NREL Bifacial Experimental Single-Axis Tracking Field

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The National Renewable Energy Laboratory, Bifacial Experimental Single-Axis Tracking Field (BEST field) is located at the NREL South Table Mountain Campus, in Golden CO (39.7398341° North, -105.1727827° West). Site characteristics are listed in Table 1.

Table 1 - Characteristics of BEST bifacial PV field test site

Information	Value	Unit	Comment
System size	75	kWp	10 rows of 20 modules; 5 rows are different bifacial technologies, the other 5 rows are the equivalent monofacial technology for comparison.
System type	Single-axis trackers		Nextracker trackers, with backtracking algorithm.
Site albedo	26	%	Yearly average. 1-min measurements available from 3 albedometers on site
Bifacial gain	8.9	%	Based on 1 min data from Jun 2019 to April 2020
Mounting height	1.5	m	Axis of rotation of modules
Array azimuth angle	180	deg	
Ground cover ratio	0.35		
Module bifaciality	73.14	%	5 different technologies, 4 PERC ranging 65-75% and one HJT at 90%
Array configuration	1up portrait		
Electrical info	Row DC Power, kWh, V_{DC}, I_{DC}, module's DC power		High-accuracy (0.5%) DC string monitoring. Module-level power electronics on each module (SolarEdge)
Further data	Rear Irradiance, Albedometers, Module temperature, weather data		Nine front and rear POA irradiance sensors throughout the field. 4 rear facing reference cells along collector width on row 3 module 4, and 2 rear-facing broadband irradiance meters (CM11 and Apogee Pyranometer) on row 3 module 10, East and West edges of the module respectively. Module temperature sensors throughout the field. Albedo measured on site with CM11, IMT reference cell and Apogee pyranometer. High-quality Weather Data available at <100m on SRRL. Time series available on Duramat.com with full data for two of the bifacial rows.

Figure 1 - 1-axis tracker testbed for the NREL bifacial module and system performance monitoring project

This array contains ten rows of single-axis NexTrackers, with tracker angle limit of 60 degrees (Figure 1). Five different bifacial technologies and their monofacial counterparts for comparison have been deployed in the field. Modules (~1m x ~2m) are installed in 1-up portrait orientation, with 72-cell each. GCR is 0.35. Tracker hub-height is 1 m. Ground cover of the area is natural field, which is mowed and maintained. Various plane-of-array sensors in row 2 and row 3 measure front and rear irradiance. The location of the sensors is highlighted in Figure 6 and Figure 7.

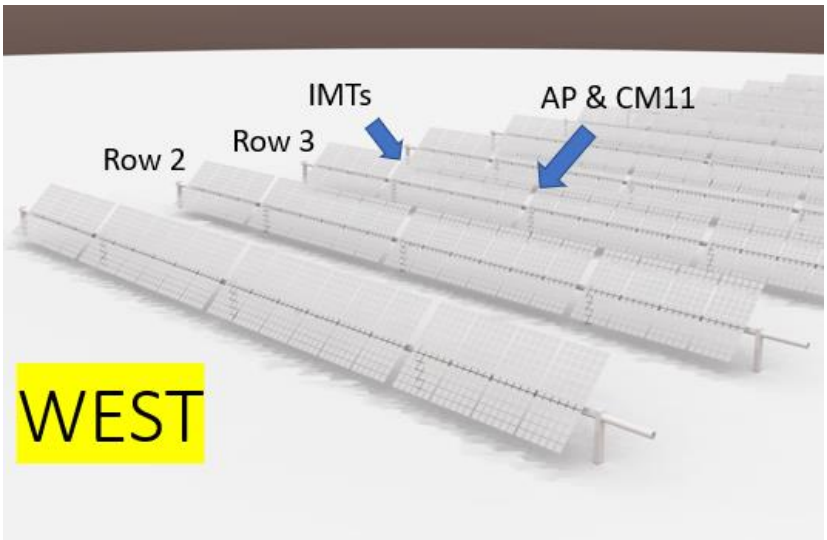

Figure 2 - Schematic of the array showing row 2 and 3, and location of the front and rear irradiance sensors on row 3.

