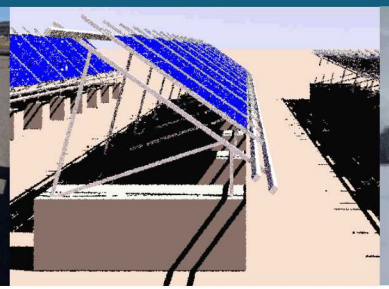
SAND2020-9271C

Estimation of Maximum Current Generated by Bifacial PV Arrays for System Design



PRESENTED BY

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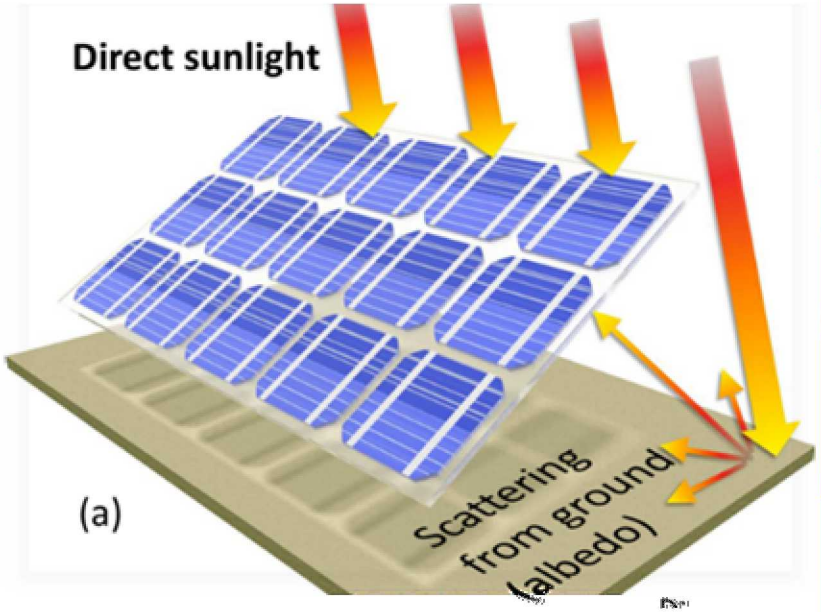
Introduction

- The market for bifacial PV technology is rapidly increasing and bifacial PV systems on single axis trackers have the lowest LCOE [1]
- Bifacial PV arrays capture more light and generate higher currents than similar monofacial arrays.
- The current photovoltaic system design standard (IEC 62548 Ed. 1.0 b:2016) does not consider specific design and safety implications of using bifacial PV modules.
- This standard is currently being updated to add procedures for considering the design of bifacial PV systems, including the extra current expected.
- Higher currents may affect wire and fuse sizing in system designs.
- Sandia has contributed to this effort by analyzing measurements of DC current and plane-of array irradiance from a variety of bifacial and monofacial modules in systems with the same orientations and site conditions (albedo).



[1] C. D. Rodríguez-Gallegos *et al.*, "Global techno-economic performance of bifacial and tracking PV systems," *Joule*, vol. 4, pp. 1–28, 2020.

System Descriptions

- Three nearly identical systems were installed in New Mexico, Nevada, and Vermont in the USA
- Each is system comprised of five orientations

Data Start Date	Albuquerque, New Mexico	Henderson, Nevada	Burlington, Vermont
Data End Date	2020-07-01 09:29	2020-07-01 11:30	2019-04-01 08:41
Number of observations	2,218,361	1,850,648	869,540
Natural Albedo	0.22	0.2	0.18-0.22 (depends on grass condition)
Enhanced Albedo	0.6	0.3	0.25
System 1 Orientation	West-facing, 15° tilt, high albedo	West-facing, 15° tilt, high albedo	West-facing, 30° tilt, high albedo
System 2 Orientation	South-facing, 15° tilt, high albedo	South-facing, 15° tilt, high albedo	South-facing, 30° tilt, high albedo
System 3 Orientation	South-facing, 30° tilt, natural albedo	South-facing, 30° tilt, natural albedo	South-facing, 30° tilt, natural albedo
System 4 Orientation	South-facing, 90° tilt	South-facing, 90° tilt	South-facing, 90° tilt
System 5 Orientation	West-facing, 90° tilt	West-facing, 90° tilt	West-facing, 90° tilt

