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Results of I-V Curves and Visual Inspection of PV Modules Deployed at TEP Solar Test Yard

Peter McNutt, John Wohlgemuth, David Miller, Blaise Stoltenberg – NREL

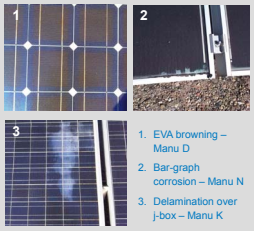
Background

- The purpose of the PV Service Life Prediction project is to examine & report on how modules fielded 5 or more years are holding up
- Testing performed January 13-16, 2014
- NREL compared test results to 2012 testing performed by University of Tucson (Kopp, et. al.) as well as against STC nameplate ratings
- Details of module tests from three manufactures are presented
- Present the common problems crystalline-silicon and thin-film modules exhibit

Tucson Electric Power Solar Test Yard

Test Method

- Perform visual inspection (per Packard 2012 paper)
- Take IR images
- Take photos
- Take I-V traces



1. EVA browning – Manu D
2. Bar-graph corrosion – Manu N
3. Delamination over j-box – Manu K

Test Equipment

- **Solmetric PVA-600 PV analyzer**
- **600 Vdc and 20 Adc**
- **Capacitive load**
- **Operating temperature -0°C to 50°C**
- **~ $5000**

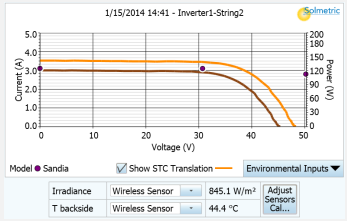
- Type K thermocouple
- 1.0°C resolution and accuracy
- Range -100°C to 200°C
- Wireless connection to PVA-600
- Field measurements include performance factor of PV modules or strings (measured / expected)

- ***FLIR T440 IR camera***
- ***320 x 240 pixel resolution***
- ***< 0.045 thermal sensitivity***
- ***Temperature range -20°C to 1200°C***
- ***7.5 to 13um spectral range***
- ***~ $11,000***

- *Reference cell – IMT Solar*
- *monocrystalline*
- *cell embedded in EVA between glass & Tedlar*
- *active temperature compensation*
- *0 to 1500 W/m² range*
- *Operating temperature -20°C to 70°C*
- *+/- 5% typical accuracy*
- *Wireless connection to PVA-600*

Manufacturer A

- Crystalline Si
- Deployed ~ 2003
- Glass superstrate and polymeric backsheet
- All 16 modules have bubbles in backsheet
- Discoloration pattern around j-box, parallel bus lines, and cell edges

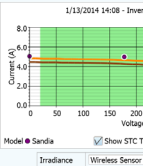


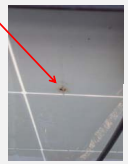
- In 2014, measured values divided by nameplate ratings were 44% and 94% for 2 modules
- In 2012 Kopp paper, the rating ranged from 44% to 94% for 8 modules

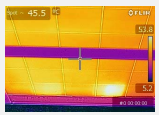
- Module Nameplate Ratings:
- Pmp = 180 W
- Imp = 3.33A
- Voc = 66.4V
- Vmp = 54V
- Isc = 3.65A

Manufacturer C

- Crystalline Si Module
- glass superstrate and polymeric backsheet
- *Deployed 2006*
- String I-V performance ranged between 78% to 89% (measured 2 strings of 9 modules – range was 58% to 89% in 2012 Kopp paper measuring 9 individual modules)
- Observed hot spots on 2 out of 18 modules







- 65% of nameplate rating I-V trace – 9 module string

- String STC Nameplate Ratings (9 modules):
- Pmp = 1521 W
- Imp = 4.77 A
- Voc = 388 V
- Vmp = 311 V
- Isc = 5.46 A

Major Visual Observations

Crystalline-Silicon modules

most have glass superstrates and polymeric backsheets

(manufacturer)

D. 9 modules, deployed 2004 - 8 modules have typical EVA browning (1 recent replacement); All have loose j-box lids; Labels have fallen off all modules. Output (I-V) of 3 modules ~ 82% of nameplate rating (see photo 1)

E. 10 modules, deployed ~ 2003 – 10 modules show no visible signs of defects. 2 modules ~ 76% of nameplate.

F. 8 modules, deployed ~ 2000) – all show typical EVA browning. No I-V taken.

G. 15 modules, deployed 2009 - 1 module had burn mark on the back; all modules have frame adhesive oozing out of frames onto module front No I-V taken.

