

The brief introduction of shingled module advantages

Reporter:Efficient module r&d project Department

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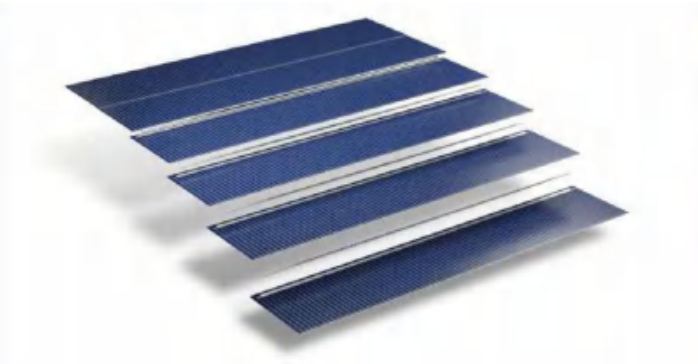
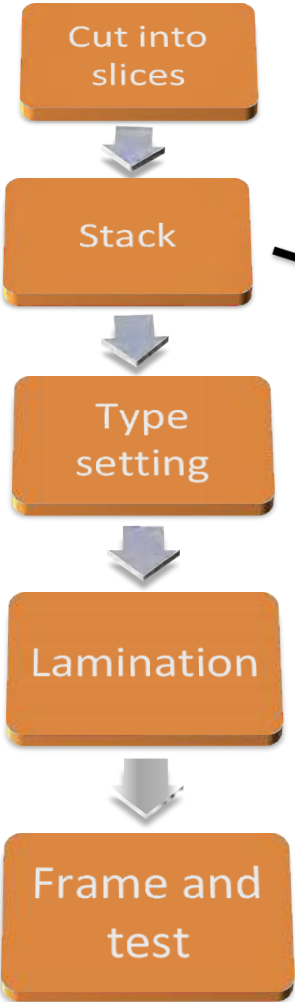
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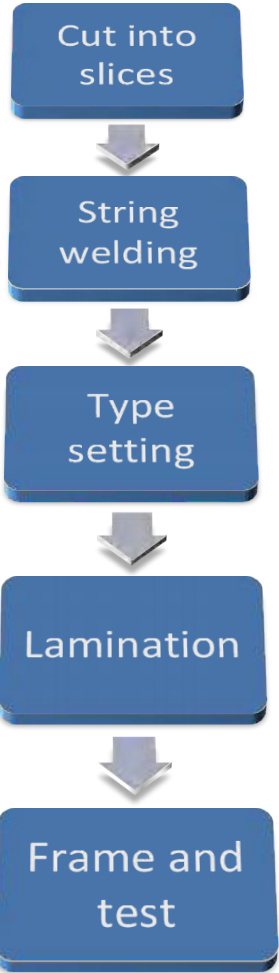
Shingled module technology-process



Shingled module

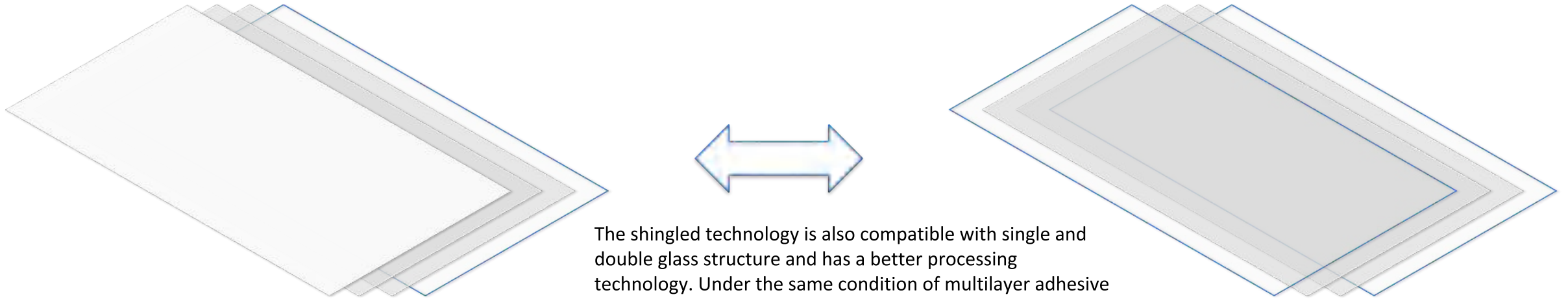


Normal module



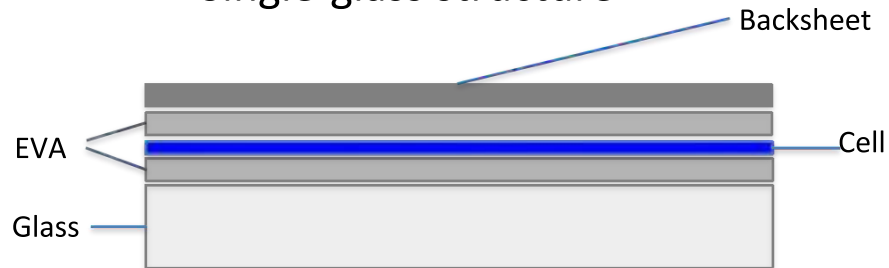
Compared with the normal module technology, the interconnected material of shingled module is different from that of normal module, whose technology is simpler and more reliable, avoiding the defects such as deviation of ribbon and cold soldering.

Shingled module-package structure

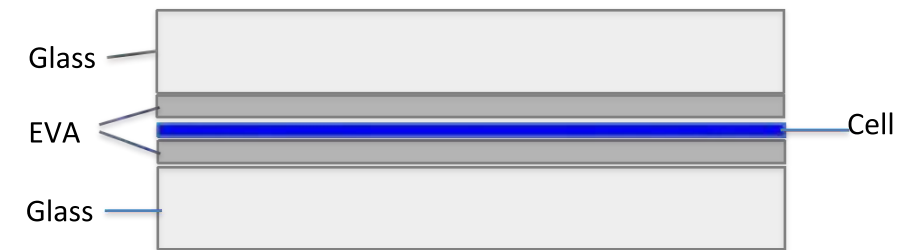


The shingled technology is also compatible with single and double glass structure and has a better processing technology. Under the same condition of multilayer adhesive packaging structure, shingled module reliability is better than normal module