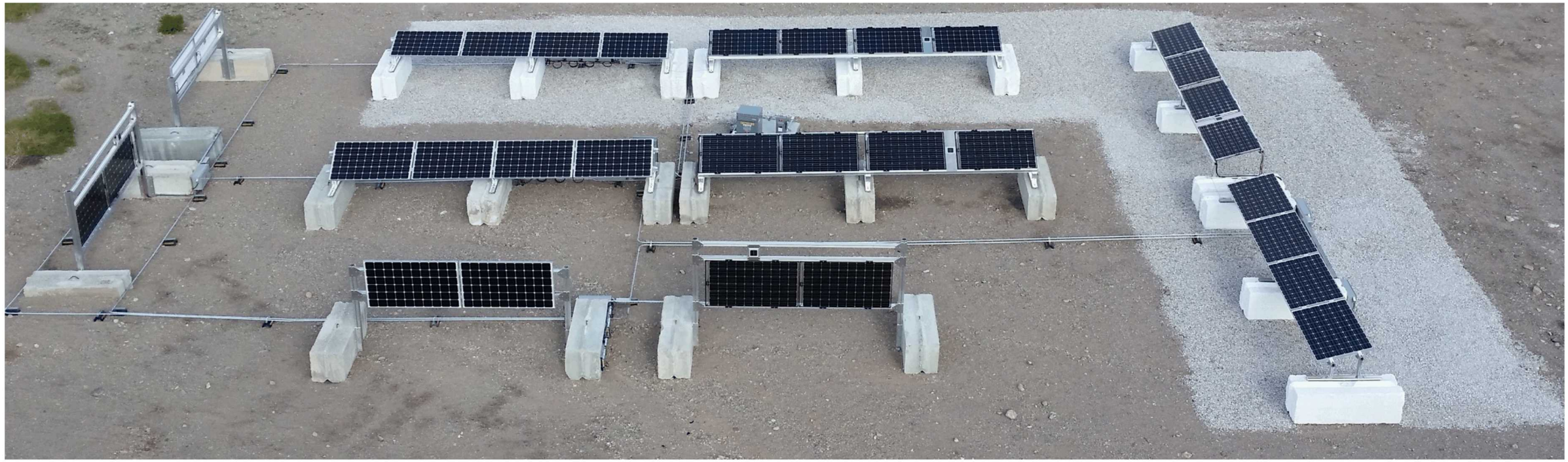
New Mexico System

Modules:

- Bifacial: Prism Solar (270 W)
- Monofacial: Suniva (265 W)

- Each orientation has half bifacial and half monofacial modules
- Modules are individually monitored for DC current and voltage and grid connected using microinverters.
- POA irradiance is measured on the front and rear of each orientation.

