



A future-proofed inverter: Huawei FusionSolar's Intersolar Award Winner SUN2000-330KTL



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1

Challenges

Carbon neutrality has become global consensus, pursuit of energy independence by major countries will accelerate energy transformation

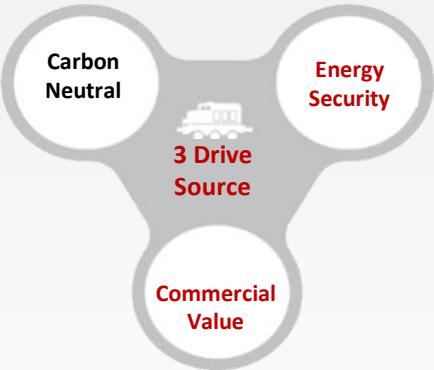
“3 drive source” accelerates renewable energy development

Carbon neutrality becomes global consensus

- **EU:** Carbon neutral in 2050
- **China:** Carbon neutral in 2060
- **Japan:** Carbon neutral in 2050

Importance of "energy security"

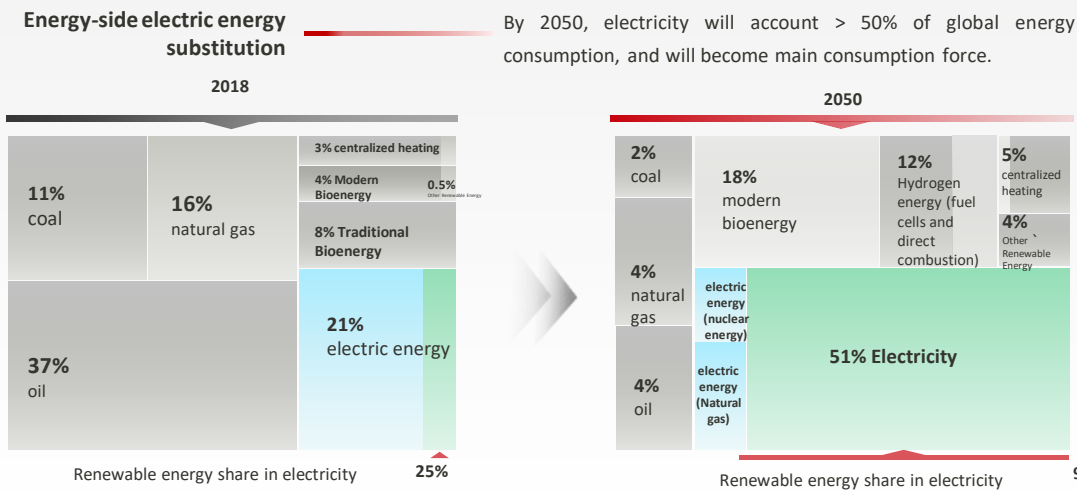
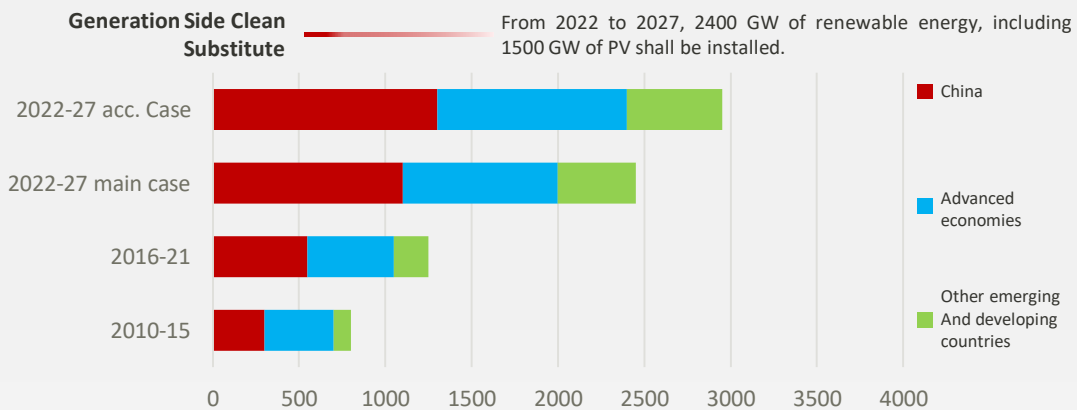
- **EU RePower EU:** Investing €288.2 billion over 22-30 years to get rid of dependence on gas
- **China:** Keeping the Bottom Line of Energy Security, Providing Energy Guarantees



PV become one of the lowest LCOE generation technologies

- **Power generation:** European gas prices in 22 years are 12 times higher than those in 20 years
- **Power consumption:** The residential electricity price in Europe is 5.6 times higher in 22 years than in 20 years, and the IRR of residential ESS investment greatly increased

“2 alternatives” as key measures to achieve carbon-neutral

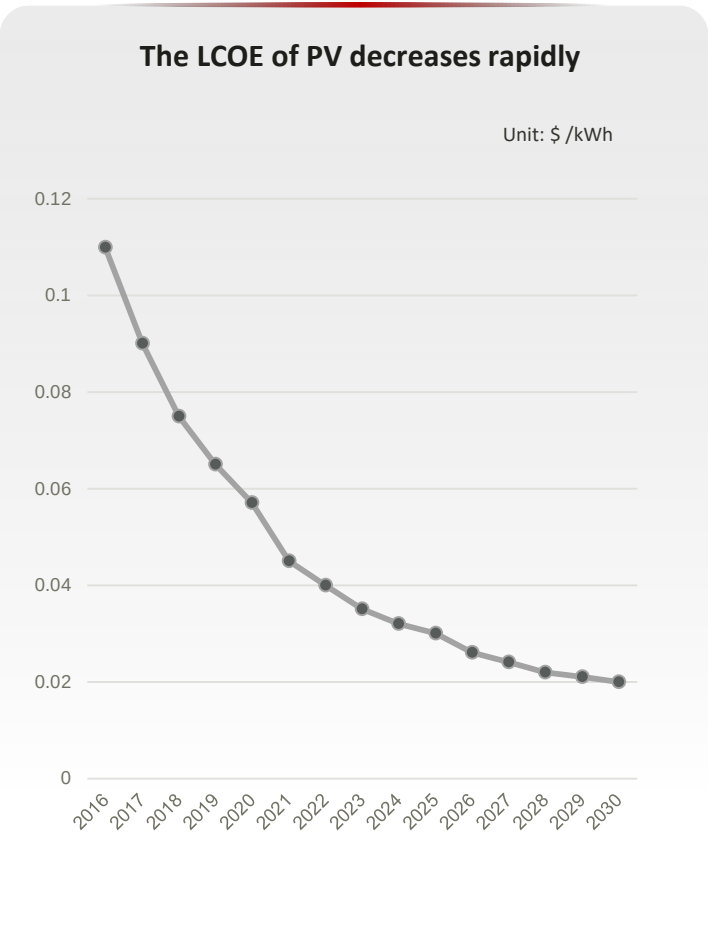


Source: IEA and IRENA



The continuous decreasing LCOE drives PV industry to grow rapidly, but still faces multiple challenges

LCOE of PV continues to decline



Low energy yield/ Unstable power

False efficiency

Traditional solution: The energy yield loss is more than 0.5%

Metrics	An inverter product	
Rated output power	100KW	50KW
European efficiency self-declared values	98.50%	98.50%
European efficiency measured (KTL/KTC/KTR institution test)	97.91%	98.03%
Difference value	- 0.59%	- 0.47%

Low reliability

The fan is clogged

Poor airtightness of air duct

Poor welding process

DC cables are cluttered

Various scenarios, complex terrains, and difficult O&M

Floating-solar power plant

O&M by boat on the surface of the water

27.3MW Solar Park Project, Netherland

Solar-agricultural power plant

Frequent O&M affects crop growth

4.1 MW Agricultural Project, Germany 640MW Baofeng Agricultural Project, China

Desert PV plant

Large area, large number of devices, and heavy O&M workload

400 MW PV + 1.3 GWh BESS Red Sea Project, Saudi Arabia 2.2GW Qinhai Utility Project, China

Safety hazards become primary challenge for PV plants

PV DC Safety Urgently Needs Attention



Fault of Insulation

DC cable breakage, damp environment, PV positive and negative terminals are short-circuited to ground



Fault of DC Side

String fault connection, DC input current reverse-flow, the cable and connector aging, poor contact



Fault of DC Connector

Connection are poor contact, aging, and poor wiring, ground settlement causes cable pulling

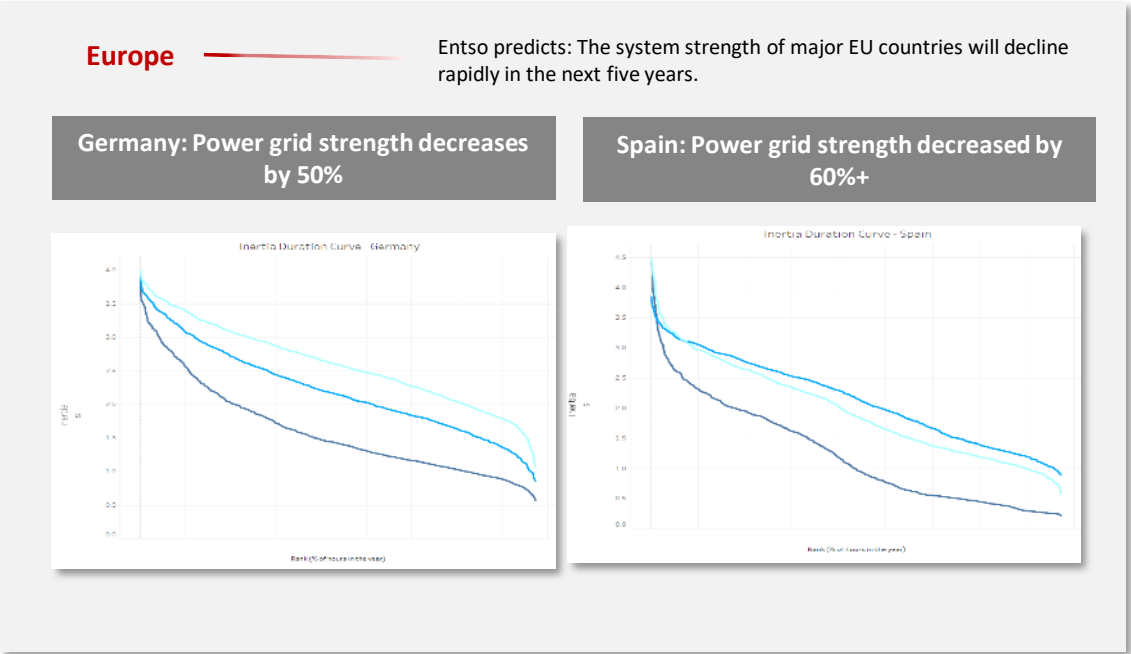


Fault of Inverter

DC capacitor damage, input to ground, AC interphase short circuit

The rising penetrations of renewables make transmission and absorption problems and decreasing grid strength problems more severe (1)

Grid strength decreasing with higher penetrations of renewables



China

It is estimated that by the end of the 14th Five-Year Plan, the penetration rate of new energy in multiple provinces will exceed 60%.

