NREL Bifacial Experimental Single-Axis Tracking Field

Data Reference Manual

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NREL Bifacial Experimental Single-Axis Tracking Field

Site and data description by Silvana Ovaitt, Chris Deline

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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 50 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 1.5 m. Ground cover of the area from start of the experiment until 06/2022 is natural field, which is mowed and maintained. On June 2022 variuos agriPV sections were planted, including crops between rows 8-10, north half of the field, pollinator habitat (rows 1 to 3, south half of the field), and pasture grass (rows 1 to 3, north half of the field). Sensors on row 3 therefore have view of this pollinator habitat and pasture grass, but the seeds take one more season (until 2023) to grow. Various plane-of-array sensors throughout the field measure front irradiance, and rows 3 and 7 are instrumented with rear-facing irradiance sensors. The location of the sensors in row 3 is highlighted in Figure 6 and Figure 7. Row 7 has the same Center Eats and East sensor location for the IMT reference cells, but placed 10 modules from north on a position between modules that has no obstruction of view from the tracker pile.

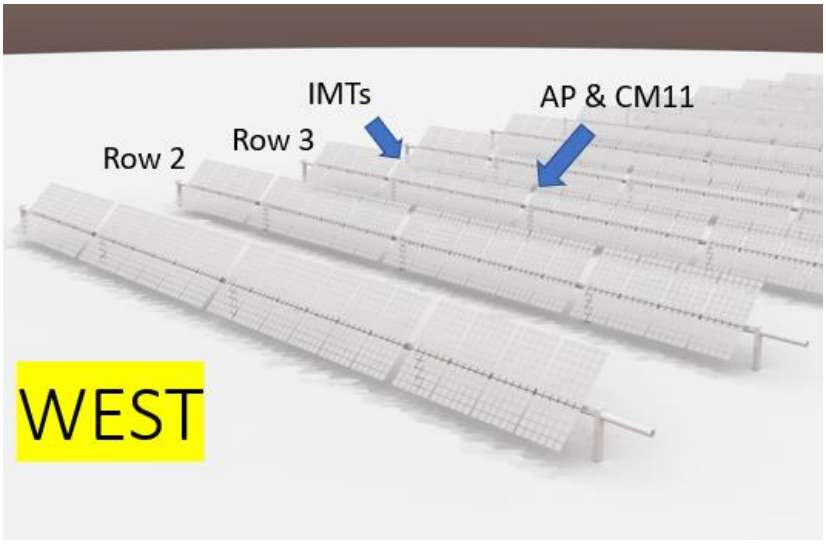

Figure 2 - Schematic of the array showing row 2 and 3, and location of the front and rear irradiance sensors on row 3.

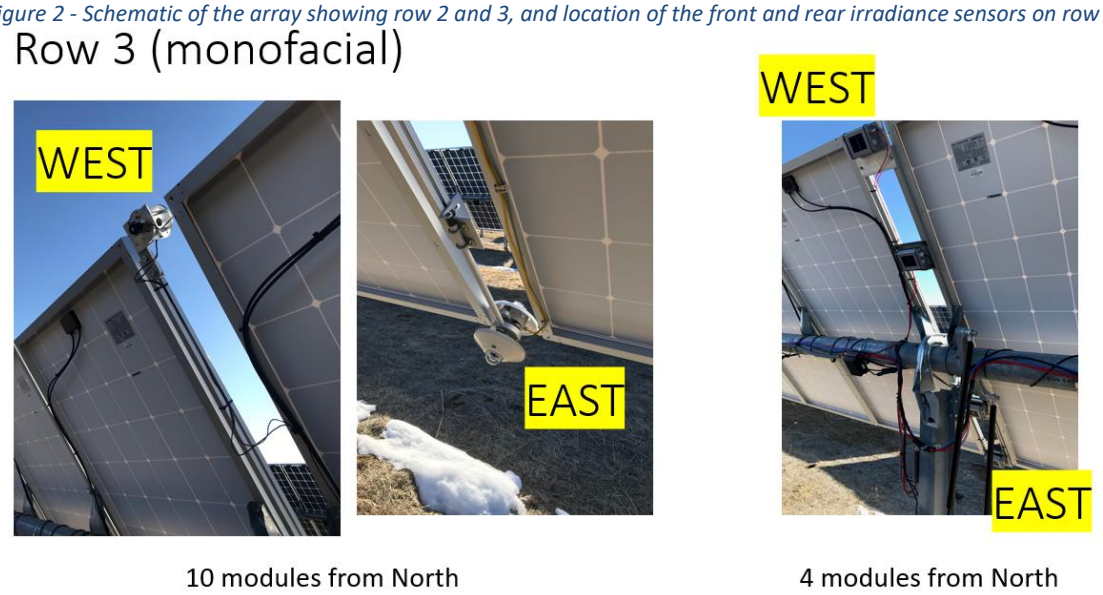

Figure 3 - The location of the front and rear irradiance sensors on row 3

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 13), 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.