Nevada System



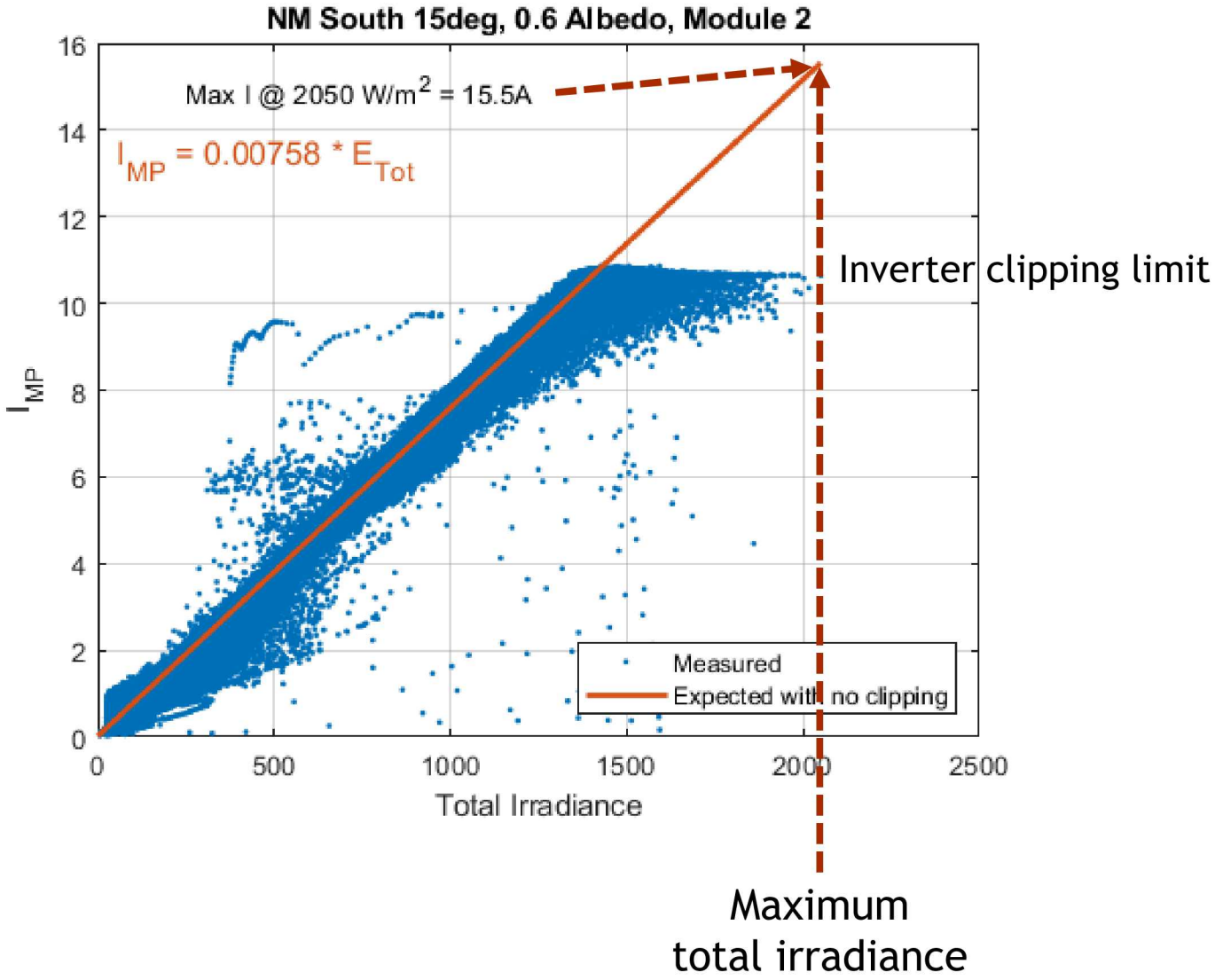
- There are slight design differences between the sites but the modules and monitoring are identical.

Vermont System

- Foundation in Vermont is driven pillars rather than concrete ballast blocks.
- All tilted arrays are at 30° in Vermont