Province	"13th Five-Year" (2016 - 2020)				14th Five-Year Plan (2021-2025)	
	PV installation GW	Wind power installation GW	Total Capacity GW	Wind & PV proportion	large base planning	Wind & PV proportion
Qinghai	16	8.6	40	61.1%	30	77.70%
Gansu	9.8	15	55	44.7%	30	64.20%
Ningxia	11.8	14	56	44.5%	20	60.50%
Hebei	25	23	93	51.6%	20	60.40%

The rising penetrations of renewables make transmission and absorption problems and decreasing grid strength problems more severe (2)

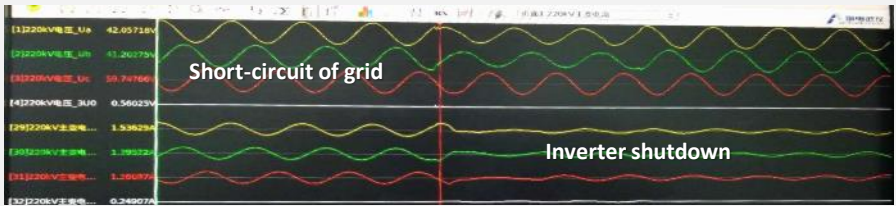
Grid stability challenged with higher proportion of renewables

Complex weak power grid

Inverter disconnection fault

SCR=1.85, when the phase-to-phase short circuit occurs, the fault ride-through of a centralized solution fails, and the control board is damaged, affecting the power generation for two weeks.

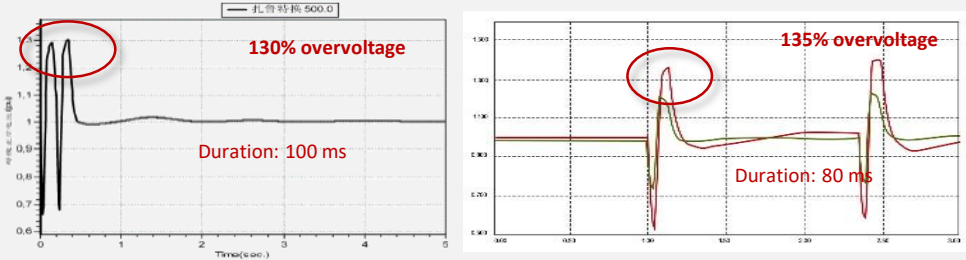
Case: Project in Heilongjiang, China



Derating during HVRT

Power limitation due to HVDC overvoltage

During the HVDC fault period, 130% + overvoltage occurs. Derating during HVRT, which limits the power of new energy generation.



Poor power quality

Inverter disconnection

DCI and THDi are inconsistent with the actual application. The actual application seriously exceeds the standard, and a large number of inverters are disconnected from the network, causing huge losses to the owner.

Case: Project in Qatar

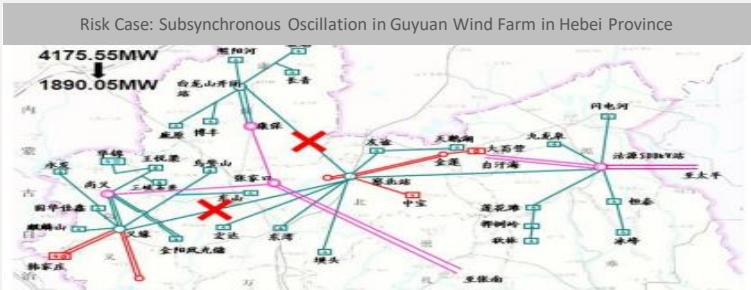
Time	Fault Code
22-09-27 14:33:56	11:DC component exceeds the standard
22-09-21 11:45:06	11:DC component exceeds the standard
22-09-21 11:10:56	11:DC component exceeds the standard
22-09-21 09:57:43	11:DC component exceeds the standard
22-09-21 08:14:02	11:DC component exceeds the standard
22-09-19 18:51:59	10:Grid Power Outage

Sample time = 0.00025 s		
Samples per cycle = 80		
DC component = 21.21		
Fundamental = 189.9 peak (134.3 rms)		
THD = 15.27%		
0 Hz (DC)	11.17%	270.0°
25 Hz	5.10%	188.0°
50 Hz (Fund)	100.00%	-33.2°
75 Hz	2.55%	217.2°
100 Hz (h2)	9.73%	71.9°
125 Hz	1.66%	150.0°
150 Hz (h3)	6.58%	266.9°
175 Hz	1.20%	95.2°

Wide frequency oscillation

Risk of long-distance transmission oscillation

After the proportion of synchronous power supplies decreases, the stability margin decreases, causing low-frequency/sub-synchronous/super-synchronous oscillation risks.





2

Innovations of SUN2000- 330KTL Smart PV Controller

The Intersolar Award 2023 Winner

FusionSolar SUN2000-330KTL Smart PV Inverter



HUAWEI

Fusionsolar

The New Generation of Smart PV Inverter

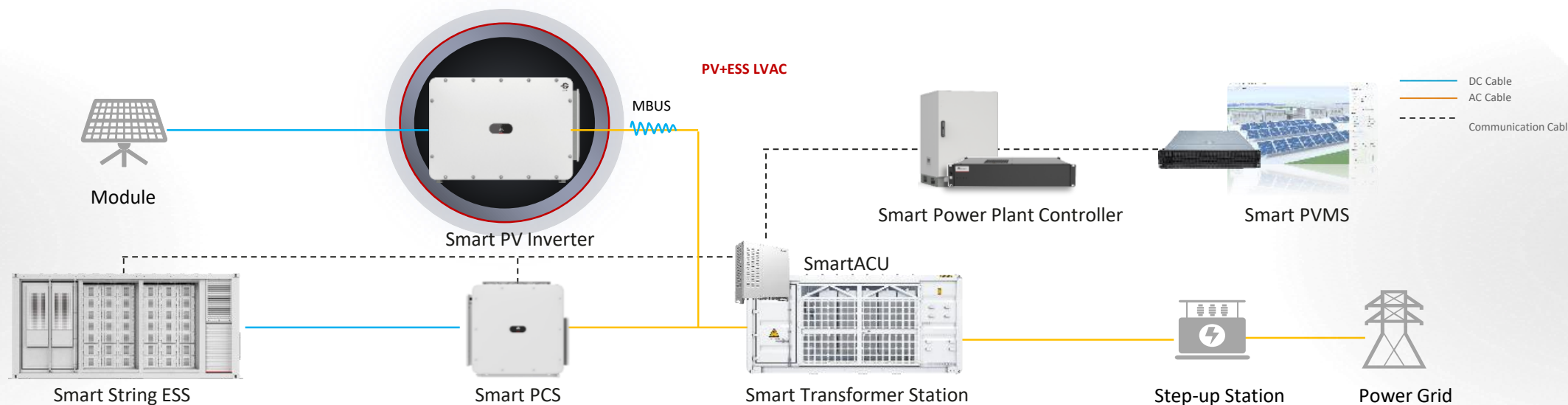
Full Intelligence, Comprehensive Safety

SUN2000-330KTL-H1/2

Higher Yields Smart O&M Safe & Reliable Grid Supporting

The advertisement features a white FusionSolar SUN2000-330KTL Smart PV Inverter with a glowing blue circuit pattern on its front panel. The inverter is set against a background of a desert landscape with solar panels and a snowy mountain range. The Huawei logo is in the top right corner, and the FusionSolar logo is in the center. Below the inverter, four icons represent its features: Higher Yields, Smart O&M, Safe & Reliable, and Grid Supporting.