Single-glass structure



Double-glass structure

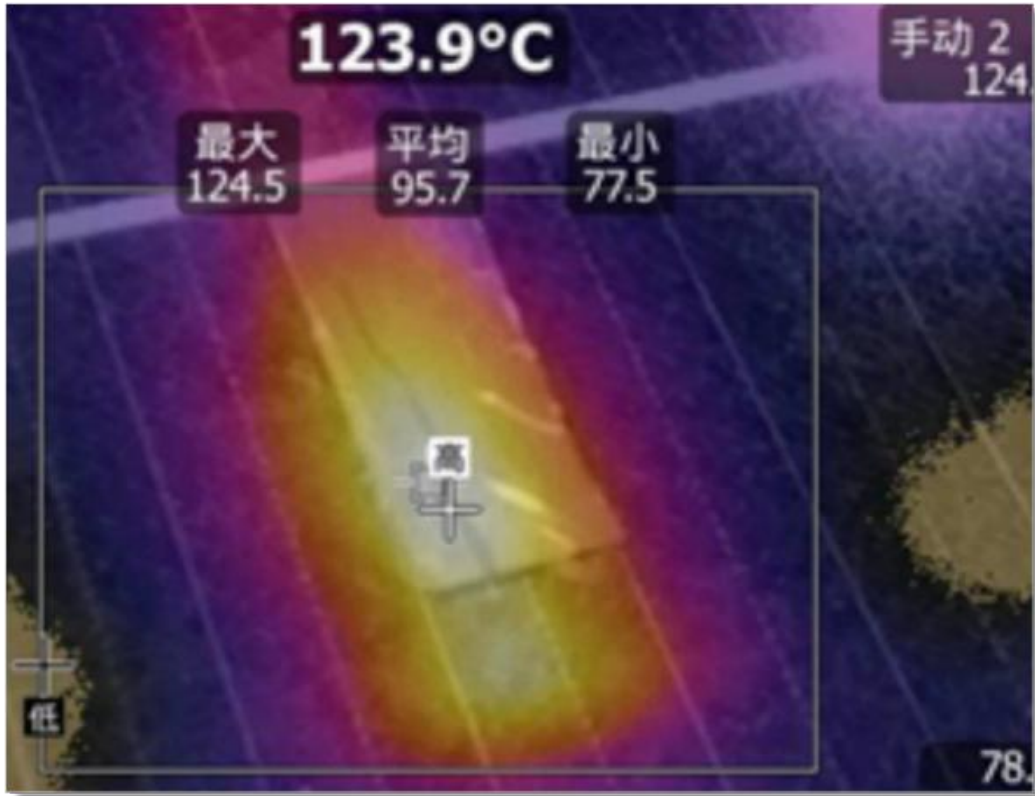


Shingled cells use flexible adhesives instead of metal alloys (Inducing micro-crack easily) to achieve interconnections between the cells, which has better flexibility

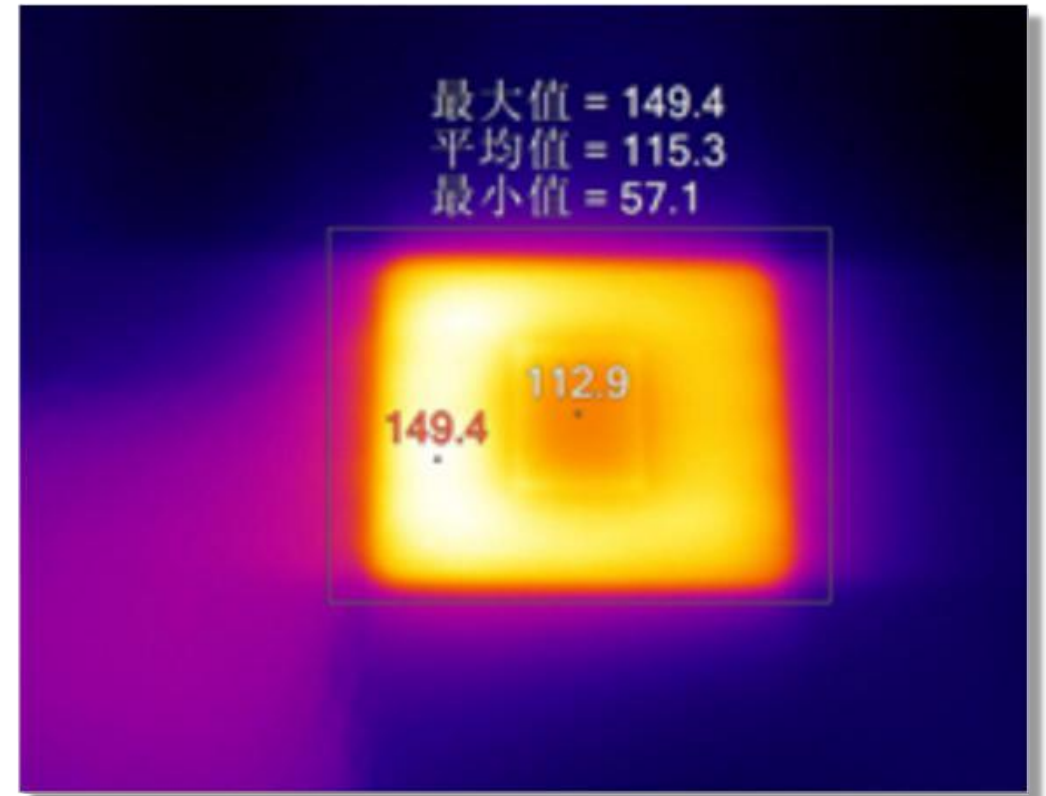
Shingled module reliability-hot spot

- The current is only 1/5 of that of the whole cell, about 1.8A
- Heat can be transmitted to adjacent cells through electric conductive adhesive to accelerate heat dissipation

- $I_{mpp} > 9A$
- The heat of hot spots is difficult to dissipate through conduction

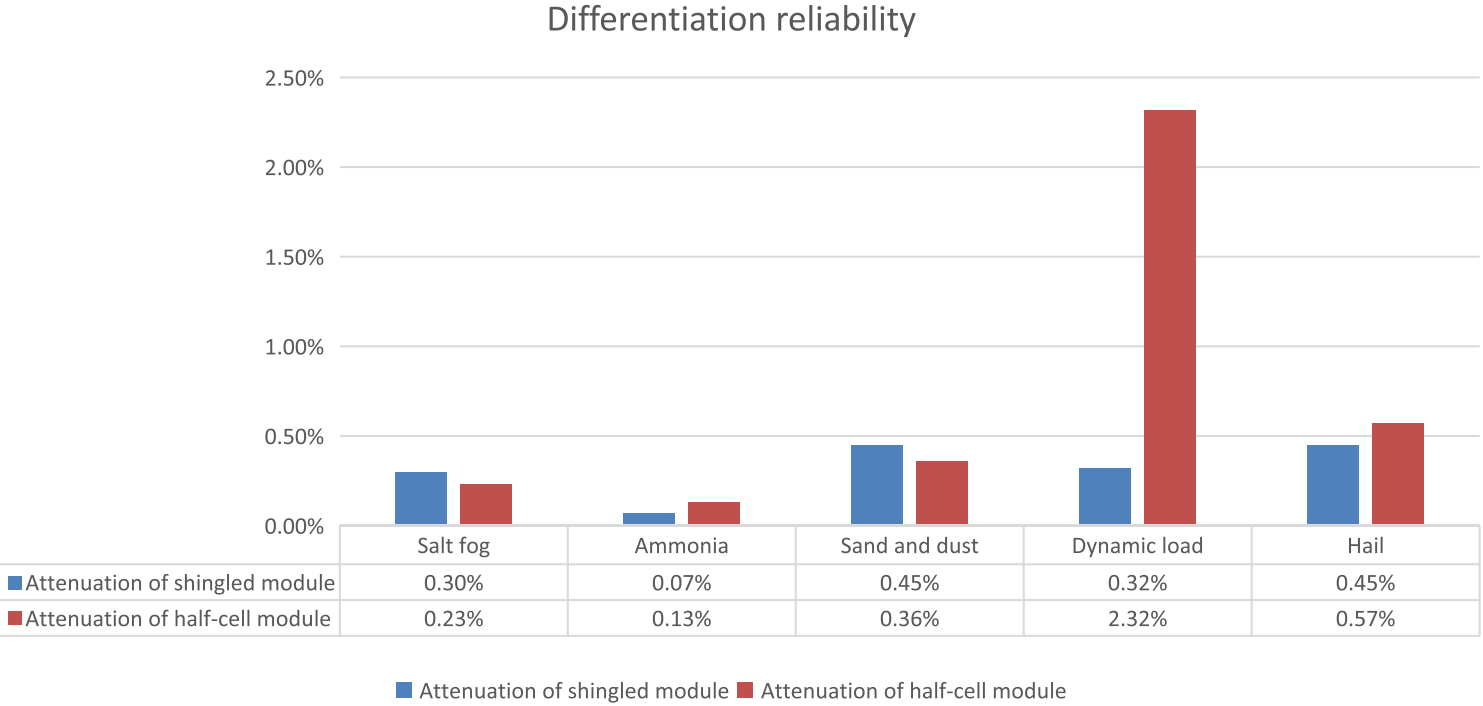


Shingled module (Hot spot temperature 124.5°C)



