Smart I-V Curve Diagnosis key value

Security Level:

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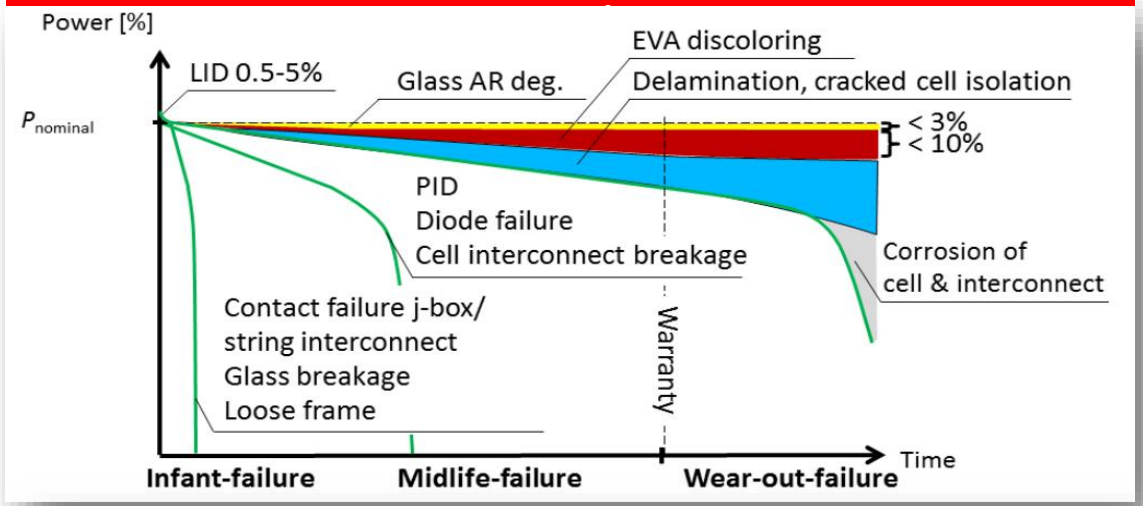
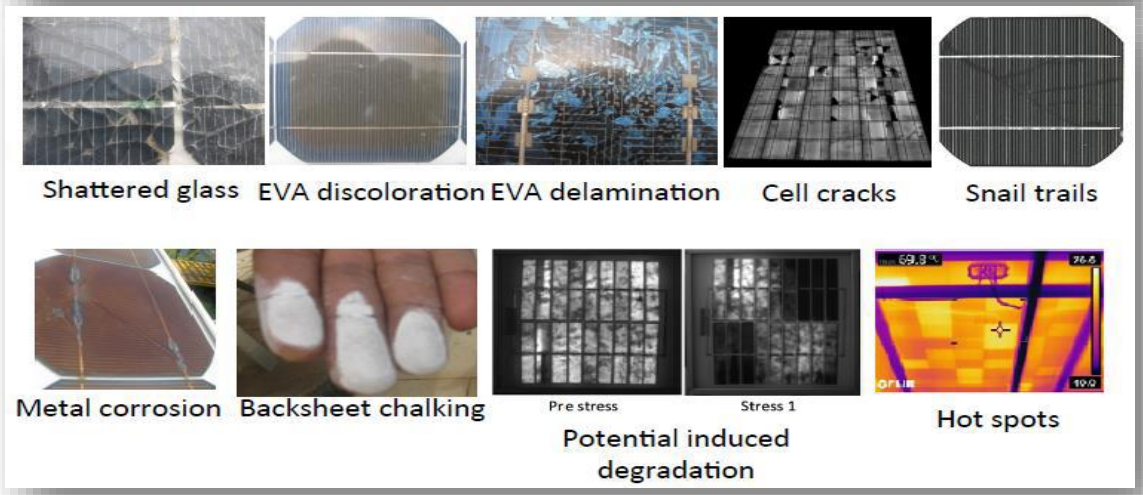
Difficulties in yield improvement during daily maintenance
The number of panels is large, and the terrain and faults type are complex

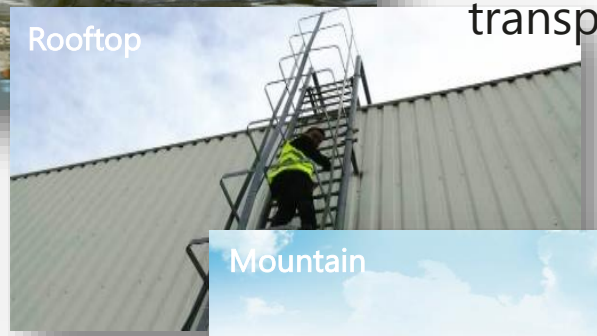
Trend of the early, middle, and late multi-type faults of