FusionSolar solution for utility PV plants: Higher Revenue, Grid Supporting, Smart O&M, Safe & Reliable



Optimal LCOE

- **PV&ESS**: LVAC solution saves BOS 1.3-1.5 cents/Wac, improves charging efficiency by ~1%
- **Inverter**: One inverter fits all modules; long-term stable operation with constant power; SDS, yields increased by ~1%
- **ESS**: Higher usable capacity with refined energy management, yields increased by ~15%

Grid Supporting

- Robust operation under all grid scenario (when $SCR \geq 1.1$): 5 core grid-connection indicators
- Power oscillation damping (POD)
- Fast active and reactive power response

Smart O&M

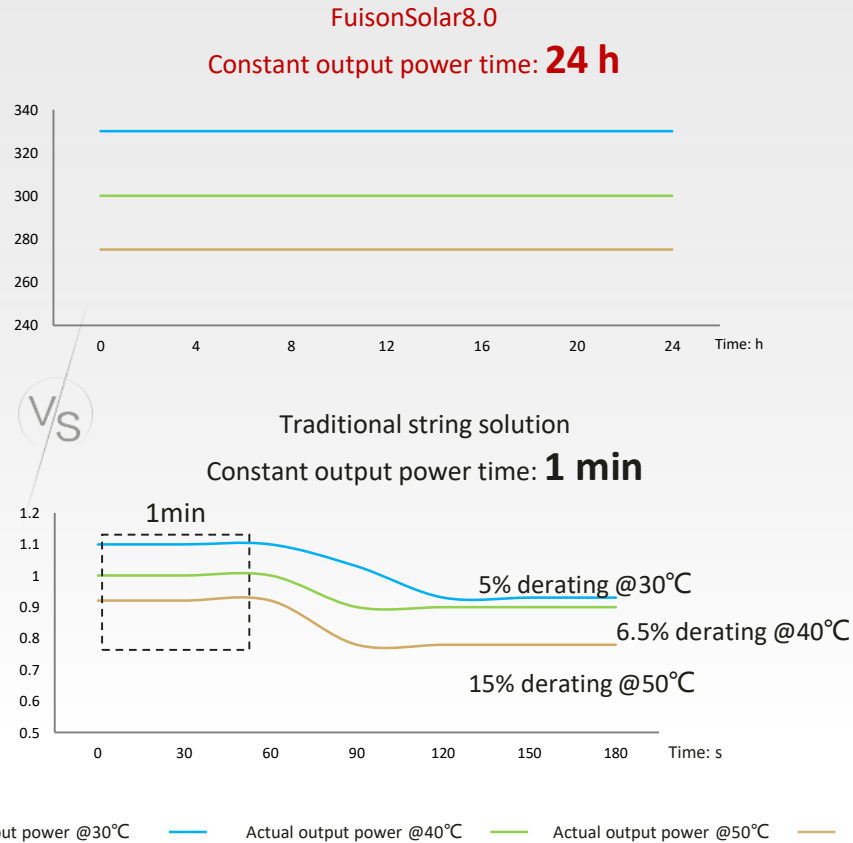
- **Smart PVMS**: Enables four-level refined detection, IV and CV Diagnosis, achieves precise, fast, and efficient O&M
- **Inverter**: SSCF-TECH, dust removal without manual O&M
- **ESS**: Automatic SOC calibration

Safe & Reliable

- **Inverter**: DC triple safety, SSLD + SCLD + MPPT-level DC Insulation Diagnosis
- **ESS**: Quadruple safety design
- **Communication**: Reliable communication at a distance of 1000 m, supporting 9MW array
- **Cyber Security**: Complies with IEC62443 standards

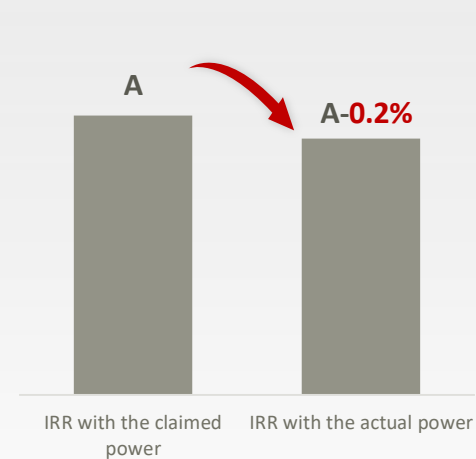
Stable power generation without derating, increasing yields by 1% to 2%

Stable operation in 24h constant power test

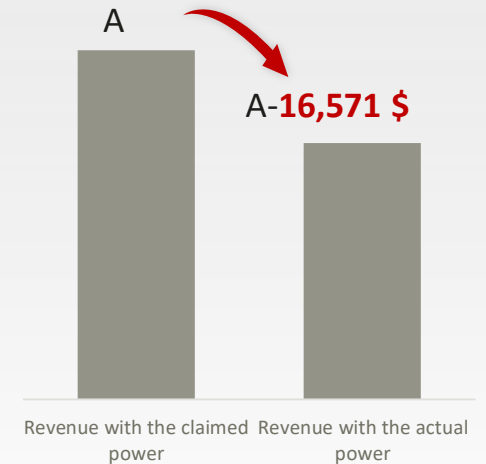


The return on investment of the plant is affected by derating

IRR loss caused by power derating



Revenue loss caused by power derating



Calculation conditions

Capacity: 100MW

Total initial investment of the plant: \$ 0.60/W

PPA electricity price: 0.64 cents/W

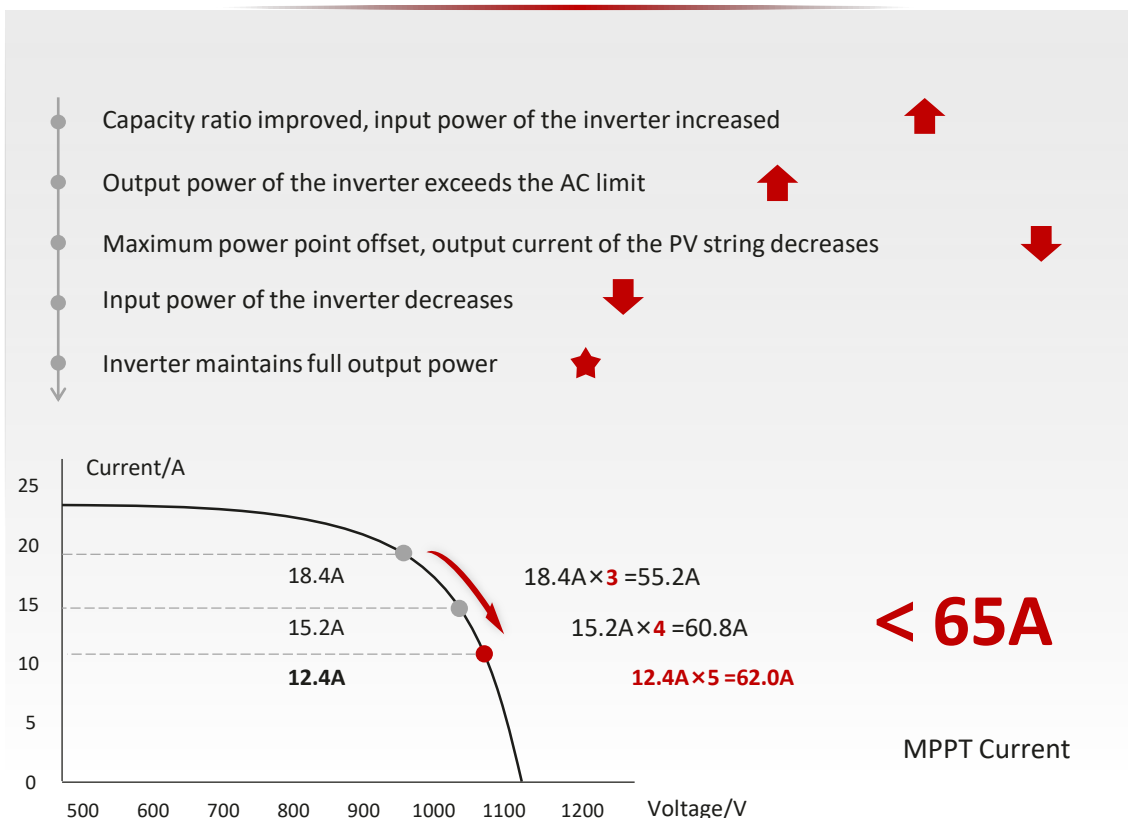
O&M cost: 8% of the annual revenue

Discount rate: 5%

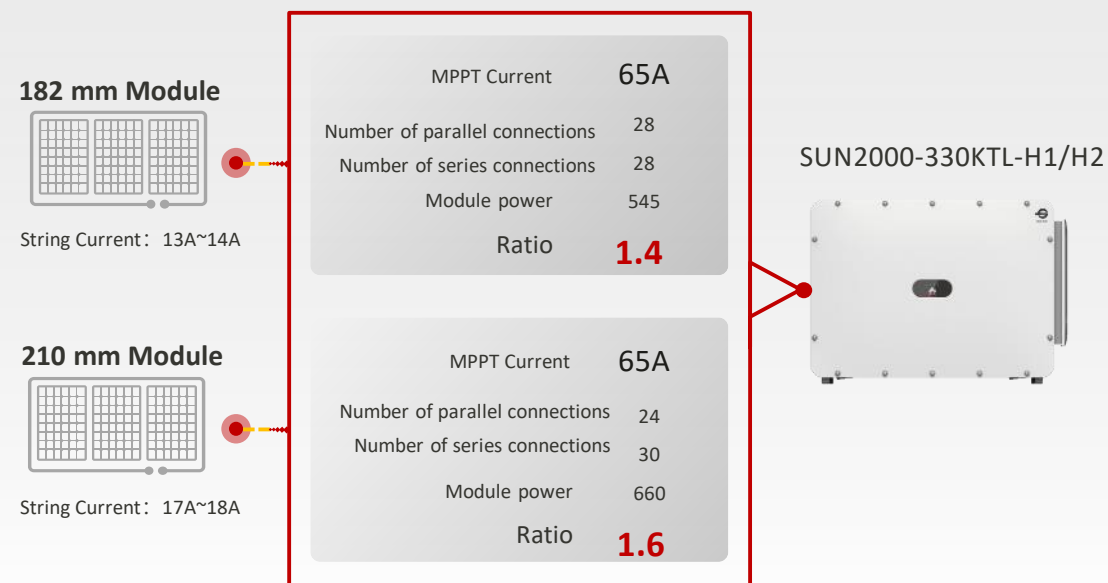
Assume that the power yields loss is 1.48% by derating

Optimal BOS: The first inverter adapts to mainstream PV modules, better MPPT input current design

