CGC Field Test in Zhangebei:Lower LID (0.65%) & Higher Yield Gain (4.8%) for N-type

N-type silicon-based solar cells are increasingly being used for achieving high efficiency and lower degradation. In order to study and compare the light induced degradation of N-type panels with P-type panels in the real world condition, an investigation had been conducted by a third party testing institution CGC (China General Certification) on generation performances, degradation (LID) and other electrical properties of n-type TOPCon solar modules are compared with those of p-type PERC modules.

The 12-months (July 1,2022 - June 31, 2023) outdoor experimental results shows the yield gain of Jinkosolar' s N-type TOPCon modules is **4.8%** over P-type PERC modules. One of the critical causes for the gain are interpreted by lower First-year degradation of N-type' s **0.65%** versus **1.72%** of P-type.

Experimental

To investigate the power generation, temperature variation and power degradation of Jinko N-type modules, this outdoor performance project conducted a field test in Zhangbei, which starting from July 1, 2022 to June 30, 2023, see figure 1-1

Figure 1-1 Zhangbei field test base

1 Brief Introduction of Zhangbei Field Test Base

The Zhangbei Field Test Base is located in Zhangbei County, Zhangjiakou City, Hebei Province, covering an area of about 5,000m2. The Field Test Base includes a ground power station and a roof-distributed PV power station. The Field Test Base is equipped with a high-precision environmental monitoring system, which can monitor and record meteorological conditions such as irradiance, temperature and humidity, wind speed, wind direction, rainfall and spectrum,et.

Zhangbei County is located in the northwest of Hebei Province. It has a Mesotemperate zone continental monsoon climate, with an average annual temperature of 4.0℃, good sunshine conditions, sufficient sunlight, rain and heat in the same season, a significant temperature difference between day and night, drought, wind, less rain and short frost-free periods. The average annual total irradiation amount is 1665.3 kWh/m2, the average wind speed is 15.4 m/s, and the average relative humidity is 51.9%RH. According to Meteonorm v8.1.1 software, the meteorological conditions in the Zhangbei region are simulated and analyzed.

2 Field Test Setup

Two PV array experimental groups are set up in the Zhangbei field test base: the Jinko N-type double-sided module array and Jinko P-type double-sided module array. By controlling module orientation, support type and other factors, the experimental groups consistently monitored and analysed the working temperature and power generation performance of different kinds of modules.

2.1 PV module sample

The sample information of PV modules used in this field test is shown in table 2-1, including the Jinko N-type double-sided module and Jinko P-type double-sided module. All the above module samples use high-efficiency single crystalline silicon technology.

Sample type	Sample I	Sample II
	Jinko N-type double-sided module	Jinko P-type double-sided module
Model	JKM560N-72HL4-BDV	JKM540M-72HL4-BDV
Specification	2278×1134×30mm	2278×1134×30 mm
No	10	10
Nameplate power	560	540
Voc(V)	50.67	49.73
Isc(A)	14.13	13.89
Vmp(V)	41.95	41.13
Imp(A)	13.35	13.13

Table 2-1 Module sample parameters

2.2 Inverter Parameter

The field test project in Zhangbei adopts a series of inverters of sunlight power supply SG20RT-P2-CN. The specific inverter parameters are shown in table 2-2. During the use of the inverter, there are no limiting factors affecting the test results, such as overmatch and current limiting.

Inverter	SUNGROW SG20RT-P2-CN Zhangbei field test base
Rated output power/kW	20
Maximum input voltage /V	1100
Starting voltage /V	180
Maximum input current /A	2×32
MPPT voltage range /V	160-1000
No MPPT	2

Table2-2 Inverter parameter

2.3 PV system and monitoring system design

Table 2-3 shows the basic parameters set at Zhangbei field test base for this field test.

