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Electroluminescent Imaging of Modules Exposed to Snow and Ice Loading: a Preliminary Analysis

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Project Overview

In 2018, Sandia began a 3-year research project to investigate the impact of snow and ice on PV performance and reliability at three field sites in the US. Here we describe our preliminary effort to identify and measure solar-cell cracking and other indicators of snow-induced damage at our field site in VT.

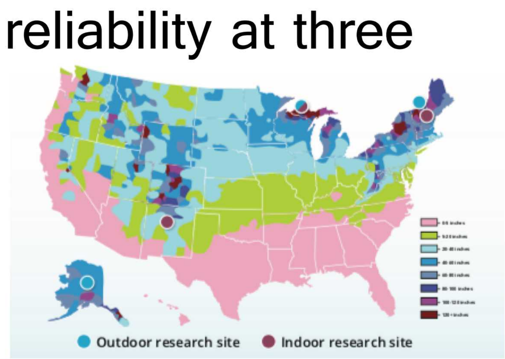

Figure 1. Map of annual snowfall across the US

Technical Objectives

- Identify—via electroluminescent (EL)imaging—module and cell damage attributable to long-term snow and cold exposure
- Correlate EL damage with specific module technologies/architectures and with recurring patterns of ice-snow build-up, as captured in visual images
- Provide data to inform the design of PV systems that are more reliable in wintry environments than climate-agnostic designs

Rationale

- **Growth of solar-electricity generation across northern latitudes** --Rough estimates of snow losses range from 1 to 15% annually, though the variables are not well understood.
- **Long-term reliability of PV modules exposed to persistent low temperatures and to ice/snow accumulation is unknown**
- **Low-temperatures can weaken solar cells,** increasing their fragility under snow load [1].
- **Encapsulant contributes to cell cracking;** cold thought to be a factor [2].
- **Snow shading of thin-film modules needs investigation, based on Silverman's shading research** [3].

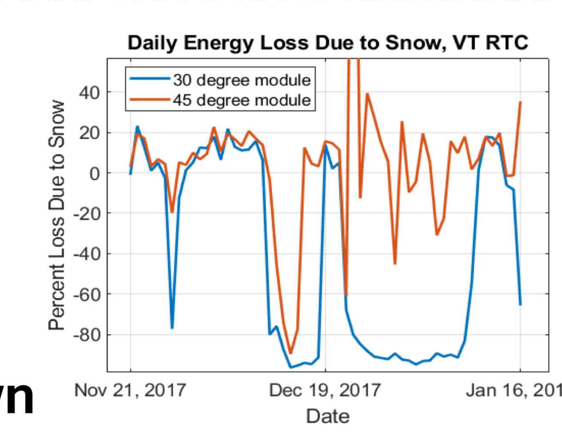

Figure 2. Monthly snow losses measured in VT

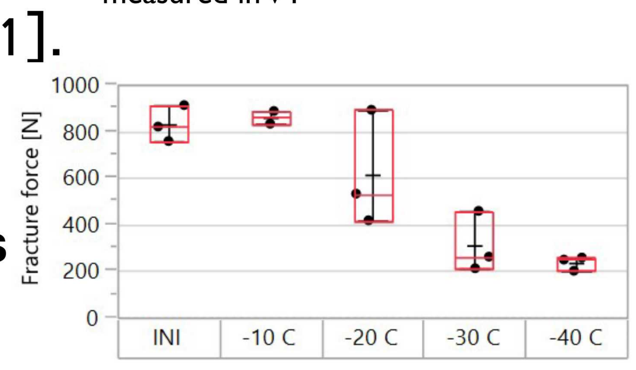

Figure 3. Susceptibility of encapsulated cells to load fracture at low temperature [1, 2]

Figure 5. Differential snow shedding across modules creates mechanical stress

Figure 4. Differential snow shedding across monolithic CIGS modules creates electrical stress

Methodology

- DSLR IR camera (6000 x 4000 pixels), with a filter calibrated for EL-spectrum sensitivity of solar cells and filter to block visible light.
- Panels were current- and voltage-biased using an external 60V, 11Amp DC power supply. Current bias set at nameplate Isc.
- Indoor imaging in darkroom setting: modules in portrait orientation, perpendicular to tripod-mounted camera.
- Outdoor imaging: modules imaged *in situ* at night; camera on a weighted boom-arm tripod.

Figure 6. Indoor darkroom

Acknowledgments

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Preliminary Results

Table 1. Module technologies imaged at the VT RTC.

