



IEC 62446-1

PV Systems – Requirements for testing,
documentation and maintenance
Part 1 – Grid connected systems – Documentation,
commissioning tests and inspection

Clause 1: Scope

- Legally required in many European countries
- Defines documentation the customer needs
- Describes commissioning tests, inspection criteria, and documentation to verify safe installation and correct operation.
- Doesn't cover systems with batteries
- Clause 2: References to other IEC standards
- Clause 3: Terms and definitions

Clause 4: Documentation

- Minimum level of documentation provided to customer
 - Basic system info: power, PV & Module info, installation/commissioning date, customer name & address
 - Designer/installer name and contact info
 - Wiring diagram with string layout
 - Datasheets: module and inverter
 - Mechanical design info: including engineering docs if it was a custom design
 - Emergency systems: fire/smoke alarms related to PV system if present
 - Operations and maintenance information
 - How to monitor the system
 - Checklist incase of system failure
 - Emergency shutdown procedures



Clause 4: Documentation Continued

- Minimum level of documentation provided to customer
 - Operations and maintenance information
 - How to monitor the system
 - Checklist in case of system failure
 - Emergency shutdown procedures
 - Maintenance and cleaning recommendations
 - Considerations for future work like roof replacement
 - Warranty documentation: modules, inverters, installation
 - Including start and end dates
 - Test results and commissioning data as required by IEC 62446-1 Clauses 5 to 9

Clause 5: Verification

- Clause 5.1: General
 - Requirements for initial and periodic verification for grid-connected systems.
 - “Initial and periodic verifications shall be made by a skilled person, competent in verification.”
 - Initial verification upon completion of installation or alteration of existing system
 - Period verification to determine equipment remains in good condition
 - Period between verifications shall be no longer than what is required by the AC electrical system
 - In some countries the interval between verifications is stipulated by national regulations.



Clause 5: Verification

- Clause 5.2.1 - 5.2.8: DC Inspection
 - Inspection shall proceed testing
 - DC voltage suitable for array location
 - Component and mounting structure installed to withstand environment
 - Roof penetrations are waterproof
 - Proper overcurrent protection device installed
 - Wiring rating matches environment and installed to minimize risk of faults
 - System is properly grounded
 - Inverter ground fault detection system is operational