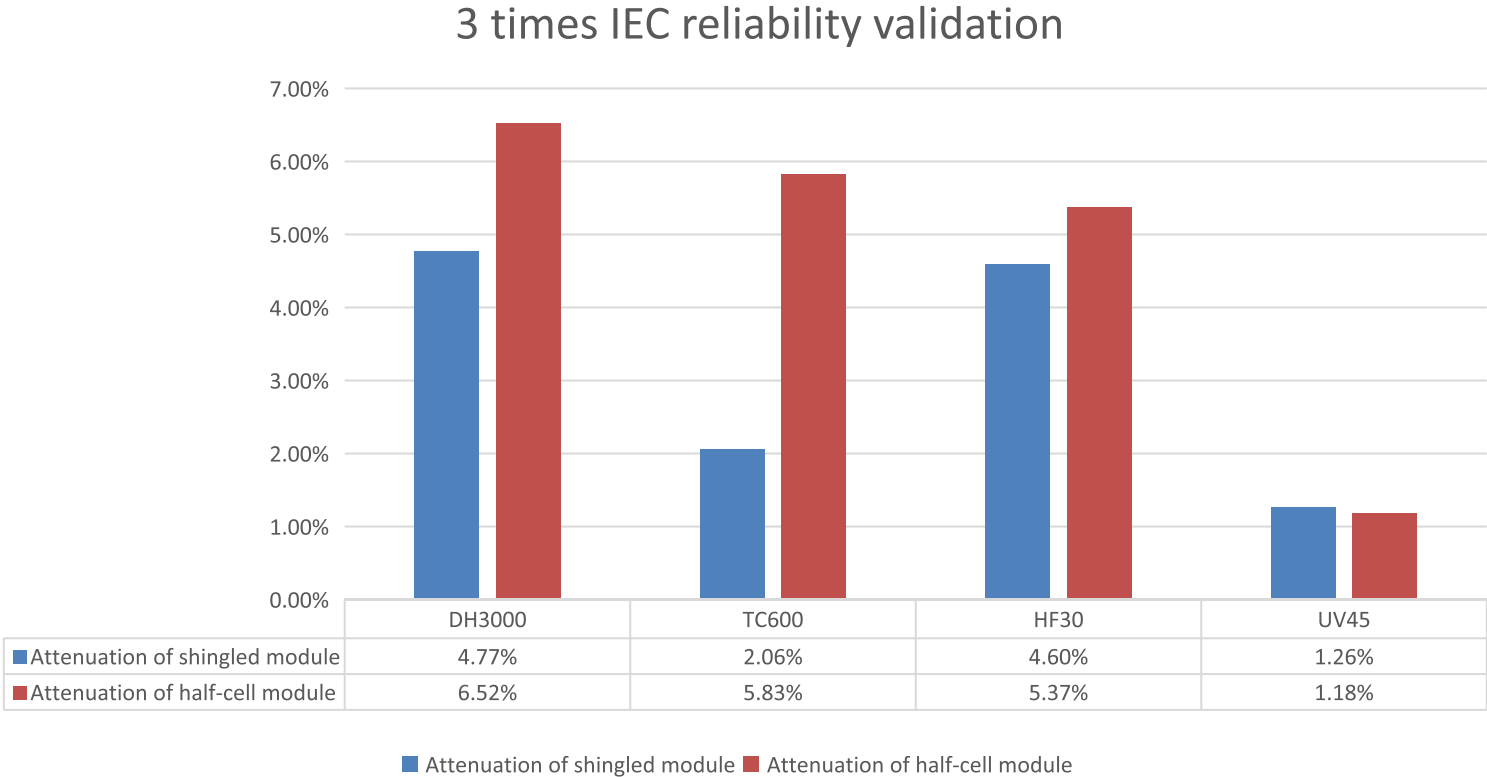
Normal module (Hot spot temperature 149.4°C)

Shingled module reliability-differentiation reliability



- In various differentiation reliability tests conducted in TUV North Germany, shingled modules perform better in dynamic loading, and in other aspects, shingled modules perform almost as well as half-cell modules.

