% compared to the other strings. However, due to the parallel connection, the total power of the array is reduced by 27%. Array 3 has a reduced power of 14%. Defective modules were found in three strings. Array 4's performance is 15% lower than expected. One string is partially shaded.

2.2 Recommendations

Regular safety checks are recommended to minimize the risk of fire and electric shock. During this measurement, three strings were found with leakage currents that could not be measured. These faults should be corrected immediately. To avoid mismatch losses, strings should not be continuously shaded and avoidable shading should be removed. Modules that were defective due to the storm should be replaced with new ones. Regular checks for hotspots and defective bypass diodes are also recommended, as these pose a fire hazard in addition to power losses. Regular power performance tests are recommended to detect performance reducing factors and to identify defective modules at an early stage. Finally, regular power performance tests ensure safe operation and are ensuring generation of the maximum possible yield.

3 Earth Leakage Measurement for Safety

The earth leakage safety check is necessary before each measurement for following reasons:

- Personal Protection
- Identifying electrical breakdown
- Identification of leakage currents
- Identification of Fault location

Regular measurements of earth leakage currents further will reduce the risk of electrical fire and the risk of electrical shock.

STRING	PLUS TO F.G. [V]	MINUS TO F.G. [V]	DISTANCE-TO-FAULT	CHECK
CH 1	305	305	-	OK
CH 2	311	312	-	OK
CH 3	316	313	-	OK
CH 4	308	304	-	OK
CH 5	433	180	8	FAULT
CH 6	311	314	-	OK
CH 7	302	307	-	OK
CH 8	309	308		OK
CH 9	350	258	3	FAULT
CH 10	307	306	-	OK
CH 11	308	305	-	OK
CH 12	311	312	-	OK
CH 13	284	315	1	FAULT
CH 14	312	313	-	OK

Figure 2: Results Leakage measurement

If there is no difference between the two values of the measured voltage (Plus to Ground and Minus to Ground), there is no leakage current and the string is in good condition. In the case of different values, the string is faulty. In this case three strings are faulty thus there is a risk to people and a risk of fire. It is forbidden to use the PV Master to measure faulty strings.

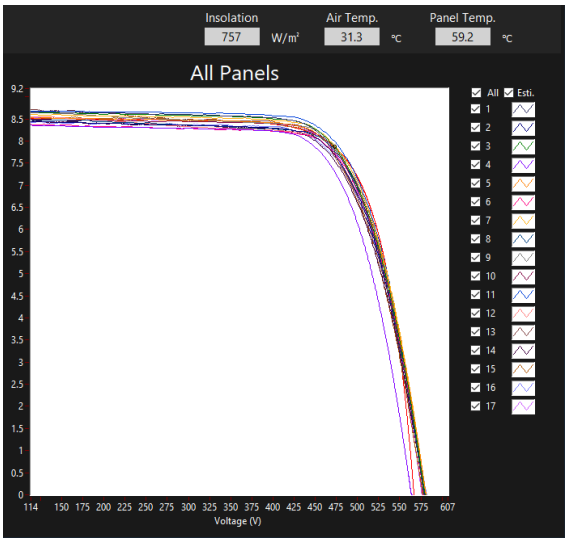
4 PV Array Results

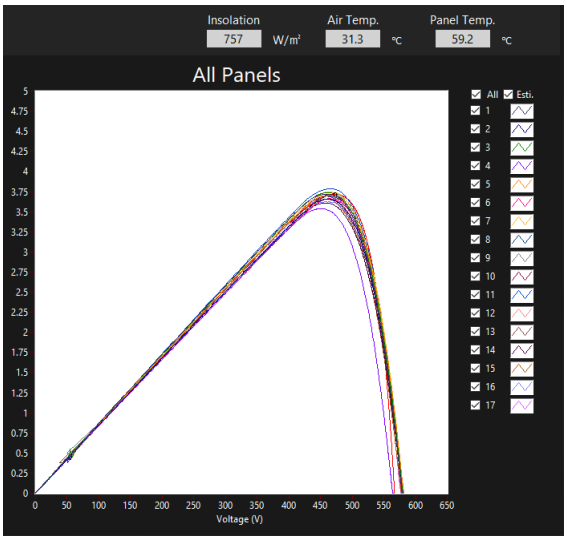
In this chapter exemplary results of different real measurements are shown. The results cover a good string (Array 1), an array with high mismatch losses (Array 2), an array with defective modules due to a thunderstorm (Array 3) and an array with shaded strings (Array 4).

4.1 Array 1 - Array in good condition

The following two figures show the IV curve and the PV curve. The IV curve is composed of the Y-current axis and the X-voltage axis. The solar irradiance, ambient temperature and module temperature at the time of measurement are shown at the top. At the right edge of the image the measured strings are displayed. The PV curve has the same structure with the difference that the Y-axis indicates the values of the power.