Clause 5: Verification

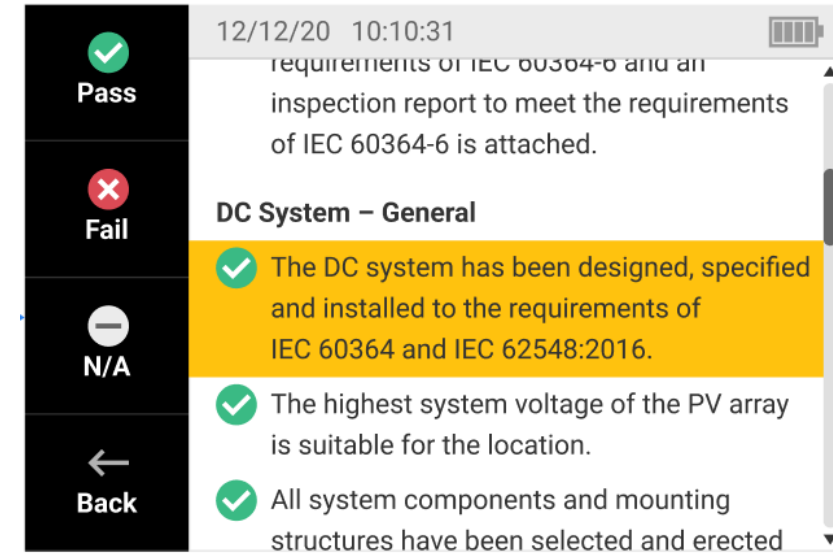
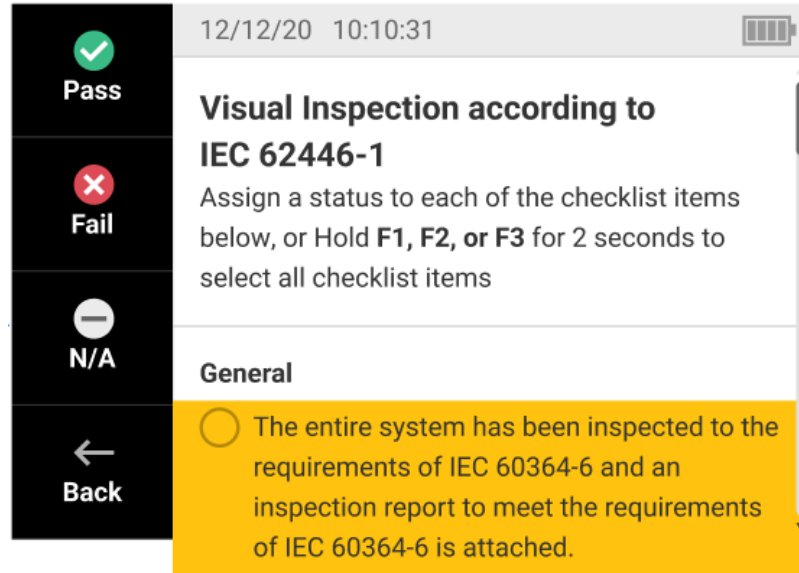
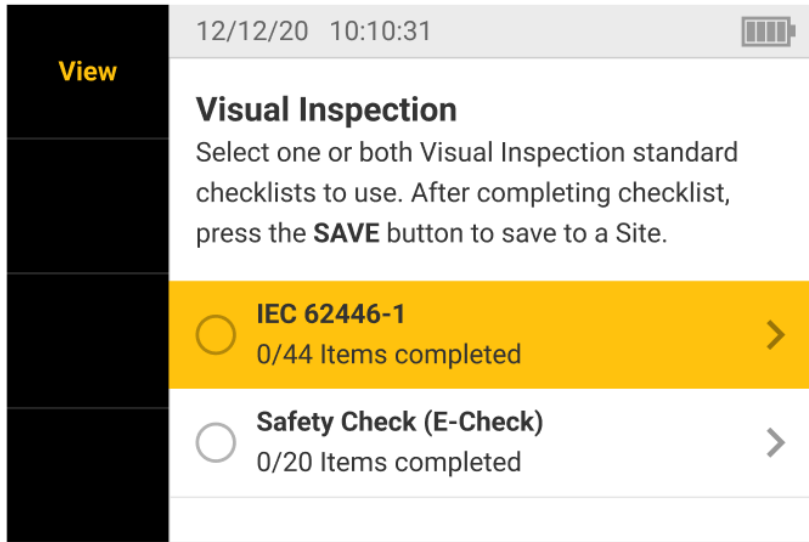
- Clause 5.2.1 - 5.2.8: DC Inspection
 - No string level OCPD: module fuse rating is greater than possible reverse current
 - String level OCPD: OCPD has correct ratings
 - Protection against lightning and overvoltage
 - Wire loops are kept as small as possible
 - Surge protection devices are in place on long cables
 - PV modules are rated for max system voltage
 - DC components are rated for continuous operation at max voltage
 - Wiring system installed to withstand environmental conditions
 - Proper disconnects are installed
 - DC quick connects (like MC4) are of the same type and properly installed

Clause 5: Verification

- Clause 5.2.9: AC Inspection
 - Proper AC disconnect installed
 - Disconnect wired with PV on “load” side and utility on “source” side
 - Inverter programmed to local regulations
- Clause 5.2.10: Labeling
 - Labeled to the requirements of IEC 60364 and IEC 62548:2016



Visual Inspections Tool – SMFT-1000



- Collect visual inspections data in the field
- Never forget to perform parts of the inspection
- No need for handwritten checklists on paper, which need transferring to software manually later
- Saving time by not having to return to locations for forgetting visual inspection and double entry of data into reporting software.

- DC System – General
 - The DC system has been designed, specified and installed to the requirements of IEC 60364 and IEC 62548:2016.
 - The highest system voltage of the PV array is suitable for the location.
 - All system components and mounting structures have been selected and erected to withstand the expected external influences such as wind, snow, temperature and corrosion.
 - Roof fixings and cable entries are

Press and hold quick keys to fill the page with inspection outcomes automatically

Clause 5.3: Testing

- Clause 5.3.1: General
 - During testing, if you find a fault/failure, once it's repaired, the tests shall be repeated
- Category 1 tests: minimum requirement for safety
- Category 2 tests: additional tests for performance
- Additional tests: may be required in some circumstances