H. 9 modules, deployed 2003 – no visual defects. 2 modules ~ 72% of nameplate.

I. 8 modules, deployed 2003 - All modules had some bubbles and ridges between cells in backsheet; EVA discoloration. 3 modules ~ 72% of nameplate.

J. 20 modules, deployed 2000 - Typical (but not pronounced) EVA discoloration. 3 modules ~ 69% of nameplate.

K. 72 glass-on-glass modules, deployed ~2001 - All have delamination above j-boxes; 6 modules have delamination in a corner or at an edge with subsequent corrosion of metallization. No I-V taken. (see photo 3)

Thin-film modules

L. CIS, glass-on-glass, (deployed ~ 2003) – 2 of 20 modules removed (due to broken glass); Remaining modules had no visual defects. 2 modules ~ 76% of nameplate

M. CIGS, polymeric front & backsheet with discreet cells (deployed ~ 2003) - Some curling of substrate and delamination of superstrate. 1 module ~ 76% and 1 module ~ 55% of nameplate.

N. a-Si, glass/glass (deployed ~ 2004) - 1 of 150 had broken back glass; Corrosion around junction box contact feed through area on all modules; About 2/3rds of the modules had bar graph corrosion in lower corners. 4 module ~ 63% of nameplate. (see photo 2)

References

- TEP Solar Test Yard PV Site Visit - 2013/2/05), David Miller, NREL, April 2013.
- I-V Curves and Visual Inspection of 250 PV Modules Deployed over 2 Years in Tucson, Emily S. Kopp et al, University of Arizona, Tucson, 2012
- Development of a Visual Inspection Data Collection Tool for Evaluation of Fielded PV Module Condition, Corrine Packard et al, NREL, August 2012.
- PV SYSTEM REPORTS AT THE TEP SOLAR TEST YARD – available at http://uapv.physics.arizona.edu/pdfs/teptestyard_field_IVcurves.pdf
- Historic data for the TEP Solar Test Yard site is also available on the website http://uapv.physics.arizona.edu/dlpvdata.php

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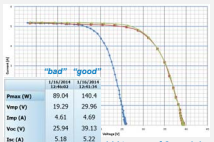
Manufacturer B

- *Crystalline Si Module –*
- *glass superstrate and polymeric backsheet*
- *deployed 2005*
- *1 out of 18 modules had burn mark on back which was also visible on front of cell*
- *Evidence of overheating at output lead solder bond (6 out of 18)*
- *IR image detected module with 2 rows of hot cells – I-V trace found module output to be 56% of expected*
- *Performance range for this module was not reported in 2012 Kopp paper*

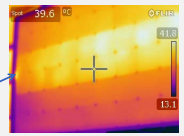


I-V traces of 3 modules – one "bad" & two "good"

comparison of "bad" (56%) and "good" (88%) modules

- Module STC Nameplate Ratings:
- Pmp = 170 W
- Voc = 44 V
- Isc = 5.4 A
- Imp = 4.9 A
- Vmp = 34.7 V

hot spot at j-box & 2 rows of hot cells



Conclusions

- *IR images quickly detect problems*
- *Visual inspection after IR image usually determines the exact cause of problem*
- *Testing should be done by teams of two or more people working closely together*
- *Best procedure would be to scan arrays & modules first with an IR camera, then take visual photos and I-V traces*
- *Major visual defects included EVA browning, delamination, burn marks, oozing adhesive, backsheet bubbles, and broken glass.*
- *Some modules show no signs of visual defects*
- *Overall, after being deployed from 4 to 12 years, the modules were found to be operating fairly well, still delivering from 55% to 82% of their nameplate rating*

- *NREL is looking for other older PV systems to do testing & analysis*
- *Contact: Peter McNutt | peter.mcnutt@nrel.gov | 303 384 6767*

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