Shingled module reliability - 3 times IEC reliability



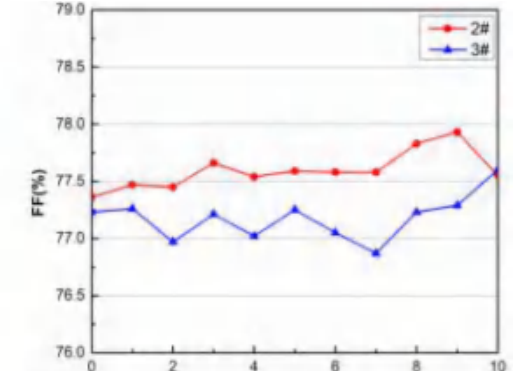
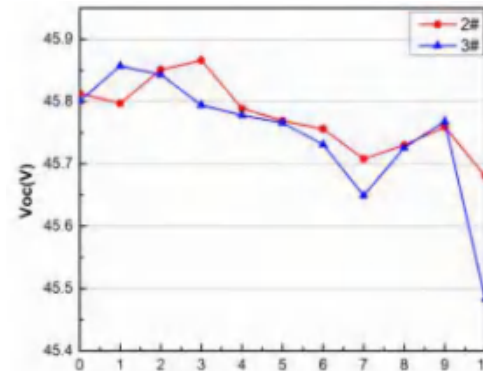
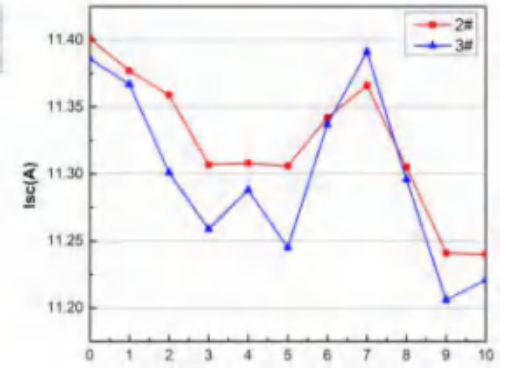
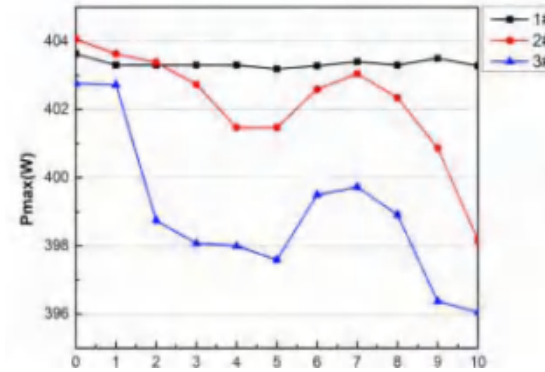
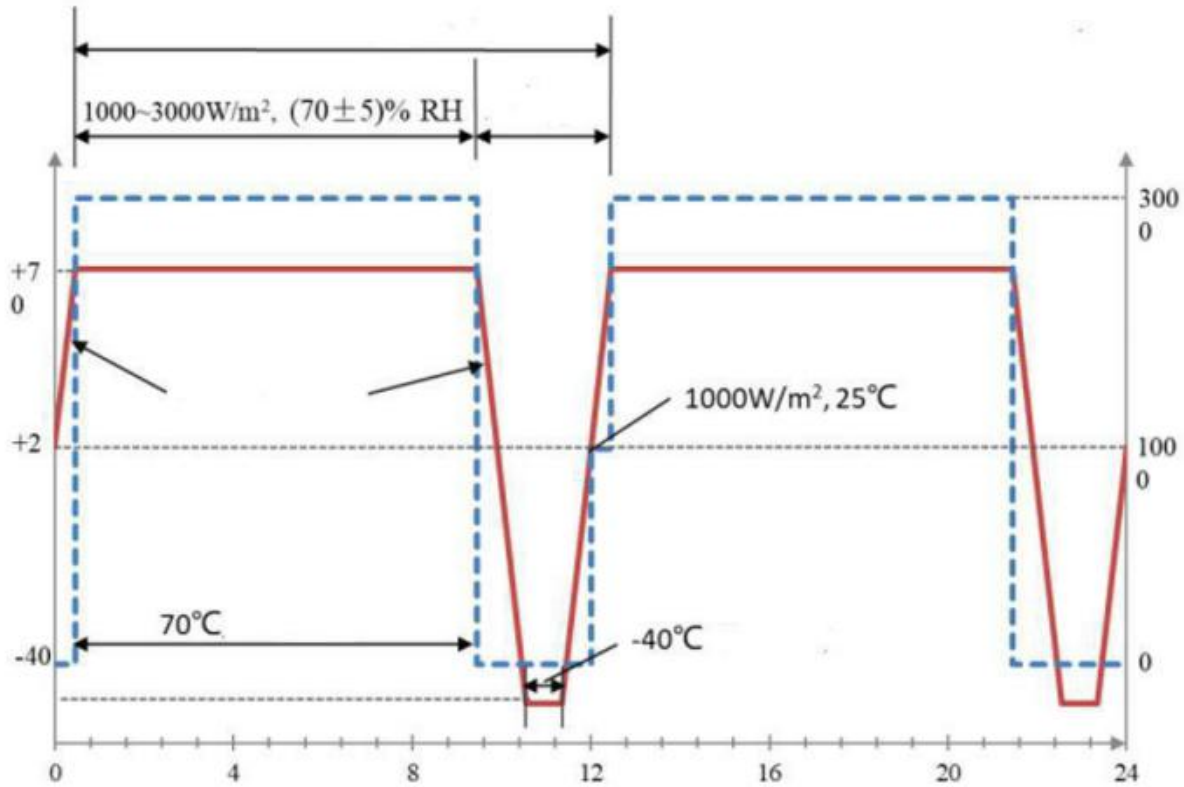
- In CPVT many times IEC reliability tests, the attenuation of all project is less than 5% of the one time IEC standard (test items were more than 3 times more stringent than one time IEC standards).
- Compared with normal half-cell modules, shingled modules are more advanced than half-cell modules in TC, DH, HF reliability testing.

Shingled module reliability-TC Reliability



- After summarizing and comparing the reliability test data of TC200 of shingled module and half-cell module, the attenuation of shingled module is about 1.9% lower than that of half-cell module

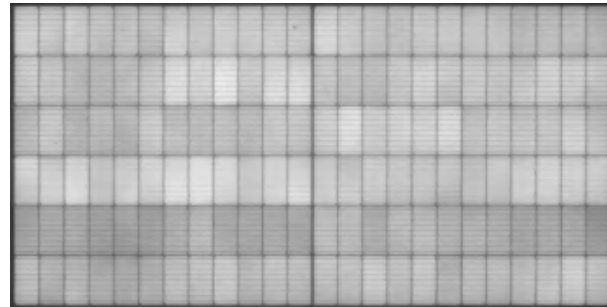
Shingled module reliability-Compound accelerated aging



The most stringent accelerated aging test in the photovoltaic module environment box, 3 times light +TC+DH, referred to as "composite acceleration". DH+TC composite aging test was carried out for the two shingled modules under 3 times of light. The cumulative irradiation dose was 1200KWh (including ultraviolet part 69.6kwh) and the attenuation was 1.46% and 1.67%

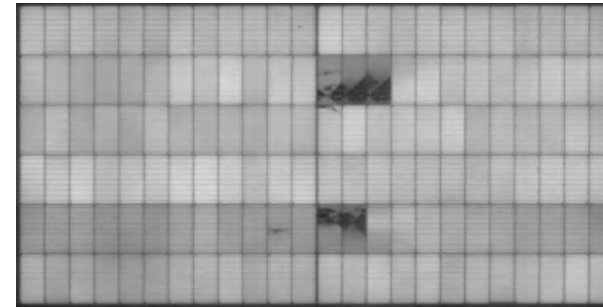
Generating capacity advantage of shingled module-load-resisting capacity