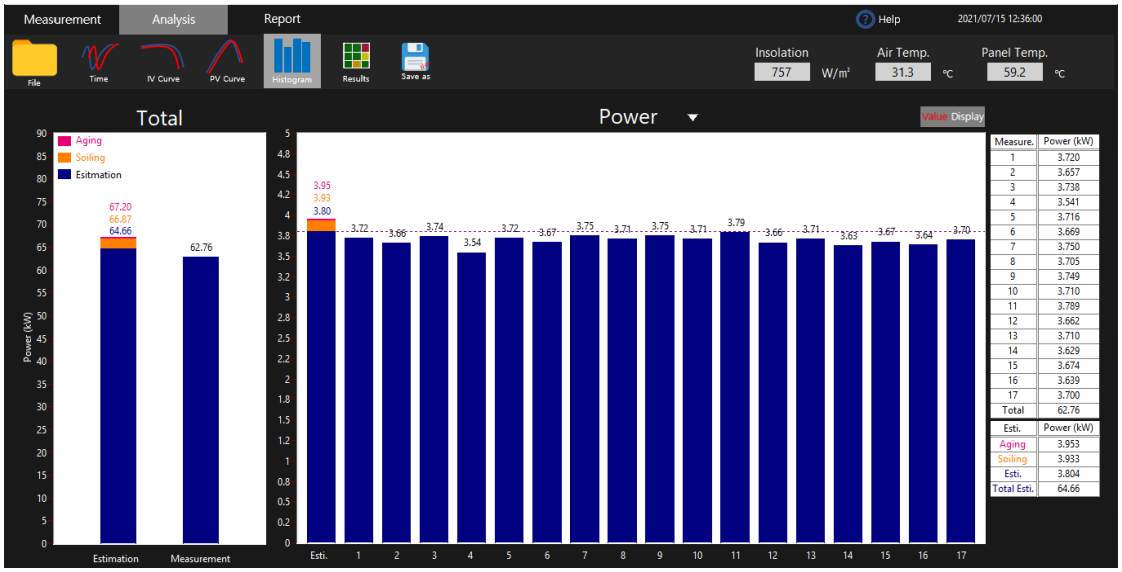
4.1.1 IV-Curve and PV-Curve





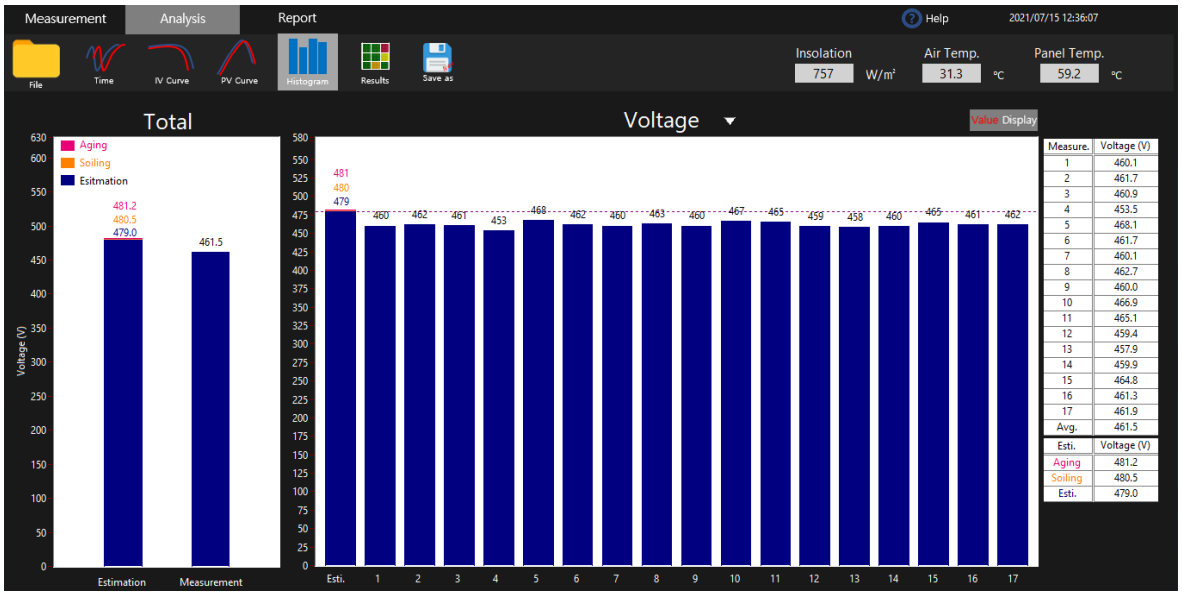
4.1.2 Power Performance Overview

The following figure shows the Power Performance overview table. In the left part at "Total" the overall power of all strings is shown as well as the target value. In case of mismatch losses, these are also shown. Furthermore, effects such as aging and contamination are taken into account here. The right side shows the power of the individual strings by means of a bar chart (in this example 17 strings). The horizontal dashed line represents the target power. The power of the individual strings can be displayed as a percentage or in absolute values and are also shown in tabular form on the right.



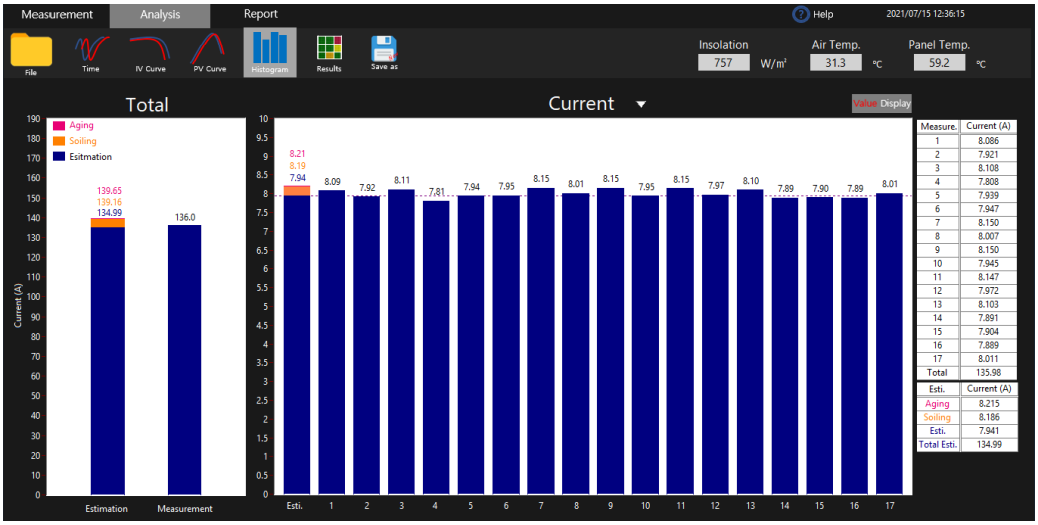
4.1.3 Voltage String-by-String

The voltage mapping is structured in the same way as the power performance, only instead of the power, the voltages are mapped here.



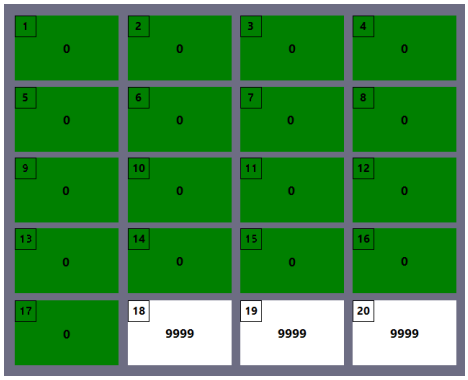
4.1.4 Current String-by-String

The currents are displayed in the same way as the voltages and powers in a bar graph. The Y-axis shows the voltage values while the X-axis shows the string numbers.



