Smart I-V Curve Diagnosis

Online I-V Curve Scanning and Intelligent Diagnosis

FusionSolar ®

HUAWEI

Background

FusionSolar ®

Panel faults increase the uncertainty of PV investment

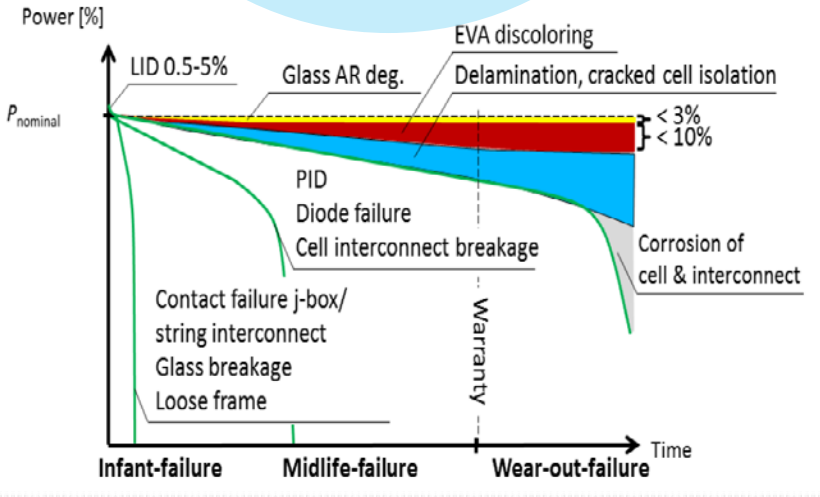
Rating	Investment risk	Technical risk	Quality	Manageable by investors and buyers?
●	High	Early-life product failure or overt safety hazard	Poor	No
●	Medium-high	Long-term product failure or significant under-performance	Below average	Complex
●	Medium	Moderate under-performance	Average	Manageable
●	Medium-low	Limited under-performance	Above average	Easy to manage
●	Low	None	Excellent	Little or no management necessary

Source: Connecting PV Module Quality to Field Degradation, **SOLARBUYER**

TUV:
An investigation indicates among 12GW plants, 30% (3.6GW) has severe defects, and 50% (1.8GW) of them results from panels

MannheimerInsurance AG:
10% of operating solar plants have panel faults

The highest technical risk involved in PV investment is early-life failure & long-term failure of panels.

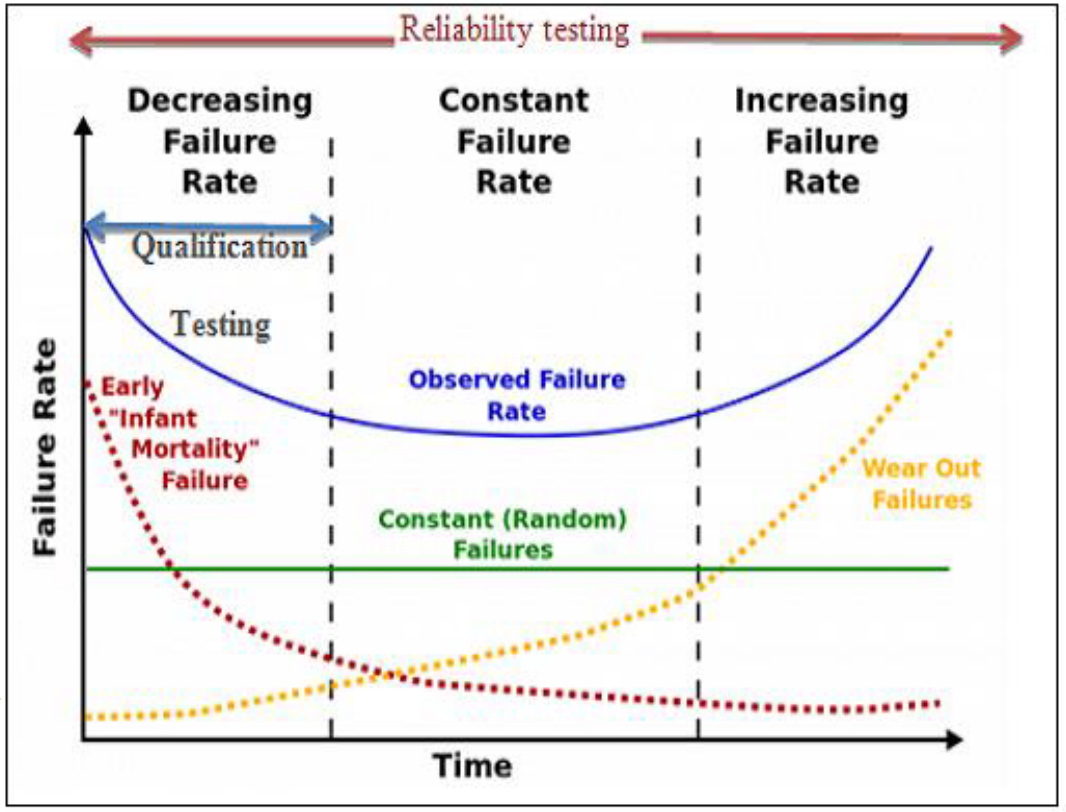


Failure rate of solar panels during entire lifespan

Early-life failure is mainly caused by quality problem and leads to heavily power output reduction