Clause 5.3: Testing

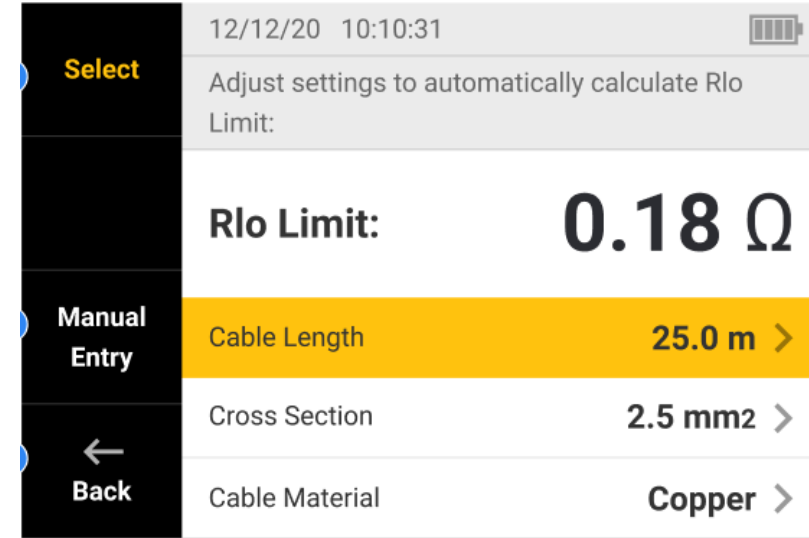
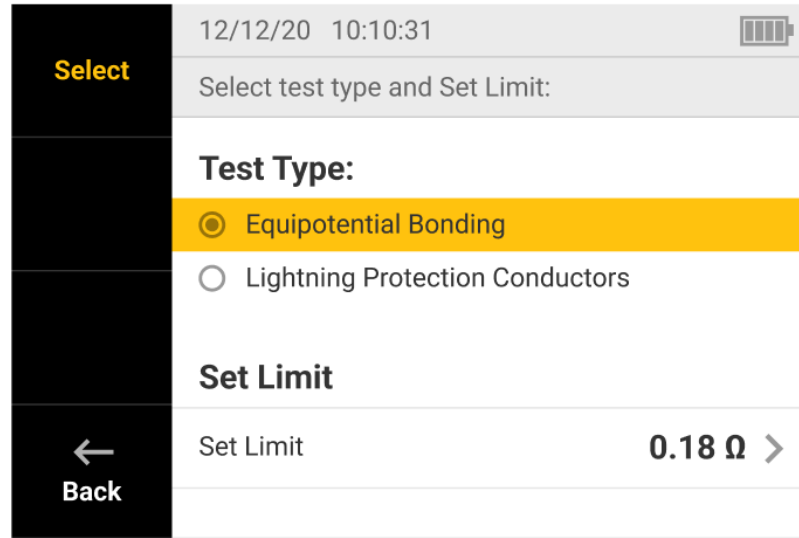
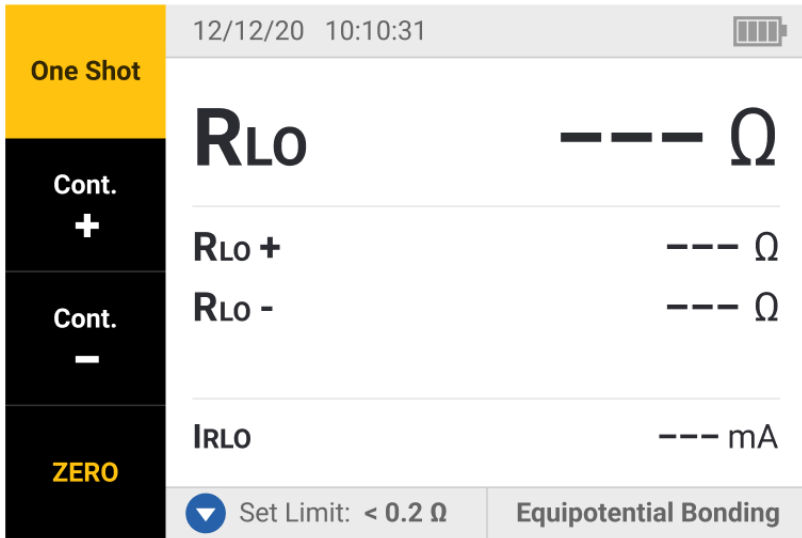
- Clause 5.3.3: Systems with MLPE
 - AC modules or micro-inverters: no DC tests or inspection required
 - Module integrated electronics: follow standard test regime, when possible, consult manufacturer to determine test restrictions and pass/fail criteria



Clause 5.3: Testing

- Clause 5.3.4: Category 1 tests
 - Tests all AC circuit(s) to the requirements of IEC 60364-6.
 - DC circuits
 - Continuity of equipment grounding conductor and bonding
 - Polarity
 - Open circuit voltage (Voc)
 - Short circuit or operational current (Isc or Imp)
 - Functional tests: switch operation, inverter operation per manufacturer
 - Insulation resistance
 - Polarity test must be conducted before strings are interconnected
 - I-V curve testing may replace Voc and current measurements

