Output Performance of TOPCon and PERC Module by TÜV Nord in Malaysia

To compare the difference in energy yield between different types of PV modules, TOPCon and PERC bifacial under the outdoor environment, a field test study had been conducted by TÜV Nord in Malaysia during the period 01/01/2023 - 03/31/2023.

According to the test result, when comparing normalized energy yield gain, 182 TOPCon bifacial module is **5.69%** higher than that of 182 PERC bifacial module. Comparing the influence of different cell size on energy yield, the normalized energy yield of 210 PERC bifacial module is 0.98% lower than that of 182 PERC bifacial module.

1 DEMONSTRATION PROJECT OVERVIEW

1.1 SYSTEM INTRODUCTION

This project is located in the PV Field Trial Base in Selangor region, Malaysia. Selangor region has a typical tropical rainforest climate, with an average temperature of 28.2 °C, extreme maximum temperature of 38.5 °C, and annual rainfall of 2628 mm.

Figure 1. Location of the power station on Google Map

6 pieces of three types of module, 182 TOPcon bifacial module type, 182 PERC bifacial module type and 210 PERC bifacial module type, were installed in fixed 1P shape and connected to the grid with HM-1500 micro-inverters. The basic module information is shown as below.

Product Name	Nominal Power	Module Type	Test Module Quantity
182 TOPcon bifacial	545W	JKM545N-72HL4-BDV	2
182 PERC bifacial	540W	JKM540M-72HL4-BDVP	2
210 PERC bifacial	645W	N/A	2

The output terminal of each module is implanted with high-precision sensors to monitor the modules' power generation parameters in real time, and the data is aggregated and calculated through Alibaba Cloud platform digital monitoring system. In addition, the cloud platform digital monitoring system can realize the monitoring of real-time meteorological data of the demonstration site, and can also calculate the performance ratio of the theoretical and actual power generation of the photovoltaic system. All the power generation test data, meteorological data and data filtering provided in this report are completed by Python programs, so as to improve the speed of data processing and reduce the inefficiency, complexity and error-prone of manual Excel processing.

Main information of the field trial system is listed in the table below.

Project Location	PV Field Trial Base in Selangor Region, Malaysia
GPS Coordinate	3°2' N,101°47' E
Annual Sun Exposure Hours	2222.3 h
Annual Global Horizontal Irradiation	5756.4 MJ/m2
Annual Average Temperature	28.2 °C
Annual Average Relative Humidity	81%
Date of Grid-connection	December 2022
Installation Method	Fixed 1P, 10°
Azimuth Angle	Due south, 0°
Height Above Ground	1m
Surface Condition	Concrete surface

1.2 MODULE INITIAL LABORATORY POWER

HALM solar simulator was used to test the modules' initial laboratory electrical performance parameters. The initial laboratory power of the 6 test modules is shown in the table below.

Module Type	Module Number	Serial Number	Pm (W)
JKM545N-72HL4-BDV	01	E3FXJ1220529610003868729	548.70
	02	E3FXJ1220529610003868860	549.17
JKM540M-72HL4-BDVP	03	E3XXF2220607180074875160	542.87
	04	E3XXF2220609180075820880	544.61
210 PERC bifacial module	05	N/A	650.59
	06	N/A	650.08

1.3 EQUIPMENT CONFIGURATION INFORMATION

The test equipment mainly includes custom-bulit data acquisition system for lab-quality DC monitoring at the module-level and multi-sensor weather station and irradiance sensor for meteorological monitoring. Monitoring system configurations are shown below. The test data acquisition interval is 5 seconds. The data recording period is 1 minute. The data acquisition accuracy of all the following equipment can meet the requirements of field trial. The module-level monitoring equipment and multi-sensor weather station connect to the data acquisition equipment through several RS485 communication cables. The data acquisition equipment can achieve stable data transmission, local stroage and remote upload to Alibaba Cloud platform using 4G wireless network.

Equipment Category	Measurement parameter	Unit	Sensor type	Accuracy
Module-level monitoring equipment	DC voltage	V	Acrel	≤0.5%
	DC current	A		≤0.5%
	DC power	W		≤0.4%
	Module temperature	℃	T-type thermocouple	±0.3℃
Multi-sensor weather station	In-plane frontal irradiance	W/m²	Kipp&Zonen CMP10	0.2%
	Atmospheric pressure	Pa	SONBEST SM2182B	±2%
	Wind speed	m/s	Metone034B windsensor	±1.1%
	Wind direction	°		±4°
	Ambient temperature	℃	Campbell CS215 temperature / RH probe	±0.4℃
	Relative humidity	%		±4%
	Rainfall	mm	SR 50A CSE sonic ranging sensor	0.25mm
Data acquisition equipment	—	—	Campbell CR1000Xsensor	—

1.4 TEMPERATURE SENSOR INFORMATION

One module of each type is selected as the temperature measuring module, and 6 temperature points are set for each selected temperature measuring module.