Long-term failure typically results from panels decay and the degree of panel decay decides its lifespan

Panels in mid-term operation are relatively stable and remains low failure rate



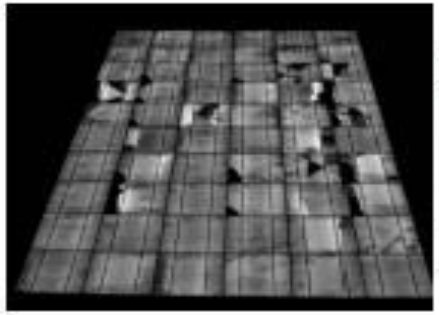
Failure rate of solar panels during lifespan: high at initial term, stable and relatively low during mid-term operation and significantly rising up at terminal phase

Typical panel faults

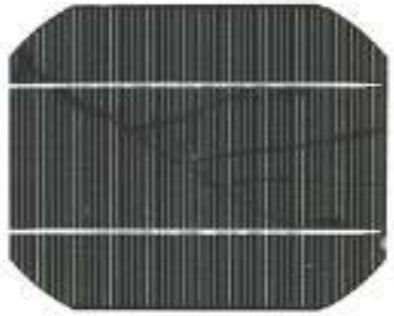
Shattered glass

EVA discoloration

EVA delamination



Cell cracks



Snail trails

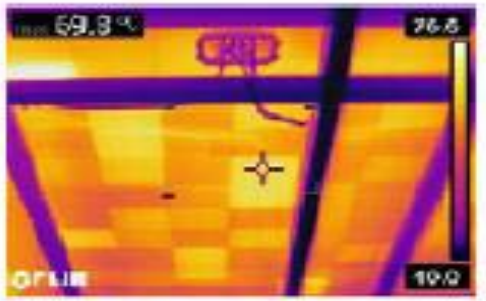
Metal corrosion

Backsheet chalking

Pre stress

Stress 1

Potential induced degradation



Hot spots

Different failure patterns in specific environments

Difficult to indentify fault panels in PV plant

Complex scenarios in PV plants

Ground: Large quantity, Extensive area
Mountain: Steep terrain, Distributed dispersion
Roof: Lots of roof, High above
Lake: Complex operation, Difficult access

Difficult to indentify fault Panels Ground

Difficult to indentify specific problems in panel strings based on current monitoring Tech.

The present PV string inspection methods

high cost, low efficiency, sampling inspection

Spot checking on PV strings via the I-V Curve tracker

1、go onsite with the I-V Curve tracer

2、remove the PV string to be inspected

3、connect the I-V Curve to PV string and start inspection

4、analyze the string faults afterwards by a team of experts

High cost, Low efficiency, no full inspection of all PV strings

Huge inspection workload, not all PV strings inspected	Since there are numerous PV strings in a PV plant, it is impossible to inspect all PV strings one by on indentify faults
Low inspection efficiency, high inspection cost	Using an IV Curve tracer to inspect PV strings in a PV plant is labor-consuming, low-efficiency, and costly
Long inspection period, high power loss	For a 100MW PV plant, it takes five to seven days to spot-check 1%to 5% PV strings, which brings over 1000kWh power loss