4.1.5 Automatic System Diagnosis

In the system diagnostics, faulty strings are displayed with the error category. The error category can be read in the legend.



Code No.	Code Color	Diagnosis
0		Normal String
1		Abnormal String (PID, Cell Crack, Not operating bypass diode(BPD))
2		Abnormal String (Hotspot, Cell Crack, Soiling, Shading, Operating BPD)
3		Abnormal & Defect String (Hotspot & PID)
4		Stop String (Short, Breakdown of PV module, Breakdown BPD)
9999		PV fault diagnosis is impossible. (Non input PV information, No I-V data)

※ This program only diagnose the possibility of PV fault.

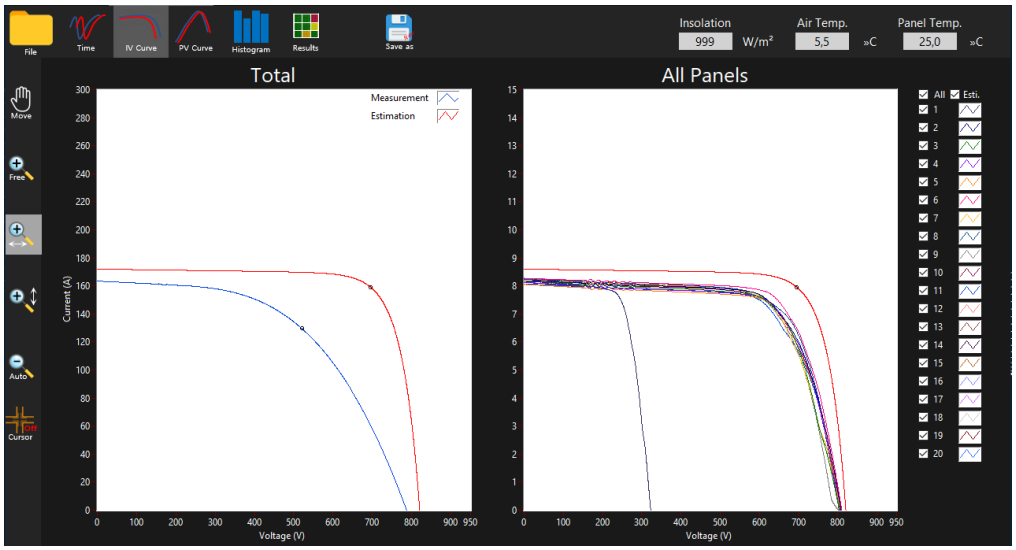
4.1.6 Analysis

For this array, there was only a slight deviation (3%) from the target values based on data sheet specifications. All strings are operating as desired and delivering the expected performance. A small deviation from the target values are common as these are based on laboratory conditions, i.e. no dirt or contamination, ideal and constant irradiation without fluctuations etc.

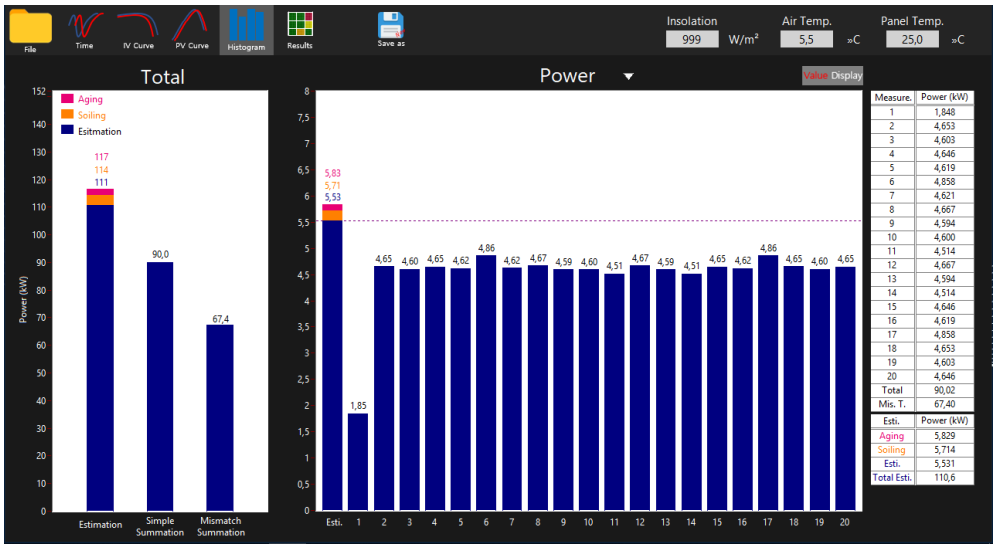
Array	Performance	IV-Curve Result	Affected Strings	Series Losses	Mismatch Losses
Array 1	-2%	OK	0	< 3%	< 3%