Better MPPT input current design, simpler design



The first inverter adapts to mainstream components

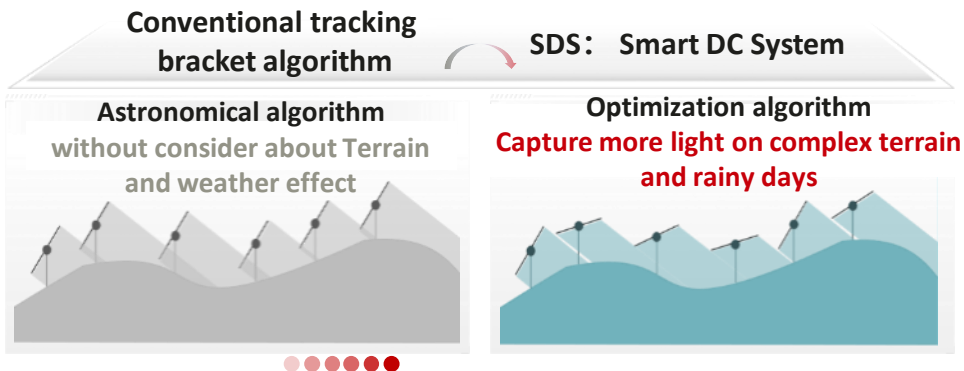
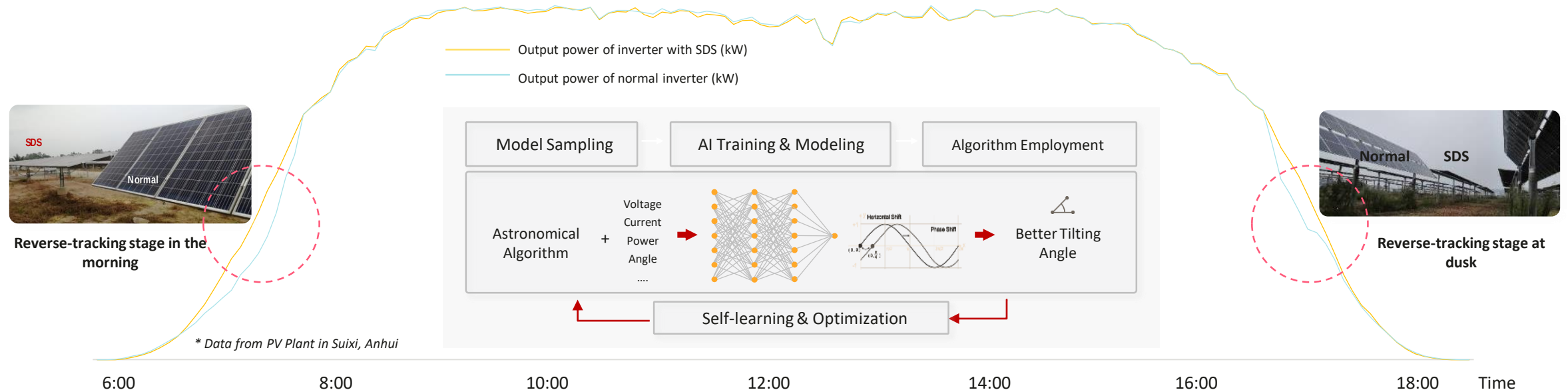


More flexible tactics for PV
Module procurement



Easier management of
Spare parts

SDS (Smart DC System): Enhanced smart tracker control algorithm, yields increased > 1%



Case Study

AP, India **+0.7%**Guangxi, China **+1.69%**Anhui, China **+1.51%**

SSCF-TECH (Smart Self-Clean Fan) dust removal without manual O&M

Traditional solution: Fans are severely blocked, requiring manual O&M and dust removal



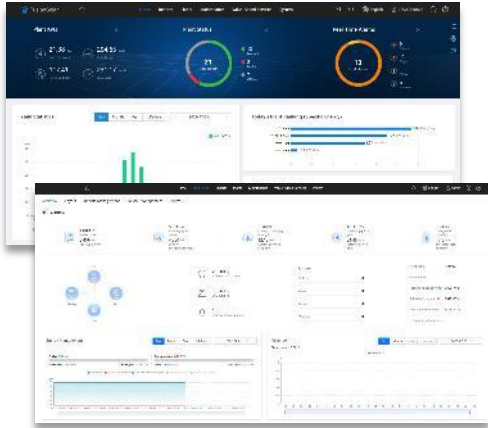
Stop to remove dust manually at least **twice** a year

SSCF-TECH Fan dust self-cleaning without manual O&M



O&M without interruption, recover **250,000\$** power loss in 25 years

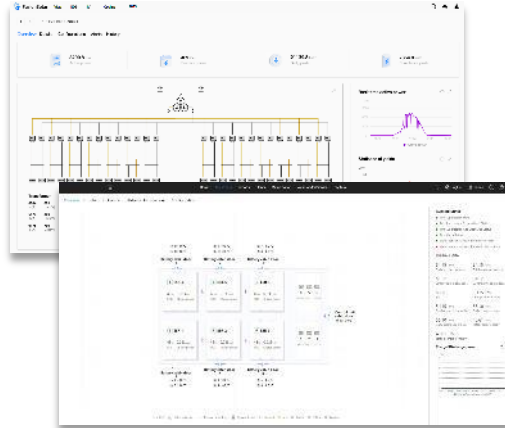
Smart PV Management System: Multi-level management enables lean operation



Plant-level detection

Visibility into the operation status of the plant

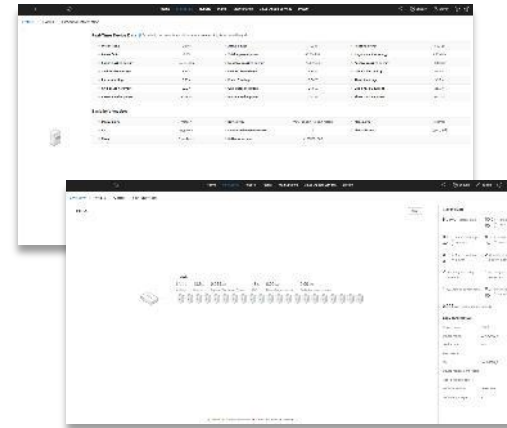
- Alarm visualization
- KPI visualization
- Energy statistics analysis
- Revenue statistics analysis



Array detection

Visibility into the PV array status

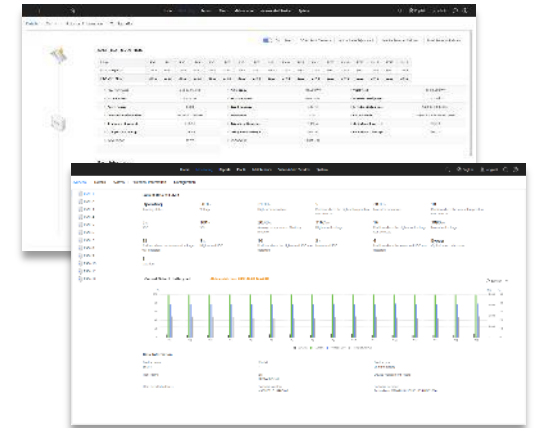
- Topology visualization
- Physical layout visualization
- Real-time data visualization
- Running status visualization



Device-level detection

Identification of device faults

- Real-time data visualization of devices
- charge/discharge data visualization



String-level detection

Real-time display of string data

- Real-time data visualization of devices
- Graphic display of the voltage and temperature

Four-level detection, shifting from large-granularity management to refined management

Smart I-V Curve Diagnosis 4.0: Online and full detection, reducing O&M costs

Authentication: **L4** - highest level in the industry

Widely used in plants around the world (> 20 GW)
to improve plant O&M efficiency

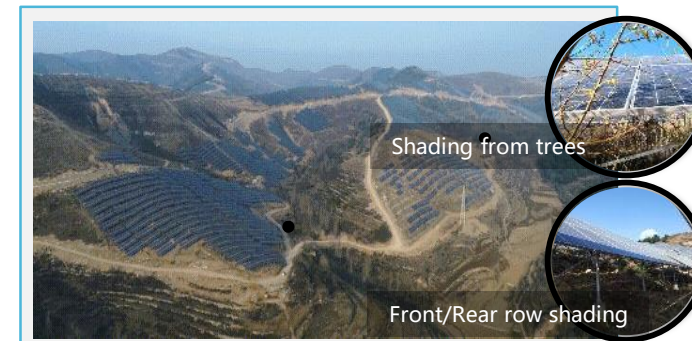
Performance Level	I-V Curve Scanning		Abnormality Identification			Fault Diagnosis
	Measurement Precision	Scanning Precision Rate	Recognition Rate ¹		Recurrence Rate ²	Root Cause Analysis Accuracy ³
			Class I defect	Class II defect		
L1	Voltage and current $\leq 1.0\%$	$\geq 70\%$	$\geq 75\%$	$\geq 70\%$	$\geq 70\%$	$\geq 70\%$
L2	Voltage and current $\leq 1.0\%$	$\geq 80\%$	$\geq 85\%$	$\geq 80\%$	$\geq 80\%$	$\geq 80\%$
L3	Voltage and current $\leq 0.5\%$	$\geq 85\%$	$\geq 90\%$	$\geq 85\%$	$\geq 85\%$	$\geq 85\%$
L4	Voltage and current $\leq 0.5\%$	$\geq 95\%$	$\geq 95\%$	$\geq 90\%$	$\geq 90\%$	$\geq 90\%$
Actual test result	$\leq 0.5\%$	97.5%	100%	96.4%	96.2%	96.8%

Project: XX rooftop PV plant in Ningbo, Zhejiang



528 Diagnosed strings 62 Faulty strings 11.7% String failure rate

Project: XX PV plant in a coal mining subsidence area of Yangquan, Shanxi



3960 Diagnosed strings 188 Faulty strings 4.7% String failure rate

Huawei Smart I-V Curve Diagnosis

VS

I-V curve scanning of other vendors

Multi-scenario adaptability

- Applicable to large-scale ground-mounted and mountainous scenarios
- Compatible with mainstream modules: half-cell/shingled/166/182/210 mm

Limited adaptability

- PV string-based diagnosis
- Hard to apply in various scenarios

Energy yield loss assessment

- Quantifying the energy yield loss of faulty strings
- Precise guidance for PV plant O&M

No energy yield loss assessment

- Not supported

Scheduled scanning

- Periodic diagnosis and email notification ensuring user experience

No scheduled scanning

- Not supported

ISV integration

- Supporting northbound interfaces
- Can be integrated by ISV

No ISV integration

- Not supported

Refined data management

- The inverter automatically obtains irradiance data.
- Parameters of PV strings can be configured.

Obtaining unrefined data from the EMIs

- Obtaining data from the EMIs
- Parameters can be configured only for inverters.

High availability of diagnostic reports

- Provide diagnosis overview report, diagnosis report, and fault O&M report.
- Provide raw data for the customer.

Poor availability of diagnostic reports

- No fault cause analysis and low availability
- Raw data cannot be exported.