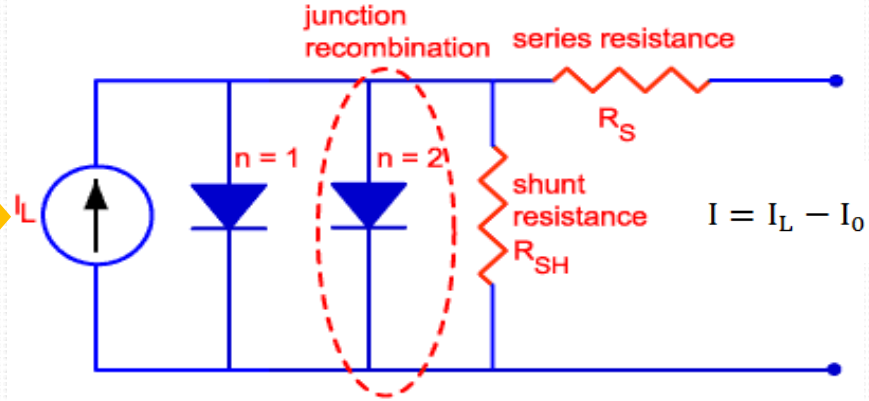
HUAWEI

Smart I-V Curve Diagnosis Solution

FusionSolar ®

Principle of the I-V Curve

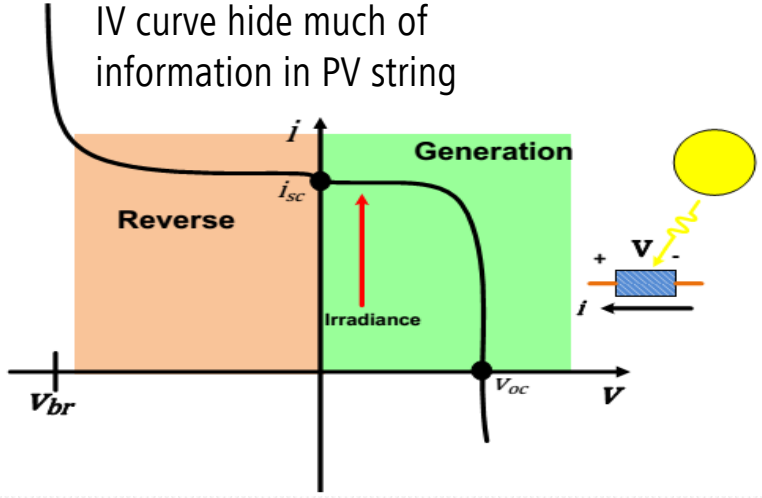
SolarCell



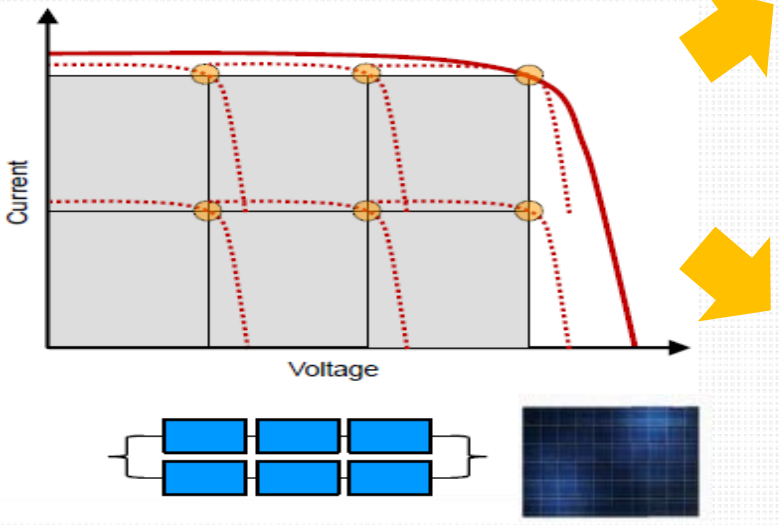
equivalent Model

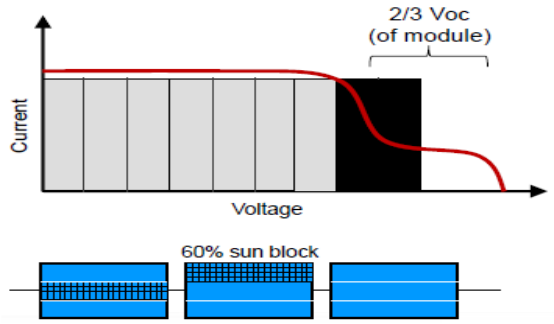
$$I = I_L - I_0 \left\{ \exp\left[\frac{q(V + IR_s)}{nkT}\right] - 1 \right\} - \frac{V + IR_s}{R_{sh}}$$

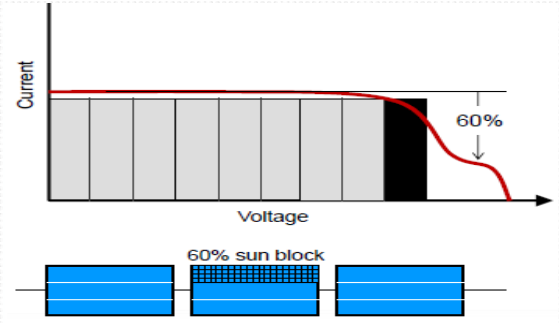
IV curve hide much of information in PV string