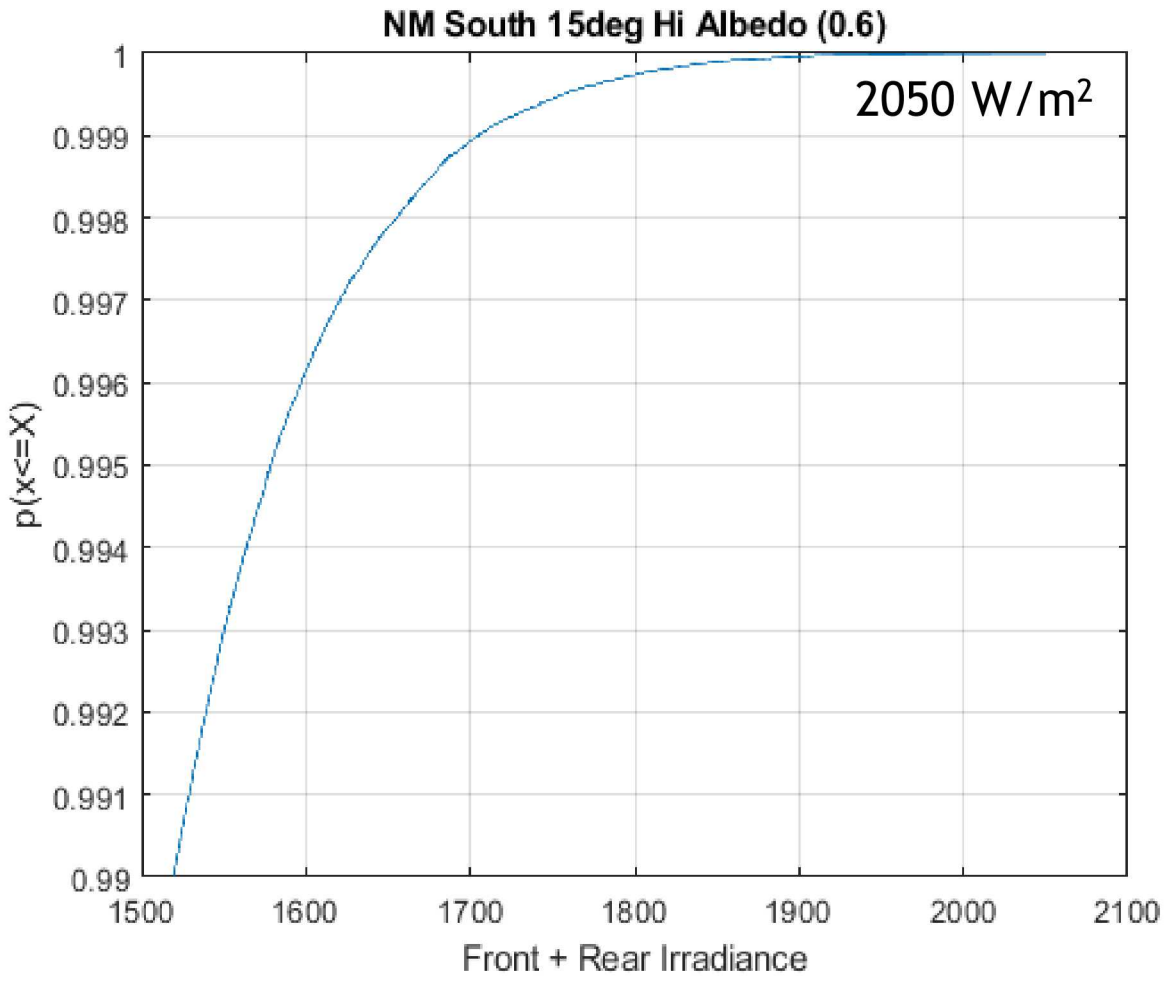
Maximum Current Analysis Method

- We calculated total irradiance for each module for each 1 min timestep
  - Monofacial total irradiance = front side POA irradiance
  - Bifacial total irradiance = front + rear-side POA irradiance
- We plotted measured module maximum power current (Imp) vs. total irradiance
- We perform a linear regression and predict the current at the maximum total irradiance.
  - This is our estimate of the maximum current in the absence of inverter clipping.