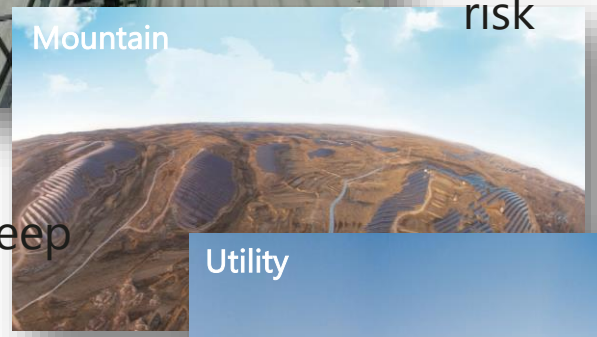


The terrain is complex, and fault detected is difficult

Floating
- Complex site
- Inconvenient transportation



Rooftop
- Dispersed
- high altitude risk



Mountain
- Rugged and steep
- Dispersed

Utility
- Large scale and wide area
- Workload is heavy

Note: currently, traditional SCADA can only monitor PV strings. But they can not find the root cause of DC faults

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Smart I-V Curve Diagnosis for fast fault recovery and easy O&M

Items	Smart I-V Curve Diagnosis Automatic 	VS	Traditional IV Scanning Manual 	Huawei Advantage
Scan Speed	＜1s for one scan but twice for one strings		＜5s for one scan	More Professional: Accuracy
	<10s for one inverter (4 MPPT)		＜1min for one inverter	
	~15min for 100 MW		~2 days for 1MW	
Scan Resolution	128points		120points	
Scan Accuracy	Voltage/Current ≤0.5%		Voltage/Current ≤1%	
Scan Convenient	Online Operation		Field Operation	More Convenient: Online
Scan Consistency	More than 200 strings at the same time		String by string at different time	
Scan Footprint	All samples		Partial samples	
Analysis & Report	Automatic Analysis and Report		Analysis by Technician	More Intelligent: Automatic
Energy Loss	≈0kWh		100MW Plant, 5% Sampling, 5~7Days Required, >1000kWh lost	More Economic: Less Yields Loss

Smart I-V Curve Diagnosis can analyze 14+ faults

14+ Faults Diagnosis

Note: The system can automatically calculate the radiation intensity without EMI.

And the Smart I-V diagnosis can be started when the irradiance>400W/M^2.

Simple:
One Click Smart I-V Curve Diagnosis

Efficient:
100 MW plant, 2,000,000 +data, 15 minutes' diagnosis(based on185KTL)

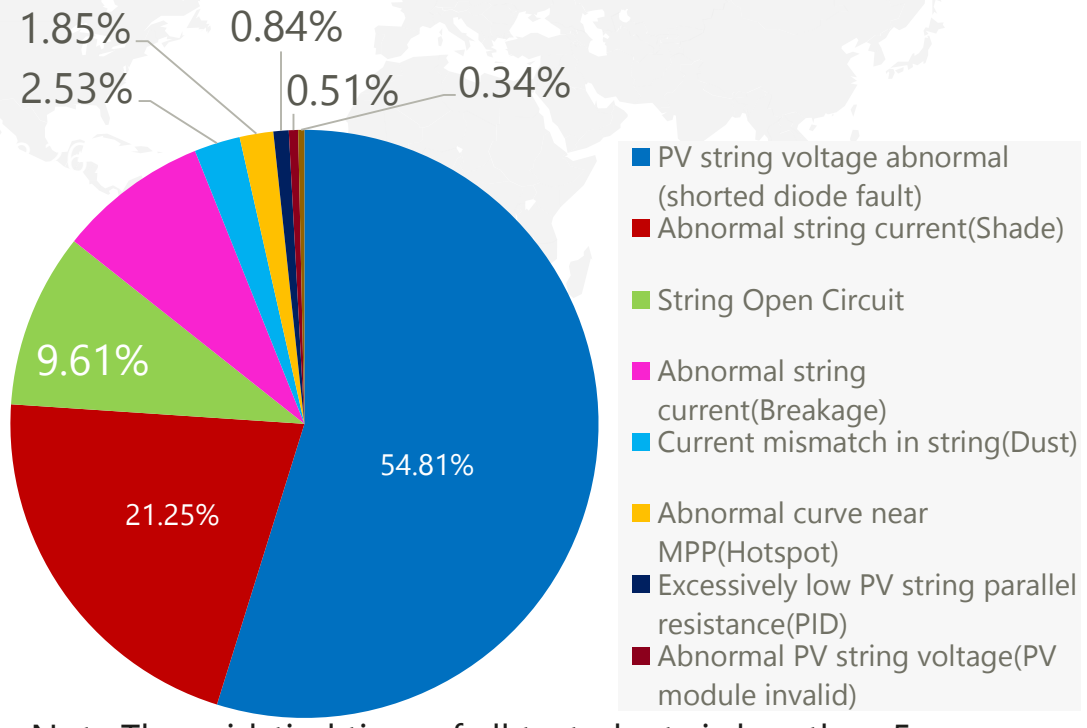
Automatic:
Diagnosis and O&M Report automatic generation