Figure 3 - The location of the front and rear irradiance sensors on row 3

Weather data is available from the SRRL station, measured at less than 100 m from the array (39.742, -105.179, 1829 m elevation). Albedo data is measured in the array itself with three albedometers (Sunkitty 1-3), two of them broadband (CM22 and Apogee Pyranometer) and one IMT reference cell. The albedometers are recorded in the data as GRI and GHI measurements.

A custom module was installed in Row 2, position 5, referred to as “Hydra“ (Figure 4). This module was designed and constructed to perform experiments on torque tube shading effects. The module has 12 strings of 5 cells each, tabbed out at each side along the horizontal axis, with a j-box or other connection at each row so they can be individually addressed. IV-curve data for the initial HYDRA module flashtest with the SPIRE meter is publicly available in the Duramat dataset.

Figure 4 - Custom module with 12 individually addressable strings. Mounted in the middle of NREL's bifacial PV field.

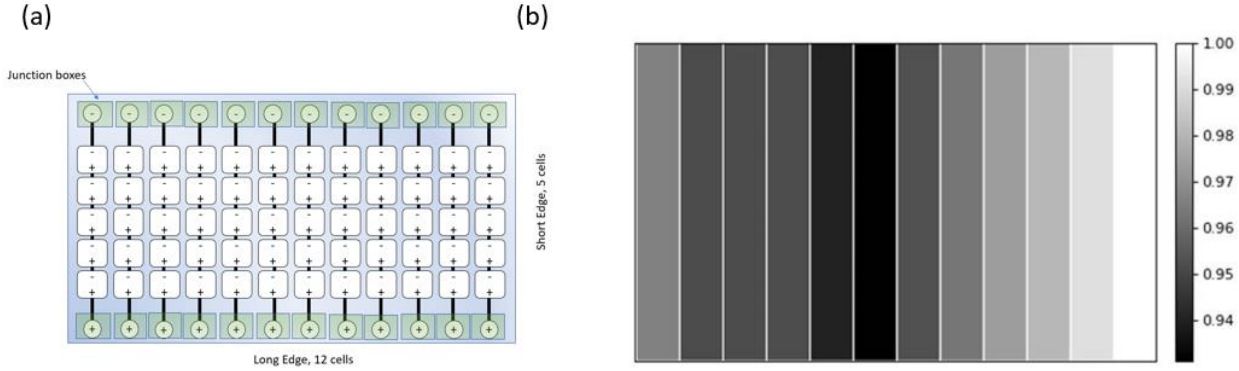

Figure 5 - (a) Diagram of the custom module with 12 individually addressable strings. (b) Cumulative irradiance distribution, normalized, for the month of December.

Collection for each of the strings data started on December 2019. Figure 5 shows the electrical diagram and preliminary results for December on cumulative irradiance distribution, normalized.

Data for the bifacial field, including bifacial rows 2 and row 9 performance data, all front and rear facing irradiance sensors, albedometers and SRRL weather data, and Hydra custom-module data has been made publicly available in Duramat's website for the period of June 2019 to April 2020. Summary of the data analysis, modeling and performance results have been presented in [1-3].

Data Description

A pickle and a .csv file has been included with the data described in Table 2.

Table 2 - Column headers, units and description of data provided.

