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

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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 manufacturers are presented
• Present the common problems crystalline-silicon and thin-film modules exhibit

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

Test Equipment
• Solmetric PVA-400 PV analyzer
• 600 Voc and 20 Adc
• Capacitive load
• Operating temperature -16°C to 55°C
• -5500
• Type K Thermocouple
• 1°C resolution and accuracy
• Range +100°C to 200°C
• Wireless connection to PVA-400
• Field measurements include performance factor of PV modules or strings (measured / expected)

Manufacturer A
• Crystalline Si Module
• 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

Manufacturer B
• Crystalline Si Module – glass superstrate and polymeric backsheet
• Deployed 2005
1. 18 of 18 modules had burn mark on back which was also visible on front of cell
2. Evidence of overheating at output lead solder bond (6 out of 18)
3. IR image detected module with 2 rows of hot cells – I-V trace found of module output to be 59% of expected
4. Performance range for this module was not reported in 2012 Kopp paper

Manufacturer C
• Crystalline Si Module
• glass superstrate and polymeric backsheet
• Deployed 2006
• String I-V performance ranked 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

Major Visual Observations

Crystalline-Silicon modules had two plane superimposed crystalline backsheet (manufacturer)
D. 8 modules, deployed 2004 – 6 module have typical EVA browning (1 recent replacement). All have loose “j-box” lids. Labels have fallen off all modules. Output (I-V) 9 modules = 82% of nameplate.
E. 10 modules, deployed – 2003 – 10 modules show visible sign of defects
• 2 modules – 76% of nameplate
• F. 8 modules, deployed 2001 – 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 into module front. No I-V taken.
H. 9 modules, deployed 2000 – 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. 25 modules, deployed 2001 – 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)
L. CIS, glass-on-glass, (deployed ~ 2003) – 2 of 20 modules removed (due to broken glass)
Remaming module had no visual defects, 2 modules – 76% of nameplate
M. CIGS, polymeric front & backsheet with discreet cells (deployed ~ 2002) – Some coating of subsurface 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. Common around junction box contact feed through area on all modules. About 2/3rds of the modules had bar graph corrosion in lower corners. 4 modules ~ 63% of nameplate, 3 modules ~ 69% of nameplate. (see photo 2)

Thin-film modules
L. CIS, glass-on-glass, (deployed ~ 2002) – 2 of 20 modules removed (due to broken glass)
Remaning module had no visual defects, 2 modules – 76% of nameplate
M. CIGS, polymeric front & backsheet with discreet cells (deployed ~ 2002) – Some coating of subsurface 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. Common around junction box contact feed through area on all modules. About 2/3rds of the modules had bar graph corrosion in lower corners. 4 modules ~ 63% of nameplate, 3 modules ~ 69% of nameplate. (see photo 2)

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 make visual photos and I-V traces
• Major visual defects included EVA browning, delamination of superstrate, corrosion of cell, corrosion of 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, all delivering from 55% to 82% of their nameplate rating
• NREL is looking for other PV systems to do testing & analysis
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References
• TEP Solar Test Yard PV Site Visit – 2013/03/04, David Miller, NREL, April 2013
• I-V Curves and Visual Inspection of 230 PV Modules Deployed 2 years in Tuscon, Emily S. Kopp et at. University of Arizona, Tuscon, 2012
• Development of a Visual Inspection Data Collection Test for Evaluation of Failed PV Module Condition, Centre-Parc Kato in et al. NREL, August 2012
• PV SYSTEM REPORTS AT THE TEP SOLAR TEST YARD – available at http://uapv.physics.arizona.edu/dlpvdata.php
• Historic data for the TEP Solar Test Yard is also available on the website http://uapv.physics.arizona.edu/dlpvdata.php

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