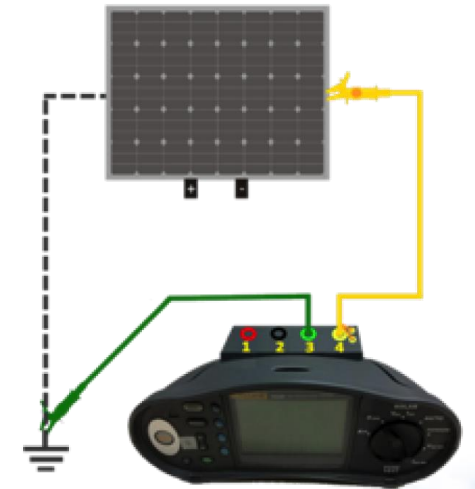
R_{LO} – Protective conductor resistance



- Lightning Protection System (LPS)
- Grounding
- Make quick point-to-point measurements using the remote probe.
- Kit includes a 30m reel to allow easy measurements along the installation
- No need to look up and calculate limits
- Continuous (Cont.) measurement for quick fault finding.
- Can also use Fluke 1507

Rpe One Shot - Before Test (blank state)

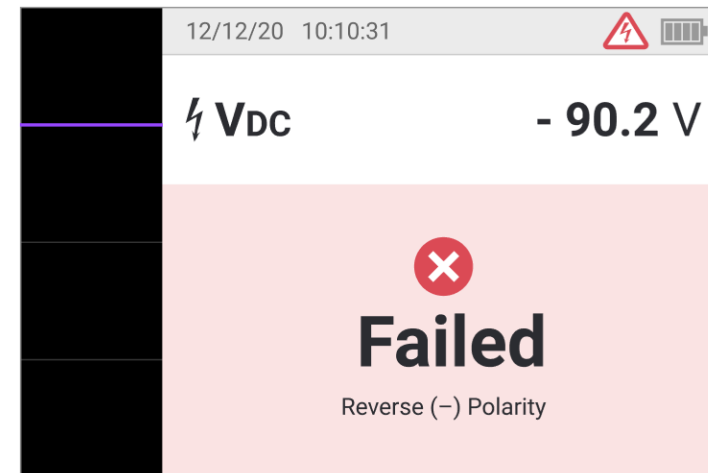
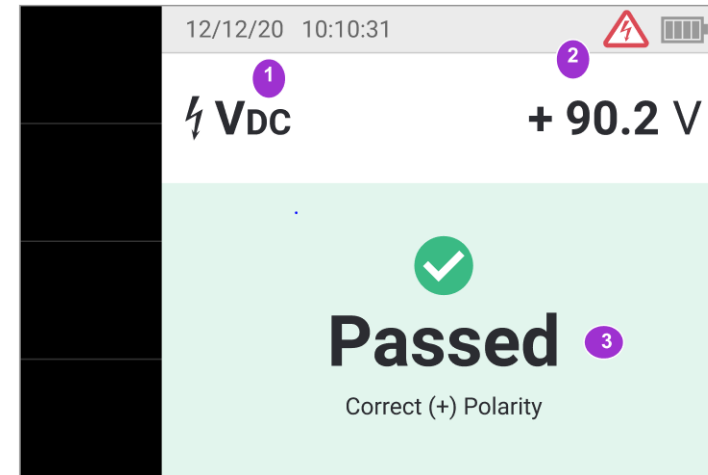
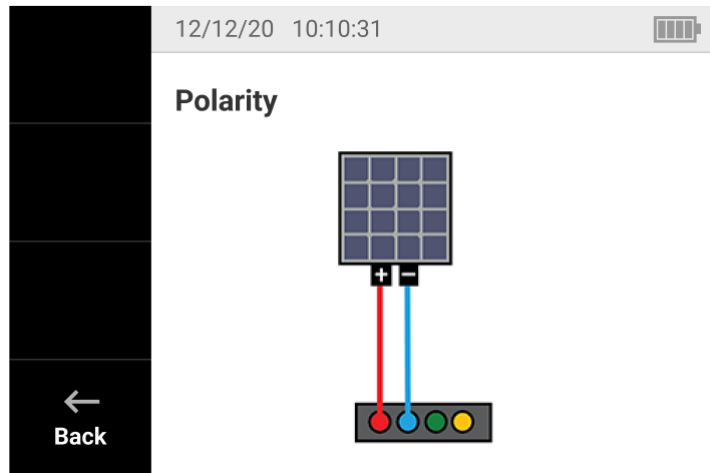
1. Rpe = Main reading
2. Rpe+ = Positive Polarity Resistance
3. Rpe- = Negative Polarity Resistance
4. Irpe = Current of Protective bonding Resistance
5. Limit (defined using down-arrow key)



V -/+ Polarity

The polarity test verifies to IEC 62446-1 Clause 6.2 that the positive and negative wires are correctly connected to the solar system combiner box, inverter, or switch gear.