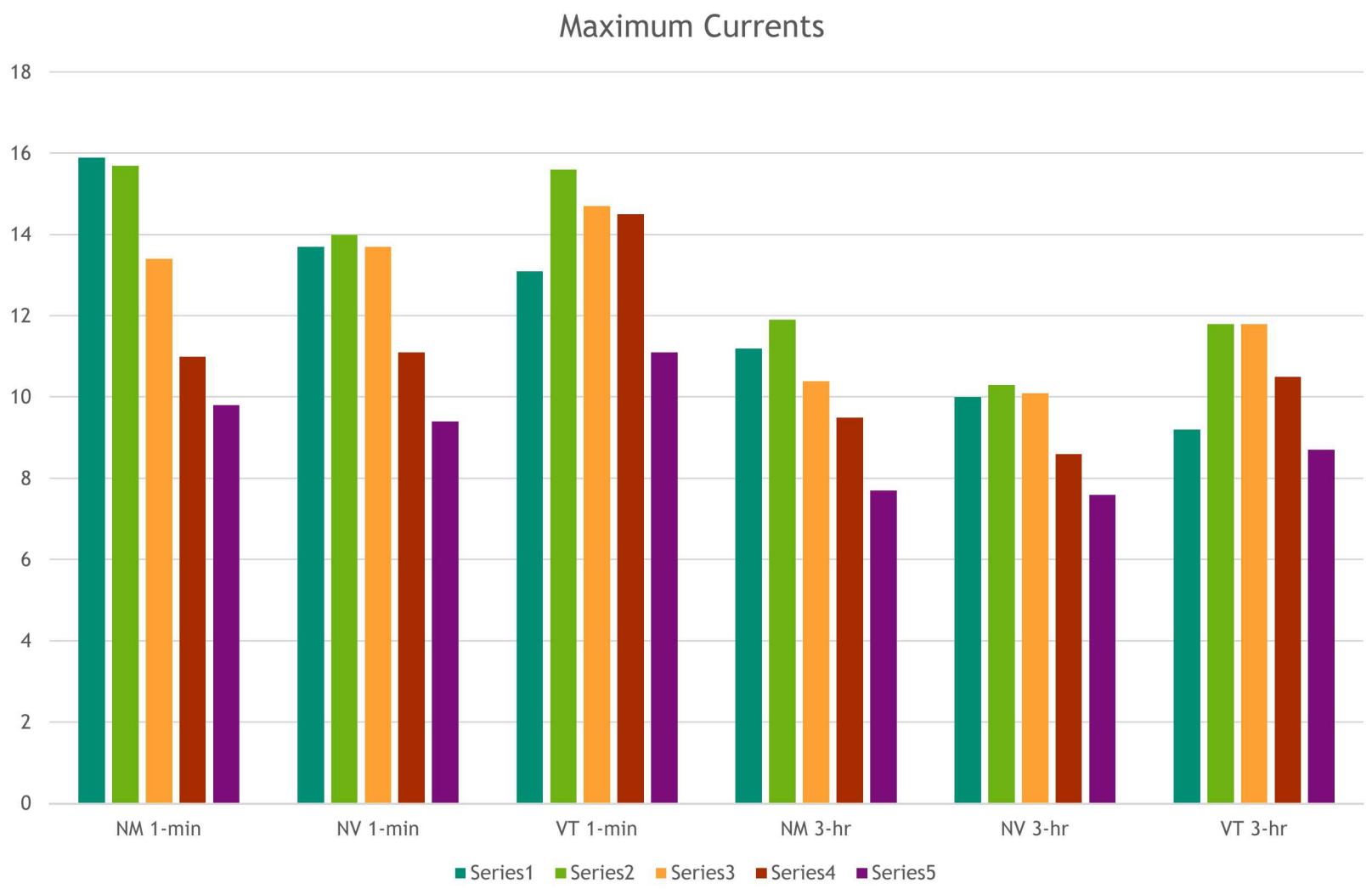


Total Irradiance Distribution

- One notable feature of the data is that the highest 1% of the total irradiance measurements can span a significant range in irradiance.
  - ~500 W/m^2 in the example shown.
- These very high irradiance values are due to cloud enhancement and last only a very short time.