Valuable:

No.	Fault	Sort the possible causes of failure	No.	Fault	Sort the possible causes of failure
1	PV string open circuit	PV string breakage/PV string mistake	8	Missing configurations of PV strings	Check whether string information configured in the system
2	Current mismatch in the string	Shade/dust/PV module current	9	Excessively low irradiance	The solar radiation is insufficient (Analyzed the data by HW inverter
3	Abnormal PV module current	Shade/glass breakage/hidden crack	10	Slight current mismatch in the PV	Dust/slight shade/glass breakage
4	Abnormal PV string	Diode short circuit/PV module module quantity incorrect	11	Excessively low PV string parallel resistance	PID degradation/dust/uneven PV irradiance
5	Low PV string short-circuit current	Abnormal orientation/dust/PV module degradation	12	Excessively high PV string series resistance	high cable resistance/abnormal resistance of the PV module
6	Low PV string power	Abnormal orientation/dust/PV module degradation	13	Abnormal curve near MPP in the PV	Hotspot/hidden crack/glass
7	No string connected	Check whether PV strings are the inverter	14	Scanning data invalid	Irradiation cause

Global Application: improve O&M efficiency and save yield

Smart IV diagnosis application > 3000 MW



Note:The grid-tied time of all test plants is less than 5 years

Address: Asia
Scale: 50MW
Number: 168436 panels
Area: ~1 sq.km.
Grid connect time: 29/7/2017

Diagnosis string: 3960
Breakage string: 65
Breakage ratio: 1.65%
String Yield Loss Estimated: ~5%

Fault Rectification Prediction save RMB 2.71 million in 20 years(~0.008 $/W)

Glass Breakage

Security: The insulation doesn't comply with the IEC standard, which may cause electric shock

Fault Rectification Prediction save RMB 0.19 million in 20 years(~0.002 $/W)

Burnt Diode

Address: Asia
Scale: 12MW
Number: 46080 panels
Area: 0.16 sq.km
Grid connect time: 30/6/2016

Diagnosis string: 1888
Diode short circuit string: 34
Diode short circuit ratio: 1.8 %
String Yield Loss Estimated: ~1.4%
Security: Panel reliability is affected

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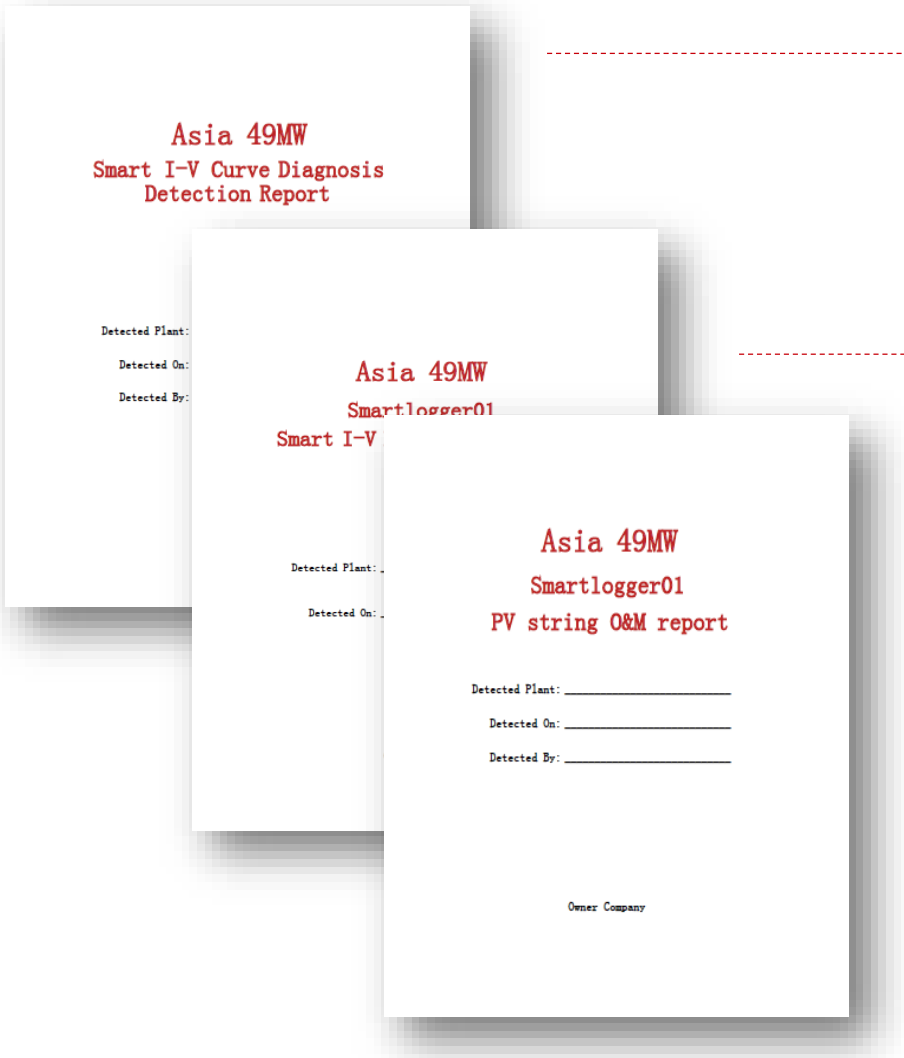
Faults impact on plant yield and DC security risk