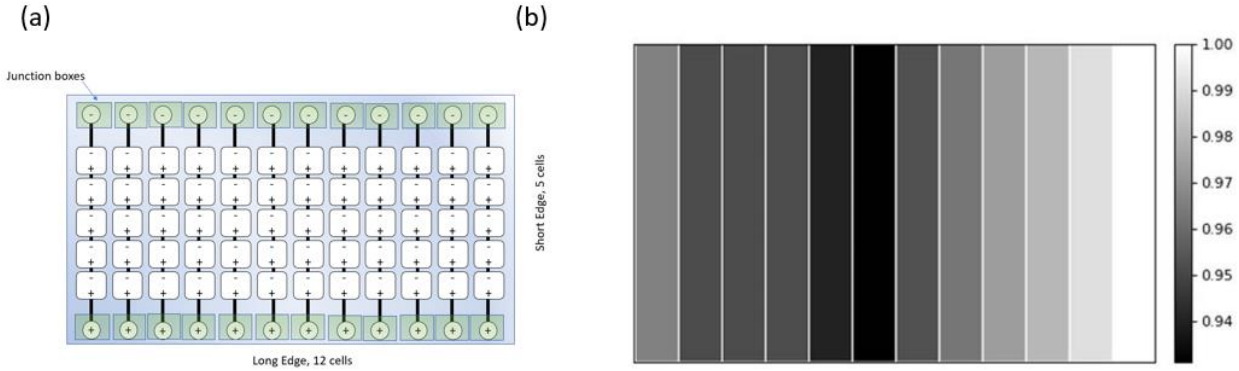

Figure 5 - (a) Diagram of the custom module with 12 individually addressable strings. (b) Cumulative irradiance distribution, normalized, for the month of December.

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
row2kWh	Bifacial Row	kWh	Row Energy
row2dcp	Bifacial Row	W	Row DC-Power
row2Gfront	POA Irradiances	W/m2	Plane of array irradiance, front-facing
Hydra_current_1	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
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
row2temperature_ambient	Bifacial Row	C	Ambient tempterature
row2tmod_1	Bifacial Row	C	Row module temperature
row2tmod_2	Bifacial Row	C	Row module temperature
row2wind_direction	Bifacial Row	degrees	Field measured wind direction
row2wind_speed	Bifacial Row	m/s	Field measured wind speed
row3Gfront	POA Irradiances	W/m2	Plane of array irradiance, front-facing
row3Grear_IMT_West	POA Irradiances	W/m2	Row 3 Module 5 from North, rear facing IMT reference cell
row3Grear_IMT_CenterWest	POA Irradiances	W/m2	Row 3 Module 5 from North, rear facing IMT reference cell
row3Grear_IMT_CenterEast	POA Irradiances	W/m2	Row 3 Module 5 from North, rear facing IMT reference cell
row3Grear_IMT_East	POA Irradiances	W/m2	Row 3 Module 5 from North, rear facing IMT reference cell
row3Grear_CM11	POA Irradiances	W/m2	Row 3 Module 10 from North, rear facing CM11 sensor
row3Grear_Licor	POA Irradiances	W/m2	Row 3 Module 10 from North, rear facing licor sensor
row3Gfront_CM11	POA Irradiances	W/m2	Row 3 Module 10 from North, front facing CM11 sensor
row3Gfront_Licor	POA Irradiances	W/m2	Row 3 Module 10 from North, front facing licor sensor
row4kWh	Bifacial Row	kWh	Row Energy