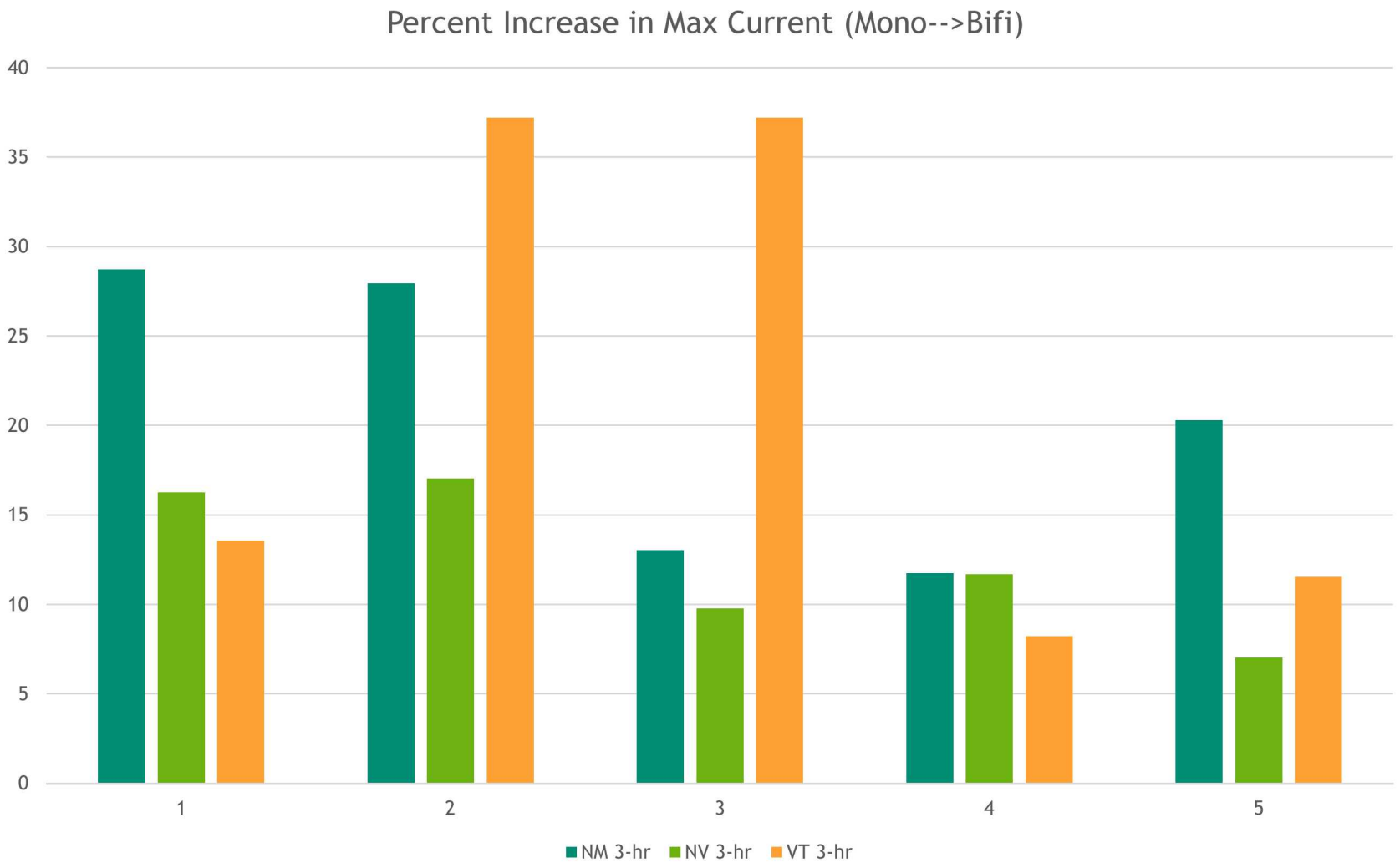


Summary of Bifacial System Max Currents



- New Mexico (sunny & high albedo) and Vermont (snowy) have the highest currents
- 3-hr average max currents are ~24% lower than 1-min values
- Vertical modules have the lowest max currents
- 3hr average max currents are most relevant for wire and fuse sizing.