4.2 Array 2 - String with high Mismatch losses

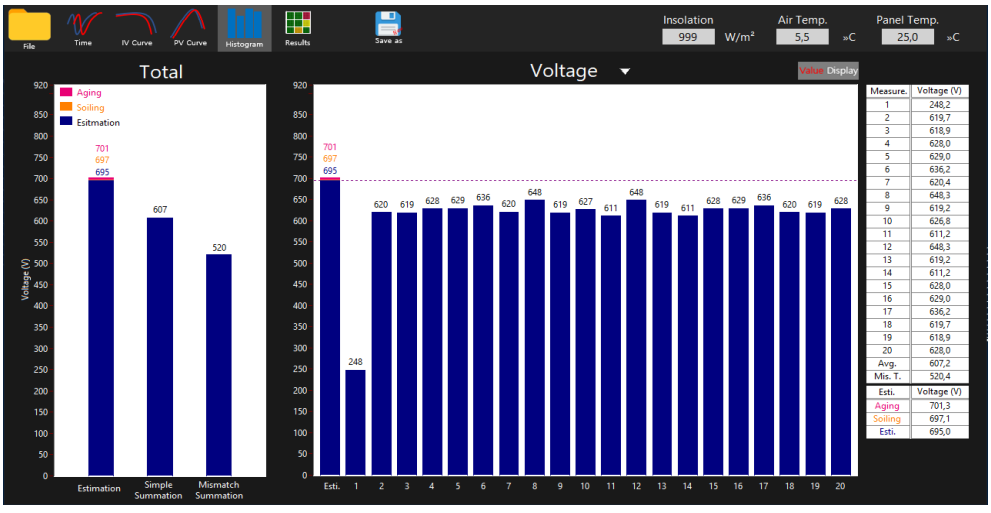
4.2.1 IV Curve



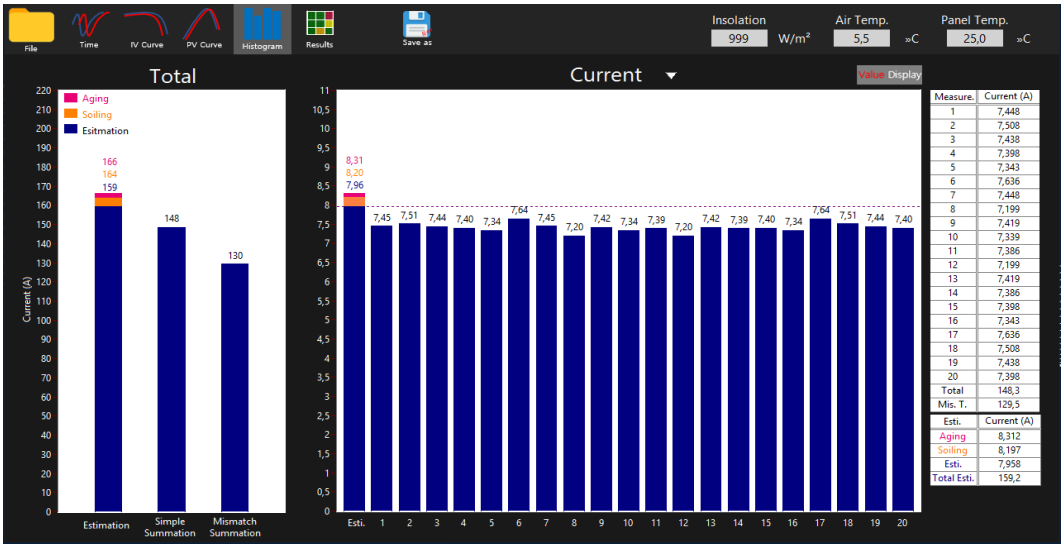
4.2.2 Power Performance Overview



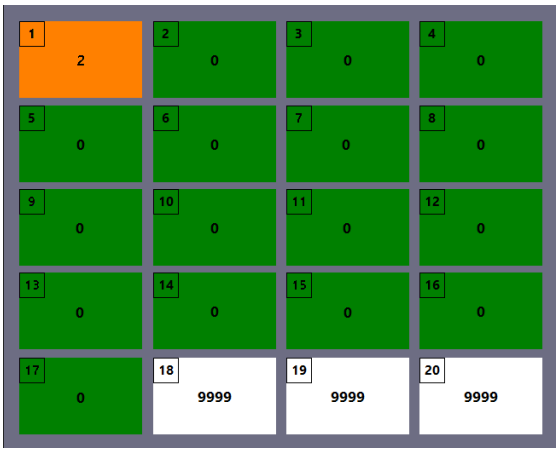
4.2.3 Voltage String-by-String



4.2.4 Current String-by-String



4.2.5 Automatic System Diagnosis



Code No.	Code Color	Diagnosis (English)
0		Normal String
1		Abnormal String (PID, Cell Crack, Not operating bypass diode(BPD))
2		Abnormal String (Hotspot, Cell Crack, Soiling, Shading, Operating BPD)
3		Abnormal & Defect String (Hotspot & PID)
4		Stop String (Short, Breakdown of PV module, Breakdown BPD)
9999		PV fault diagnosis is impossible. (Non input PV information, No I-V data)

※ This program only diagnose the possibility of PV fault.

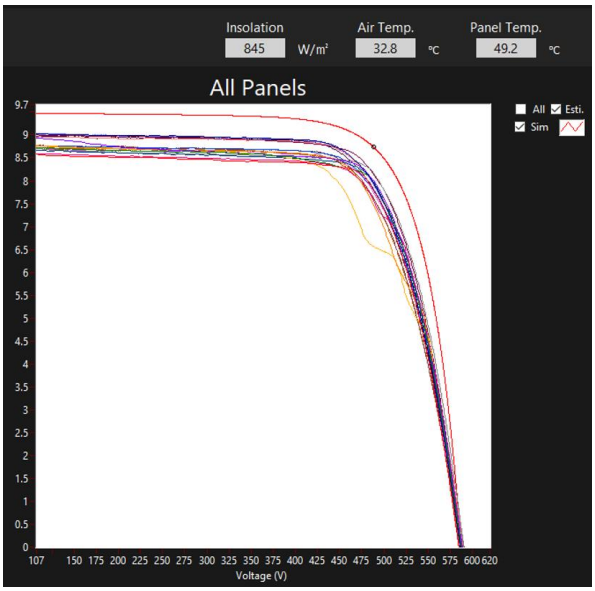
4.2.6 Analysis

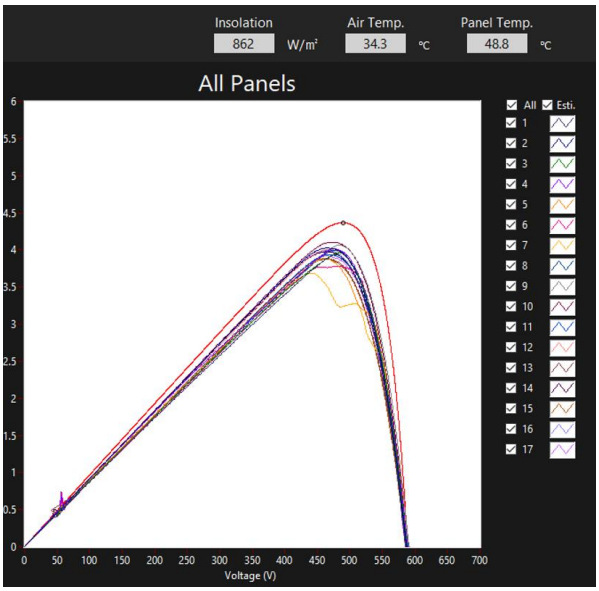
In array 2, bypass diode breaks occurred at string 1. In the power figure, it can be seen that this string has a much lower power than the other strings and consequently the overall power is reduced. Comparing the string currents and string voltages, it can be seen that the currents of the individual strings are at similar levels, but the string voltage of string 1 is far below the other string voltages and consequently reduces the overall voltage.