PV string:
series/parallel connection of Cell





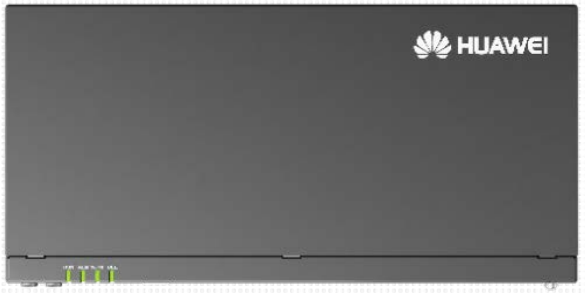


Smart I-V Curve Solution by Huawei Inverter

Inverter

1. Receive orders and implement IV curve data collection.
2. Send collected IV curve data to data logger.

Data logger



1. Receive and resend NMS orders to inverters
2. Receive and resend Inverter IV curve back to NMS

NetEco 1000S

1. Initiate diagnosis and dispatch orders to inverters.
2. Implement diagnosis analysis
3. Generate diagnosis report

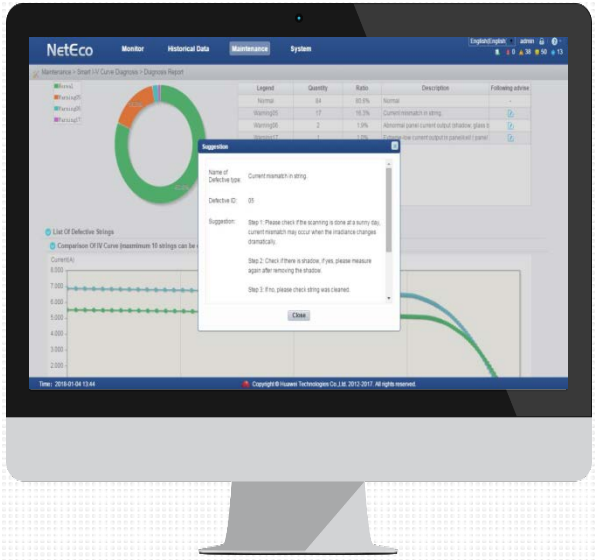
Online automatic inspection for whole PV plant

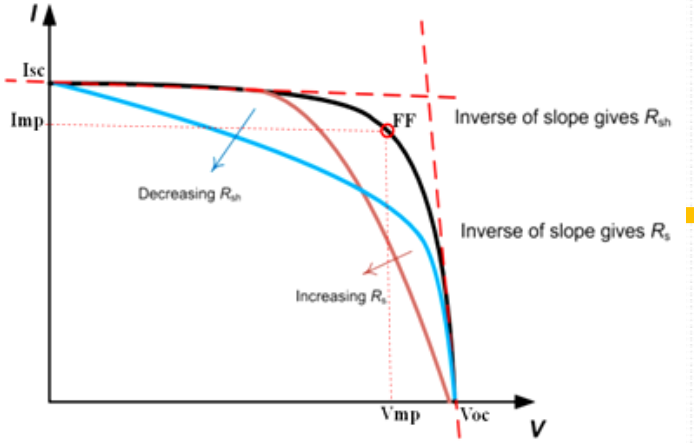
Faults identification through data mining, and algorithms of pattern recognition

One button initiate

String IV Scanning

Machine Analyze String Fault





Algorithm including

Data Processing

- nonlinear implicit fit
- optimizing algorithm
- data mining

Pattern Recognition

- classifier
- neural network

Be available for detecting over 17 kinds of Module or String Failures.
Open circuit of string
Current mismatch in string
Abnormal module current output (shadow, glass breakage, hidden cracks)
Extreme-low current output by module/cell (panel cover up / cell damage)
Diode break-over fault (diode short circuit / Bracing breakage)
Low string voltage
String with minor current mismatch
Panel with hidden cell cracks
String with high resistance
Low string short circuit current
High decay speed of string
No string connected
Incorrect string configuration
Invalid string
Invalid scanning
No string output
Risk of PID

Smart I-V Curve Diagnosis Solution VS Traditional

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

TUV Certification Qualified Smart I-V Curve Diagnosis Solution

0.5% Sensor Accuracy

General Information

制造商：	Huawei Technologies Co., Ltd.
测试项目：	I-V Curve Trace Function Test
测试产品：	Grid-Connected PV Inverter
产品型号：	SUN2000-50KTL
样品序列号：	210107302410G3000009
测试单位：	TÜV Rheinland (Shanghai) Co., Ltd.
报告编号：	15098605 002

Test Result Description:

According to the commission of Huawei Technologies Co, Ltd., TÜV Rheinland (Shanghai) Co., Ltd. Perform the tests on the accuracy of I-V curve trace function of product SUN2000-50KTL and the conclusiton is that the test results fulfill the technical requirements specified by manufacturer.

Tested by : Tobias Yang	Reviewed by : John Dai
Signature :	Signature :
Date : 2016.05.03	Date : 2016.05.03

Model List:

MODELS LIST		SUN2000-50KTL
DC INPUT	U_{dcmax} PV [Vd.c.]	1100
	Min. MPP Voltage $U_{mpptmin}$ [Vd.c.]	200
	Max. MPP Voltage $U_{mpptmax}$ [Vd.c.]	1000
	Max. Input Current I_{dcmax} [Ad.c.]	88
AC OUTPUT	Rated Output Voltage $U_{ac,r}$ [Va.c.]	3/N/PE 418
	Rated Output Frequency fr [Hz]	50
	Rated Output Power $P_{ac,r}$ [kW]	46
	Max. Output Power P_{acmax} [kW]	50.5
	Max. Output Current I_{acmax} [Aa.c.]	60.8
	Power Factor cosphi$_{ac}$	0.8over-excited....0.8under-excited
CONSTRUCTION	Type of Inverter	Non-Isolated
	Enclosure Protection (IP)	IP65
	Strength of Insulation [Va.c.]	4000
	Operating Temperature Range [°C]	-25 to 60
	Pollution Degree	PD3
	Altitude [m]	5000
	Demension [mm*mm*mm]	930*550*260
	Weight [kg]	55
I-V CURVE TRACE	Accuracy of Voltage Measurement [V]	0.5%rdg. + 1dgt. (rdg. >5, dgt. =0.3)
	Accuracy of Current sampling [A]	0.5%rdg. + 2dgt. (rdg. >0.3, dgt. =0.006)
	Range of Voltage Measurement [V]	0-1100
	Range of Current Measurement [A]	0-22
	Firmware version	FusionSolar 智能光伏管理系统 V100R003