1. DC/AC Autodetect
2. Measured results $> +5.0V$
3. Passed message



Voc / Isc (Open circuit voltage / Short circuit current)

Open circuit voltage measurement (Voc)

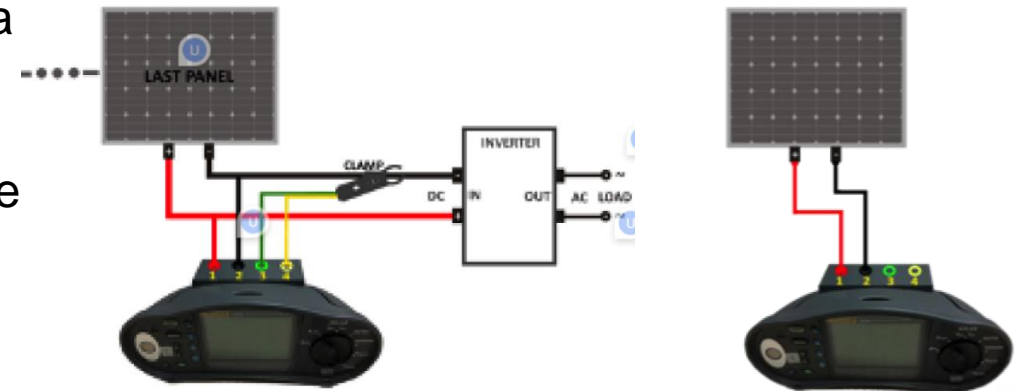
Open circuit voltage (Voc) measurement to IEC 62446-1 Clause 6.4. This test checks that module strings are correctly wired and that the expected number of modules are connected in series within the string. For strings connected in series, the measured voltage should be a sum of the voltages of individual solar panels in the string. This test can also be used to verify open circuit voltage of the individual module.

Circuit current test - short circuit test (Isc)

The PV string circuit current test to IEC 62446-1 Clause 6.5.2 is a short-current measurement test to verify the correct operational characteristics of the system and that no major faults are within the PV array wiring. These tests are not to be taken as a measure of module/array performance. Compare the results of the short-circuit current measurement with solar panel specifications.

- Simultaneous Voc and Isc measurements
- Quick calculations of limits using module data, quantity, and irradiance

Voc/Isc		12/12/20 10:10:31	
		Irr: 1000 W/m ²	Tcell: 73 °F
		⚡ Voc	515.2 V
PV Module	Voc	512.2 V	✓
IRR Meter	Isc	19.2 A	✓
		Voc STC: > 500.0 V	Isc STC: > 19.0 A



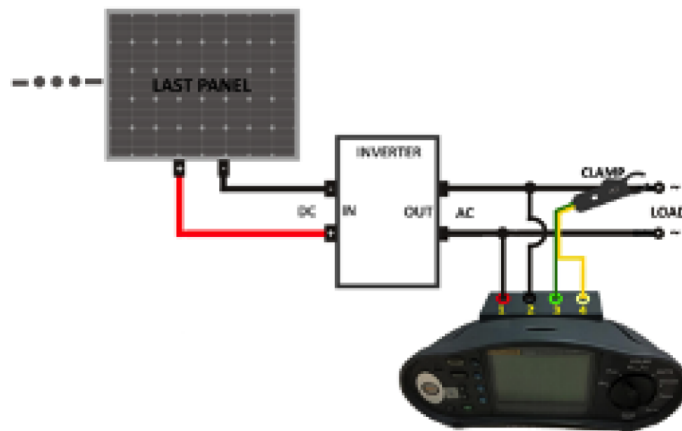
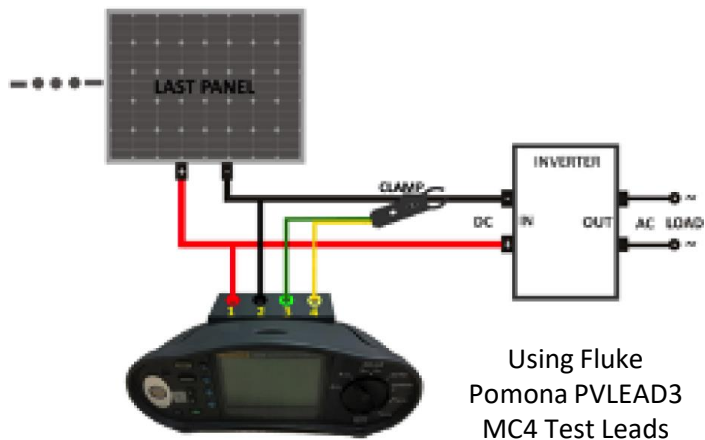
Fluke Pomona
PVLEAD3
MC4 Test Leads