Variable	Category	Units	Description
row2dcp	Bifacial Row	W	Row DC-Power
row2Gpoa_front	Bifacial Row	W/m2	Plane of array irradiance, front-facing
row2kWh	Bifacial Row	kWh	Row Energy
row2dcv	Bifacial Row	V	Row Voltage
row2dci	Bifacial Row	A	Row Current
row2tmod	Bifacial Row	C	Row module temperature
Yf2	Bifacial Row		Row DC-power normalized by row nameplate capacity measured on Spire
PR2	Bifacial Row		Row Performance Ratio, calculated with row 9 front POA irradiance
row8dcp	Monofacial Row	W	Row DC-Power
row8Gpoa_front	Monofacial Row	W/m2	Plane of array irradiance, front-facing
row8Gpoa_rear	Monofacial Row	W/m2	Plane of array irradiance, rear-facing

Yf8	Monofacial Row		Row DC-power normalized by row nameplate capacity measured on Spire
PR8	Monofacial Row		Row Performance Ratio, calculated with row 9 front POA irradiance
row9dcp	Bifacial Row	W	Row DC-Power
row9Gpoa_front	Bifacial Row	W/m2	Plane of array irradiance, front-facing
row9Gpoa_rear	Bifacial Row	W/m2	Plane of array irradiance, rear-facing
row9kWh	Bifacial Row	kWh	Row Energy
row9dcv	Bifacial Row	V	Row Voltage
row9dci	Bifacial Row	A	Row Current
row9tmod	Bifacial Row	C	Row module temperature
Yf9	Bifacial Row		Row DC-power normalized by row nameplate capacity measured on Spire
PR9	Bifacial Row		Row Performance Ratio, calculated with row 9 front POA irradiance
poa_irradiance_front_IMT	POA Irradiances	W/m2	Row 3 Module 5 from North, front facing IMT reference cell
poa_irradiance_rear_IMT_West	POA Irradiances	W/m2	Row 3 Module 5 from North, rear facing IMT reference cell
poa_irradiance_rear_IMT_CenterWest	POA Irradiances	W/m2	Row 3 Module 5 from North, rear facing IMT reference cell
poa_irradiance_rear_IMT_CenterEast	POA Irradiances	W/m2	Row 3 Module 5 from North, rear facing IMT reference cell
poa_irradiance_rear_IMT_East	POA Irradiances	W/m2	Row 3 Module 5 from North, rear facing IMT reference cell
poa_irradiance_front_licor	POA Irradiances	W/m2	Row 3 Module 10 from North, front facing licor sensor
poa_irradiance_rear_licor	POA Irradiances	W/m2	Row 3 Module 10 from North, rear facing licor sensor
poa_irradiance_front_cm11	POA Irradiances	W/m2	Row 3 Module 10 from North, front facing CM11 sensor
poa_irradiance_rear_cm11	POA Irradiances	W/m2	Row 3 Module 10 from North, rear facing CM11 sensor
sunkitty_albedo_1	Albedo		Albedo measured by Sunkitty CM22
sunkitty_GRI_CM22	Albedo	W/m2	Ground Reflected Irradiance measured by CM22
sunkitty_GHI_CM22	Albedo	W/m2	Ground Horizontal Irradiance measured by CM22
sunkitty_albedo_2	Albedo		Albedo measured by Sunkitty IMT reference cell
sunkitty_GRI_IMT	Albedo	W/m2	Ground Reflected Irradiance measured by IMT reference cell
sunkitty_GHI_IMT	Albedo	W/m2	Ground Horizontal Irradiance measured by IMT reference cell
sunkitty_albedo_3	Albedo		Albedo measured by Sunkitty Apogee Licor pyranometer
sunkitty_GRI_AP	Albedo	W/m2	Ground Reflected Irradiance measured by Apogee Licor pyranometer
sunkitty_GHI_AP	Albedo	W/m2	Ground Horizontal Irradiance measured by Apogee Licor pyranometer
Hydra_current_1	Hydra	A	Custom Module measured short-circuit current
Hydra_current_2	Hydra	A	Custom Module measured short-circuit current