SSLD-TECH (Smart String Level Disconnection):

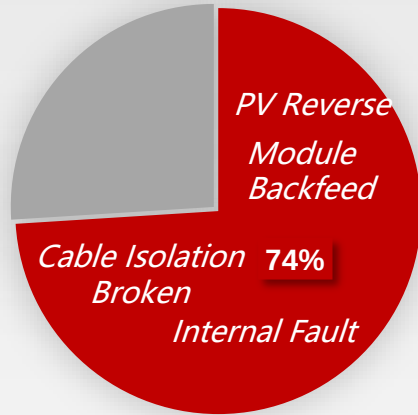
Precise fault detection, rapidly disconnect DC system faults

74% failure from DC side



SSLD-TECH

Huawei received the World's First Smart String-Level Disconnect certificate from DEKRA and Intertek



*Source: Statistics based on Huawei 300GW operation data



DC cable breakage



DC disconnecter unbroken



MC4 burned out



DC Capacitor damage



String fault connection
Disconnect time $\leq 250\text{ms}$



DC input current reverse-flow
Disconnect time $\leq 250\text{ms}$



Inverter internal short circuit
Disconnect time $\leq 16\text{ms}$

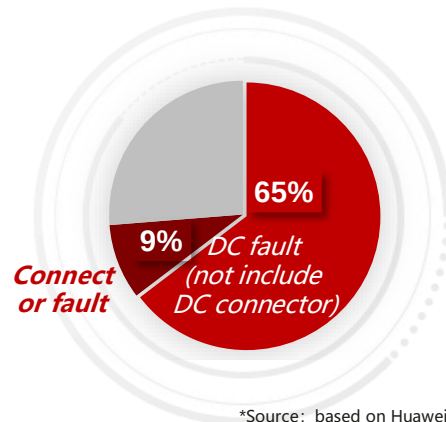


(meet IEC 60947-2)

SCLD-TECH (Smart Connector Level Detection):

Sensitively detect connector temperature abnormality, implement timely protection

High failure rate for DC connector



*Source: based on Huawei 300GW operation data analysis result



Connector plugging is not in place



Poor metal core contact



Poor contact due to external force



Chemical contamination

Smart PV: Smart connector temperature detector (SCLD)



PV connector design on board

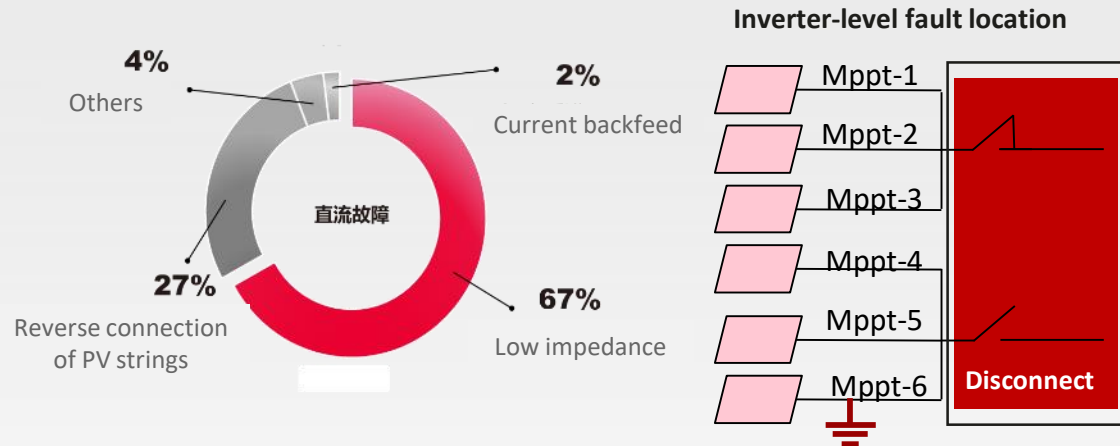
SCLD

✓ Automatic production, ensuring high reliability

✓ When the connector temperature is abnormal, the invert alarms or shuts down to prevent fault spread.

MPPT-level DC Insulation Diagnosis: Fault locating precision improved by 6 times

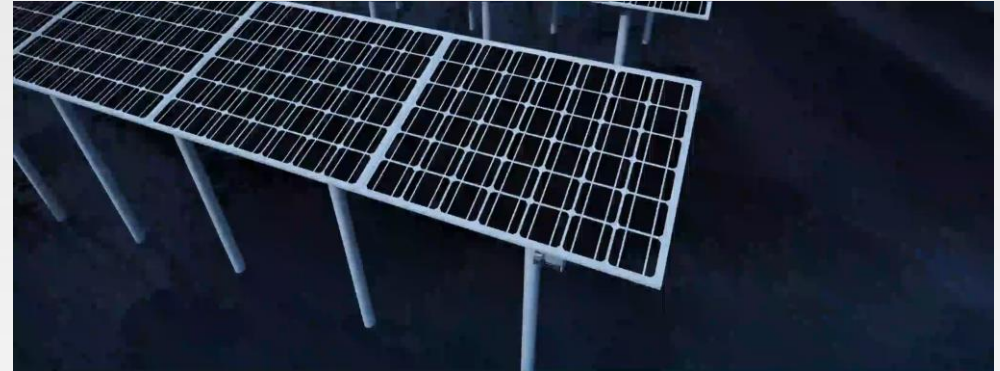
Traditional solution: Inverter-level fault location, inaccurate positioning



Low positioning accuracy 28+ PV strings and 56+ cables need to be checked

High yields loss Long-term multi-point grounding fault occurrence

Smart PV: MPPT-level DC insulation diagnosis



High positioning accuracy

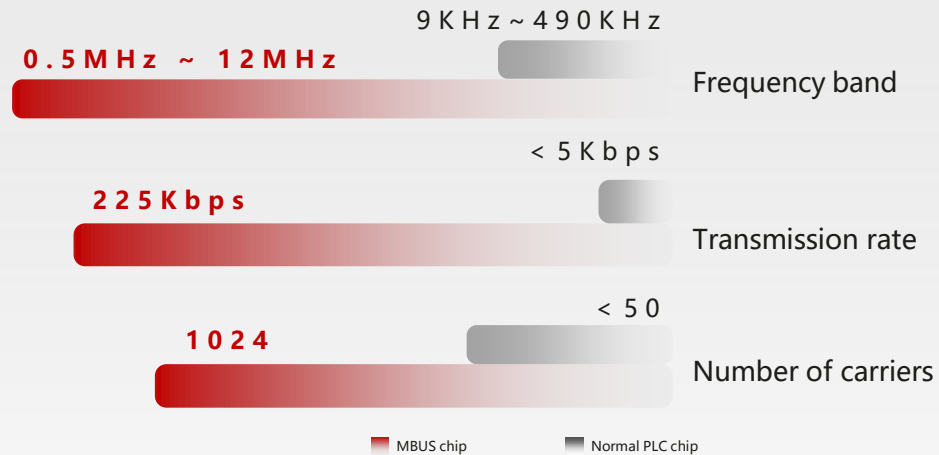
- Only **4~5** PV strings and **< 10** cables need to be checked
- Fault locating precision improved by **6** times,

Low yields loss

- Check time is reduced by **15 mins** per time, and safety issues are quickly closed.

Patented PLC Tech: The MBUS enables more stable communication

Broadband MBUS chip, better performance



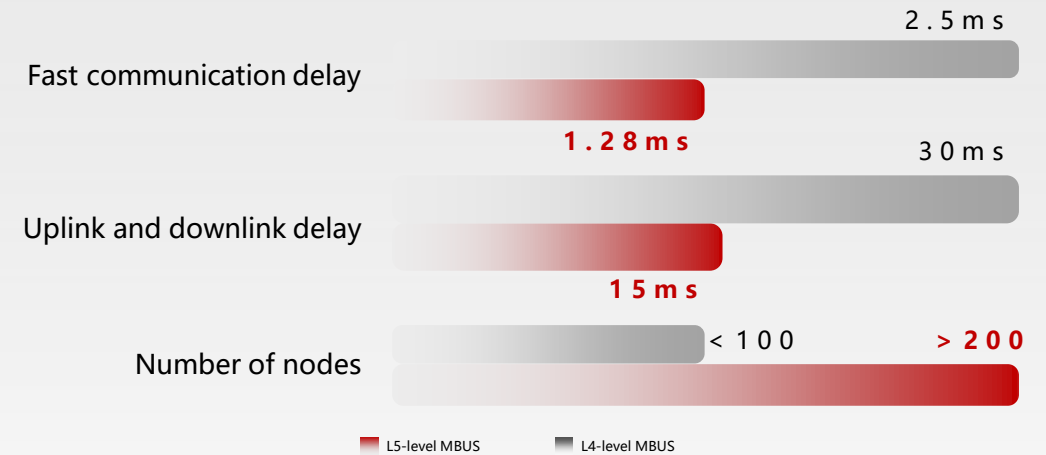
Faster
transmission rate

MBUS **broadband** PLC

More reliable
communication

customized chip

Authoritative certification



Longer
transmission distance

1000m

Larger
array

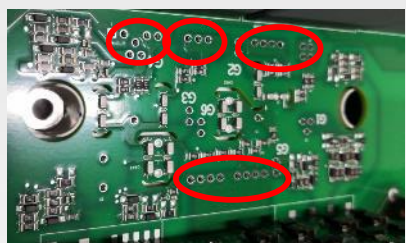
9MW long-span arrays

Ensure reliable communication of large-span stations like mountains

Multi-reliability design: stable operation in harsh environment

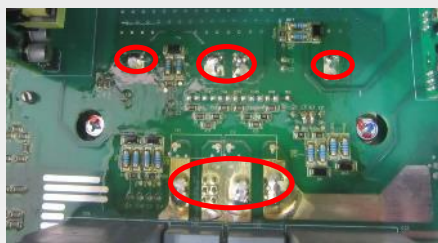
Reliability design

The Press Fit crimping process improves reliability by 100 times*



FuisonSolar8.0

Automation equipment crimps the module to the PCB



Traditional String Solution

Components are fixed to the PCB through the soldering process.

