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Photovoltaic Module Imaging for Hail Damage Assessment with Multi-Year Follow Up

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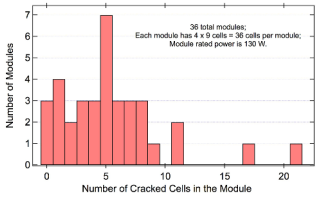
An array of 36 multicrystalline silicon modules installed in 2007 is oriented facing south at a tilt angle of 30 degrees above horizontal. It is located approximately 2 km southwest of NREL in Golden, CO.

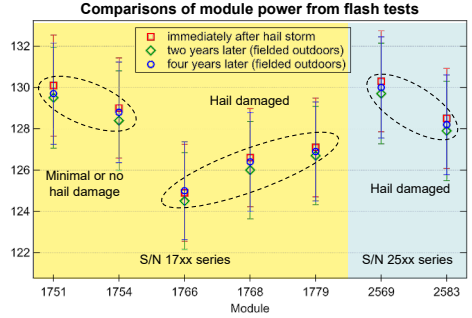
Hail storm

May 8, 2017

Histogram of hail-induced cracked cells per module

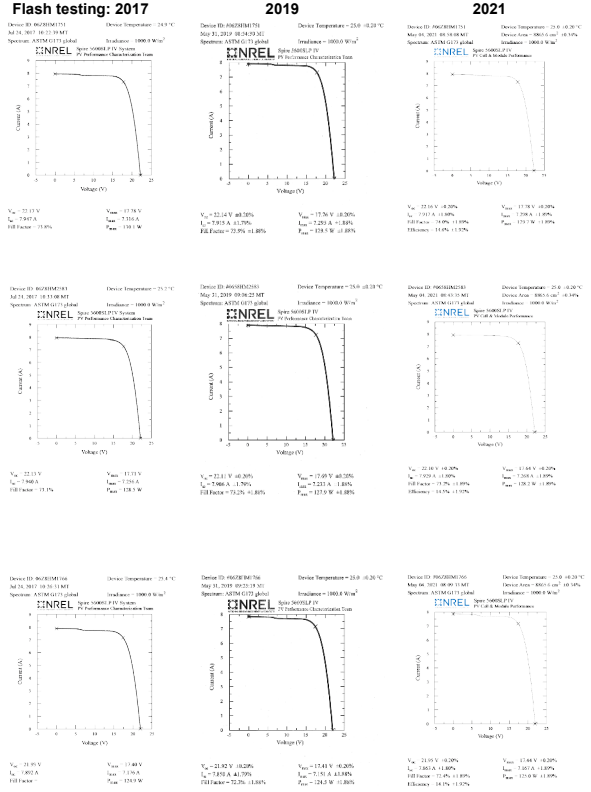


Comparisons of module power from flash tests



	2017 EL, 5A, 10s	2019 EL, 5A, 10s	2021 EL, 5A, 10s	Contactless EL	DLIT, 5A, 0.2Hz, 300s	PL, 808nm, 0.25 Sun intensity, 20s	UVF, 360nm
1751							
2583							
1766							

Flash testing: 2017 | **2019** | **2021**



Electroluminescence (EL) images are collected cell-by-cell using a Princeton Instruments PIXIS 1024BR Si CCD camera with 1024 x 1024 pixels. The images are stitched together into a montage to show the full module EL image of all cells. The EL imaging was collected using parameters of 5 A of forward bias current and a 10 second exposure time per cell.

Contactless EL images are acquired by imaging one half of a cell while the other half is illuminated with light emitting diodes (LEDs).

Dark Lock-in Thermography (DLIT) images are collected for entire module in one back-side image (flipped for comparison). Forward-bias with a current of 5 A is pulsed at 0.2 Hz.

Photoluminescence (PL) images are collected cell-by-cell using uniform excitation light from 808-nm laser diodes of ~0.25-Sun intensity.

Ultraviolet Fluorescence (UVF) cell-by-cell imaging collects the fluorescence of polymer fluorophores to reveal cells with cracks. Laser diode light of 360nm is swept across in a raster pattern.

Summary

- For series S/N 17xx, hail-damaged modules exhibit <4% power loss due to cell cracking, even when up to half of the cells in a module have cracks.
- After four years, modules with hail-induced cell cracks do not yet appear to have a higher degradation rate than same-series modules with little to no hail-induced cracks (based on room temperature flash testing and imaging).
- Series S/N 25xx may have started with higher initial power since hail-damaged modules have higher power compared to similarly-damaged 17xx modules.
- Cell cracks appear dark in UVF for series S/N 25xx modules. However, cell cracks for 17xx modules are bright in UVF due to strong UVF of the backside polymer layers. The different series have a different bill of materials.

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