Hydra_current_3	Hydra	A	Custom Module measured short-circuit current
Hydra_current_4	Hydra	A	Custom Module measured short-circuit current
Hydra_current_5	Hydra	A	Custom Module measured short-circuit current
Hydra_current_6	Hydra	A	Custom Module measured short-circuit current
Hydra_current_7	Hydra	A	Custom Module measured short-circuit current
Hydra_current_8	Hydra	A	Custom Module measured short-circuit current
Hydra_current_9	Hydra	A	Custom Module measured short-circuit current
Hydra_current_10	Hydra	A	Custom Module measured short-circuit current
Hydra_current_11	Hydra	A	Custom Module measured short-circuit current
Hydra_current_12	Hydra	A	Custom Module measured short-circuit current
temp_ambient	Weather	C	Ambient tempterature
wind_direction	Weather		Wind direction
wind_speed	Weather	m/s	Wind speed
SRRL Tower Dry Bulb Temp [deg C]	SRRL	C	SRRL ambient temperature
SRRL Avg Wind Speed @ 6ft [m/s]	SRRL	m/s	SRRL wind speed
SRRL Direct CHP1-1 [W/m^2]	SRRL	W/m2	SRRL DNI
SRRL Diffuse 8-48 (vent) [W/m^2]	SRRL	W/m2	SRRL DHI
SRRL Global CMP22 (vent/cor) [W/m^2]	SRRL	W/m2	SRRL GHI
SRRL Albedo (CMP11)]	SRRL		SRRL Albedo

Other Values of Interest are included included in Table 3.

Table 3 - Other values of interest of the bifacial field

Bifaciality Factor **Row 2: 0.694** **Row 8: 0.0 (monofacial row)** **Row 9: 0.87**
Nameplate Row Pmp: **Row 2: 6840 W (19 modules, custom module not contributing (Hydra))** **Row 8: 7159 W (20 modules 360 W monofacial PERC, half-cell modules)** **Row 9: 7701 W (20 modules)**
Nameplate measured by SPIRE: **Row2: 6721 (19 modules, custom module not contributing (Hydra))** **Row 8: 7239 (20 modules)** **Row 9: 7701 (20 modules)**

Measurements and standard deviations for row 2, as published in [2]

TABLE I. MEASUREMENT AND STD DEVIATION FOR ROW 2

CODE	Measurement Front Avg	StD	Measurement Back	StD
Isc [A]	9.50	0.03	6.56	0.11
Voc [V]	48.0	0.23	47.3	0.25
Imp [A]	9.0	0.02	6.2	0.11
Vmp [V]w	39.2	0.2	39.5	0.22
Pmp [W]	354	2.7	246	4.4
FF [%]	77.5	0.2	79.1	0.7

Solar Edge Data

Hourly data for each module in rows 2 and 9 are included for the months of January 2020 to May 2020. Modules are labeled such that Module 1 is the northmost module. Row 2, module 5 corresponds to the Hydra module location, hence that row is 0 for all the dataset.

References

[1] Ayala Pelaez, S., Delince C., "Ultimate Bifacial Showdown: 75kW Field Results", 7th bifiPV Workshop 2020 (virtual). Proceedings available on: https://www.nrel.gov/docs/fy20osti/77486.pdf and recording of presentation on https://www.bifipv-workshop.com/2020-virtualbifipv-proceedings

[2] Ayala Pelaez, S., Deline C., Marion, B., Sekulic, B., McDanold, B., Parker, J., Stein, J. S. "Field-Array Benchmark of Commercial Bifacial PV Technologies with Publicly Available Data", in proceedings of 46th IEEE PVSC, 2020, virtual. D.O.i: 10.1109/PVSC45281.2020.9300379

[3] Deline, C., Ayala Pelaez, S, Marion, B. et al "Understanding bifacial PV's potential: field performance", as part of Taiyang News Webinar "Bifacial solar's True Potential", Dec. 3rd. Slides: https://www.nrel.gov/docs/fy20osti/75532.pdf. Youtube: https://www.youtube.com/watch?v=uRvxol7Y-Hg&feature=youtu.be