Test site	Zhangbei	**Latitude**	41°
Support type	Tracking support	**Spacing**	7.5 m
Component size	2278×1134×30 mm	**Mounting height**	The lowest point of the module is 0.8m from the ground
Array number	2	**Inverter**	SUNGROW SG30CX-P2-CN
Environmental monitoring	Automatic meteorological station at the base	**Ground condition**	Meadow
Temperature measurement method	In the two PV arrays, thermocouples are selected to be attached to the upper and lower two points of the back of the module in the same position and under the same irradiation condition for comparative analysis of the working temperature of each array module.		

Table 2-3 Basic parameters of Zhangbei field test base

The direct current (DC) side of each PV array is connected to an induction DC meter, which is used to collect the voltage, current and power data of the DC side of each variety. Then, each array is separately connected to an inverter with one MPPT channel to avoid array mismatch loss. Zhangbei Base is equipped with professional meteorological equipment for monitoring the meteorological data of the base environment. Data collection and storage frequencies refer to IEC 61724-1. The sensor data is transmitted to the verification cloud platform through the data collector and data services. During the test period, raw data such as power generation and working temperature are fed back monthly, and data analysis reports prepared according to power generation and temperature changes are provided back quarterly. Table 2-5 Data monitoring system of Zhangbei field test base.

No.	Parameter	Number of sensors	Sensor type	Acquisition frequency	Recording interval	Precision class
1	Total irradiance of PV array	1	Kipp&Zonen CMP10	1Hz	1min-avg	0.2%
2	Total irradiance of horizontal plane	1	Kipp&Zonen CMP10	1Hz	1min-avg	0.2%
3	Scattered irradiance	1	Kipp&Zonen CMP10	1Hz	1min-avg	0.2%
4	Normal direct irradiance	1	Kipp&Zonen CHP1	1Hz	1min-avg	0.2%
5	Dc voltage, current, power	2	Acrel	1Hz	1min-avg	I、V：0.5% P：0.4%
6	PV module temperature	4	T-type thermocouple	1Hz	1min-avg	±0.3℃
7	Ambient temperature and humidity	1	Campbell CS215 Temperature/RH probe	1Hz	1min-avg	T：±0.4℃ H：±4%
8	Wind speed and direction	1	Metone 034B windsensor	1Hz	1min-avg 1min-max	WS：±1.1% WD：±4°
9	Rainfall	1	SR 50A CSE Sonic Ranging Sensor	1Hz	1min-avg	0.25mm
10	Snowfall	1	SR 50A Snow depth sensor	1Hz	1min-avg	±1.0 cmor±0.4%, Take the largest of the two
11	Data collector	1	Campbell CR1000X	1Hz	N/A	N/A
12	Video surveillance	1	Fluorite		N/A	N/A

Table 2-5 Data monitoring system of Zhangbei field test base

3 Indoor Electrical Performance Test

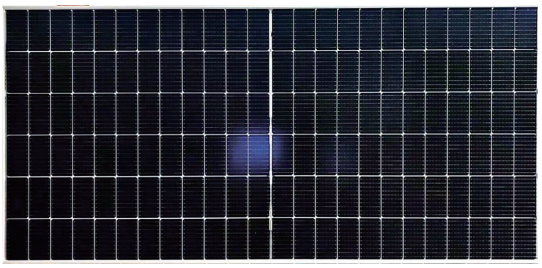
Before the field test, the laboratory electrical performance test is carried out in CGC Zhejiang Branch. Table 3-1 lists the test contents and standards.