EL imaging of PV modules at the VT Regional Test Center – Feb 2019				
Module Type	# modules imaged	Years in field	Camera setting f-stop/ISO/sec exp	Nameplate Isc () I and V during image
Mono-c-Si– baseline	tbd	0		
Mono-c-Si – outdoor 35° tilt	12	4	f 6.3/iso 320/ 48 sec	(9.18 Isc; 38.4 Voc,) 40.89 V, 9.21 A
Monolithic thin-film – indoor spare	1	0	(See CFV files)	
Monolithic thin-film – outdoor 35° tilt	10	4	framed- f 5.6/ iso 500/ 58 sec- shot in lab	framed (2.65 Isc; 78.8Voc)
Bifacial glass-glass module – indoor spare	1	0		
Bifacial glass-glass– outdoor on 2-axis tracker	2	2	f11/ iso 500/ 15 sec	(12.0 Isc; Voc 40.2,) 40.25 V, 10.91 A
Shingled cell modules – indoor spare	1	0	f3.8/ iso 2500/ 30 sec	(8.57 Isc, Voc 51.5) 58 V, 8 A
Shingled cell module—outdoor 35° tilt	2	2.5	f-9/iso 500/ 63 sec	(8.57 Isc, Voc 51.5) 59.07 V, 8 A

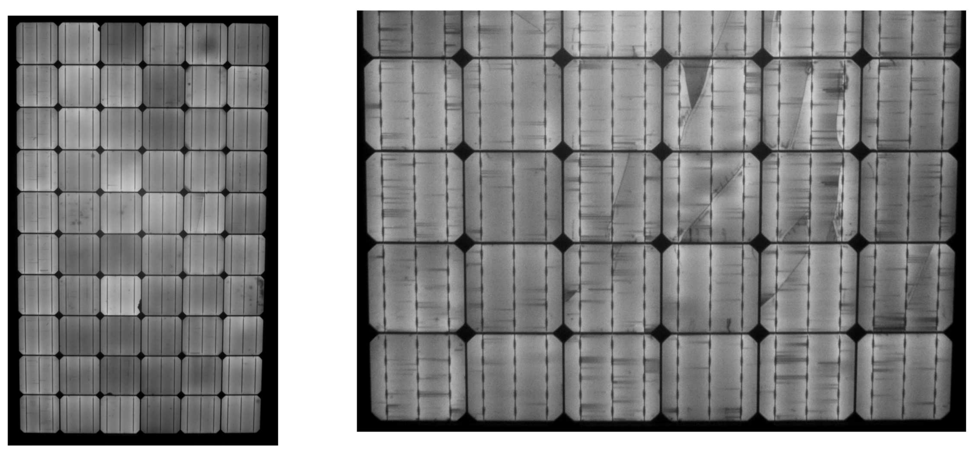

Figure 7. Mono-crystalline modules. These modules reflect separate bins, as indicated by their serial numbers, and likely reflect different manufacturing processes, as they can be divided into one of two categories: with or without busbar discontinuity. Note that the image on the left has a clear crack and electrically dead area; Image on the right shows evidence of multiple cracks and discontinuities where the fingers meet the busbars. Although it is impossible for us to say when and how these cracks formed, at a minimum, this image reinforces the need for post-transportation, pre-installation imaging.

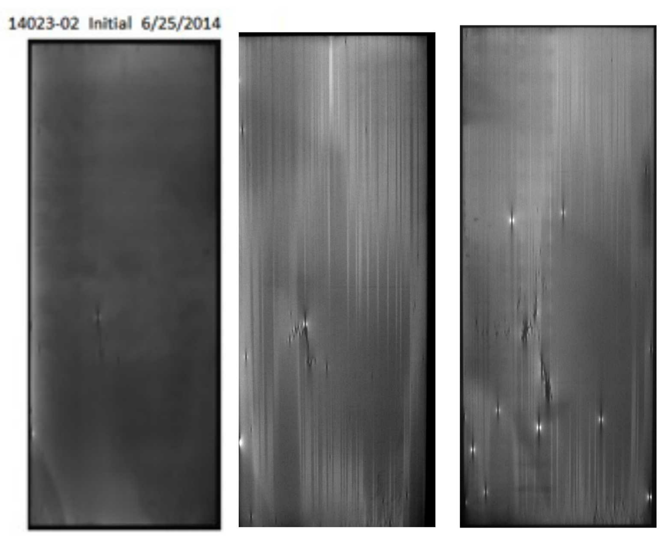

Figure 8. Thin-film modules, with baseline image (*left*); fielded module four years later (*center*) and second fielded module (*right.*) Deterioration can be seen, with a worsening shunt in the module's center and new shunts on the left edge. The far right image, which lacks a baseline counterpart, is more typical of the thin-film modules we imaged.

