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Increasing Photovoltaic Efficiency in Snowy Climates: Design Considerations

Project Mission

This 3-year, DOE funded research project, "Snow as a Factor in PV Performance and Reliability," aims to: Increase the performance and resilience of PV systems in snowy regions by identifying and validating design features that reduce snow shading, increase module reliability and boost energy yields.

Background

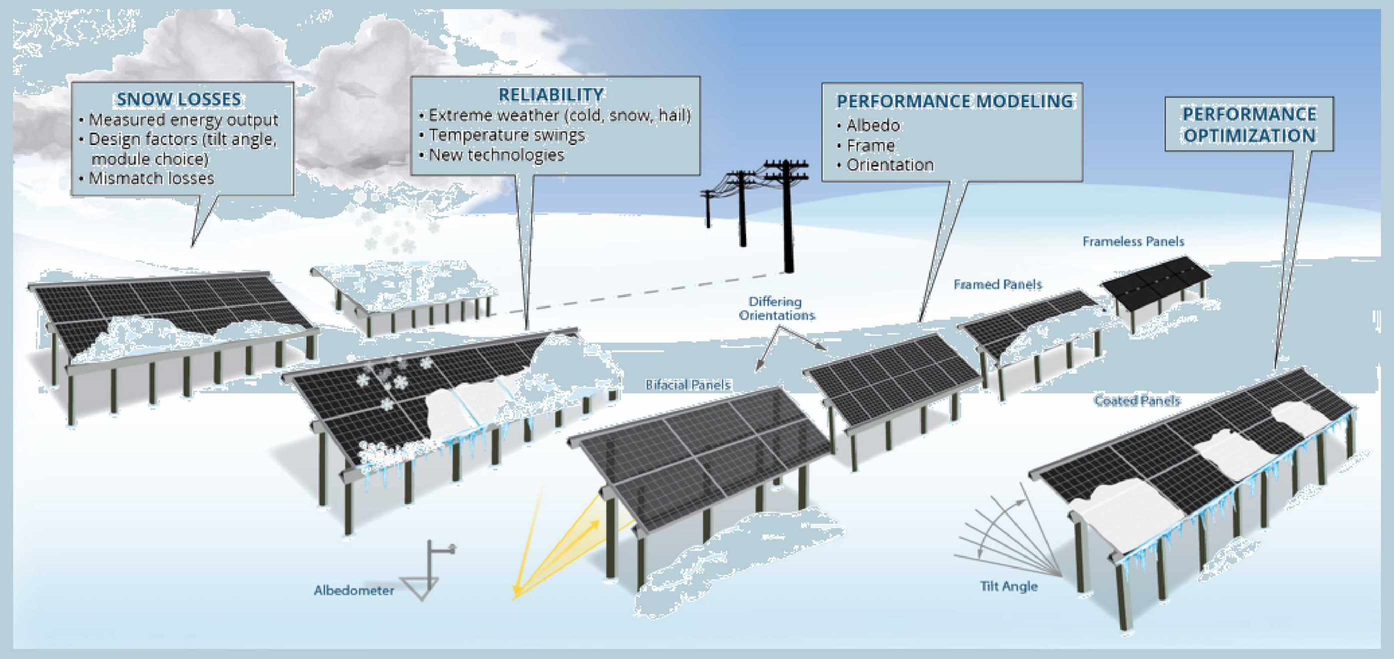
- Growth of PV in northern latitudes is expanding rapidly (rapid drop in costs; performance benefits)
- But energy losses from snow-shaded PV modules are significant and investors and asset owners are increasingly concerned about the impact of snow and ice on system lifetime rates of return
- Mechanical loading from snow and ice also introduces reliability challenges
- At the same time, technological innovation is rampant
- Research on impact of winter on PV systems is just beginning

Study Objectives

- Document the winter performance of paired PV arrays that differ in a single design feature:
  - Frame architecture (framed vs frameless)
  - Module orientation (portrait vs landscape)
  - Module technology (framed vs frameless)
- Quantify differences in energy yield and rates of snow shedding
- Validate results across multiple northern latitude sites that reflect different winter climates.
- Produce set of design guidelines for regions of the world that see persistent snow in winter.