FUNC./P_{AC/DC} - Power AC/DC and Function test

Tests the power output from the PV system to make sure that the DC power produced by the modules is inverted properly into AC power as required by IEC 62446-1 Clause 6.6.

- Simultaneous voltage and current (V&I) measurements
- Easy comparisons of V&I on either side of the inverter
- No need to calculate inverter efficiency.
- Also performs 3-Phase inverter performance check



12/12/20 10:10:31

Power	DC	AC
Voltage	V --- Vdc	--- Vac
Current	I --- Adc	--- Aac
HOLD	P --- kW	--- kVA

Measure DC side
Press F3 to hold DC measurements.

3-Phase Set Limit: > 70%

12/12/20 10:10:31

2. Measure AC

← Back

Rins- Insulation resistance test

Rins Test Method 1

Test between the PV array negative and earth, followed by test between PV array positive and earth. The connections do not change (Keep the Leads option).

Rins Test Method 2 (Default)

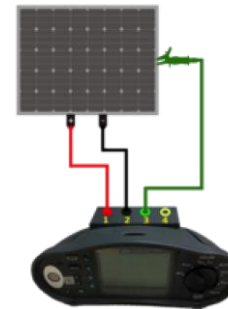
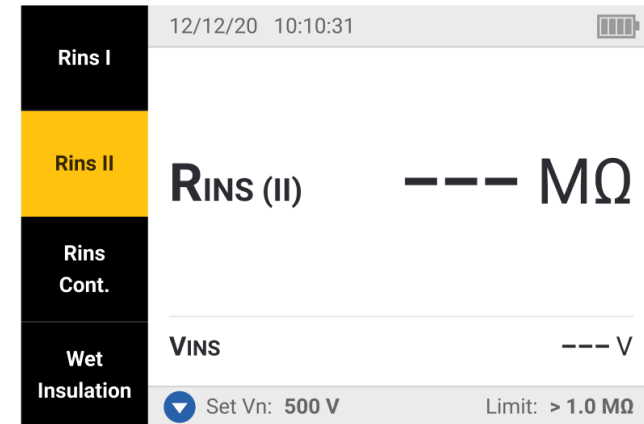
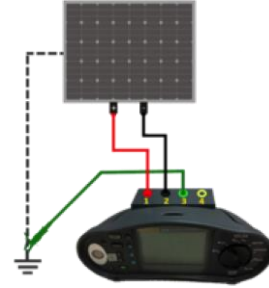
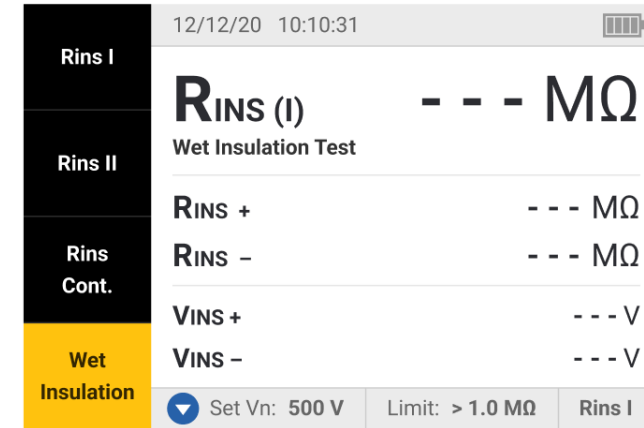
Tests between earth and the short-circuited array for a positive and then negative measurement.

Continuous Measurement

Measures Rins between any two points. Used to troubleshoot insulation faults on the wiring cables.

Table 2 – Minimum values of insulation resistance – PV arrays up to 10 kWp

System voltage (V_{oc} (stc) × 1,25)	Test voltage	Minimum insulation resistance
V	V	MΩ
<120	250	0,5
120 to 500	500	1
500 to 1 000	1 000	1
> 1 000	1 500	1



*PV arrays up to 10 kWp means the array/string you're testing, not the entire system.