Array	Performance	IV-Curve Result	Affected Strings	Series Losses	Mismatch Losses
Array 2	-27%	Mismatch	1 (all)	- 14%	-27%

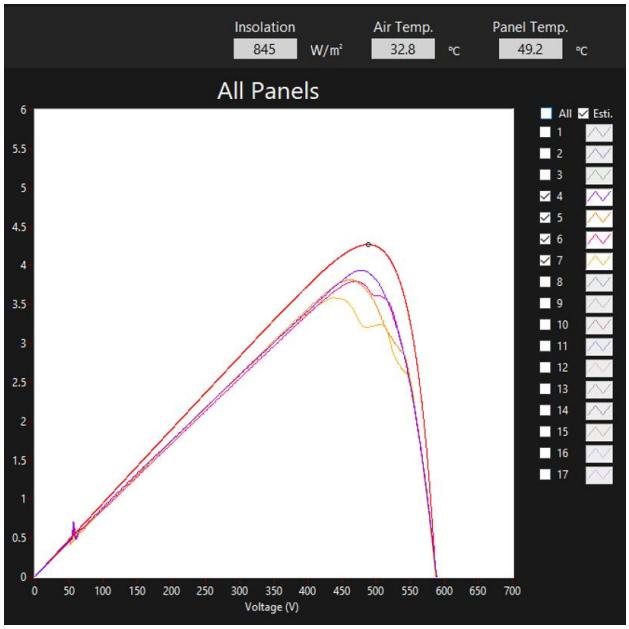
4.3 Array 3 - String with defective modules