Fault Type	Impact on Yield	DC security risk	Possibility of occurrence
PV string open circuit	100% for each string	The risk of electric shock is in O&M	High
Current mismatch in string (Dust)	3-30% for each string	Severe blockage causes hotspot risks on panels and affects panels reliability within the life cycle	High
Abnormal PV module output current(Breakage)	5% for each string	Energy yield loss, panels reliability risks, and personal safety O&M risk	Very High
Current mismatch in string (Shade)	1-5% for each string	Same with the dust	Very High
Slight current mismatch in string (Slight shade)	1-4% for each string	Maybe there is dust, shade or other problems	Very High
String connection reverse	0.5-0.7% for each string	The risk of electric shock is in O&M	Very Low
Low PV string power(PV module degradation)	3-7% for the whole plant	Panel reliability is affected within the life cycle	Inevitable
Abnormal PV string voltage(Diode short circuit)	1.4% for each string	Panel reliability is affected within the life cycle	High
Abnormal PV string voltage(PV module invalid)	0.5-0.7% for each string	The string information may not be configured successfully in system	Very Low
Low PV string power(Abnormal orientation)	0.5-0.7% for each string	Inherent problems in PV plant design and cause energy yield loss	Very Low
Excessively low PV string parallel resistance(PID)	5-50% for the whole plant	Affecting the service life of the panels.	High Temperature and Humidity Scenario
Abnormal curve near MPP(Hotspot)	0.01% for each panel hotspot	In severe cases, panels are burnt, causing insulation deterioration, accelerating aging, and prolonging the service life of panels	Very High
Excessively high PV string series resistance(High cable resistance)	0.5-5% for the whole plant	There is a fire risk caused by DC arcing.	Low
Abnormal PV module output current(Hidden crack)	Uncertain	The panel causes hot spot risks, and reliability is affected within the life cycle.	Very High

Smart I-V Curve report introduction



Detection Report- Entire strings in the plant

- Plant base information
- Evaluation of the PV String Failure Rate
- Fault Type Analysis

Diagnosis Report- each string in the subarray

- Information of Task
- Overview on Diagnosis
- PV String I-V Curve Details
- PV String Performance Data Details

O&M Report – How to handle each failure in the subarray

- Information of Task
- Overview on Diagnosis
- Following advice

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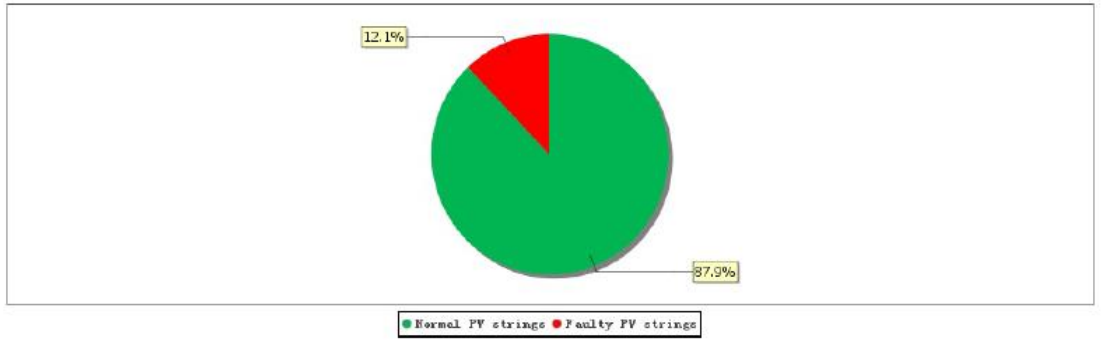
Smart I-V Curve Detection Report overview introduction