	No.	Test item	Test standard/method	Clause	Test result	Evaluation
Test items& Test standards/ methods	1	Visual inspection	IEC 61215-2:2021 Crystalline silicon PV modules for ground use - Design qualification and specification	4.1 MQT01	In section 3.2	P
	2	Performance at STC		4.2 MQT02	In section 3.2	—
	3	EL test	IEC TS 60904-13:2018 PV equipment	Part 13 Electroluminescence of PV modules	In section 3.4	N/A
Assessed measurement uncertainty	The uncertainty of electrical performance measurement under STC condition is as follows Urel(Isc)=2.3% (k=2) ; Urel(Voc)=0.8% (k=2) ; Urel(Pmax)=2.5% (k=2) 。					
Test period	Started on:February 18, 2022; Completed on:February 25th, 2022					
Testing location	China General Certification, LTD. Zhejiang Branch					

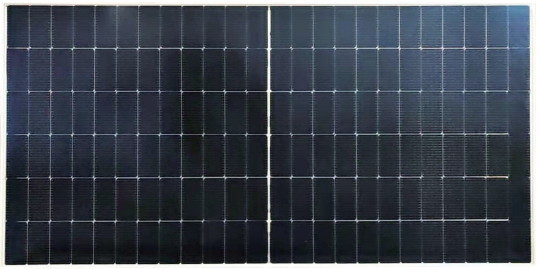
	No.	Test item	Equipment Name	Equipment No.	Calibration valid date	Remark
Test equipments /reagents	1	Performance at STC	Solar simulator	CGCZJ-EQ1074	2023.05.13	N/A
	2		Standard solar cell	CGCZJ-EQ1003	2023.04.12	N/A
	3	Visual inspection	Illumination	CGCZJ-EQ1013	2023.01.06	N/A
	4		Tape measure	CGCZJ-EQ1014	2023.01.06	N/A

Table 3-1 Indoor electrical performance test summary

3.1 Visually inspect results



Front view of Jinko P - type double-sided



Front view of Jinko N type double-sided

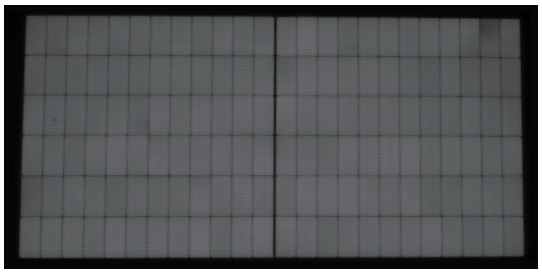
3.2 Performance at STC

Before the field test, sample statistics of the experimental group for electrical performance tests under STC, and the test results are shown in table 3-2.

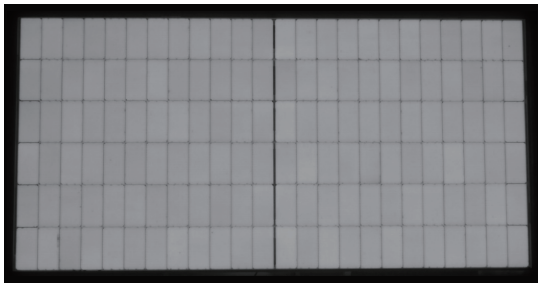
Experimental group	Type	Voc (V)	Vmp (V)	Isc (A)	Imp (A)	Pmax (V)	FF (V)	Array Power (V)	Sample Serial No.
A	JKM560N-72HL4-BDV	51.96	43.65	13.548	12.906	563.29	80.03	5639.60	1
		52.02	43.61	13.560	12.921	563.43	79.88		2
		52.02	43.68	13.554	12.927	564.65	80.09		3
		52.11	43.72	13.559	12.915	564.68	79.92		4
		52.08	43.67	13.582	12.922	564.22	79.76		5
		52.08	43.69	13.536	12.908	563.95	80.01		6
		52.07	43.68	13.551	12.929	564.70	80.03		7
		51.95	43.67	13.535	12.908	563.63	80.17		8
		52.09	43.62	13.531	12.906	562.91	79.86		9
		52.01	43.70	13.591	12.909	564.13	79.80		10
B	JKM540M-72HL4-BDVP	50.11	41.80	13.659	13.020	544.17	79.51	5429.31	1
		50.10	41.74	13.733	13.037	544.14	79.08		2
		50.06	41.83	13.715	12.970	542.61	79.03		3
		50.09	41.71	13.651	12.985	541.60	79.22		4
		50.03	41.77	13.610	12.937	540.44	79.37		5
		50.07	41.71	13.677	13.001	542.25	79.19		6
		50.03	41.81	13.657	12.982	542.76	79.44		7
		50.08	41.79	13.637	12.975	542.20	79.39		8
		50.13	41.79	13.703	13.037	544.83	79.32		9
		50.33	41.94	13.636	12.979	544.31	79.31		10