Connectors on-board design, automatic production, high consistency



FuisonSolar8.0

On-board design, integrated temperature detection



Traditional String Solution

Nearly 100 DC cables, manually connected

*Source: Reliability comparison between soldering and Press-Fit in SIEMENS NORM SN29500-5

IP66 protection grade



Poor sealing of the transfer air duct at the air outlet



power cavity
maintenance cavity

- Direct ventilation design, poor sealing, unable to prevent water vapor, dust and salt mist from entering

- ✓ Split-cavity design to prevent foreign objects from entering
- ✓ One-piece stretching aluminum panels to reduce splicing gaps
- ✓ High weather resistant coating material

Harsh environments

Dozens of rigorous environmental tests



Anti-salt spray test

Severe test in high humidity and high salt spray environment

TÜV certification, availability> 99.999%



Qinghai 2.2GW ultra-high voltage project



TUV Report



Fuse Free



No Manual O&M

NO. of Inverter	COD	Altitude	Total Available Time	Availability
9216 pcs	Sep. 2020	3100m	20,000,000 hours+	99.9990%

*Certified Model:SUN2000-175KTL-H0 Certified time:2022.03

Reference cases in different delivery scenarios

World's largest single PV plant



2.2 GW
Qinghai, China
SCR low to 1.2

World's largest solar-fishery PV plant



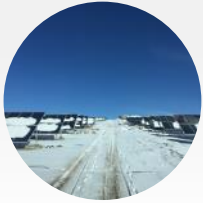
300 MW
Shandong, China
High temperature, humidity
& salt spray

Utility scenario with trackers



220 MW
Mexico
2.3% higher yields
11% lower yields

Ultra-low temperature



100 MW
Inner Mongolia
-40°C low temperature

European largest floating PV plant



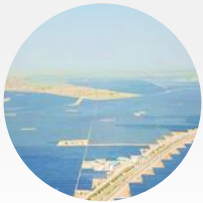
27 MW
Netherlands
High temperature,
humidity & salt spray

High altitude



50 MW
Sichuan, China
Altitude > 4300 m

Deserts



450 MW
India
>48°C high temperature

High salt-spray



2 MW
Japan
200m by the sea

High altitude



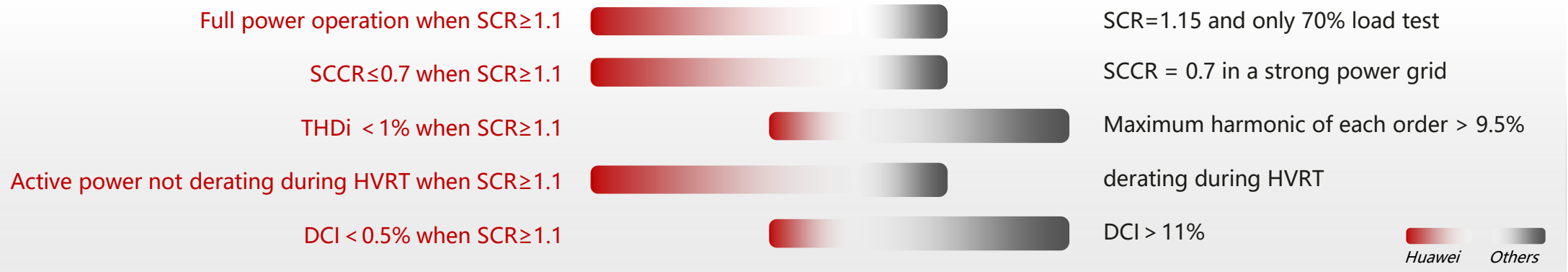
315 MW
Argentina
Altitude > 4200 m

Huawei Smart PV inverters with strong grid-connected capabilities, supporting stable operation in all grid scenarios

Robust Operation under All Grid Scenario

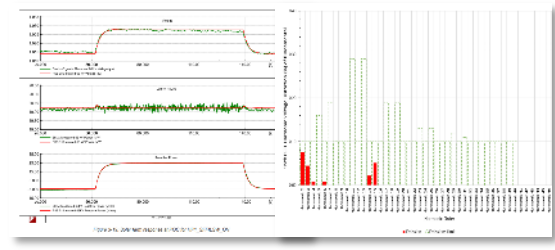
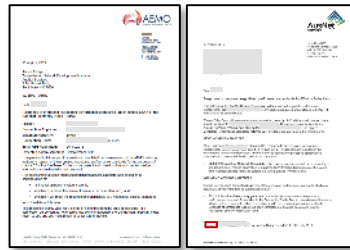
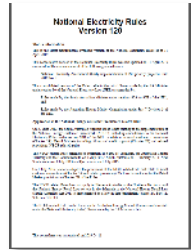


Smart PV: Continuously improve the "five" core grid-connection indicators



Australia : Huawei smart PV fully compliance with world's strictest grid code

Huawei Smart PV: Unique string solution fully compliance with Australian new strict grid code



New Grid Code Launched in Australia

2019.02

New Australian grid code

- Strictest grid code for HVRT/LVRT

GPS Simulation

2019.08

Fully compliance with new code

- First approval letters compliance with new code within half year

R1 Simulation & Construction

2020

Successfully pass strict model audits

- Fully compliance with new Australian dynamic models
- SCR low to 1.5

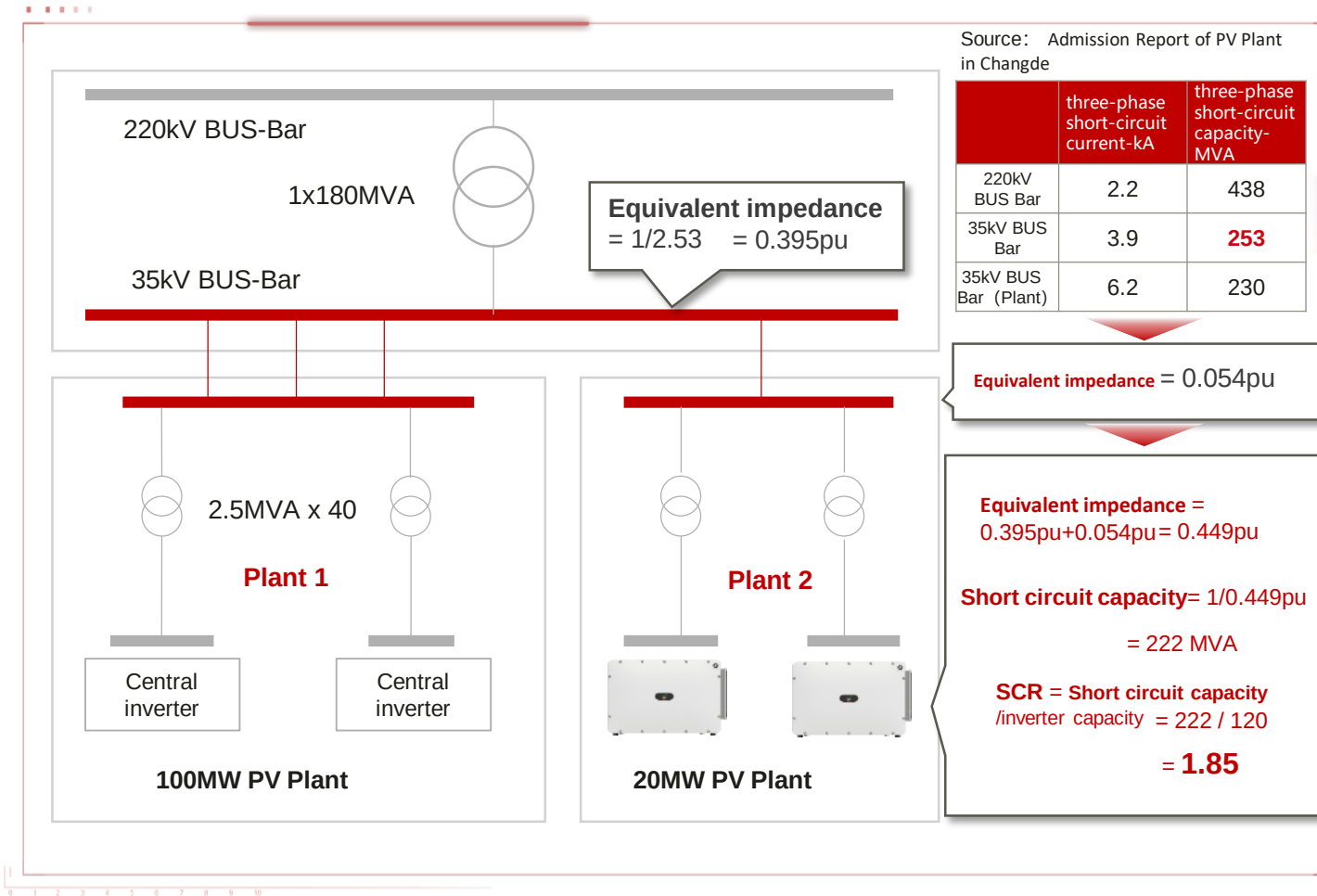
R2 Testing & Commissioning

2021.04~08

300+ onsite tests, **100%** fully grid-connected

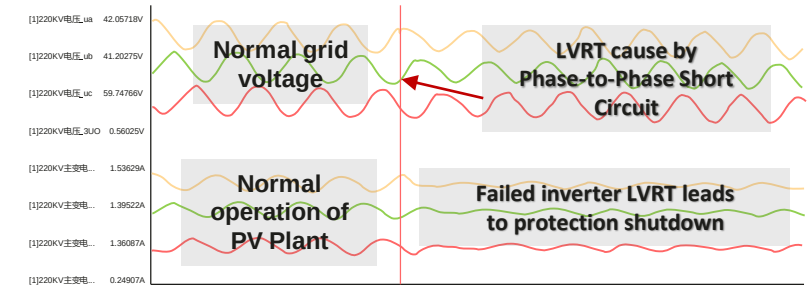
- Onsite results fully overlay with simulation
- Superior power quality: $THD_u < 0.37\%$
- Better communication: 40 ms instruction cycles and < 10 ms time delay

Inverter encounters the challenge of weak grid problem after the increased capacity of PV plant in Heilongjiang, China



09:32:26, 4th April, 2020

100MW Central PV Plant Fault recording diagram
630kW central inverter



Onsite feedback: most of the inverter were damaged due to failed LVRT caused by grid short-circuit, and 35 PV block (40 in total) were out of service and waited for repairing.