4.3.1 IV-Curve and PV-Curve

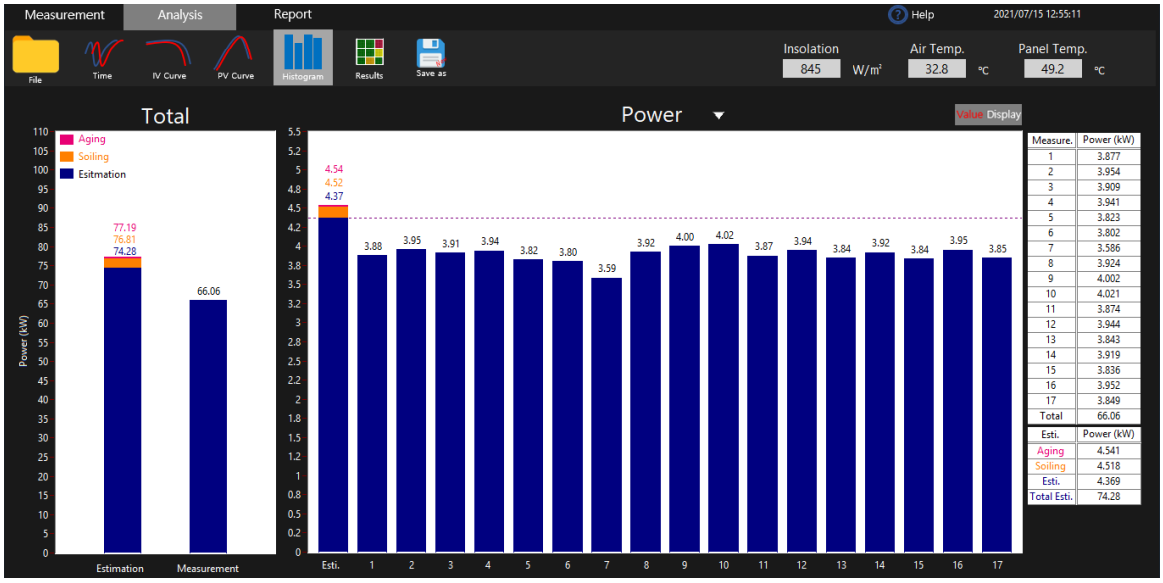




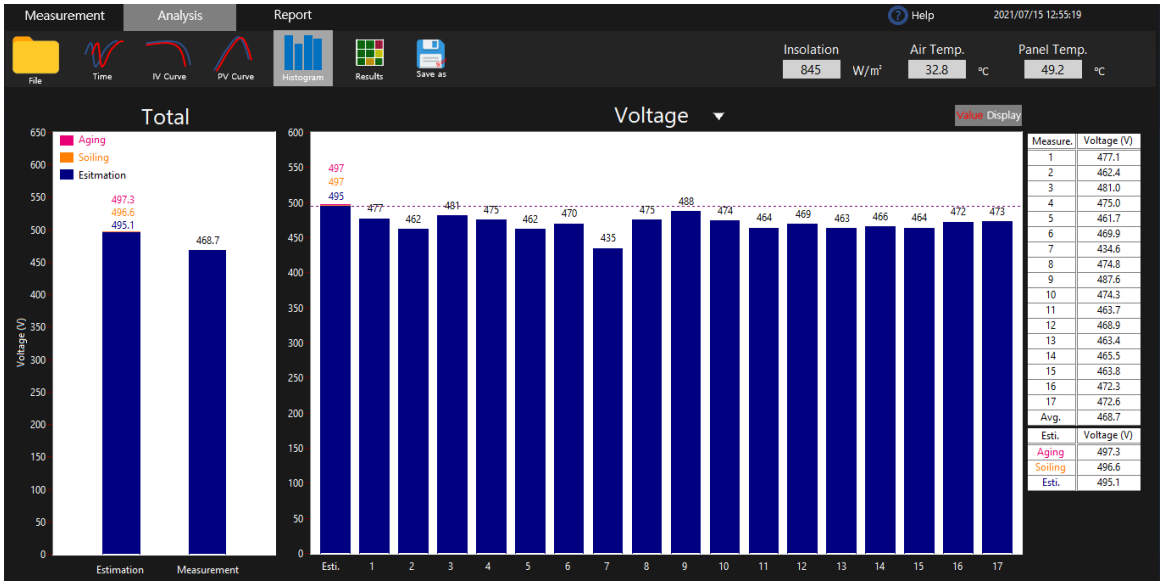
4.3.2 Detailed analysis



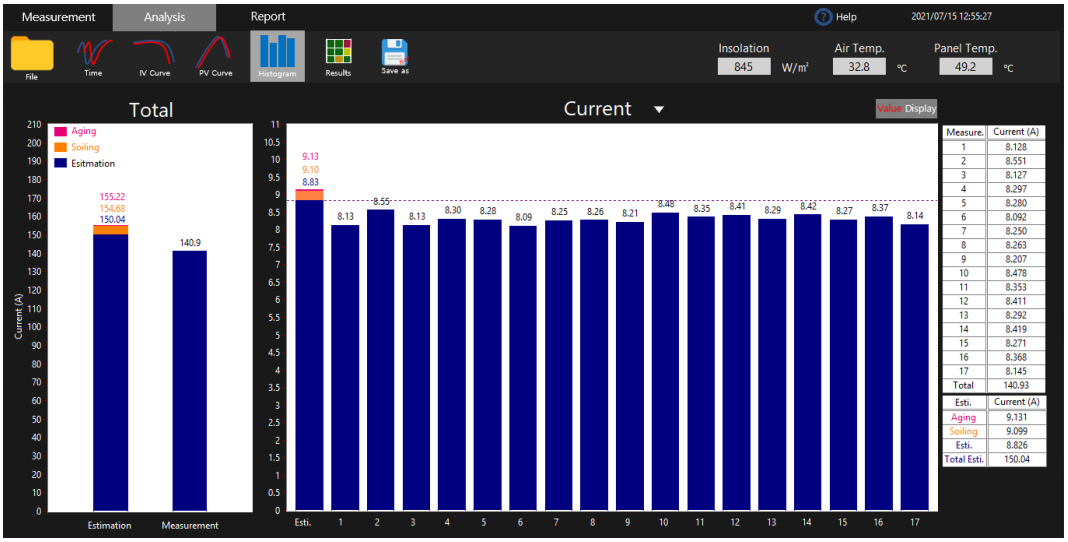
4.3.3 Power Performance



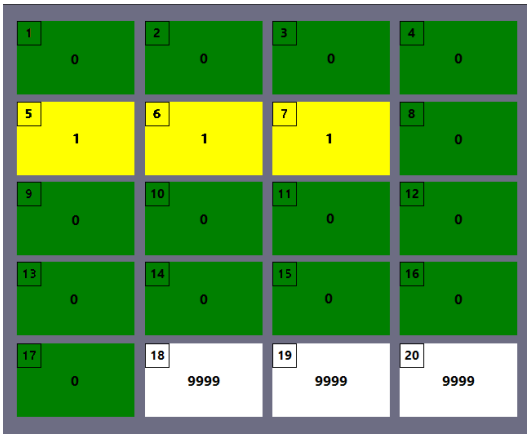
4.3.4 Voltage String-by-String

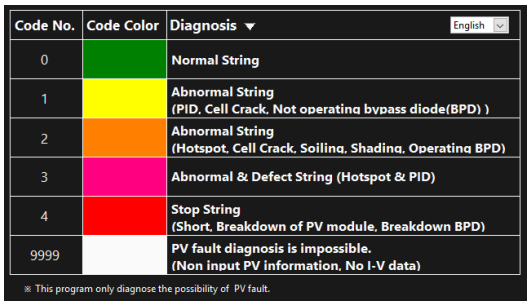


4.3.5 Current String-by-String



4.3.6 Automatic System Diagnosis





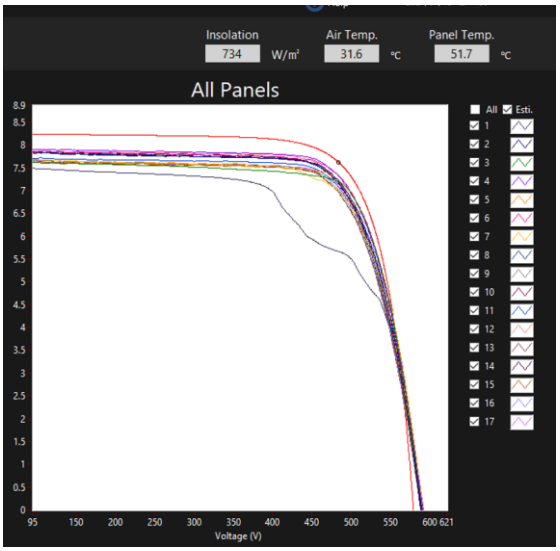
4.3.7 Analysis

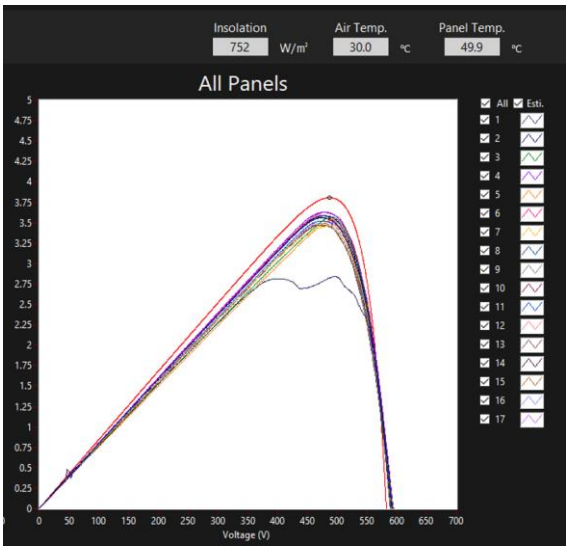
In this array, especially recognizable in the PV-characteristic curve, there are defects in three strings (string 5, 6 and 7). Modules were mechanically damaged (cell cracks, etc.) by a storm (thunderstorm with hail). Initially, only visually damaged modules were replaced by the insurance company. Due to these power performance measurements, further defective modules became visible and were finally compensated by the insurance company. This example emphasizes the need of full IV curve analysis, as comparing short-circuit current or open-circuit voltage of the strings will not show this error.