Table 3-2 Electrical performance test results of experimental group samples under STC

3.3 EL test result



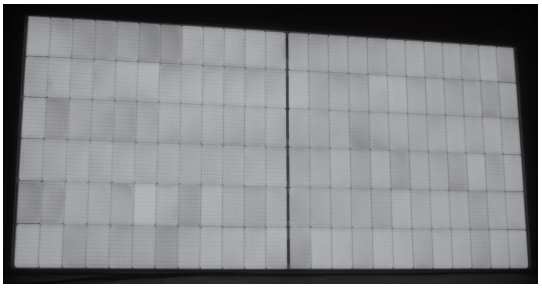
EL image of Jinko P - type double-sided module



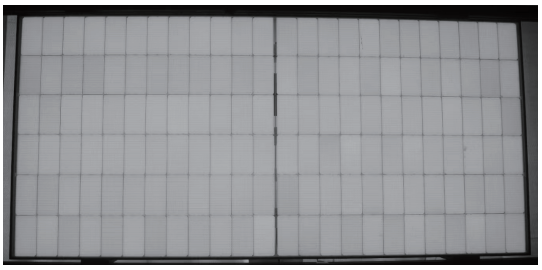
EL image of Jinko N - type double-sided module

3.4 Module EL test results after operating one year

The annual Jinko Solar N module empirical EL test results show no significant change in EL during the empirical period.



EL image of Jinko P - type double-sided module



EL image of Jinko N - type double-sided module

3.5 First-year Power Degradation

Based on first-year degradation, Jinko's average degradation of N-type module was 0.65%, and this of P-type module was 1.75%

Parameter	No.	Voc (V)	Vmp (V)	Isc (A)	Imp (A)	Pmax (V)	FF (V)	Pmax Change (%)
JKM560N-72HL4-BDV	1	51.57	43.14	13.510	12.941	559.28	80.10	0.71%
	2	51.65	43.19	13.574	13.015	562.07	80.20	0.24%
	3	51.55	43.19	13.456	12.882	560.4	80.20	0.75%
	4	51.67	43.19	13.531	12.970	561.16	80.10	0.62%
	5	51.53	42.95	13.571	12.999	560.22	79.80	0.71%
	6	51.60	43.19	13.580	12.997	560.22	80.00	0.66%
	7	51.50	42.85	13.499	12.983	561.3	80.00	0.60%
	8	51.54	42.90	13.520	13.027	559.8	80.20	0.68%
	9	51.61	42.85	13.513	13.001	558.03	79.90	0.87%
	10	51.65	42.84	13.519	13.059	560.49	80.10	0.65%
JKM540M-72HL4-BDVP	1	49.43	40.48	13.623	13.206	534.6	79.40	1.76%
	2	49.43	40.43	13.748	13.251	535.74	78.80	1.54%
	3	49.45	40.48	13.575	13.178	533.44	79.50	1.69%
	4	49.37	40.43	13.588	13.193	533.4	79.50	1.51%
	5	49.46	40.43	13.602	13.119	530.46	78.80	1.85%
	6	49.43	41.32	13.599	12.839	532.52	78.90	1.79%
	7	49.34	40.43	13.603	13.132	532.99	79.10	1.80%
	8	49.35	40.48	13.583	13.118	532.05	79.20	1.87%
	9	49.40	40.48	13.727	13.236	535.79	79.00	1.66%
	10	49.32	40.38	13.621	13.191	534.7	79.30	1.77%

4 Results

The power generation performance of the Jinko N-type double-sided module and Jinko P-type double-sided module are shown in table 4-1 and Figure 4-1. The power generation data from 8:00 to 17:00 every day is selected, and Jinko P-type double-sided modules are taken as the performance baseline. According to the data in Figure 4-1, the power generation performance of Jinko N-type double-sided modules are superior to that of Jinko P-type double-sided modules, and the cumulative power generation of Jinko N-type double-sided modules reaches 11710.23 kWh. The cumulative power generation of Jinko P-type double-sided modules gets 10757.43 kWh. The relative performance of total effective hours for N-type double-sided models can reaches 4.8%.