2 PROJECT OPERATION

2.1 DATA QUALITY CHECK

Since the test system was connected to the grid on December, 2022, the test system has been running steadily and healthily. No serious system failure occurred. This report covers test data from January 1 to March 31,2023.

Check the meteorological data every minute, such as in-plane frontal irradiance, ambient temperature, wind speed and relative humidity. Check the module temperature data, calculate the temperature difference between each temperature sensor and the average of the six temperature sensors. Check the PV modules' output power data, plot scatter diagram of output power varies with in-plane frontal irradiance.

2.2 METEOROLOGICAL DATA

Based on the statistical data of the meteorological sensor configured in the cloud platform digital monitoring system, it can be seen that accumulated quarterly in-plane frontal irradiation is 389.48 kWh/m^2. The average quarterly atmospheric pressure is 994.74 Pa, wind speed is 3.25 m/s, ambient temperature is 28.34 ℃, relative humidity is 71.11%.

3 DETAILS OF MONITORING INDICATORS

3.1 MODULE TEMPERATURE PERFORMANCE ANALYSIS

According to the module temperature and output power data collected by the the cloud platform digital monitoring system in this quarter, the normalized energy yield performance at each module temperature range can be recorded under the normal working state of each module type.

Plot to compare the normalized energy yield gain in different temperature ranges.

Module temperature range	JKM545N-72HL4-BDV (kWh/kW)	JKM540M-72HL4-BDVP (kWh/kW)	210 PERC bifacial module (kWh/kW)
20~30℃	26.93	25.06	25.55
30~40℃	91.27	85.62	82.51
40~50℃	164.15	155.28	151.20
>50℃	91.68	87.92	91.16

Normalized energy yield and gain in different module temperature ranges

3.2 MODULE LOW-IRRADIANCE PERFORMANCE ANALYSIS

According to the frontal irradiance and output power data collected by the the cloud platform digital monitoring system in this quarter, the normalized energy yield performance at each irradiance range can be recorded under the normal working state of each module type.

Plot to compare the normalized energy yield gain in different irradiance ranges.

Irradiance range	JKM545N-72HL4-V (kWh/kW)	JKM540M-72HL4-BDVP (kWh/kW)	210 PERC bifacial module (kWh/kW)
≤200 W/m^2	31.44	34.32	34.55
200~400 W/m^2	61.81	66.28	66.33
400~600 W/m^2	65.45	69.37	69.22
600~800 W/m^2	54.85	57.49	57.01
800~1000 W/m^2	55.82	58.00	56.95
>1000 W/m^2	66.26	68.43	66.36

3.3 QUARTERLY ENERGY YIELD

Based on the statistical data from the first quarter of 2023, the energy yield of each module type is compared in the following table, the calculation results are the average values of each module type. When we calculate normalized energy yield gain, module type 182 PERC bifacial JKM540M-72HL4-BDVP is used as baseline.

Module Type	Accumulated Energy Yield (kWh)	Accumulated Normalized Energy Yield (kWh/kW)	Accumulated Normalized Energy Yield Gain
182 TOPcon bifacial	205.32	374.03	5.69%
182 PERC bifacial	192.42	353.88	BL
210 PERC bifacial	227.89	350.42	-0.97%

4 PERFORMANCE RATIO

4.1 TEST INTRODUCTION

In order to test the overall performance ratio of the PV power station, a high-precision meteorological data acquisition device is used to continuously collect the solar radiation data and analyze the performance ratio of the PV power station.

4.2 TEST RESULTS

The performance ratio of each module type in the first quarter of 2023 is listed in the table below.

Module Type	Theoretical Energy Production (kWh)	Actual Energy Production (kWh)	Quarterly Performance Ratio PR
182 TOPcon bifacial	213.80	205.32	96.03%
182 PERC bifacial	211.77	192.42	90.86%
210 PERC bifacial	253.29	227.89	89.97%

5 OVERALL EVALUATION

At Malaysia field trial base, the four module types successfully completed the outdoor energy yield test in the first quarter of 2023. Test results demonstrated that for the 182 TOPcon bifacial module, JKM545N-72HL4-BDV, the normalized energy yield is 374.03 kWh/kW and PR is 96.03%. For the 182 PERC bifacial module, JKM540M-72HL4-BDVP, the normalized energy yield is 353.88 kWh/kW and PR is 90.86%. For the 210 PERC bifacial module, the normalized energy yield is 350.42 kWh/kW and PR is 89.97%.

When comparing normalized energy yield gain, 182 TOPCon bifacial module is **5.69%** higher than that of 182 PERC bifacial module. Comparing the influence of different cell size on energy yield, the normalized energy yield of 210 PERC bifacial module is 0.98% lower than that of 182 PERC bifacial module.