At the same moment

Smart PV Controller operation log
Accurately identified grid faults and ensures stable operation after successful LVRT

Summary Analysis result RPT Log Main Log Vene Log

Row: 0 Content:

File	Pr	Time	ID	LVRT	RRRT	Grid_AB	Grid_BC	Grid_CA	Grid_FaultSeq	Grid_RestSeq	I_d_Ref	I_q_Ref
0	A	0... 2020/4/4 9:38:54	INV_VRT_INFO_LOG_VRT	1	0	5062	5042	5047	3343	627	1128	65352

LVRT Record



3

Typical Project Case Studies

Ali "Zero Carbon" Demonstration Project in Tibet

In the harsh application environment and power grid environment,
Reliable operation at full power, setting an industry benchmark

Capacity: **150MW**

Grid Supporting: High power quality, stable grid connection

SCLD + SSLD: Ensuring safe and reliable operation at high altitude

SSCF: Intelligent application, reducing manual onsite O&M

热烈祝贺中广核阿里雪域高原“零碳”光储热电示范项目并网发电
—— 华为数字能源川藏业务部

SUN2000-300KTL-H0, COD: 2022.12

Water and PV Complementary Project of Yalong River, Sichuan Province

Huawei Smart PV Assist

Construction of the world's largest water-PV complementary
power station

Capacity: **1 GW**

Energy yields - 2 billion kWh/year

High altitude - 4000m in Yalong River Basin

Reduced carbon emissions - 96t/year





Datang Yuhu Floating PV Plant in Fuzhou, China

World's first plant using the Smart Co-Diagnosis System

The largest solar-fishery plant in Jiangxi in 2021

The total capacity of the plant is **260 MW**, among which **34 MW** is deployed with the co-diagnosis system in the first phase.

After the co-diagnosis system identifies faults and guides troubleshooting, the energy yield increases by **1%–2%**.

It is estimated that the annual revenue of the 34 MW project will increase by about **CNY236,000**.*

Within 5 months after the system is deployed, the average O&M efficiency is improved by **about 80%**

**The energy yield increases by 1.5%. The plant has a total of 1112.9 equivalent sun hours annually, and the electricity price is CNY0.4143/kWh.*

Thank you.

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.

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DEKRA Insights of Inverter Safety

VISION 2025

We will be the
global partner
for a
safe, secure and sustainable world



OUR MISSION

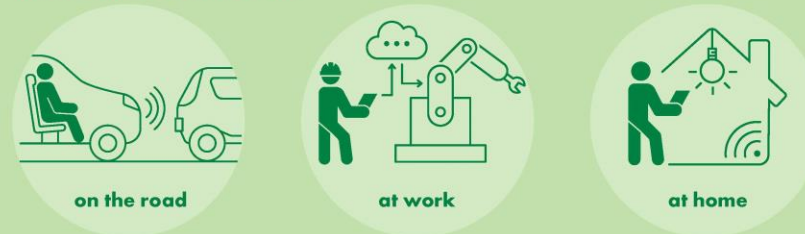
The Mission describes our purpose for society.

We ensure safety, security and sustainability

... by the interplay of



in the three areas of life



OUR CORPORATE PRINCIPLES

The Corporate Principles are our strategic imperatives to help to translate our vision into action.



Innovation



Integration



People focus



Growth



Economic success



Customer focus



Globalization

OUR PEOPLE VALUES

The People Values serve as a guide for the day-to-day behavior of all DEKRA employees.



Responsibility for safety, security and sustainability



Customer orientation



Entrepreneurship



Team Spirit



Integrity

Content



- ▶ Safety aspects of a PV inverter
- ▶ DC side
- ▶ Cyber security

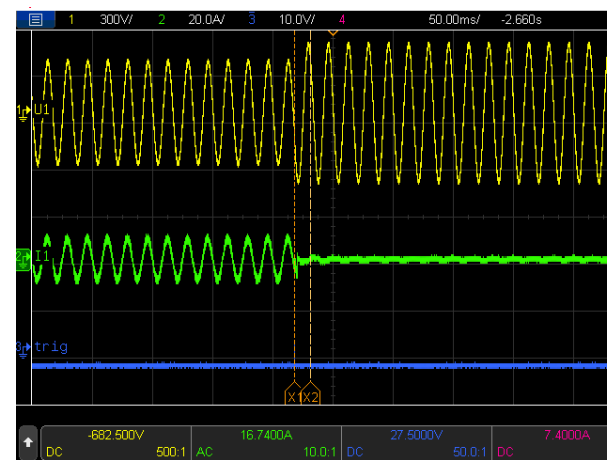
Safety aspects of a PV inverter



Safety



EMC

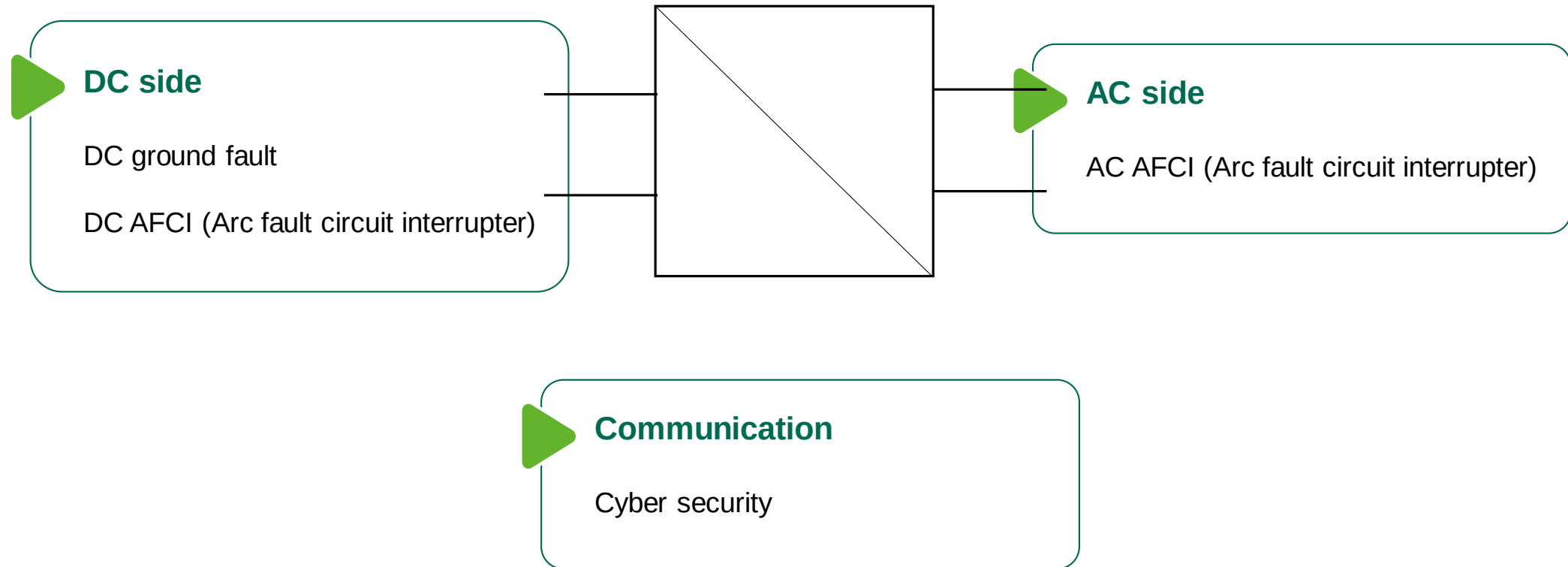


Grid code

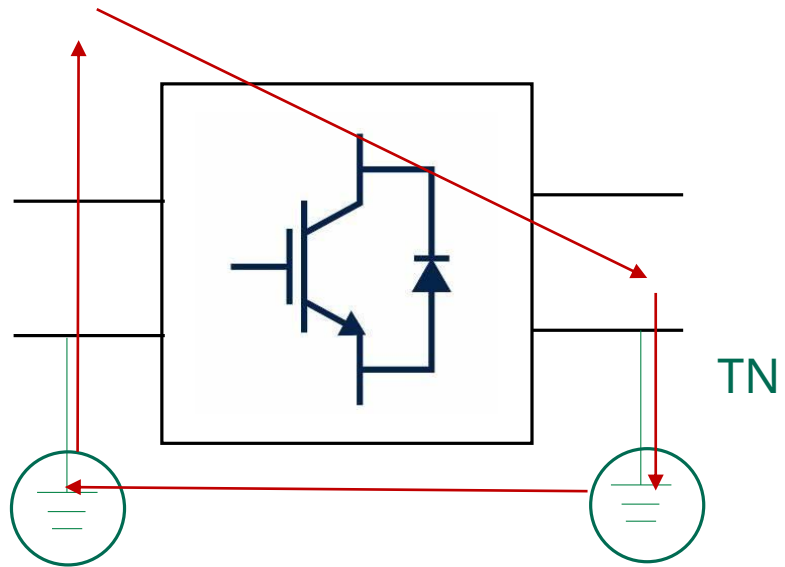


Cyber security

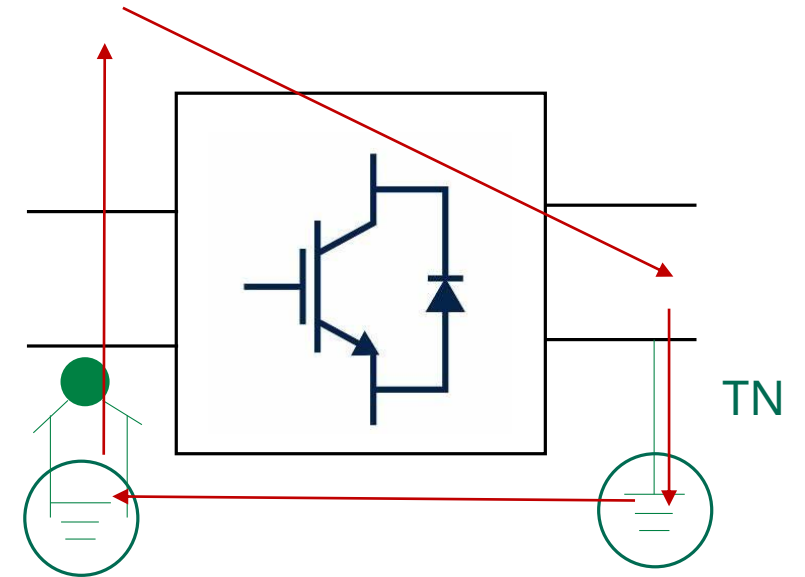
Important safety requirements in safety & security