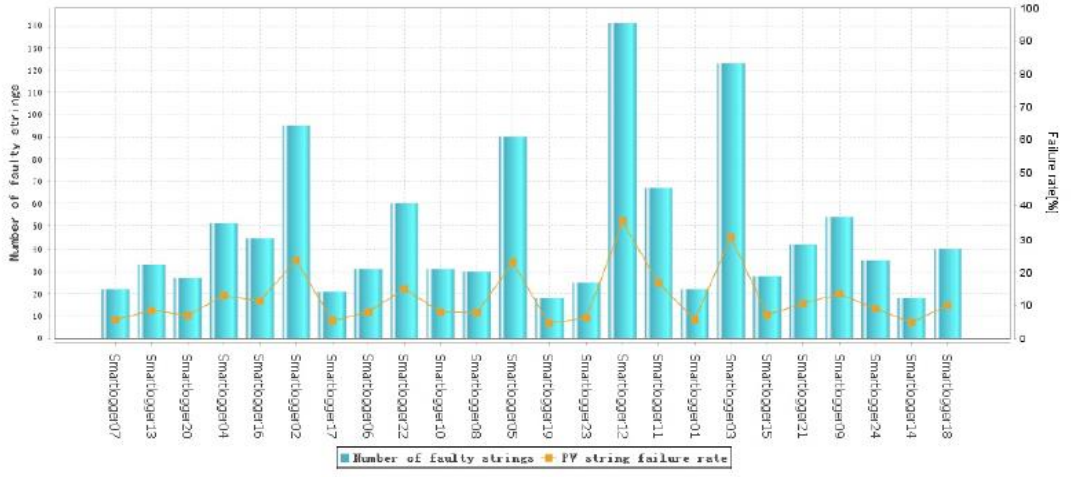
Failures Number Ratio

1. Evaluation of the PV String Failure Rate

In total, 9496 PV strings are scanned in this task.Faulty PV strings: 1149Total failure rate: 12.1%



Distribution of Failure in Each subarray



Failure Types Ratio

2. Fault Type Analysis

In total, 24 SmartLoggers are scanned in this task.1149 PV strings are faulty. The distribution is as follows:

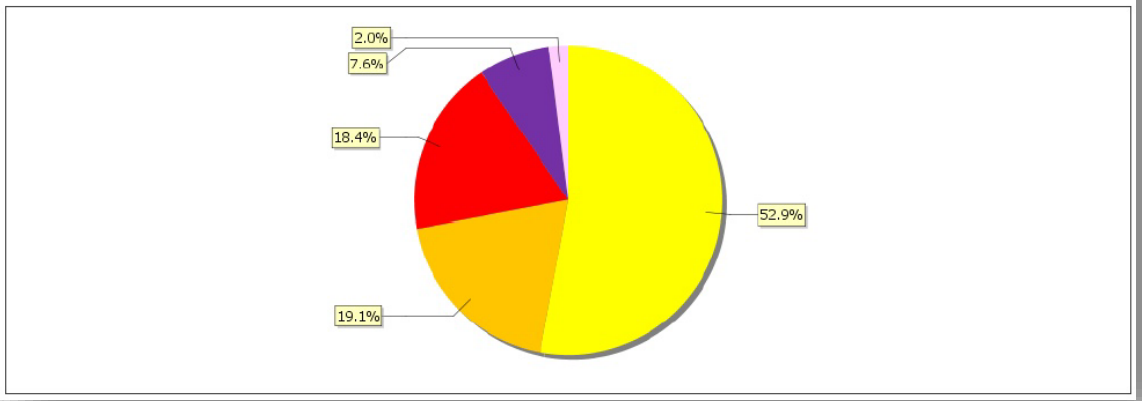
The common faults are:

1) PV module output current abnormal (shade/glass breakage/hidden crack),Percentage:52.9%

2) Current mismatch in the PV string (shade/dust/PV module current inconsistent),Percentage:19.1%

3) PV string open circuit (PV string breakage/PV string configured by mistake),Percentage:18.4%

First 3 common faults vs. total faults:90.4%



Failure	Ratio	Cause
PV module output current abnormal	52.9%	Shade, glass breakage or hidden crack
Current mismatch in the PV string	19.1%	Shade, dust or PV module current inconsistent
PV string open circuit	18.4%	PV string breakage or PV string configured by mistake
Abnormal curve near MPP in the PV string	7.6%	Hotspot, hidden crack or glass breakage
PV string voltage abnormal	2.0%	diode short circuit, PV module invalid or PV module quantity incorrect