Methodology

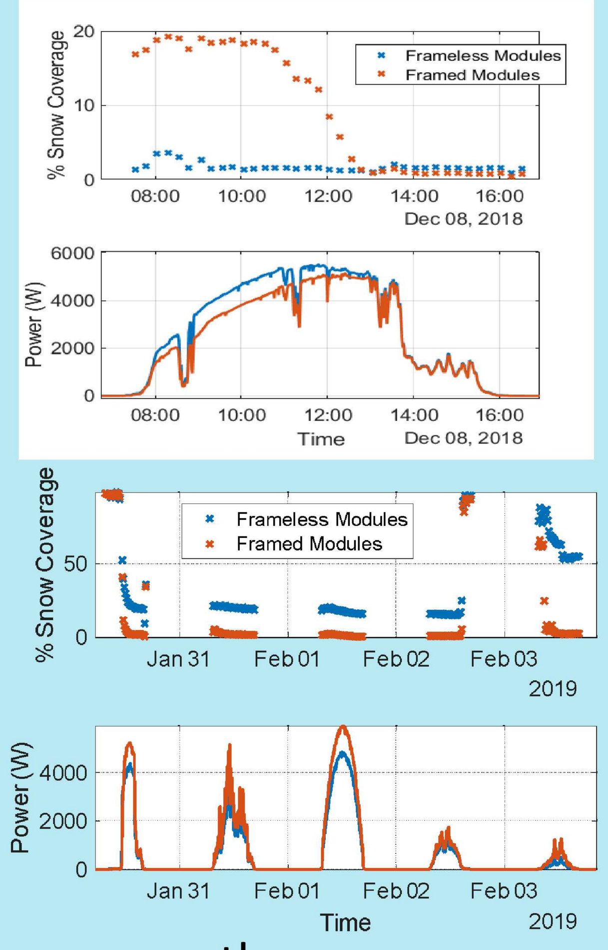
- Data collected from two PV sites in US state of Vermont (VT):
  - Williston, VT (lat. 44.4º N)
  - Bradford, VT (lat. 43.9º N)
- Total of six PV systems (different configurations, technologies)
- Data varies by site but includes plane-of-array (POA) irradiance, ambient air, DC voltage and current, AC energy, digital imagery



Sandia-led investigation of the impact of snow on PV system performance and reliability is focused on the multiple challenges shown in this figure.
Source: Sandia National Laboratories

Preliminary Results

1. Framed vs Frameless Modules



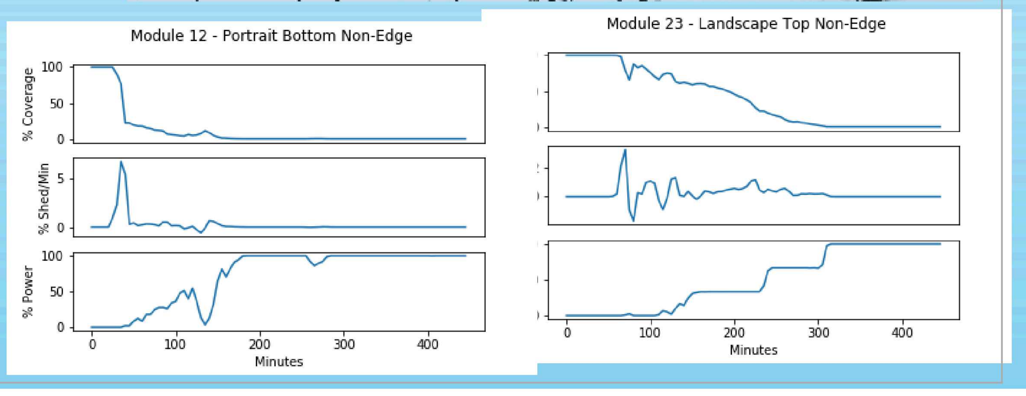
- Adjacent PV arrays have identical electrical and physical properties but differ in the presence/absence of a module frame.
- Data (module temp., DC electrical, POA, and images) synchronized.
- Image analysis software used to determine percentage of module covered with snow.

Results: Frameless modules made up to 10% more power than framed modules but gains are temperature dependent