row4dcp	Bifacial Row	W	Row DC-Power
row4tmod_1	Bifacial Row	C	Row module temperature
row4tmod_2	Bifacial Row	C	Row module temperature
row5Grear	POA Irradiances	W/m2	
row5Gfront	POA Irradiances	W/m2	Plane of array irradiance, front-facing
row5temperature_ambient	Row	C	Ambient tempterature
row6tracker_angle	Row	degrees	Tracker's angle
row7Grear	POA Irradiances	W/m2	
row7Gfront	POA Irradiances	W/m2	Plane of array irradiance, front-facing
row7tracker_angle	Row	degrees	
row7wind_direction	Bifacial Row	degrees	Field measured wind direction
row7wind_speed	Bifacial Row	m/s	Field measured wind speed
row7Grear_IMT_CenterEast	POA Irradiances	W/m2	
row7Grear_IMT_East	POA Irradiances	W/m2	
row7RotatingAlbedometer_CM11_Down	POA Irradiances	W/m2	
row7RotatingAlbedometer_CM11_Up	POA Irradiances	W/m2	
row8dcp	Monofacial Row	W	Row DC-Power
row8tmod_1	Monofacial Row	C	Row module temperature
row8tmod_2	Monofacial Row	C	Row module temperature
row8tracker_angle	Monofacial Row	degrees	Tracker's angle
row9kWh	Bifacial Row	kWh	Row Energy
row9dcp	Bifacial Row	W	Row DC-Power
row9Grear	POA Irradiances	W/m2	
row9Gfront	POA Irradiances	W/m2	Plane of array irradiance, front-facing
row9tmod_1	Bifacial Row	C	Row module temperature
row9tmod_2	Bifacial Row	C	Row module temperature
row9tmod_3	Bifacial Row	C	Row module temperature
row9tmod_4	Bifacial Row	C	Row module temperature
Grear	POA Irradiances	W/m2	Average of row3GrearIMT sensors
Gfront	POA Irradiances	W/m2	Same as row5Gfront. Plane of array irradiance, front-facing
temp_ambient_FieldAverage	Weather	C	Average of field measured temperatures
sunkitty_GRI_CM22	POA Irradiances	W/m2	Ground Reflected Irradiance measured by CM22
sunkitty_GRI_IMT	POA Irradiances	W/m2	Ground Reflected Irradiance measured by IMT reference cell
sunkitty_GRI_AP	POA Irradiances	W/m2	Ground Reflected Irradiance measured by Apogee Licor pyranometer
sunkitty_GHI_CM22	POA Irradiances	W/m2	Ground Horizontal Irradiance measured by CM22
sunkitty_GHI_IMT	POA Irradiances	W/m2	Ground Horizontal Irradiance measured by IMT reference cell
sunkitty_GHI_AP	POA Irradiances	W/m2	Ground Horizontal Irradiance measured by Apogee Licor pyranometer
sunkitty_albedo_CM22	Weather		Albedo measured by Sunkitty CM22
sunkitty_albedo_IMT	Weather		Albedo measured by Sunkitty IMT reference cell
sunkitty_albedo_AP	Weather		Albedo measured by Sunkitty Apogee Licor pyranometer
albedo	Weather		Values from sunkitty_albedo_CM22
row2Pmp	Bifacial Row	W	Row's Pmp
row4Pmp	Bifacial Row	W	Row's Pmp

row9Pmp	Bifacial Row	W	Row's Pmp
Yf2	Bifacial Row		Row DC-power normalized by row nameplate capacity measured on Spire
Yf4	Bifacial Row		Row DC-power normalized by row nameplate capacity measured on Spire
Yf8	Monofacial Row		Row DC-power normalized by row nameplate capacity measured on Spire
Yf9	Bifacial Row		Row DC-power normalized by row nameplate capacity measured on Spire
PR2	Row Performance Ratio, calculated with row 5 front POA irradiance		Row Performance Ratio, calculated with row 5 front POA irradiance
PR4	Row Performance Ratio, calculated with row 5 front POA irradiance		Row Performance Ratio, calculated with row 5 front POA irradiance
PR8	Row Performance Ratio, calculated with row 5 front POA irradiance		Row Performance Ratio, calculated with row 5 front POA irradiance
PR9	Row Performance Ratio, calculated with row 5 front POA irradiance		Row Performance Ratio, calculated with row 5 front POA irradiance
SRRL_albedo	Weather		SRRL albedo
SRRL_windspeed	Weather	m/s	SRRL Avg Wind Speed @ 6ft [m/s]
SRRL_DHI	Weather	W/m2	SRRL Diffuse 8-48 (vent) [W/m^2]
SRRL_DNI	Weather	W/m2	SRRL Direct CHP1-1 [W/m^2]
SRRL_GHI	Weather	W/m2	SRRL Global CMP22 (vent/cor) [W/m^2]
SRRL_temperature_ambient	Weather	C	SRRL Tower Dry Bulb Temp [deg C]

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 5: 0.73** **Row 8: 0.0 (monofacial reference row)** **Row 9: 0.87**
Nameplate Row Pmp: **Row 2: 6840 W (19 modules, and 1 custom module not contributing (Hydra))** **Row 5: 7273 W (20 modules 370 W bifacial PERC)** **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 5: 7211
Row 8: 7239 (20 modules)
Row 9: 7701 (20 modules)

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

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.

If you Reference this data, please cite the dataset:

Silvana Ovaitt & Chris Deline (2022). NREL Bifacial Experimental Single-Axis Tracking (BEST) Field Dataset. Duramat Datahub. DOI: 10.21948/1787805

References

[1] Ayala Pelaez, S., Deline 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