5400Pa Static mechanical load test



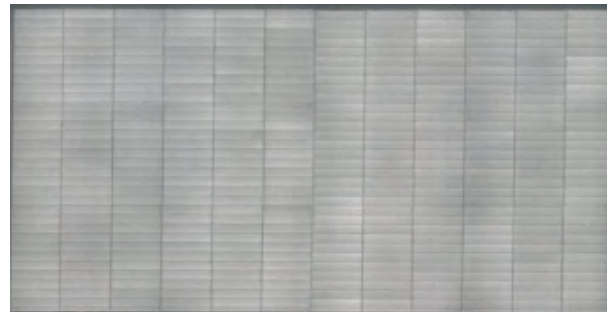
Before test

Half-cell module



After test

Power attenuation is 1.2%



Shingled module

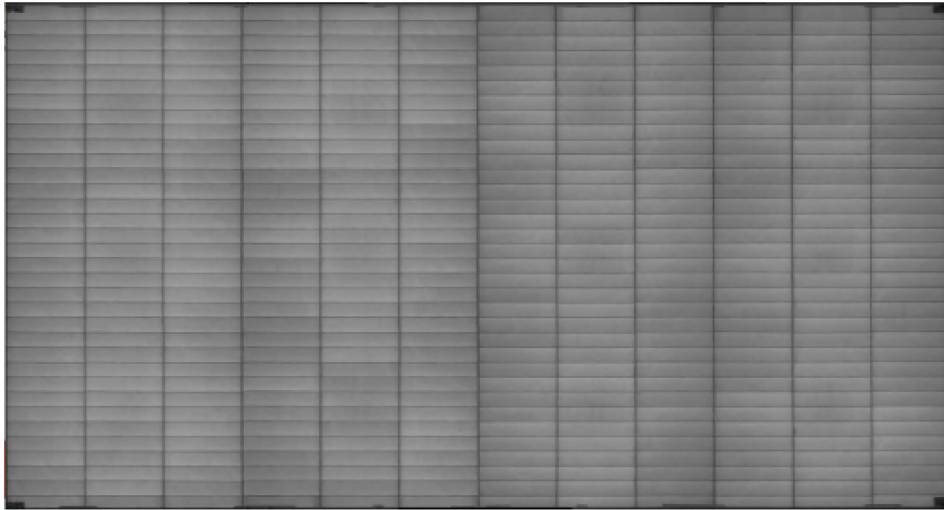


There's no power attenuation

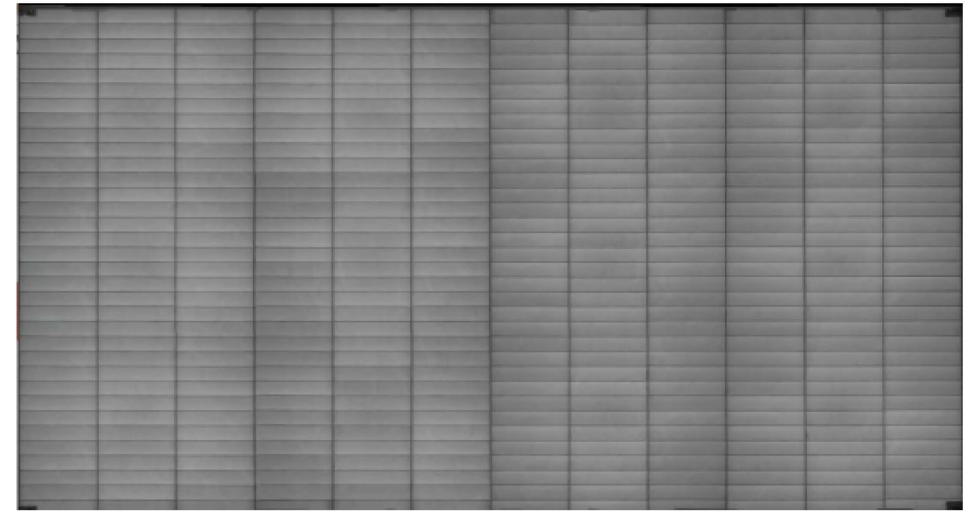
- Under the load of IEC 5400Pa, shingled has no new micro-cracks, although both shingled module and half-cell module passed the test(attenuation < 5%)
- High load resisting capacity reduces the production of micro-crack during transportation and power station installation

Generating capacity advantage of shingled module-
load-resisting capacity

8100Pa Static mechanical load test



Before test



After test

**Shingled module has passed the more stringent 8100Pa mechanical load tests,
the module has no micro-crack and no power attenuation.**

Generating capacity advantage of shingled module- load-resisting capacity



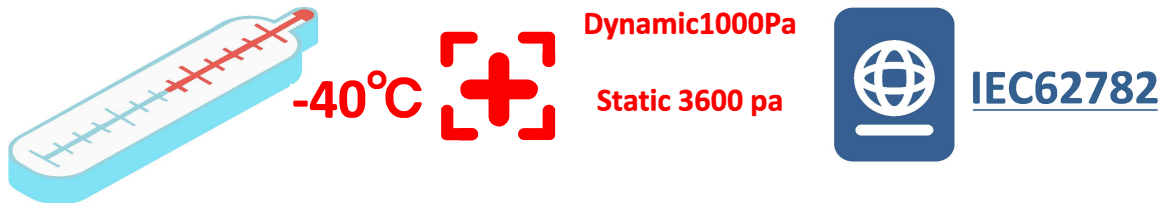
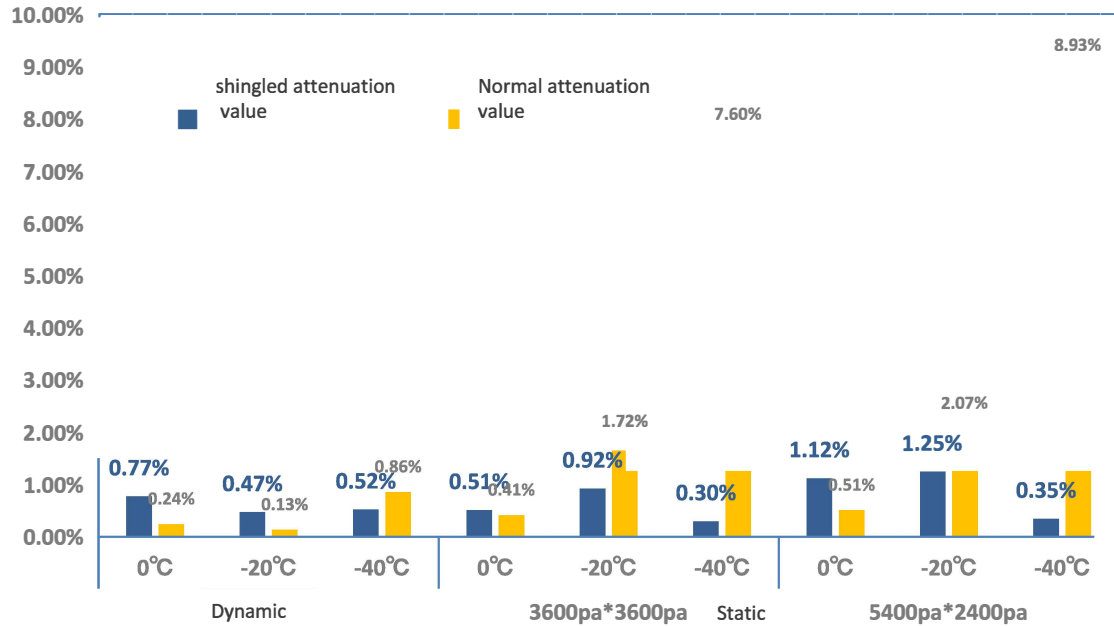
Module transverse deformation



Module longitudinal deformation

- The Load resisting capacity of shingled modules is verified by simulating the maximum deformation of the module (the maximum deformation of the module glass & frame)
- Experimental results show that there is no new micro-crack and power attenuation (0.26%)