Array	Performance	IV-Curve Result	Affected Strings	Series Losses	Mismatch Losses
Array 3	-14%	Defective Module	3	-11%	-14%

4.4 Array 4 - String with shading

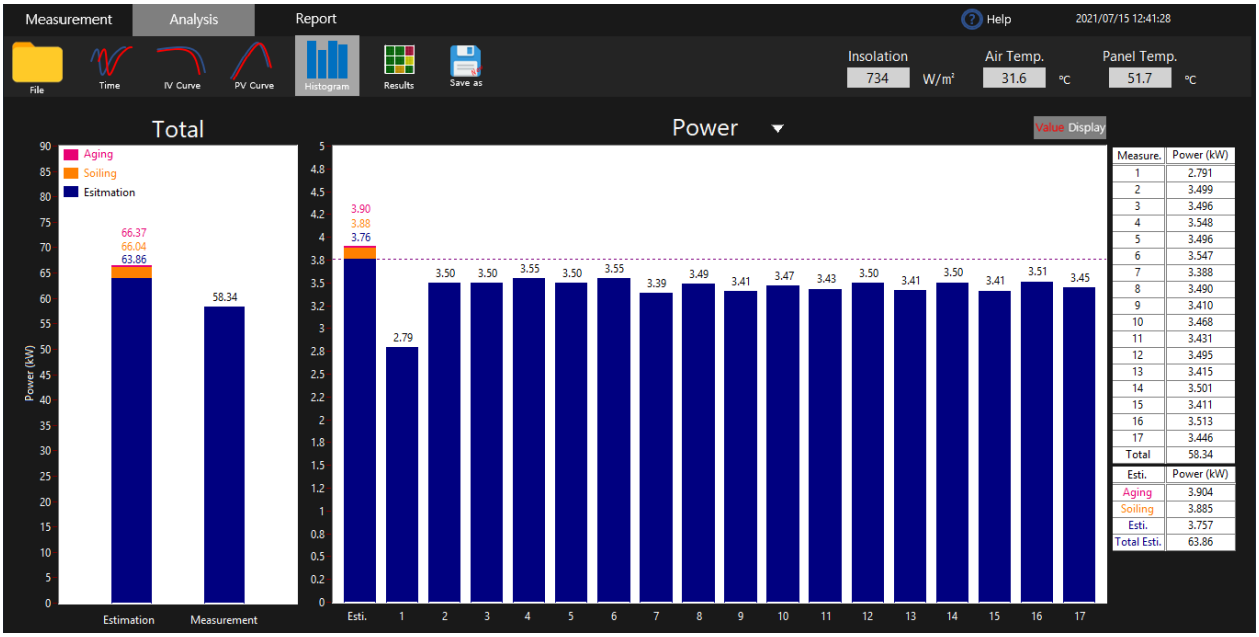
4.4.1 IV-Curve and PV-Curve



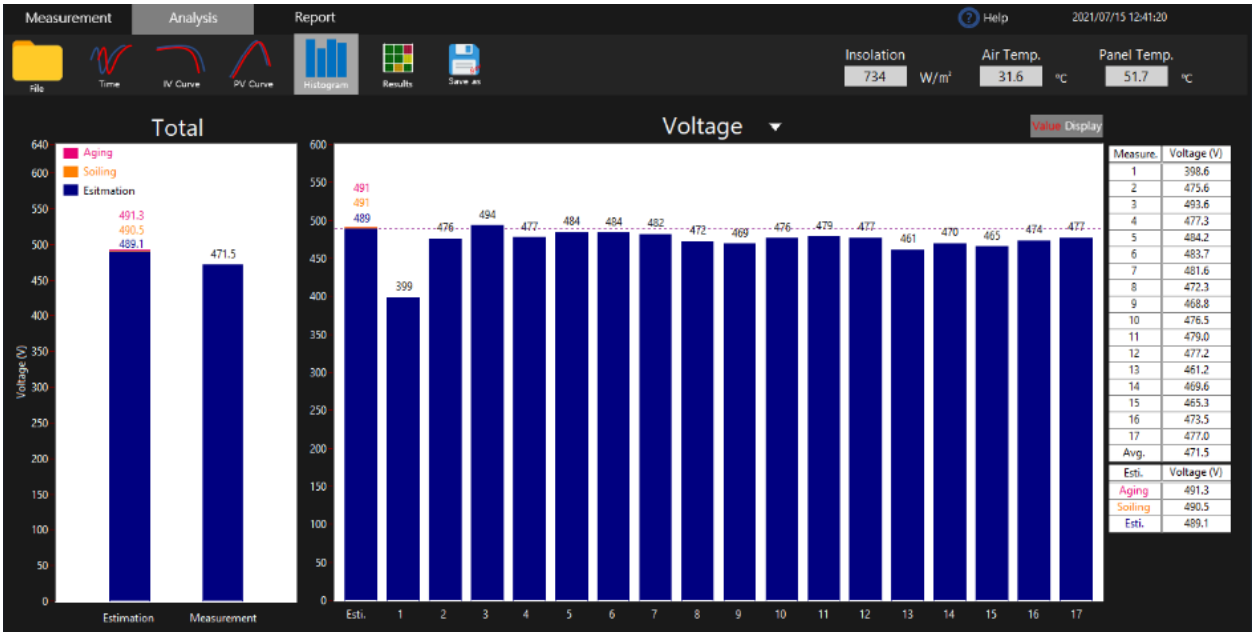


*Note: One string is affected by **near shading.***

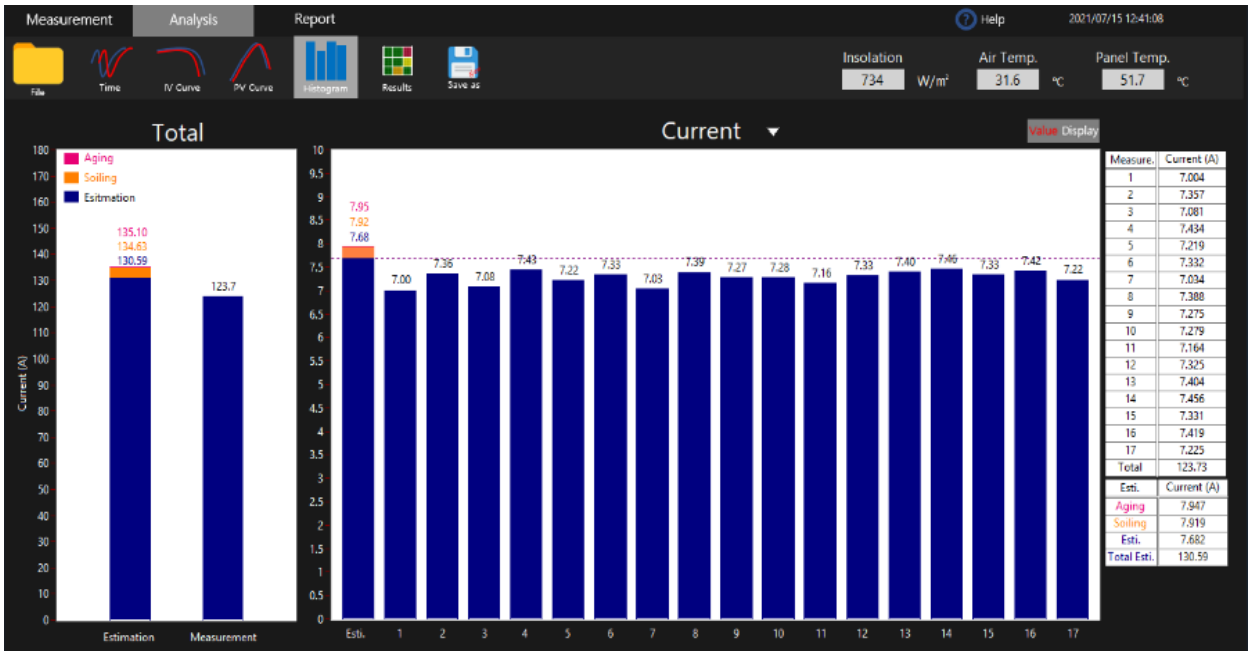
4.4.2 Power Performance



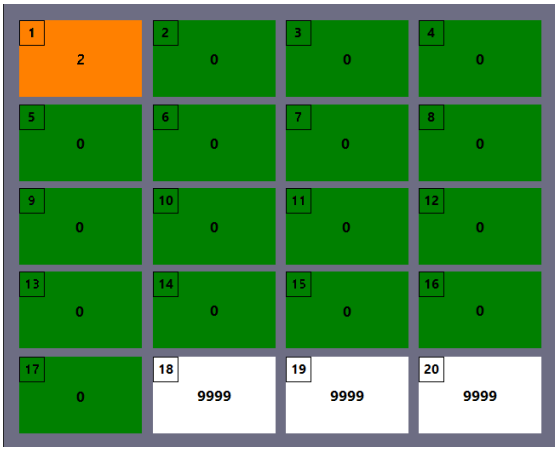
4.4.3 Voltage String-by-String



4.4.4 Current String-by-String



4.4.5 Automatic System Diagnosis



Code No.	Code Color	Diagnosis ▼ English
0		Normal String
1		Abnormal String (PID, Cell Crack, Not operating bypass diode(BPD))
2		Abnormal String (Hotspot, Cell Crack, Soiling, Shading, Operating BPD)
3		Abnormal & Defect String (Hotspot & PID)
4		Stop String (Short, Breakdown of PV module, Breakdown BPD)
9999		PV fault diagnosis is impossible. (Non input PV information, No I-V data)

※ This program only diagnose the possibility of PV fault.