Remark：rdg.: Reading Value, dgt: Digital Resolution

Panel Failure Test Passed

Project Description

Power Plant Holder:	Huanghe Hydropower Development Co., Ltd.
Acceptance Location:	Huanghe Longyangxia Hydropower&Solar energy Power Plant
Acceptance Product:	Huawei Intelligent PV array Management Function
System Information:	Huawei Intelligent PV array Management Function System (Version：FusionSolar Intelligent PV array Management Function System V100R003) SUN2000-40KTL-NOC
Power Plant Capacity:	850MW
Testing Laboratory:	TÜV Rheinland (Shanghai) Co., Ltd.
Test Report No.:	15098807 002
Order No.:	154162322

Test Result Description:

According to the technical requirements provided by Huawei Technologies Co., Ltd., after Huawei Intelligent PV array Management Function tested by TÜV Rheinland (Shanghai) Co., Ltd in Huanghe Longyangxia Hydropower&Solar energy Power Plant. The result is:

Huawei Intelligent PV array Management Function were found to meet the requirements of the technical requirements. The detail test results are as follow test report.

Signature	
Tested by : John Dai	Reviewed by : Tobias Yang
Signature :	Signature :
Date : 2016.05.13	Date : 2016.05.13

Test Result

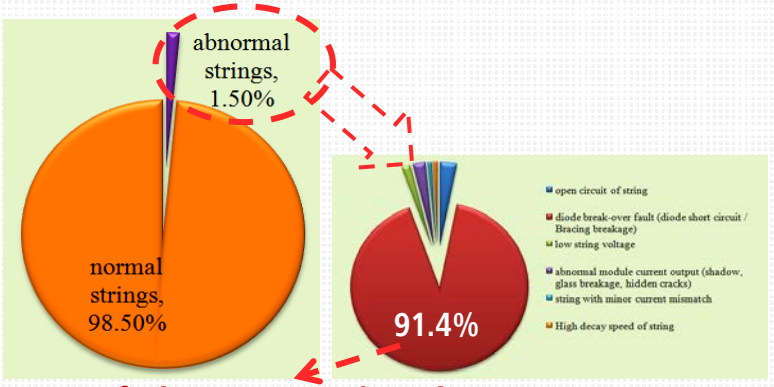
Test Item	Fault description	Remark	Result
No output	No output in a string due to cell's disconnection	See below test result	P
Soiling	More than ¼ areas of 2 cells were soiled in a string	See below test result	P
High series resistance (Rs)	Series resistance increased more than 5Ω in a string	See below test result	P
Potential induced degradation (PID)	More than 4 cells in a string have PID caused power degradation (>20%)	See below test result	P
Cell Shadowed	More than 1 cell was shadowed in a string.	See below test result	P
Current mismatch	Short-circuit current of cells mismatch in a string	See below test result	P
Low current output	More than one cell have no output current in a string	See below test result	P
Front glass breakage	More than one cell's front glass were broken in a string	See below test result	P
Cell output current abnormal	More than one cell in a string output current abnormal	See below test result	P
Cracked cells	More than one cell cracked in a string cause more than 50% power loss	See below test result	P
Bypass diode short-circuit	More than one defective bypass diode short-circuit in a string	See below test result	P
Broken cell interconnect ribbons	More than one cell interconnect broken in a string	See below test result	P
Lower short-circuit current	The short-circuit current lower 85% than normal value	See below test result	P
Rapid power degraduation	MPPT power lower than 90% normal value in a string	See below test result	P
Note：PV module failures refer to attachment <Review of Failures of Photovoltaic Modules».			

Case Study

String-Fault diagnosis Case, 60MW-plant

100% Accuracy: 141 failure panels

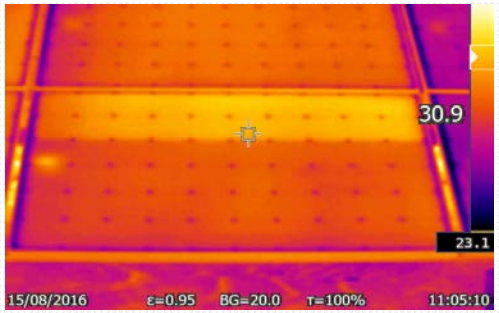
Warned String-Failure by System	No. of Strings (proportion)
open circuit of string	4(0.04%)
diode break-over fault (diode short circuit / Bracing breakage)	117(1.12%)
low string voltage	2(0.01%)
abnormal module current output (shadow, glass breakage, hidden cracks)	3(0.03%)
string with minor current mismatch	1(0.01%)
High decay speed of string	1(0.01%)