Clause 5.3: Testing

- Clause 5.3.5: Category 2 tests
 - I-V curve test
 - IR inspection
 - Requirements
 - Additional tests for larger or more complicated systems
 - Must pass category 1 tests before starting category 2 tests
- Notes
 - Both tests not required, may do one test or the other
 - Tests may be done on a sample of the system



Clause 7: Test Procedures Category 2

- Clause 7.2: I-V curve measurement
 - Can be used to measure V_{oc} , I_{sc} , V_{mp} , I_{mp} , and P_{mp}
 - Irradiance must be at least 400 W/m^2 and stable
 - Irradiance meter must be mounted to match the plane of array angle
 - Temperature probe should be attached to back of module at center

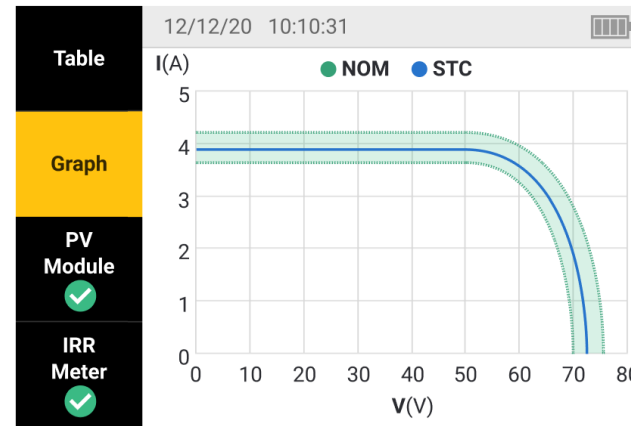


I-V Curve Test – SMFT-1000



The I-V curve is a graphical representation of the relationship between the voltage applied across an electrical device and the current flowing through it.

- Provides a quick and effective means of accessing the true performance of solar PV modules or strings.
- Best in class for in-field IV Curve diagnostics
- Nominal curve-based PV module data
- Min/max area curve allows fast data diagnostics by showing limit range. E.g., $\pm 5\%$ (default)
- IRR2 allows irradiance and temperature adjustment to manufacturer-published specifications
- Color display allows quick test review



12/12/20 10:10:31

Irr: 1000 W/m² Tcell: 73 °F

	NOM	STC
Voc	44.4 V	40.2 V ✓
Isc	5.4 A	5.1 A ✓
Vmpp	50.2 V	50.1 V ✓
Impp	6.4 A	6.1 A ✓
Pmpp	175 W	170 W ✓
FF	95 %	92 % ✓

Pass Criteria: 5%

12/12/20 10:10:31

Table

To get accurate STC measurements, now you can download data from the IRR meter.

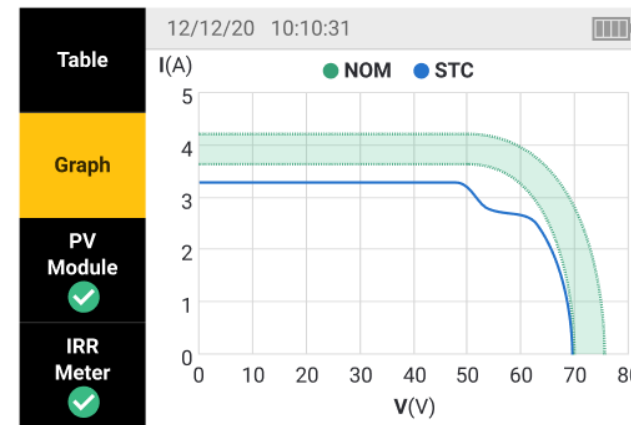
Graph

Make sure the IRR meter is turned on, and within bluetooth range of this device in order to download data.

PV Module ✓

IRR Meter ☹

Manually Enter Irradiance Data



12/12/20 10:10:31

Irr: 1000 W/m² Tcell: 73 °F

	NOM	STC
Voc	44.4 V	30.3 V ✗
Isc	5.4 A	3.3 A ✗
Vmpp	50.2 V	40.1 V ✗
Impp	6.4 A	4.4 A ✗
Pmpp	175 W	122 W ✗
FF	95 %	81 % ✗

Pass Criteria: 5%

Fluke I-V Curve Tracers



	SMFT-1000	PVA-1500T2	PVA-1500HE2
Maximum Voltage (Voc)	1000V DC	1500V DC	
Maximum Current	20A DC	30A DC	
Module Eff $\geq 19\%$	May not test above $\sim 19\%$	10A DC	30A DC