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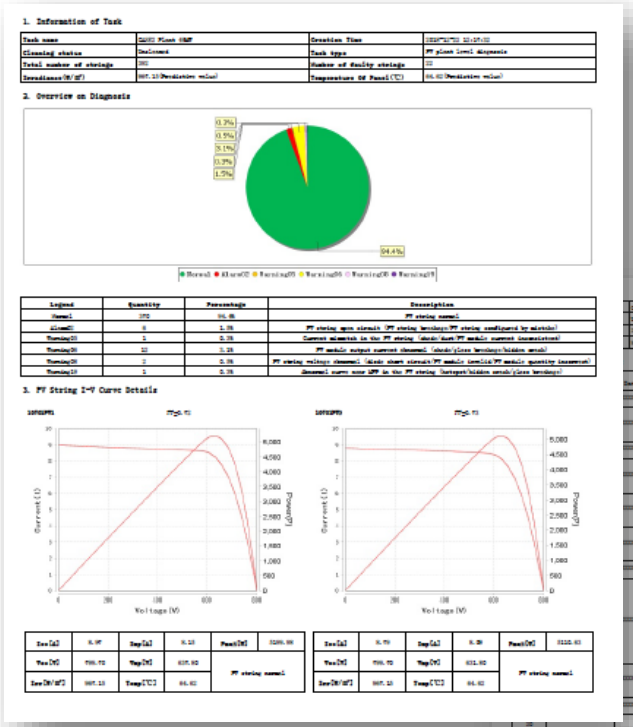
Smart I-V Curve test in Asia: Diagnosis report & O&M report

Plant Scale: 50MW

Plant Location: Asia

Plant Introduction: Mountain, complex terrain, and difficult O&M

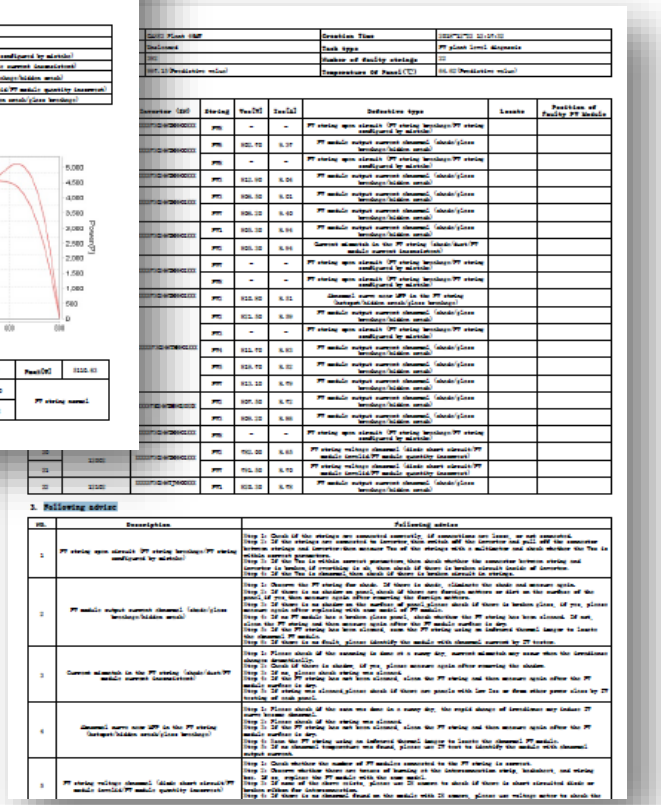


Diagnosis report

Total 3960 strings are scanned

188 Fault strings are found

Fault rate : 4.7%



O&M report

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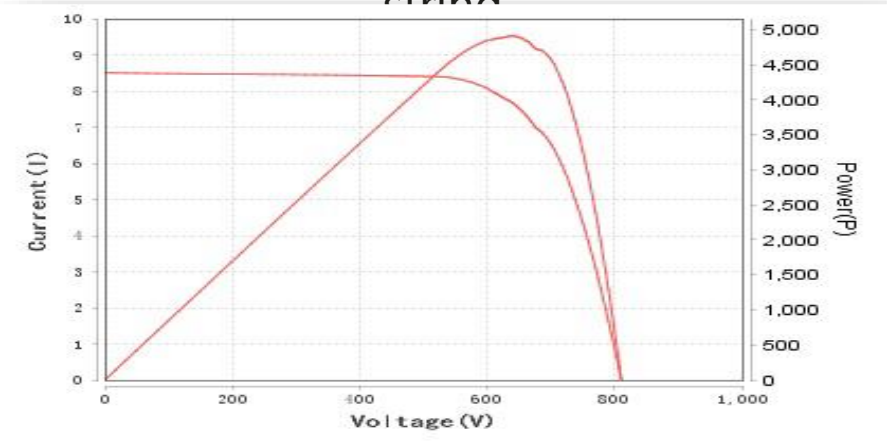
Smart I-V Curve test in Asia: Diagnosis report & O&M report