4.4.6 Analysis

In this array, there is an 8% power reduction in string 1 due to near shading from plant growth. The lower voltage on string 1 reduces the total voltage of the array and thus the total power. The resulting parallel mismatch losses are 7%. The total power of the array is reduced by 15% overall.

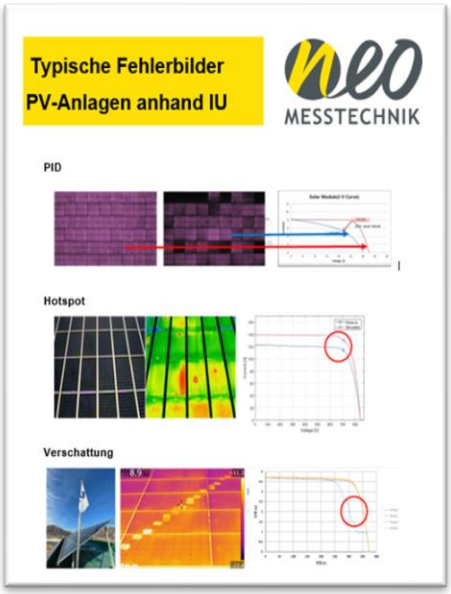
Array	Performance	IV-Curve Result	Affected Strings	Series Losses	Mismatch Losses
Array 4	-15%	Shading	1	-8%	-15%

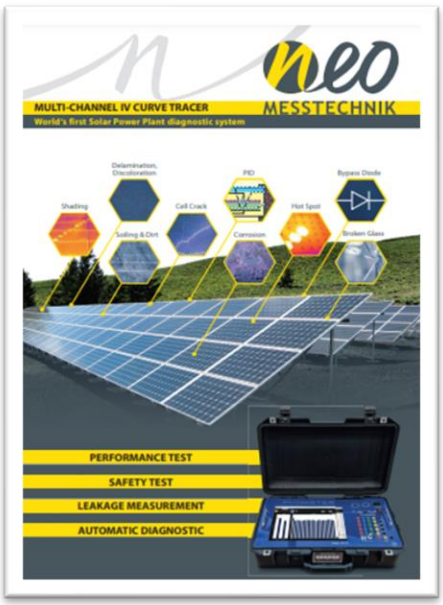
5 Further Information

Further information can be found on the NEO website:

www.neo-messtechnik.com/downloads

- PV-MASTER Datasheet
- PV-MASTER Manual
- PV-MASTER Brochure
- IV Curve Library and typical Fault Pictures





Contact

When you are working with our products we want to provide you with the greatest possible benefits. If you need any support, we are her to assist you.

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