Clause 7: Test Procedures Category 2

- Clause 7.3: PV array infrared camera inspection procedure
 - Array should be operating with irradiance above 400 W/m², preferably above 600 W/m²
 - Scan array, paying attention to diodes, junction boxes, electrical connections
 - Looking for temperature differences that are abnormal
 - Use further inspection / testing to determine root cause



Commissioning/O&M – Thermal Imaging

- Electrical equipment
 - Disconnects, combiners, inverters, transformers
- Modules
 - Aerial or handheld
 - Module interconnects
- With system operating at high irradiance
- TI testing requires training

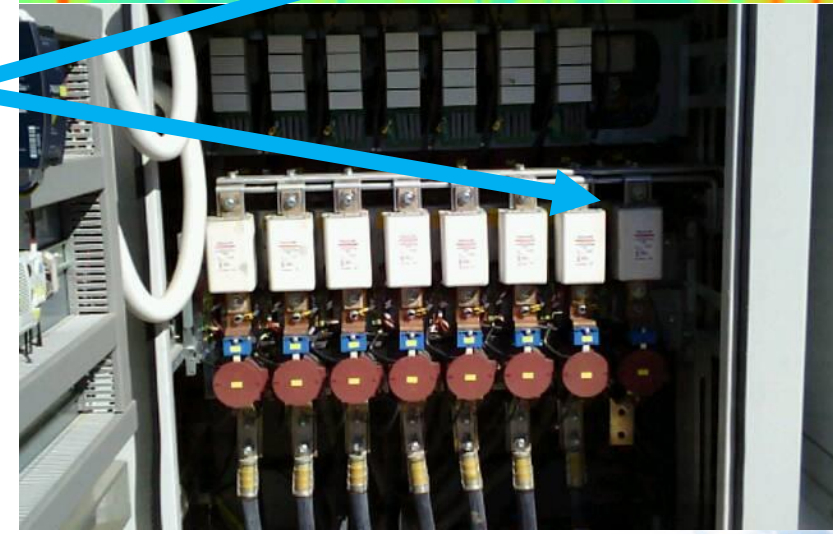
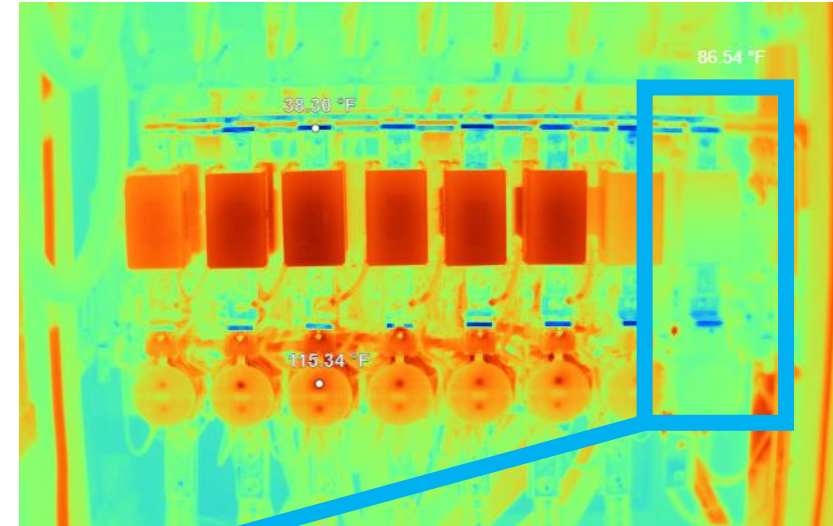


Commissioning/O&M – Thermal Imaging



- Hot equipment = increased resistance
- Cool equipment = no/low current
- Set baseline to ensure proper operation and create historical record
- Appropriate tools
 - Aerial TI cameras
 - Drone-based or fixed wing
 - Handheld TI cameras
 - Fluke Ti480 Pro, TiS55+, PTi120

The circuit is cold because there's no circuit connected.



Clause 5.3: Testing

- Clause 5.3.6: Additional tests
 - Voltage to ground
 - Blocking diode test
 - Wet insulation resistance test
 - Used to find faults when dry test results are questionable or ground faults were detected
 - Shade evaluation
 - Can be used to set a baseline for future evaluation
 - SMFT-1000 can do all but shade evaluation



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Contact America: will.white@fluke.com

Contact Europe: krzysztof.ulfig@fluke.com

Contact Rest of World: felix.baer@fluke.com