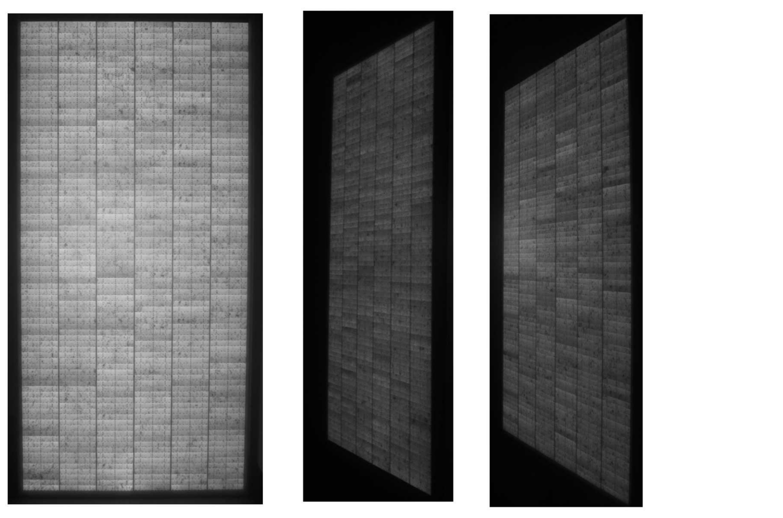

Figure 9. Shingled-cell modules, with spare (*left*) and two fielded modules (*right.*) Exposures make for difficult comparison but the fielded modules appear to have had electrical degradation, with no discernible pattern to the latter.

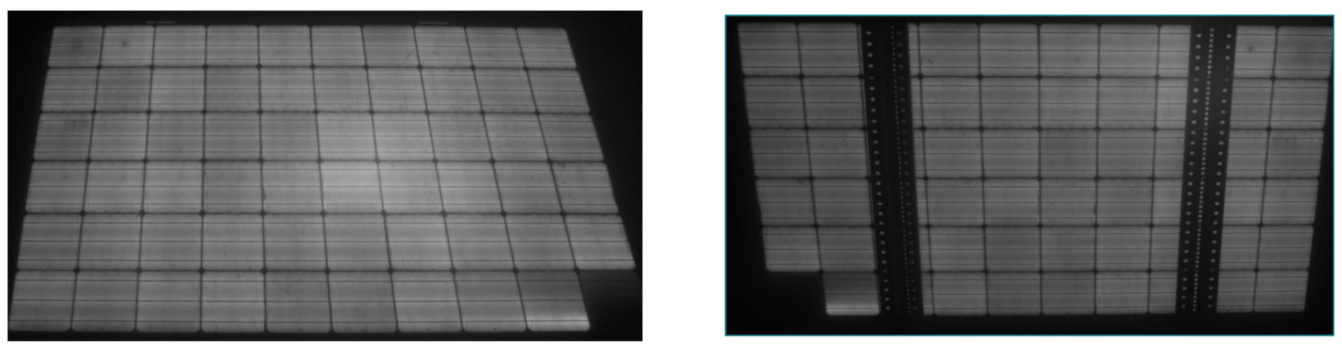

Figure 10. Front and backside images of frameless bifacial modules. No cracks are visible after two years on a dual-axis tracker but note the black, or dead, cell, which was likely damaged during handling.

- The above results, which represent a relatively small subset of modules, are both preliminary and inconclusive. Without a baseline EL image of every module, against which subsequent images can be compared, lacking signature damage patterns, no conclusions can be drawn.
- Even so, we believe this work underscores the need for further investigation into the impact of snow and ice loads, as well as sub-zero temperatures, on PV reliability.

Planned Research

- Numeric quantification of cracks across all module types [4]
- Longitudinal field studies to track changes annually; more diversity
- Laboratory analysis under controlled, low-temperature conditions of cell-fracture strength, thin-film snow shading and encapsulant behavior

References

[1] M. Rowell, S. Daroczi, D. Harwood, and A. Gabor. "The Effect of Laminate Construction and Temperature Cycling on the Fracture Strength and Performance of Encapsulated Solar Cells," 4th WCPEC, June 15, 2018.

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