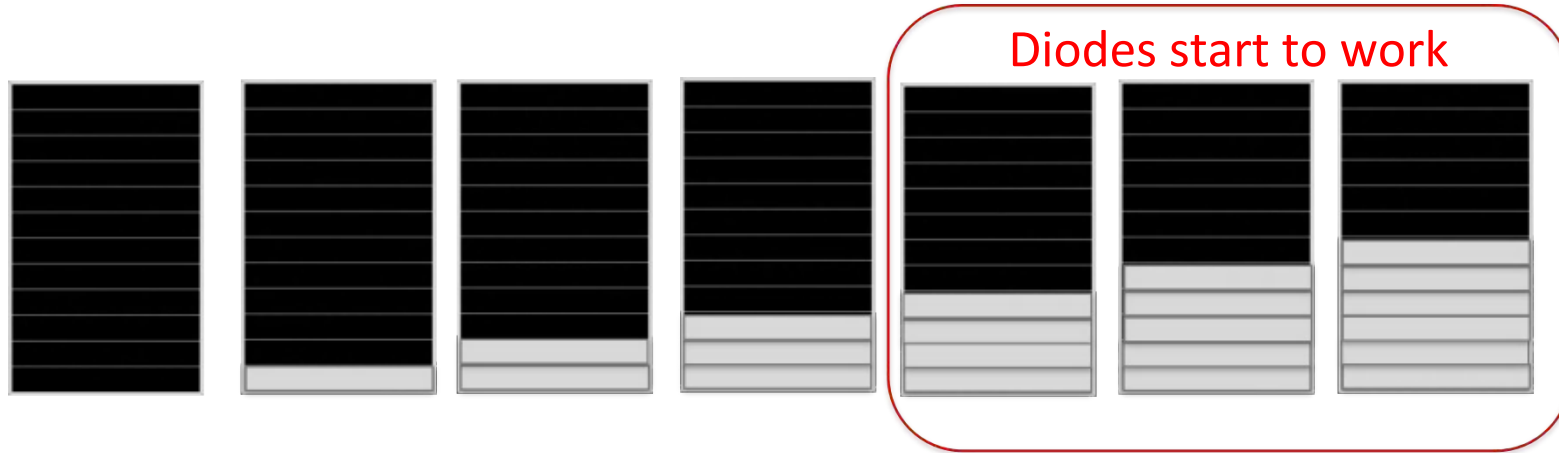
Generating capacity advantage of shingled module-load-resisting capacity



We have passed the 1000Pa low temperature dynamic load test and obtained the IEC 62782 certificate. In addition, in the IEC 61215 certificate, our modules have also passed the static mechanical load test of design load of 3600Pa front side load / 1600Pa back side load.

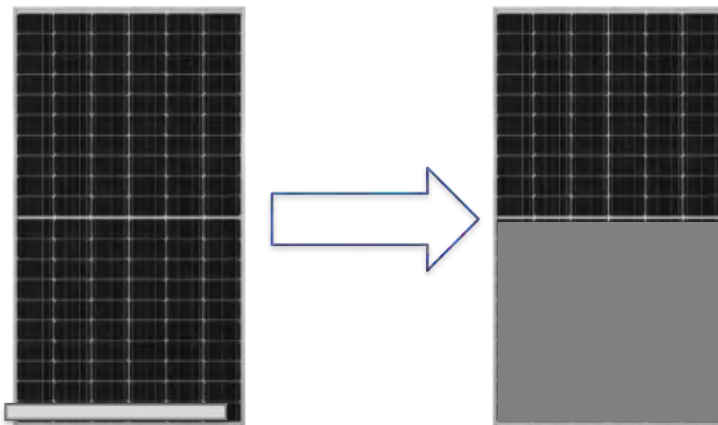
Generating capacity advantage of shingled module-shaded by shadow

When shaded by shadow, shingled modules have the best output power if the shingles modules are installed vertically.



The number of cells shaded by shadow	I(A)	Pm(W)	Power retention rate
Without occlusion	12.69	481.32	100.00%
1A row of cells is shaded	10.81	417.08	86.65%
Two rows of cells are shaded	8.70	309.33	64.27%
Three rows of cells are shaded	6.55	259.12	53.83%
Four rows of cells are shaded	12.63	230.59	47.91%
Five rows of cells are shaded	12.63	229.51	47.68%
Six rows of cells are shaded	12.62	229.39	47.66%

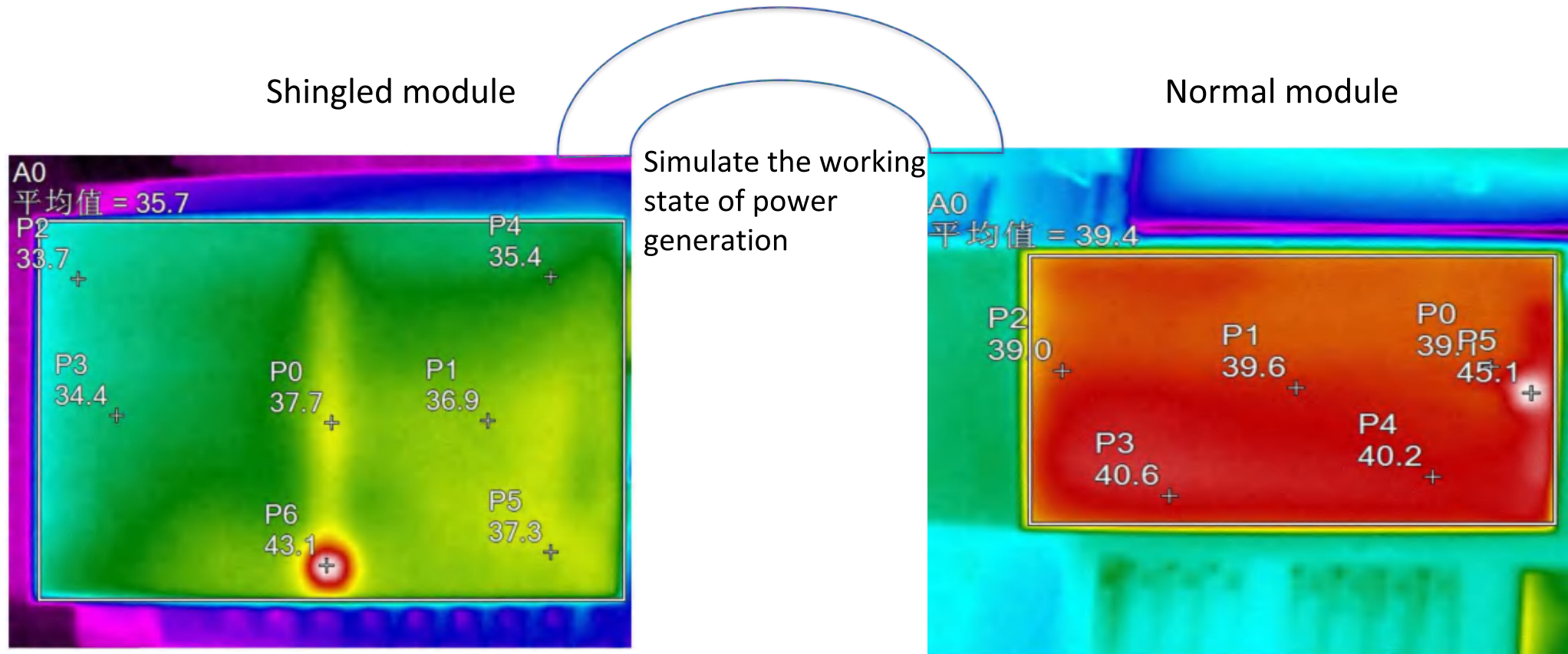
Diodes don't work



The number of cells shaded by shadow	I(A)	Pm(W)	Power retention rate
Without occlusion	11.304	446.252	100.00%
One to six rows of cells are shaded	5.671	222.092	49.77%

When the shingled module is installed vertically and the single cell string is shaded, the output power of the shingled module can reach 86.65% of the normal operation. That's 35% more power than the half-cell module.

Generating capacity advantage of shingled module-lower operating temperature



- Shingled module has lower operating temperature and higher output power than normal modules.
- Without occlusion, the experimental data show that the operating temperature of shingled modules is about 4°C lower than normal modules, and the output power/generating capacity is about 2% higher than normal modules.

