Sandia National Laboratories

Snow as a Factor in Photovoltaic Performance and Reliability

A three-year research project funded by the US DOE

Background

Snow and ice accumulation on the front surface of photovoltaic (PV) panels is a recognized—but poorly understood—contributor to lifetime PV performance and reliability, not only in areas of the US that see persistent snow throughout the winter but also at lower latitudes, where frozen precipitation routinely damages infrastructure from North Dakota to Texas and Georgia.[1]

As deployments of multi-megawatt solar installations proliferate across the northern US, energy losses attributable to ice and snow are a growing concern. Estimates for such losses range from 1 to 15 percent annually, reaching as high as 90 percent in a month[2, 3], introducing uncertainty regarding lifetime performance and revenue projections. In addition, snow- and ice-buildup and differential loading across an array can create multiple points of physical stress, resulting in failure mechanisms uniquely attributable to snow load.[4] Also, the abrupt and massive snow shedding from utility-scale arrays can introduce grid challenges, underscoring the need for better forecasting algorithms.

Primary Objectives

This three-year project[5] aims to increase the performance and resilience of PV systems deployed in regions of the US that regularly experience below-freezing precipitation, thus aiding in the adoption, integration and optimal operation of the nation's solar resources.

OUR SPECIFIC RESEARCH OBJECTIVES ARE TO:

1. Quantify PV snow losses across multiple locations, module technologies and system configurations
2. Identify topological and other component features that either impede or accelerate snow-shedding
3. Develop advanced snow models, which include such variables as adhesion and surface-roughness measurements, for more accurate estimates of snow shedding
4. Identify and mitigate reliability issues specific to snow and ice adhesion

Figure 1. *Snow cover on PV systems can block light and create ice dams, resulting in significant power losses and reliability concerns (left); and can shed unevenly, introducing mismatch losses (right.)*

[1] rsgisias.crrel.usace.army.mil/ice/icegis.html
[2] Marion, B., R. Schaefer, H. Caine, and G. Sanchez, 2013. Measured and modeled photovoltaic system snow losses for Colorado and Wisconsin locations. Solar Energy, 9 Nov. 2013:112-121
[3] Andrews, R.W, A. Pollard and J.M.Pearce, 2013. The effects of snowfall on solar photovoltaic performance. Solar Energy 92 (2013): 84-97.
[4] Althaus, J. et al. Experimental testing of PV modules under inhomogeneous snow loads. https://www.tuv.com/media/00_global/qrcodepicture/Poster_Snow_Load__JA_Kompatibilitaetsmodus.pdf
[5] The project commenced on October 1, 2018

Research Team

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Multi-Pronged Technical Approach

LABORATORY ANALYSIS AND MATERIALS CHARACTERIZATION

This work, which is taking place at the Cold Regions Research and Engineering Laboratory, focuses on the characterization—under low-temperature conditions—of advanced anti-icing coatings for PV applications. Variables to be measured include:

- Mechanical and physical properties of module surfaces and coatings (including roughness, wettability, tensile and adhesive forces, etc.)
- Optical transmissivity of different glass and coating types
- Optical transmissivity of different snow structures, measured as a percentage of incident radiation available to the solar cell

FIELD ANALYSIS OF INSTALLED PV SYSTEMS

Quantification of system-level snow losses from existing field sites in Vermont, Michigan and Alaska (see figure 2) includes:

- High-frequency image-capture of snow-shedding for multiple PV systems, correlated with module/cell types, surface characteristics, frame and rack architectures, module angles, and meteorological data
- Monitoring and analysis of DC-energy yields for the above systems

FIELD EXPERIMENTATION

We will conduct a series of field experiments to determine the:

- *In situ* spectral-filtering properties of different snow types and the implications of the latter on choice of solar-cell technology
- Relative contributions to snow shedding of surface topologies and component technologies, such as frames and clips, as well as design parameters, such as tilt angle and module orientation

RELIABILITY ASSESSMENT

Advanced-coating materials will be subjected to reliability testing; fielded PV systems will be monitored for signs of snow- and ice-induced degradation. Our analysis will include:

- High-resolution imaging of coatings to monitor for physical degradation
- Electro-luminescent imaging of modules to reveal microcracking of solar cells induced by snow/ice build-up
- Differential-load and accelerated-stress testing of modules/systems to assess the impact of snow weight on module integrity

VALIDATION OF "OPTIMIZED" SYSTEMS

Incorporating the results from the above investigations, we will:

- Design and deploy "climate optimized" PV systems
- Quantify annual energy gains, snow retention and shedding patterns (uniformity, duration), relative to an adjacent baseline PV system.

Value to the US Solar Sector

01 SITE PROFITABILITY

Systems optimized for snowy climates will generate more electricity, lowering the levelized cost of energy (LCOE)

02 LIFETIME PERFORMANCE MODELING

Increasing the accuracy of snow-loss models translates into more accurate LCOE calculations, which helps expand solar markets

03 RESOURCE AVAILABILITY/ENERGY RESILIENCE

Systems that shed snow quickly make more energy available to the grid, which increases grid resilience in the aftermath of severe storms

04 MODULE AND SYSTEM RELIABILITY

Identification and mitigation of design weaknesses that contribute to snow and ice buildup leads to more robust and productive systems

05 GRID STABILITY

Predictive modeling of snow shedding increases the accuracy of solar-forecasting tools and allows electric utilities to plan for sudden oscillations in power

Multi-site Project

Field research for this project is taking place at three sites: the US DOE Vermont Regional Test Center in Williston, Vermont (N 44°, W 73°); Michigan Technical University in Houghton, Michigan (N 47°, W 88°); and the University of Alaska, Fairbanks (N 64°, W147°). Indoor research, including materials analysis and characterization of the snow-ice interface, will be conducted in laboratories at the US Army Corps' Cold Regions Research and Engineering Lab in Hanover, NH and at Michigan Technical University in Houghton, MI.

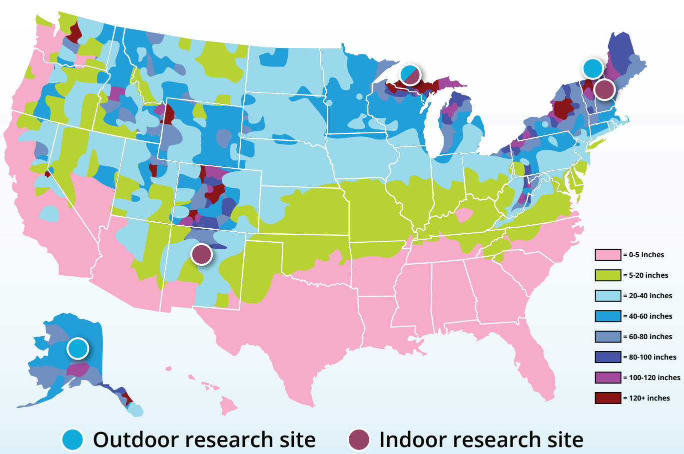

Figure 2. *Map of average annual snowfall across the US. Locations of the three outdoor field sites for this project are indicated by [color] circles; indoor research sites are in [color.]*

U.S. DEPARTMENT OF ENERGY
NNSA National Nuclear Security Administration

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