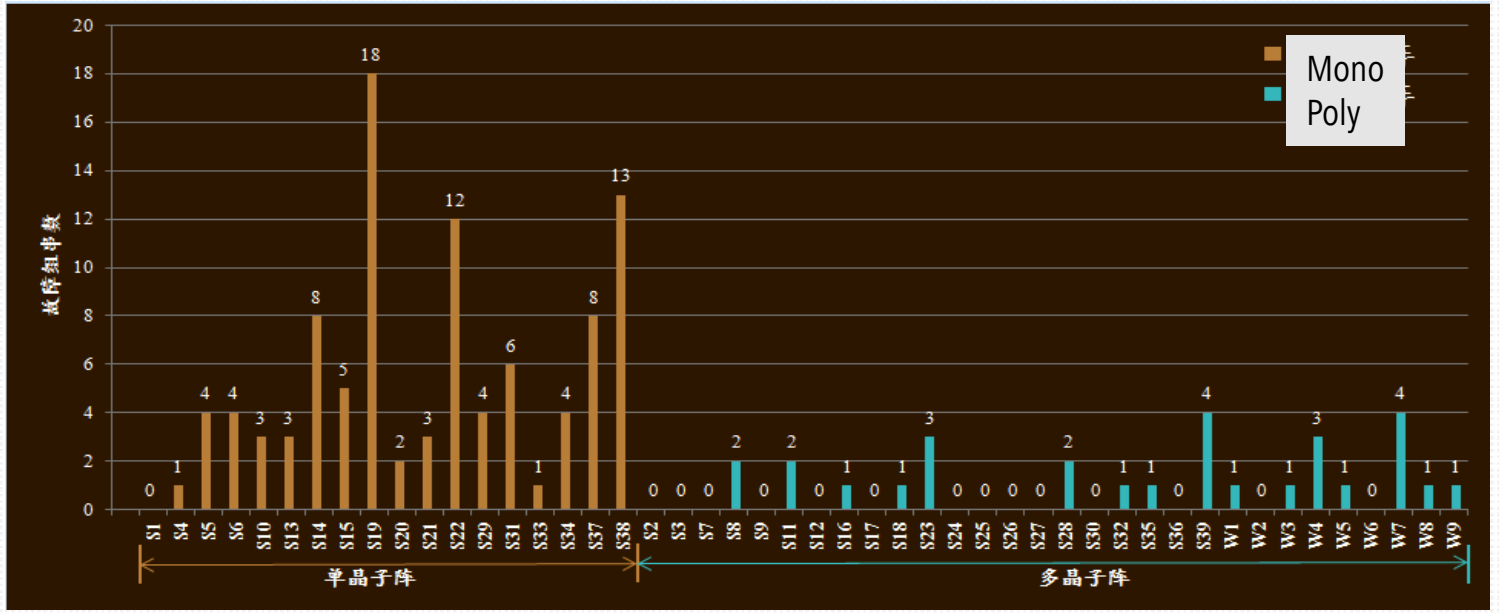
most failure type is 'Diode break-over fault'