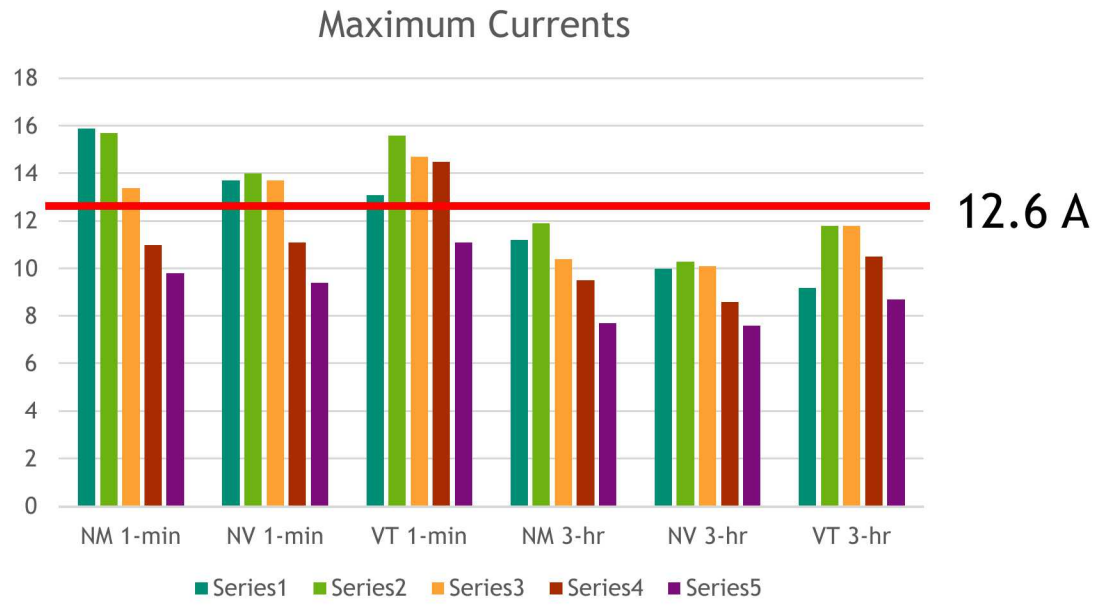
Compare Max Current Between Monofacial and Bifacial



- New Mexico and Vermont show the highest percent increases, which are due to high albedo
  - 0.55 white rock in NM
  - Snow in VT

Implications for System Design Standards

- IEC 62548 Ed 2 is still in draft form but it currently has the following specifications:
  - Bifacial nameplate current (BNPI): current at 1,000 W/m^2 on front and 135 W/m^2 on rear.
  - Isc_BNPI = Isc_STC *(1+0.135*BF), where BF is the bifaciality factor of the module (typically 0.7-0.9)
  - Max current rating = Isc_BNPI * 1.25 (high irradiance)
  - When BF = 0.9, Isc_BNPI = Isc_STC * 1.4
- Prism Solar modules have Isc_STC = 8.98A
  - Isc_BNPI = 8.98 * 1.4 = 12.6A
  - 1-min max currents can exceed this limit
  - 3-hr average maximum currents all fall below limit



Summary

- Analysis of bifacial and monofacial PV system performance monitoring data in three climates covering a range of orientations were analyzed for maximum current levels.
- Bifacial systems exhibited about 24% higher maximum currents than their monofacial counterparts.
- Albedo plays a significant role in the magnitude of the maximum current.
- Proposed changes to the PV design standard IEC 62548 introduce a max current rating for bifacial systems that is based on Bifacial Name Plate Current (BNPI) and bifaciality factor (BF).
- System data from this study indicates that real bifacial systems can exceed this rating for short periods of time.
- However, fuse and wire size limits are designed to withstand sustained conditions at the limit.
- Maximum currents determined from 3-hr rolling averages were all below the maximum current rating for the systems.
- Maximum currents measured in this study are likely to be greater than for commercial and utility-scale bifacial systems because the test systems were small and widely separated, which allows more light to reach the rear-side of the array.

Thank you for your attention
Please email questions to
jsstein@sandia.gov