Cracked Cells and PV System Performance

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D2 solar

Powered by SunShot
U.S. Department of Energy

PVRD2

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EL/PL cameras & light source

Mechanical Load Testing

“Lab” IV and EL in the field

UV Fluorescence Testing

EL Camera CellSpot-PL

Look while you load

LoadSpot

MobileTestSpot

UVF

Drone Image
Standard Testing Conditions (STC)

• 25°C, 1000 W/m²

• How used?
  – Get as close to STC as possible during measurement
  – Apply correction factors to translate results to STC

• Why important?
  – Enables test labs worldwide to obtain similar results
  – In a $/W_p$ world, STC for IV testing determine $
STC - shortcomings

- Some degradation modes with shunting and diode degradation characteristics affect low light performance **more** than at STC
  - PID (Potential Induced Degradation)
  - Cell cracking
  - Shunting in thin film modules
- Series resistance problems may affect low light performance **less** than at STC
- If just measure STC degradation, may miss a big part of the picture
- Energy delivery degradation rates may be worse than STC degradation rates

[Schneller, 2017 NREL PVRW]
Crack effects – single cell

<table>
<thead>
<tr>
<th>Cell</th>
<th>Eff @1Sun</th>
<th>Eff @ 0.4Sun</th>
<th>rel. % diff</th>
<th>Eff @ 0.2Sun</th>
<th>rel. % diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>18.7%</td>
<td>18.5%</td>
<td>-1.0%</td>
<td>17.9%</td>
<td>-3.9%</td>
</tr>
<tr>
<td>Cracked</td>
<td>15.7%</td>
<td>14.7%</td>
<td>-6.7%</td>
<td>13.2%</td>
<td>-15.9%</td>
</tr>
<tr>
<td>Badly Cracked</td>
<td>11.8%</td>
<td>10.0%</td>
<td>-15.4%</td>
<td>8.3%</td>
<td>-29.9%</td>
</tr>
</tbody>
</table>

- Eff loss correlated to total length of cracks
- Worse at lower irradiances/currents due to shunting/recombination
Crack effects - module

Sinton FMT-500 IV Flash tester (Eff vs Irradiance)

- Faster falloff at low irradiance due to cracks

Initial

After static loading
Energy Delivery Calcs (hypothetical)

• Might miss significant energy loss by just measuring 1-Sun $P_{\text{max}}$

Most valuable electrons
How Do Cracks Evolve?

- **Microcracks** (<1mm) are nuclei of most cracks
  - Soldering, laser cutting, rear impacts, <-30°C exposure
  - Front side pressure puts cells into tension and microcracks propagate into full cracks visible by EL
- Front side hail or Rear side impacts on polymer backsheets can create “X” or “spider cracks”
  - Can later propagate with front side pressure
- Strong shocks (dropped panel) can also create cracks
- Most cracks are closed at first
  - Metallization continuous across crack
  - Minimal power loss at STC
- Cracks open over time with
  - Cyclic loading
  - Thermal cycling

[Schneller, 2019 IEEE PVSC]
LoadSpot – Mechanical Load Tester

• Static and Cyclic loading vs EL(time)

• See huge differences between panels

Look while you load
Electroluminescence (EL) Equipment

BrightSpot Automation
Low-cost, high resolution solutions

AePVI
Drone solution

Daylight solution
Contactless & Daylight solution

Auto histogram stretch software

High throughput string biasing solution
UV Fluorescence

Every O&M group should have a UVF handheld system!

**Pros**
- No biasing of panels!
- Quick
- Low cost
- Tell when cracks happened

**Cons**
- Not for glass/glass panels
- Not for panels < 1 year in field
- Can’t tell how “bad” a crack is

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Handheld

Pole-mount

Drone-mount

Smart UV Light

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**RailPad** — protective compressive stress

- Greatly reduce deflection vs load
- Prevent cracks from forming
- Prevent existing cracks from opening
- New and Retrofit designs
- Better financing and insurance rates?
- Contact BrightSpot for field trials
Technology Trends – overall in the right direction!

**Lower Crack Risk**
- Glass/glass – no tensile stress
- More interconnect wires – smaller disconnected areas
- Conductive adhesive (some shingled) - fewer microcracks
- Parallel wiring – cells less likely to enter reverse bias
- Better packaging
- More EL quality control testing – factory, pre and post install

**Increased Crack Risk**
- Laser cut cells (half-cut, shingled) - microcracks
- Larger modules - more deflection and tensile stress
- Thinner wafers – easier crack propagation

[Crack Worry Trendline]

[Gabor, 2017 NREL PVRW]
Thank You

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