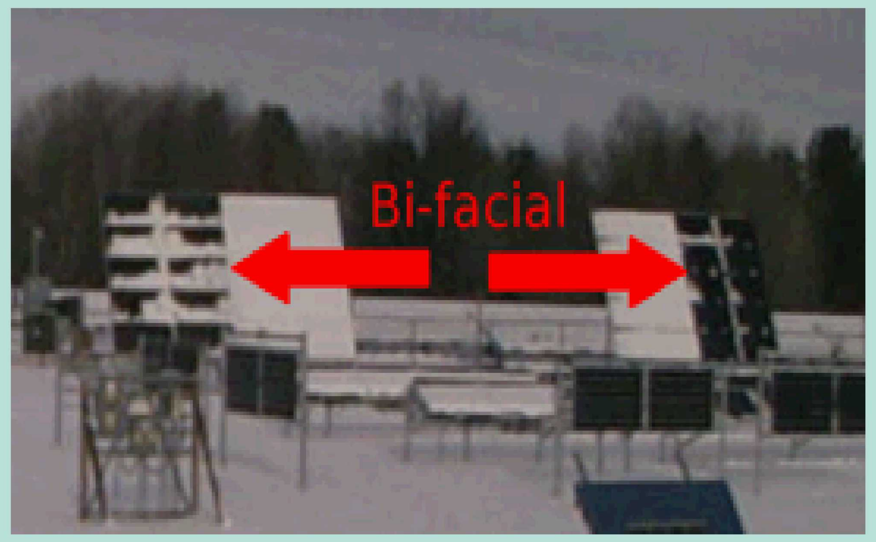
2. Module Orientation

- Adjacent arrays: 58kW landscape; 74kW portrait
- One 23cm snowfall on 24/3/20
- Time-series data extracted and analyzed for 28 modules; 14 portrait and 14 landscape

Results: In this limited study, portrait modules out-performed their landscape counterparts in energy yield and shedding time, although module location matters.



3. Monofacial vs Bifacial



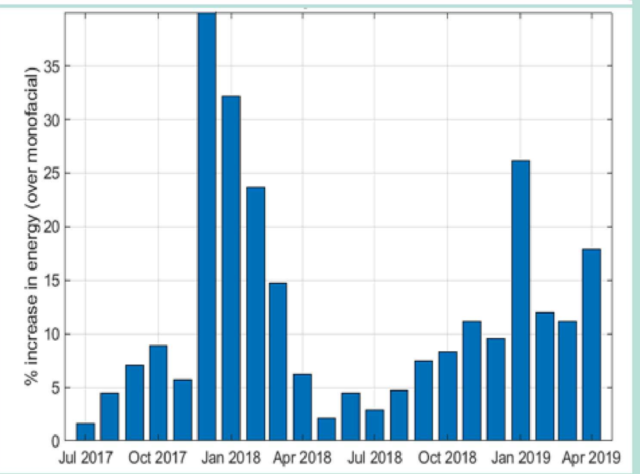
Adjacent 2l-axis trackers, half-populated with mono-facial and bifacial modules.

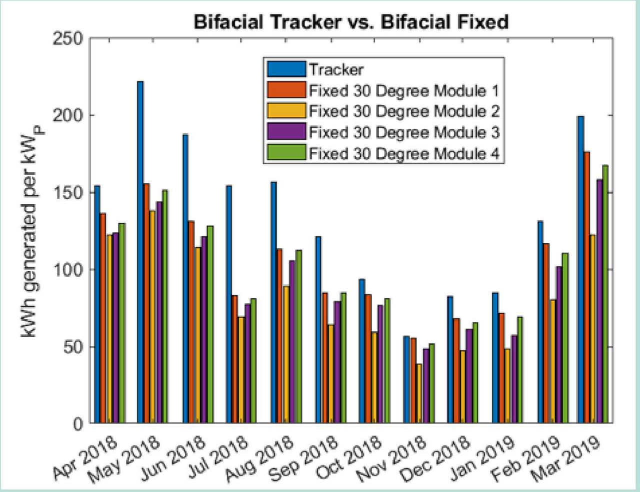
Results:

- Tracker 1 frameless bifacial string produced 14% more power than monofacial string (ann. average); Tracker 2 framed bifacials produced 4% more.
- Dual-axis trackers produced 41% more than fixed-tilt bifacials.
- High-albedo months saw bifi gain of >90%

Table 1. Bifacial dual-axis tracker systems at Vermont test site.

Tracker	Strings	Modules	Module/Cell Technology	Max Power
Tracker One	2	10	Monofacial mono c-Si, 60-cell *framed*	290W
		10	Bifacial N-type mono c-Si, 60-cell; glass/glass; *frameless*	290W
Tracker Two	2	10	72-cell mono c-Si monofacial, *framed*	325W
		10	72-cell mono PERC c-Si bifacial, glass/backsheet *framed*	325W





Conclusions

- Snow losses can be reduced with region-specific system design choices such as:
- **Frameless modules,** which accelerate snow shedding and boost energy yields although the advantage diminishes as temps drop;
- **Modules in portrait orientation** appear (based on preliminary results) outperform those in landscape orientation but stringing architecture must be considered; also placement in the array.
- **Bifacial modules on a dual-axis tracker** will produce 41% more energy than the same fixed-tilt bifacials, the result of multiple performance benefits, including the tracker's wide field of view that captures a large amount of the backside irradiance, the high tilt angle that accelerates snow shedding and two-axis tracking ability that maximizes normal irradiance to the frontside.
- The above studies will be expanded in the the winter of 20-21 to gather more data and better understand such dependent factors as ambient air temperature and snow depth.

References

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