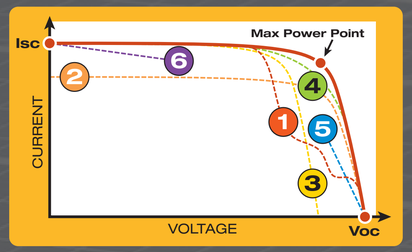
PV Array Performance Troubleshooting Flowchart

FLUKE



START

Does the measurement return an I-V curve?

NO → **No I-V curve?**
Check for missing or blown fuse, and for open circuit in external string conductors. Check for burn marks on module ribbon conductors, overheated module J-boxes, or bad PV connectors.

NO → **Drop-outs in I-V curve?**
Narrow vertical dropouts (downward spikes) or randomly oriented straight line segments may indicate intermittent electrical connection in the PV source circuit. Troubleshoot and repair.

Check for setup problems
Are the test leads connected?
Are PV modules interconnected?

YES ↓

PF > 90% and normal shape?

NO → **Steps in the I-V curve?**

YES ↓

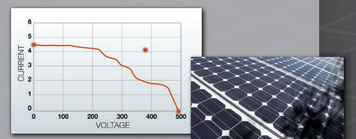
PF = Performance Factor
= Pmax (measured) / Pmax (predicted)

YES ↓

Save Data and Test Next String

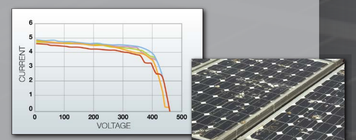
1

Shading?
Remove obstructions or re-test when un-shaded.



NO ↓

Random soiling, debris or snow?
Clear modules and re-test.



NO ↓

Mismatched modules?
A string of modules with significantly mismatched currents will show slight steps along the I-V curve.

NO ↓

Cracked cells?
Cell cracks may not be visible to the eye, but can take part of a cell out of production. Find the bad module using the Selective Shading Method. Cracked glass is always cause for replacement.

NO ↓

Burn marks?
Replace module.

NO ↓

Other causes: Failing cells; Non-uniform backside irradiance (bifacial modules); Non-uniform module orientation (terrain-following arrays).

TROUBLESHOOTING TIP
In some cases the I-V curve trends down and to the right with less distinct steps.

YES → **Low Isc?**

2

Uniform soiling?
Clean modules and re-test.

NO ↓

Dirt dams? / Strip-shade?
A narrow strip of dirt or shade that is consistent across all cell groups in all modules of the string can reduce current without causing steps in the curve. Re-test after cleaning or removing shade.

NO ↓

Inconsistent string orientation (terrain-following arrays).

NO ↓

Possible performance degradation. Re-test in future to reveal trend.

Check for setup problems
Is the irradiance sensor oriented in the plane of the array?

Are the irradiance sensor and the string under test seeing the same irradiance? (Under patchy clouds, there may be a difference.)

Does the sensor have the same view of the sky as the strings under test?

Is the sensor free of local reflected light?

Do the modules in the string match the module in the Properties menu?

TROUBLESHOOTING TIP
Voc normally ages very slowly (adjusted for temperature). Check for other causes before concluding that Voc has degraded.

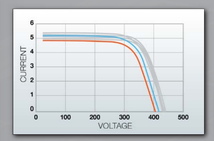
YES → **Low Voc?**

3

Low by multiple of module Voc?
The string may be missing a module. (The voltage reduction is smaller if measuring strings in parallel).

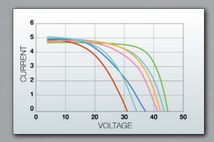
NO ↓

Low by multiple of cell group Voc?
Possibly shorted bypass diode, especially if Voc is reduced by the Voc of a cell group. Locate the module using Selective Shading Method. Replace affected modules.



NO ↓

Combined with other deviations?
When Voc and Fill Factor are randomly low from string to string, Potential Induced Degradation (PID) is a likely cause. Break down the worst string and measure each module (example below). PID affects modules operating at high **negative** voltage.



NO ↓

Replace module or re-test in future to reveal trend.

Check for setup problems
Is the thermocouple attached to an average temperature location? Attaching the TC near the cooler edges of the table causes over-prediction of Voc.

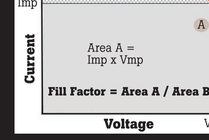
Is the tip of the thermocouple in good contact with the module backside?

If using two thermocouples, are they both attached to the backside of the module? If one of them is measuring air temperature and the two TC readings are being averaged, Voc is overpredicted.

YES → **Rounder knee?**

4

Possible cell degradation
(ideality factor)



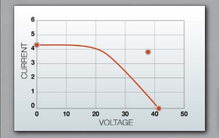
Most often a softer (less square) knee is just the result of the tilting inward of the vertical or horizontal (or both) legs of the I-V curve, deviations 5 & 6. A much less common cause is cell degradation involving a change in the cell ideality factor.

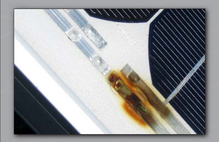
TROUBLESHOOTING TIPS
- For best agreement between measured and predicted I-V curves measure with irradiance > 700W/m2 in the plane of the array.
- A bad PV module can often be identified without disconnecting modules from one another, using the Selective Shading Method. For a string of N modules, measure the I-V curve N times, applying hard shade to a different module each time. Cover at least two cells in each cell group. Shading forces the module's bypasses to conduct, removing the shaded module's influence of the shape of the I-V curve. If shading a certain module improves the shape of the curve, then that's the problem module.

YES → **Reduced slope in the vertical leg of the curve?**

5

Possible excess series resistance
Excess series resistance reduces the slope of the vertical leg of the I-V curve. Check modules and external wiring for bad connections and overheating.





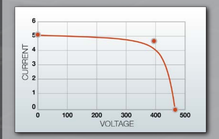
Potential Induced Degradation (PID)
Excess series resistance reduces the slope of the vertical leg of the I-V curve.

Check for setup problems
Are the home run conductor length, gauge, and metal (copper or aluminum) correctly entered in the PV model?

YES → **Increased slope in the horizontal leg of the curve?**

6

Thin sliver of shade or soiling across all cell groups
A tapered sliver of shade or dirt across all cell groups causes a steeper slope in the horzontal leg of the curve. Retest after clearing shade or dirt. Re-test clean and un-shaded.



Increased slope can also be caused by long-term degradation of cell shunt resistance or Potential Induced Degradation

Definition of Fill Factor
Low Fill Factor indicates poor I-V curve shape. An ideal I-V curve would be a rectangle (square knee). Crystalline silicon modules typically have FF values between 0.7 and 0.8.

Indicates Possible PV Module Replacement

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