Open Circuit

Glass Breakage

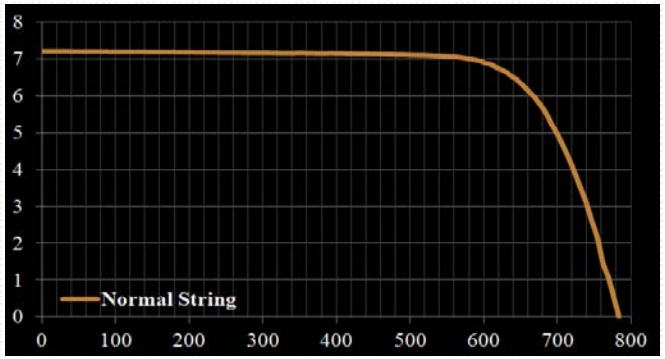


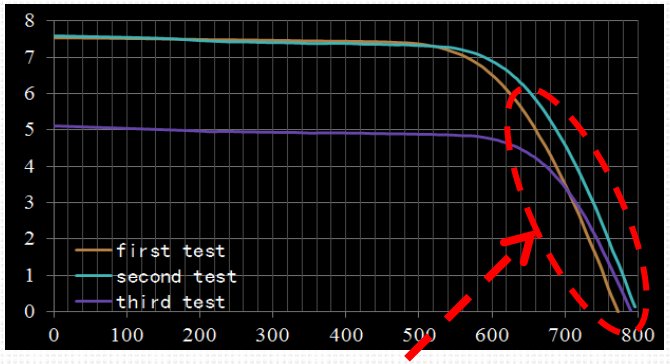
Diode Short Circuit

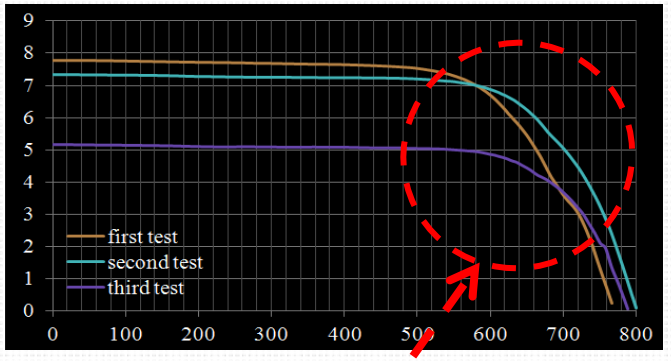


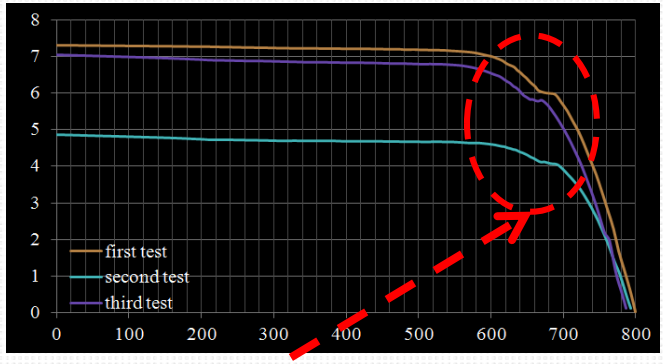
- Support device selection according to the results.
- Like example, multi's quality is better than mono's quality in this PV plant.

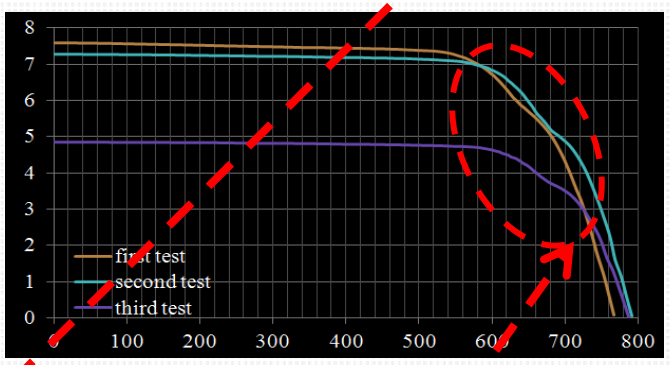
Typical failure patterns detected in the field

