PV Array Performance Troubleshooting Flowchart

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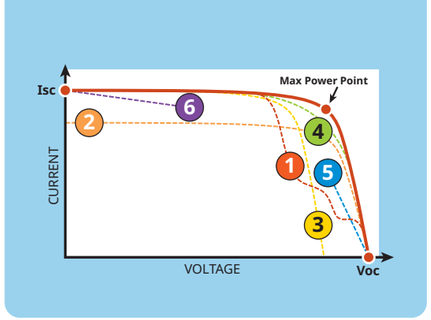

Indicates Possible PV Module Replacement

START

Does measurement return a useful I-V curve?

NO → **Are the test leads connected? Are PV modules interconnected?**

No I-V curve? NO → **Drop-outs in I-V curve?**

- **No I-V curve? YES:** 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. Replace affected modules.
- **Drop-outs in I-V curve? YES:** Narrow vertical dropouts (downward spikes) in the I-V curve may be caused by intermittent electrical connections in the PV source circuit. Troubleshoot to locations and repair.

YES → **PF > 90% and normal shape?**

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

NO → **Steps in the I-V curve?**

YES → **Save Data and Test Next String**

SunEye 210
Shade Measurement Tool

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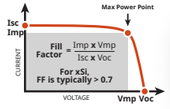
- **Steps in the I-V curve? YES:** **Shading?** YES: Remove obstructions or re-test when un-shaded.
- **Random soiling, debris or snow?** YES: Clear modules and re-test.
- **Mismatched modules?** YES: A string of modules with significantly mismatched currents will show slight steps along the I-V curve.
- **Cracked cells?** YES: Cracked cells may not be visible to the eye. Find the bad module using the **Selective Shading Method**. May be cause for module replacement if cracked segment is electrically isolated. Cracked glass is always cause for replacement.
- **Burn marks?** YES: Replace module.

Check again for shade. Diffuse shade is hard to detect by eye. Look for more distinct shadows alongside the array. Light reflected from nearby objects can also cause steps. When testing strings in parallel a step in the curve can also be caused by a shorted bypass diode.

NO → **Low Isc?**



Smooth curve but Low Fill Factor?

YES → **2**

- **Is the irradiance sensor oriented in the plane of the array? Does it have the same view of the sky as the strings under test? Is the sensor free of reflections? Is the correct module selected for the PV model?**
- **Uniform soiling?** YES: Clean modules and re-test.
- **Dirt dams?** YES: A strip of shade or soiling that is consistent across the string can reduce current without causing steps in the curve. Re-test after cleaning or removing shade.
- **Strip-shade?** YES.
- NO → **Possible performance degradation. Re-test in future to reveal trend.**

NO → **Low Isc?**

NO → **Low Voc?**

YES → **3**

- **Is the thermocouple attached at a typical temperature location, and is it contacting the module backside? Is the irradiance high enough for a reliable Voc test?**
- **Tip:** Voc normally ages very slowly *(adjusted for temperature)*. Check for other causes before concluding that Voc has degraded.
- **Low by multiple of cell group Voc?** YES: Possibly shorted bypass diode(s), especially if Voc is reduced by a multiple of the Voc of a cell group. Locate the module using **Selective Shading Method**. Replace affected modules.
- **Combined with other deviations?** YES: Possibly Potential Induced Degradation (PID), especially if combined with reduced Fill Factor. Replace affected modules.
- NO → **Replace module or re-test in future to reveal trend.**

NO → **Rounder knee?**

YES → **4**

Possible cell degradation *(ideality factor)*. Re-test in future to reveal trend.

NO → **Low Voltage Ratio? Vmp/Voc**

YES → **5**

Are the home run wire length and gauge correctly accounted for in the PV model?

Possible high series resistance. Check modules and string wiring for bad connections or overheating. Replace affected modules.

NO → **Low Current Ratio? Imp/Isc**

YES → **6**

- **Tapered shade or soiling across modules?** YES: Re-test clean and un-shaded.
- **Slightly current-mismatched modules?** YES: I-V curve may show increased slope in the horizontal leg, with or without slight steps. Document mixed module types.
- NO → **Possible degradation of cell shunt resistance. Serious shunts may be visible to IR imager or to the eye. May also be symptom of PID. Possible module replacement.**

TROUBLESHOOTING TIPS

- For best performance measurement accuracy, 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 the bad module bypasses it and returns a normal curve shape. In the case of a shorted bypass diode, shading the bad module causes a smaller drop in Voc.
- See the NREL module inspection checklist at www.nrel.gov/docs/fy12osti/56154.pdf. To contribute to NREL research, send failure observations to Corinne.Packard@nrel.gov.

Fluke Solmetric PVA 1500HE
I-V Curve Tracer

Fluke Solmetric SolSensor
Wireless PV Reference Sensor