Generating capacity advantage of shingled module-excellent temperature coefficient

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 Rev.<00>
 Dated 2018-11-05

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Manufacturing place: BLUESUN Solar Co.,Ltd
 Production Facility Code:90075
 No.7,1499 Zhenxing Road, Shushan Dist,230031 Hefei,PEOPLE'S REPUBLIC OF China

Test subject: Product: Photovoltaic modules

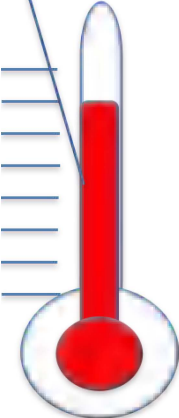
Test specification: IEC 61215: 2005, clause 10.4 Measurement of temperature coefficients

Purpose of examination: Test according to the test specification

Test result: The test results show that the presented product is in compliance with the specified requirements.

Ambient air temperature [°C] high/low	25	
Irradiance [W/m²]high/low	1000	
Module temperature [°C] high/low	55.0/25.0	
Sample #	Parameter	Calculated Value
	α [%/°C]	0.043
GDP180541-2	β [%/°C]	-0.268
	δ [%/°C]	-0.340
Supplementary information: N/A		

Temperature coefficient



- NMOT 42.3±2°C
- Open circuit temperature coefficient -0.27%/°C
- Short circuit temperature coefficient -0.04%/°C
- Max power temperature coefficient -0.34%/°C

Shingled module adopts the self-produced shingled cells, and the measured temperature coefficient is excellent.

Taking the working temperature of 45°C as an example, the influence of the temperature coefficient is calculated only (other factors are removed), and the default power is 410W:
 The power of half-cell module at 45°C: 410- (-0.354%*410)*20=380.972
 The power of shingled module at 45°C: 410- (-0.34%*410)*20=382.12

Generating capacity advantage of shingled module-Better ability to melt snow



Vertical installation, shingled module cells series and parallel structure, as soon as the snow on one string of cells melts, the module is ready to work, the temperature rise during work further accelerates snow melting. It can effectively increase module power generation time.

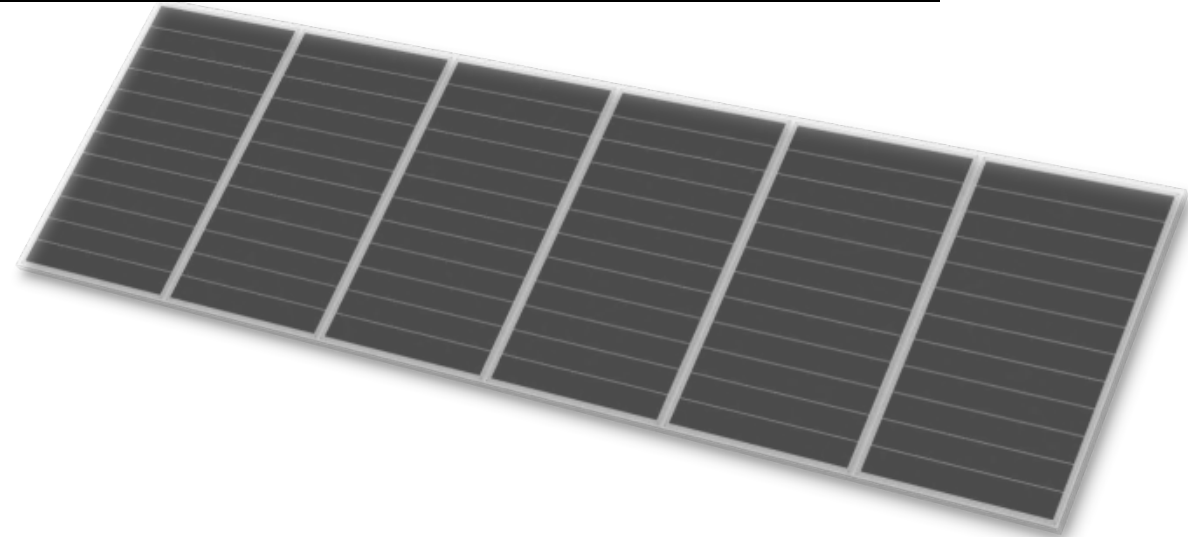
Normal module, it can only melt snow naturally under environmental conditions



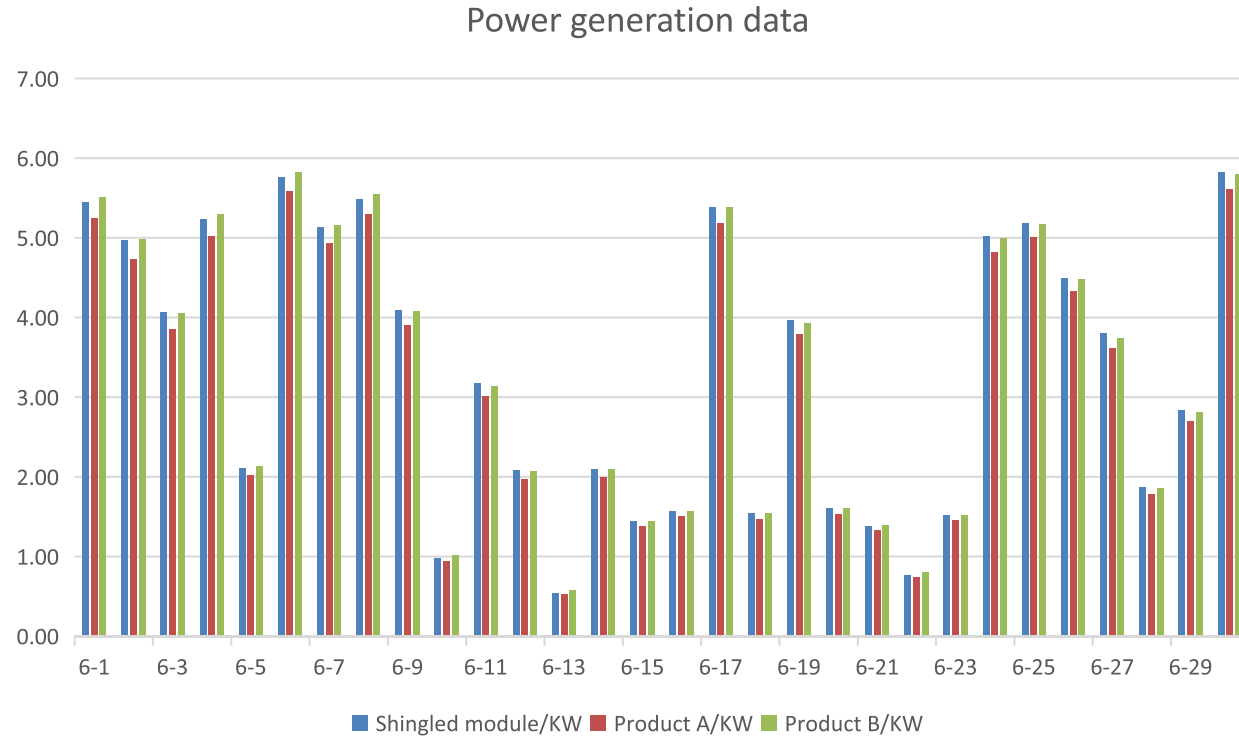
Generating capacity advantage of shingled module-higher PV string power

	Cell size	Power	Open circuit	System voltage	Environment tmpeature	Voltage tempeature coefficient	Module number of PV string	Theoretical power of PV string (W)
Shingled module	156.75	420	46	1500	-40	-0.27%/°C	27	10920
	158.75	430	46	1500	-40	-0.27%/°C	27	11180
	166	480	46	1500	-40	-0.27%/°C	27	12480
	210	500	44	1500	-40	-0.27%/°C	29	14000
Shingled VS Half-cell 1500V PV string power								
Half-cell module	210-9BB	500	51	1500	-40	-0.28%/°C	24	12000
	180-9BB	530	49	1500	-40	-0.28%/°C	25	12720
	166-9BB	445	49	1500	-40	-0.28%/°C	25	10680

- It is recommended to install shingled module transversely. When it is shaded by the array shadow in the morning and evening, the power output is obviously higher than that of other types of modules
- Bluesun large type shingled modules have lower open circuit voltage, more modules can be installed in the PV string for higher power and lower LCOE.