Diagnosis report: PV String I-V Curve Details

Abnormal curve near MPP in the PV string



Isc[A]	8.51	Imp[A]	7.69	Pmax[W]	4908
Voc[V]	810.80	Vmp[V]	638.5	Abnormal curve near MPP in the PV string (hotspot/hidden crack/glass breakage	
Irr[W/㎡]	967.15	Temp[°C]	64.62		

Actual situation on site

A module has hot spot

O&M report: Following advice

Handling Suggestion

- Step 1: Please check if the scan was done in a sunny day, the rapid change of irradiance may induce IV curve become abnormal.
- Step 2: Please check if the string was cleaned.
- Step 3: If the PV string has not been cleaned, clean the PV string and then measure again after the PV module surface is dry.
- Step 4: Scan the PV string using an infrared thermal imager to locate the abnormal PV module.
- Step 5: If no abnormal temperature was found, please use IV test to identify the module with abnormal output current.

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Smart I-V Curve test in Asia: Diagnosis report & O&M report

Diagnosis report: PV String I-V Curve Details

PV string voltage abnormal

Isc[A]	8.65	Imp[A]	7.88	Pmax[W]	4808
Voc[V]	782.00	Vmp[V]	638.5	PV string voltage abnormal (diode short circuit/PV module invalid/PV module quantity incorrect)	
Irr[W/㎡]	967.15	Temp[°C]	64.62		

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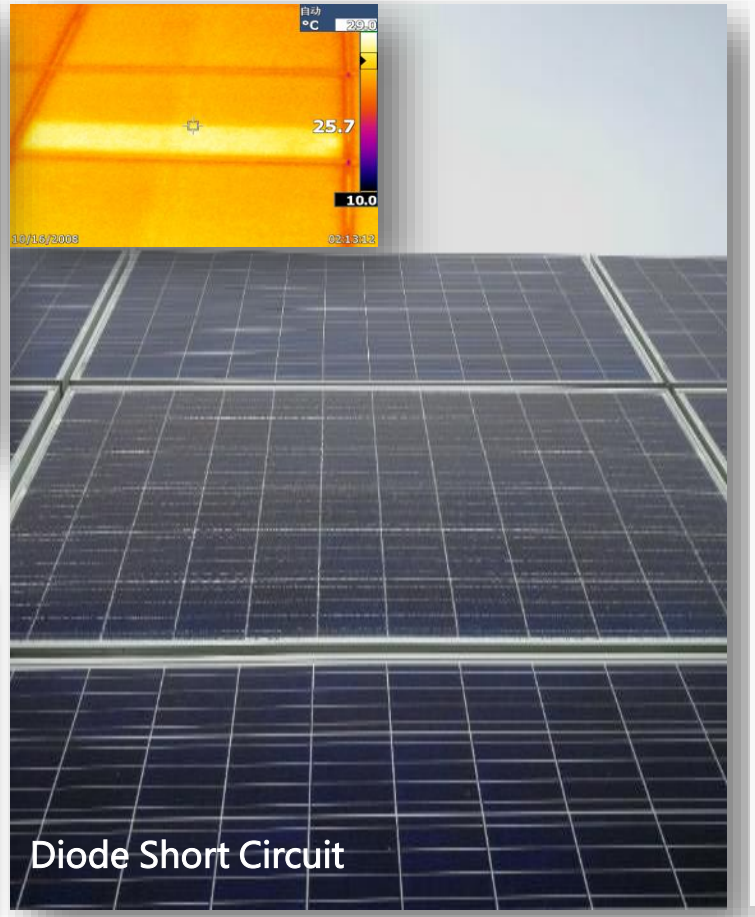
Actual situation on site

A module has diode short circuit



O&M report: Following advice

Handling Suggestion

- Step 1: Check whether the number of PV modules connected to the PV string is correct.
- Step 2: Observe whether there are traces of burning at the interconnection strip, back sheet, and wiring box. If so, replace the PV module with the same model.
- Step 3: If none of the above exists, please use IR camera to check if there is short circuited diode or broken ribbon for interconnection.
- Step 4: If there is no abnormal found on the module with IR camera, please use voltage meter to check the

the voltage of the strings (from same MPPT), to see if it is too low. And if yes, please