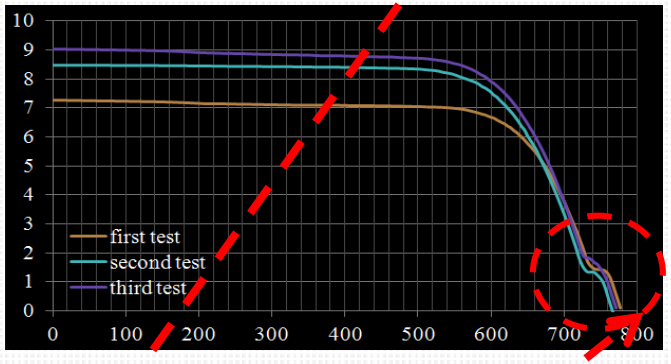




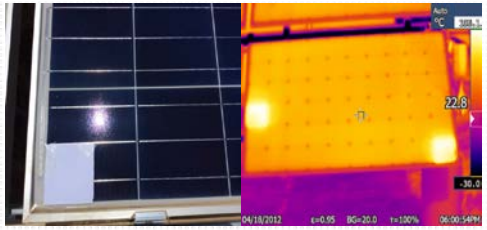




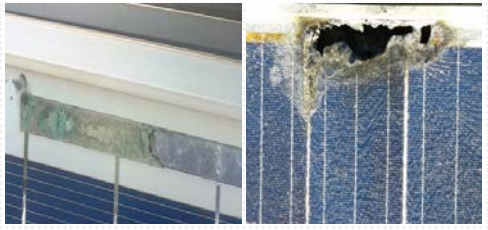




dirt-cover



high string-resistance



glass breakage

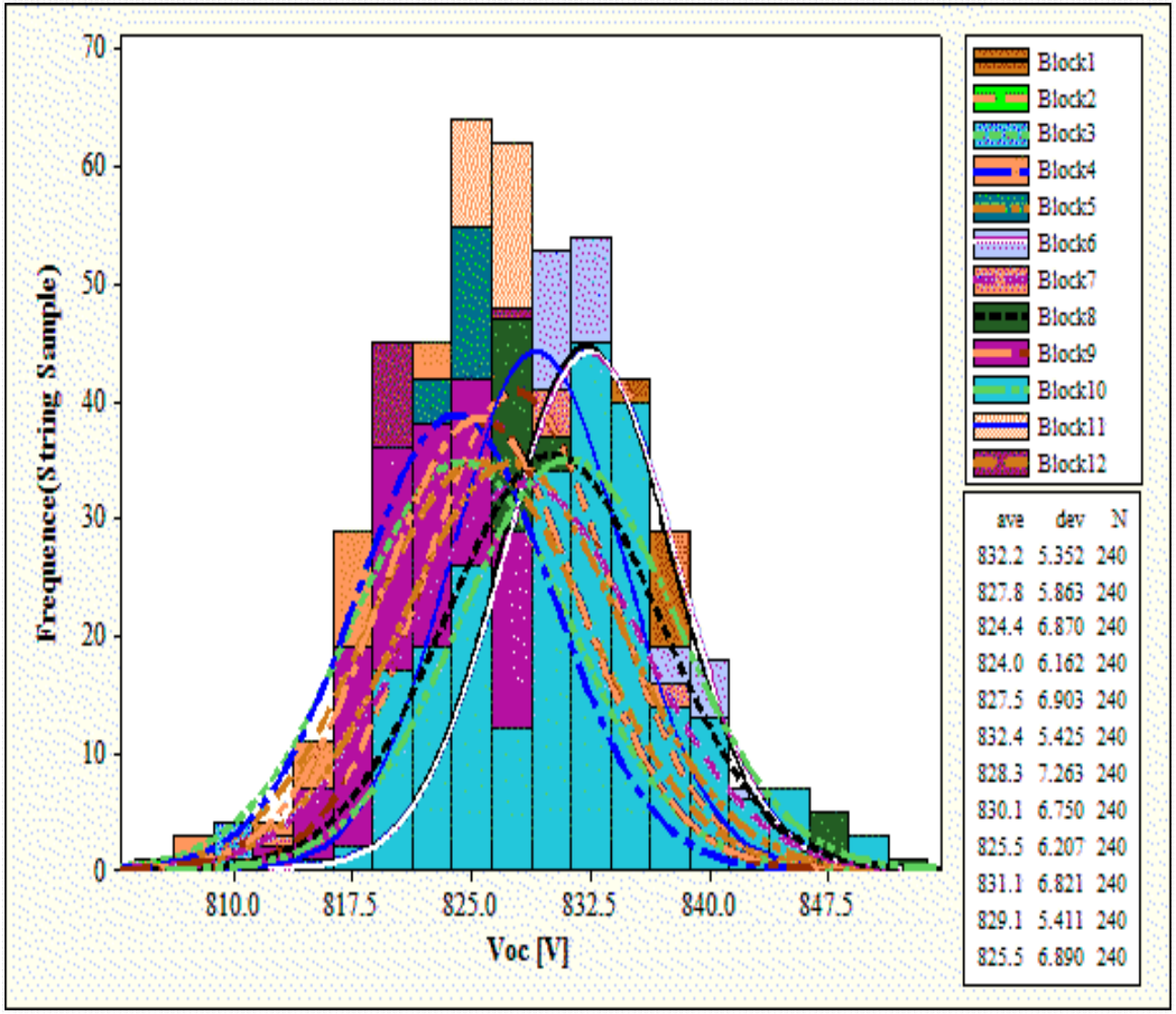
hidden cracks

partial shadowing

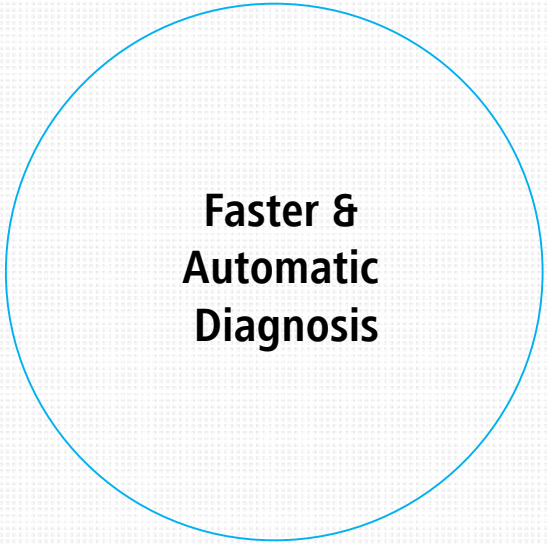
Statistics of the Arrays: monitor the historical array conditions

PV Array Sample	8 mono Blocks, 240strings(1.6MW)/Block, 24Panels/String

	irradiation[W/m2]	panel temp[oC]	Voc[V]	Voc_stdDev[V]	norm-Voc_stdDev
Block1	619.5605	46.4886	832.18	5.352	0.643%
Block2	824.2333	50.9131	827.78	5.863	0.708%
Block3	954.9192	53.9151	824.36	6.87	0.833%
Block4	813.0036	52.6105	823.99	6.162	0.748%
Block5	683.993	49.7431	827.48	6.903	0.834%
Block6	714.5211	48.45	832.40	5.425	0.652%
Block7	863.7304	51.3184	828.31	7.263	0.877%
Block8	926.5664	52.301	829.96	6.75	0.813%
Block9	590.1452	47.3535	825.48	6.207	0.752%
Block10	713.735	48.6004	831.10	6.821	0.821%
Block11	757.2439	50.4362	829.10	5.411	0.653%
Block12	869.9601	53.3409	825.36	6.89	0.835%



Smart IV Curve Diagnosis,
To precisely manage your utility-scale PV plant



- Annual PV plant health check
- Single unit diagnosis

- No onsite sampling diagnosis
- Inspection with purpose, reducing labor cost

- Future procurement suggestion
- O&M Strategy suggestion

Always Available for Highest Yields