Generating capacity advantage of shingled module-outdoor validation



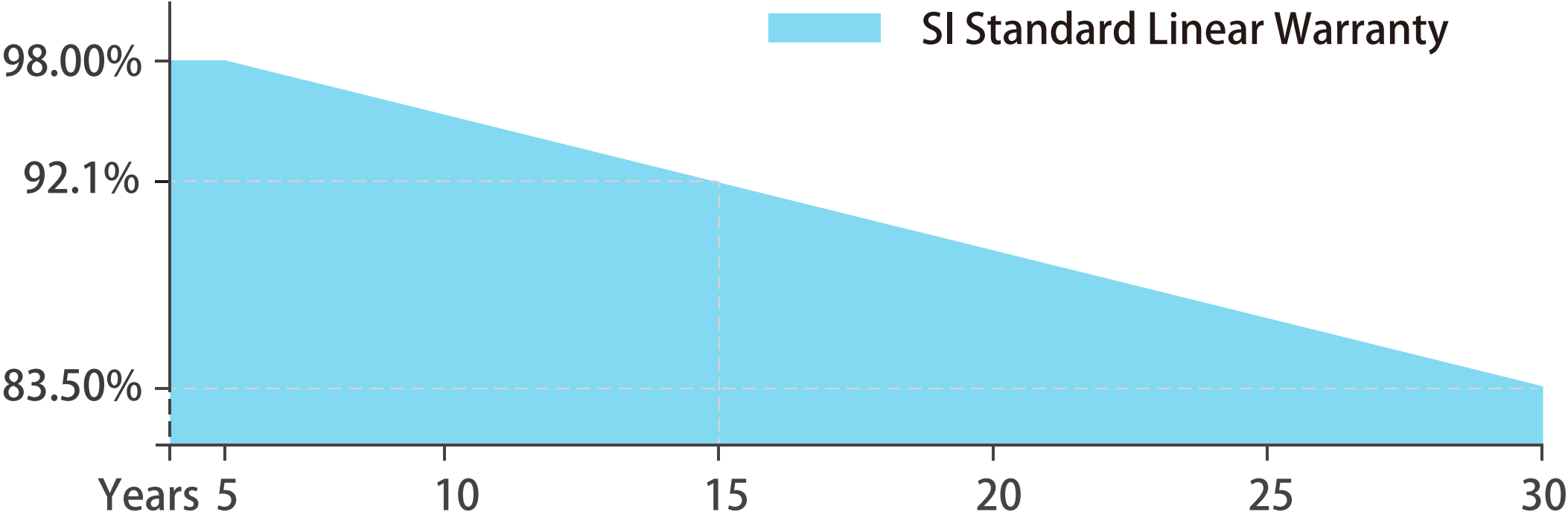
Data are from self-built power stations

In terms of the comparison of power generation, the shingled module is compared with the mainstream products of two first-tier large factories. The overall output of shingled module is superior to that of Product A and equal to that of product B.

Products A and B are mainstream large-size half-cell modules of first-tier manufacturers.

The ultra long warranty of shingled module

The limited warranty of shingled module is 15 years



- Will provide 15 years limited warranty for all shingled modules, 30 years limited power output warranty for all shingled modules.

Conclusion

- Shingled modules are more beautiful than normal modules and are suitable not only for power stations but also for rooftop projects
- The reliability of shingled modules has advantages over normal ones, especially in high and low temperature cycling and load resistance
- The shingled module has lower temperature coefficient and lower operating temperature, and has better power output in high temperature weather
- The open circuit voltage of 72 type module is relatively low, which can bring higher PV string power and reduce BOS effectively
- Parallel connection structure makes shingled modules have better power output under occlusion
- Shingle modules have the highest product limited warranty of 20 years on the market

Conclusion

Serial number	Item	Shingled module	Normal module	Result	
1	Appearance	No cell connector, beautiful appearance. (especially all black modules)	Have cell connector	Shingled module has more beautiful appearance	
2	Hot spot	Low working current, low hot spot temperature	High working current, high hot spot temperature	The hot spot temperature of normal module is 25 C higher than that of shingled module	
3	Differentiation reliability test	The attenuation of the dynamic load sample after testing is 0.32%	The attenuation of the dynamic load sample after testing is 2.32%	Shingled products are superior to normal products	
4	3 times IEC reliability	D113000	The attenuation of the sample after testing is 4.77%	6.52%	Shingled products are superior to normal products
		TC600	The attenuation of the sample after testing is 2.06%	5.83%	Shingled products are superior to normal products
		UV30	The attenuation of the sample after testing is 4.60%	5.37%	Shingled products are superior to normal products
		UV45	The attenuation of the sample after testing is 1.26%	1.18%	Shingled products are superior to normal products
5	TC200	The average attenuation of samples after testing is 0.68%	The average attenuation of the sample after testing is 2.59%	Shingled products are superior to normal products	
6	Resistance to mechanical load	a) There's no power attenuation after 5400Pa static mechanical load test b) There's no power attenuation after 8100Pa static mechanical load test c) The products have passed the TUV's most stringent low temperature dynamic 1000Pa and low temperature static 3600Pa mechanical load tests, and obtained the IEC62782 certificate.	The attenuation of the sample after 5400Pa static mechanical load testing is 1.2%	Shingled products are superior to normal products	

Conclusion

Serial number	Item	Shingled module	Normal module	Result
7	When module is shaded by shadow	When the shingled module is installed vertically and the single cell string is shaded, the output power of the shingled module can reach 86.65% of the normal operation	It is 35% lower power than the Shingled module.	Shingled products are superior to normal products
8	Operating temperature	The average temperature of samples after testing is 35.7°C	The average temperature of samples after testing is 39.4°C Normal module can only melt snow naturally	Shingled module has lower operating temperature, and the generating capacity of shingled module is 2% higher than normal module
9	The ability to melt snow	Parallel structure, as soon as the snow on one string of cells melts, the module is ready to work	under environmental conditions Take the 166 module for example, In theory,	Shingled products are superior to normal products
10	PV string power	Take the 166 module for example, In theory, the 1500V PV string can install 27 modules, theoretical power is 12480W	the 1500V PV string can install 25 modules, theoretical power is 10680W The average daily generating capacity of two	Same PV string, The power output of shingled PV string is 1800W more than normal PV string
11	Generating capacity	The average daily generating capacity of the shingled module is 3.31KWh per kW	kind of half-cell module is :A(3.17KWh per kW)/B (3.17KWh per kW)	The generating capacity of shingled PV string is equal to normal modules and even superior to normal modules'