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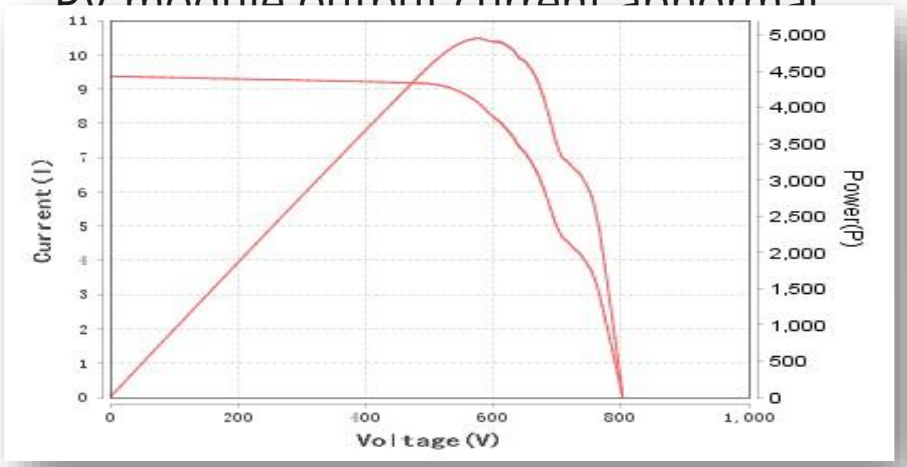
Smart I-V Curve test in Asia: Diagnosis report & O&M report

Diagnosis report: PV String I-V Curve Details

PV module output current abnormal



Isc[A]	9.37	Imp[A]	8.62	Pmax[W]	4957
Voc[V]	782.00	Vmp[V]	575.3	PV module output current abnormal (shade/glass breakage/hidden crack)	
Irr[W/㎡]	967.15	Temp[°C]	64.62		

Actual situation on site

PV modules have shadow

O&M report: Following advice

Handling Suggestion

Step 1: Observe the PV string for shade. If there is shade, eliminate the shade and measure again.

Step 2: If there is no shadow on panel, check if there are foreign matters or dirt on the surface of the panel, if yes, then measure again after removing the foreign matters.

Step 3: If there is no shadow on the surface of panel, please check if there is broken glass, if yes, please measure again after replacing with same model of PV module.

Step 4: If no PV module has a broken glass panel, check whether the PV string has been cleaned. If not, clean the PV string and then measure again after the PV module surface is dry.

Step 5: If the PV string has been cleaned, scan the PV string using an infrared thermal imager to locatethe abnormal PV module.

Step 6: If there is no fault, please identify the module

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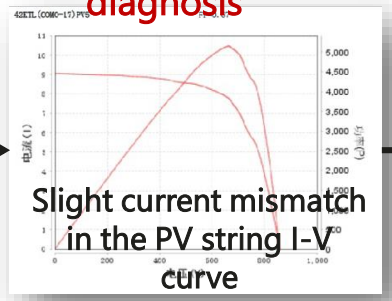
Smart I-V Curve test in Asia: Diagnosis report & O&M report

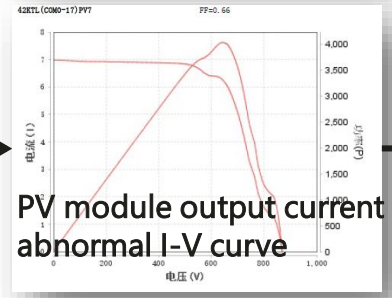
Step1: start I-V scanning

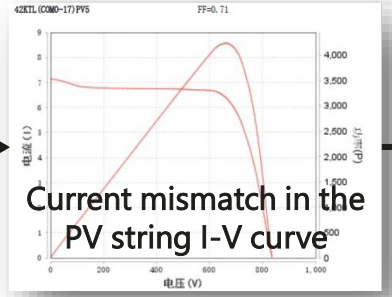
Step2: I-V algorithm diagnosis

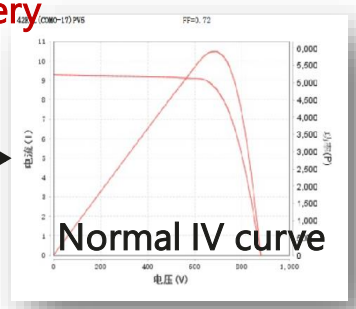
Step3: verify faults on site

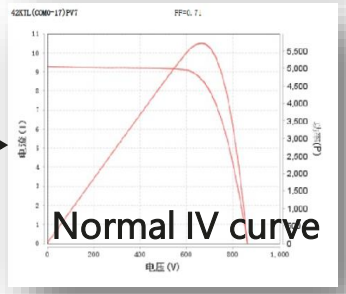
Step4: handling and recovery

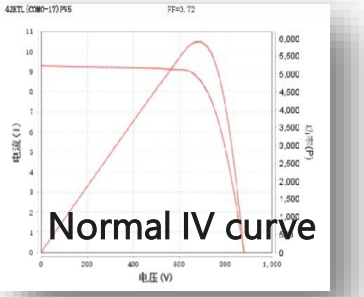












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愿景和使命

把数字世界带入每个人、每个家庭、每个组织，

构建万物互联的智能世界

Bring digital to every person, home and organization

for a fully connected, intelligent world