Experimental group	Type	Cumulative power generation（kWh）	Total effective hours（kWh/kW）	Relative performance（%）
A	Jinko N type double-sided module	11710.23	2076.43	104.80
B（Baseline）	Jinko P type double-sided module	10757.43	1981.36	100.00

Table 4-1 Comparison of power generation performance of Jinko N-type and P-type double-sided modules

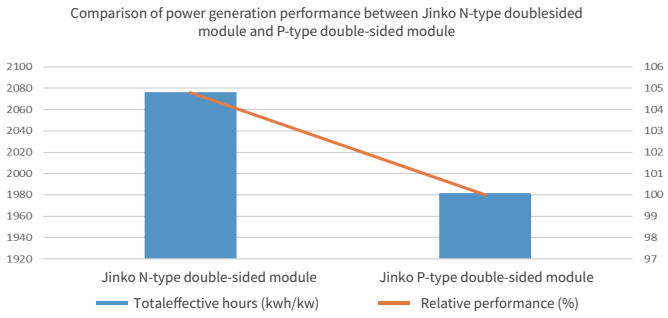


Figure 4-1 Comparison of power generation performance between Jinko N-type double-sided module and Jinko P-type double-sided module

5 Module Operating Temperature

To accurately monitor and analyze the temperature changes of Jinko modules during the field test process, a thermocouple is passed on the top, and bottom two points of an element in the same position of each array, and the operating temperature changes of the module are monitored by the thermocouple sensor. Temperature data of members from 8:00 to 17:00 every day is selected, abnormal data points are screened, and statistical analysis is carried out. The operating temperature changes of modules in the Zhangbei field test base experimental group in the first year are shown in table 5-1.

Taking Jinko P-type double-sided module s as the temperature reference, the maximum operating temperature of Jinko N-type double-sided module s is 0.05℃lower than that of Jinko P-type double-sided modules.

Experimental group	Maximum temperature /°C	Mean temperature /°C	Maximum temperature /°C	Mean temperature /°C	Maximum temperature /°C	Mean temperature /°C	Maximum temperature /°C	Mean temperature /°C
A	65.51	40.11	44.57	9.46	48.66	12.79	63.94	24.84
B (Baseline)	66.50	40.84	54.33	10.43	48.95	13.09	63.99	25.67

Table 5-1 operating temperature changes of modules in the Zhangbei field test base experimental group in the first year

6 Conclusion

This field test project is conducted in Zhangbei field test base to compare and analyze the power generation performance and temperature changes of the Jinko N-type double-sided module and the Jinko P-type double-sided module. Test results for the whole year (July 1, 2022, to June 31, 2023) are as follows:

1) According to the comparison of power generation performance data of the Jinko N-type double-sided module and Jinko P-type double-sided module, it can be concluded that the power generation performance of the Jinko N-type double-sided module is better than that of the Jinko P-type double-sided module, and the relative performance of total effective hours for Jinko N-type double-sided module is **4.80%** higher than that for Jinko P-type double-sided.

2) According to the operating temperature change of the experimental group of Zhangbei Base, it can be concluded that the maximum operating temperature of the Jinko N-type double-sided module is **0.05** ℃ lower than that of the Jinko P-type double-sided module.

3) According to Zhangbei project, the first year power degradation of Jinko's N-type module is **0.65%**, and that of P-type module is **1.72%**.