DC ground fault



Fire hazard caused by DC ground fault



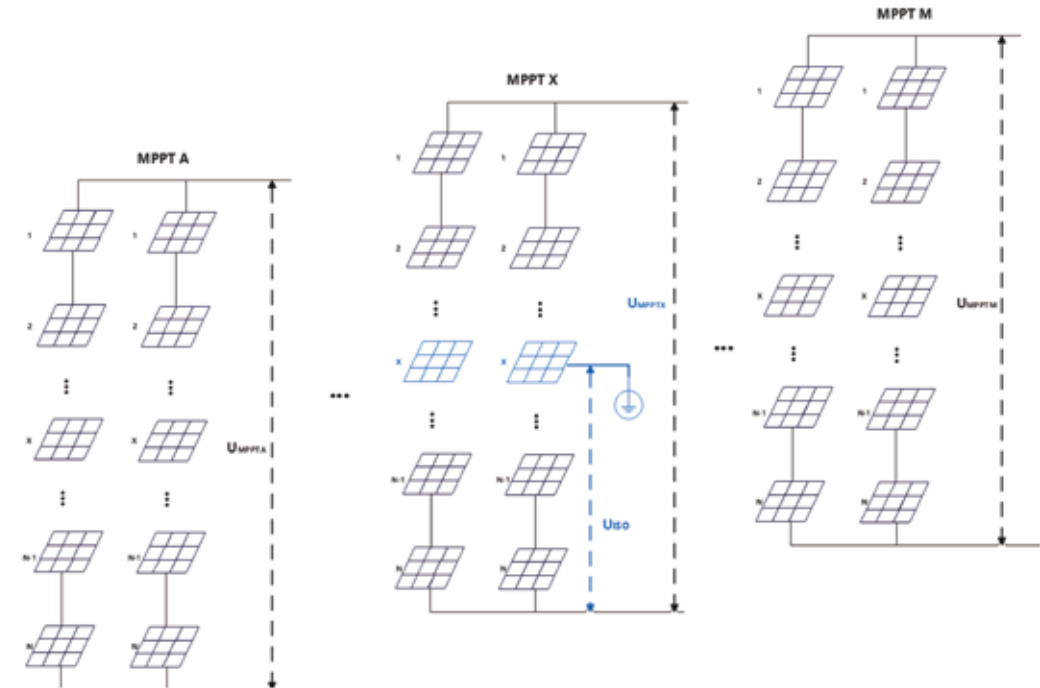
Electric shock hazard caused by DC ground fault

DC ground fault

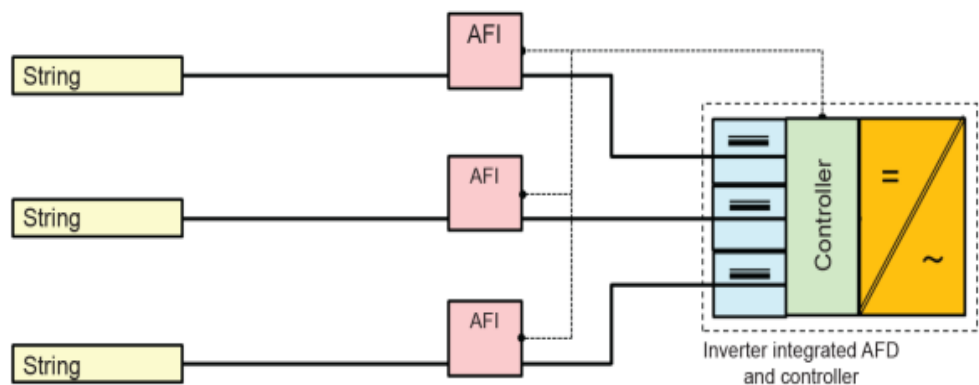


As required by several standards (e.g. EN 62109-2 in EU), inverters for use with ungrounded arrays shall have means to measure DC insulation from the PV input (array) to ground before starting operation. If DC insulation is lower than limit, inverter shall indicate a fault and shall not connect to the mains.

The standards only require a detection means for array level. It is difficult to locate specific fault PV module in this case. By MPPT level ground fault detection, specific fault PV module can be located as shown in the picture.



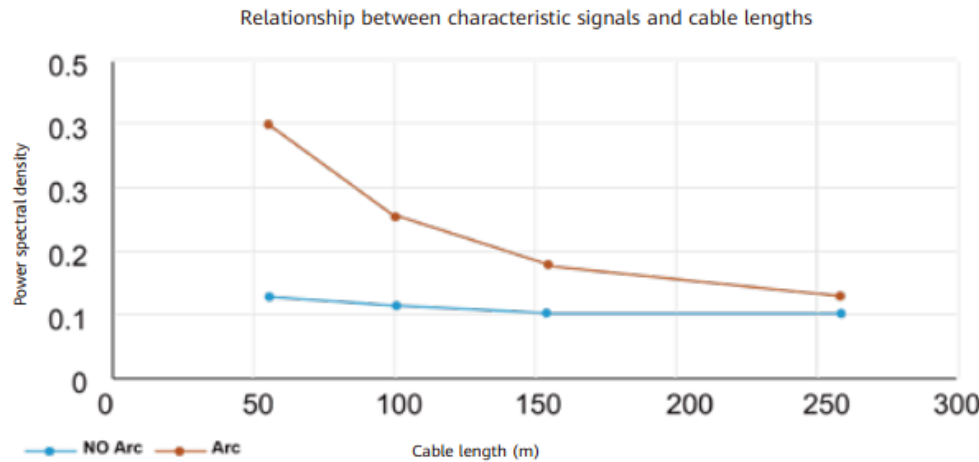
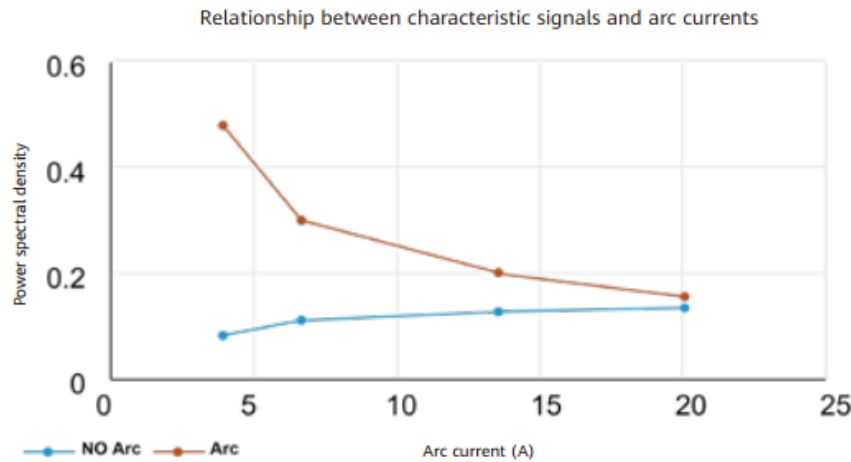
DC AFCI



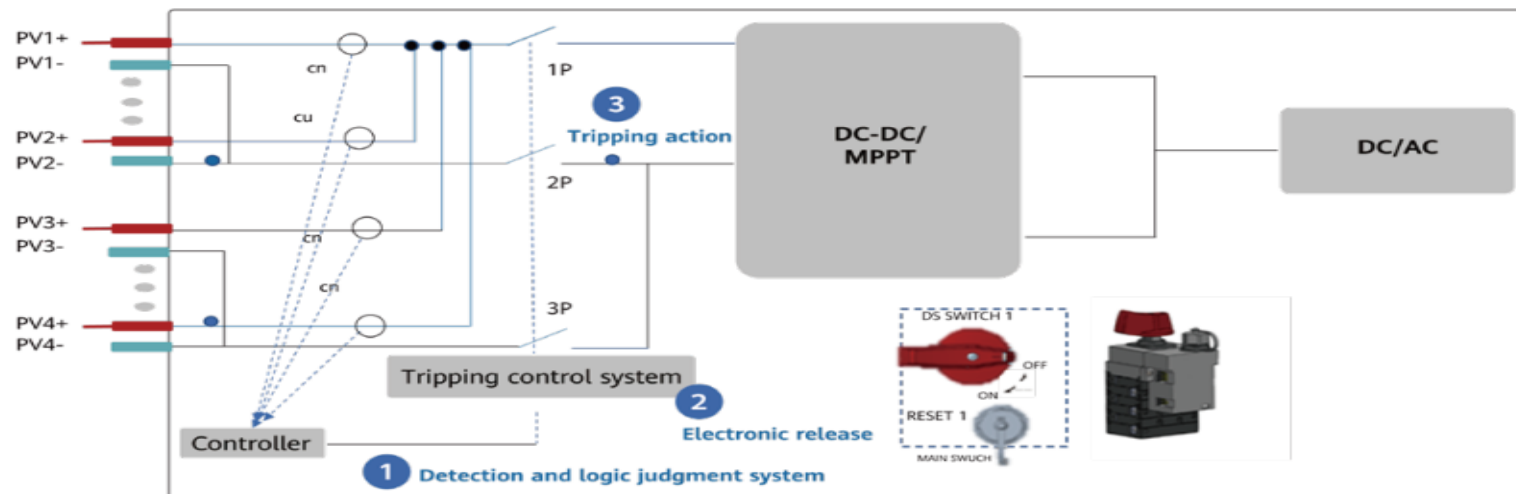
DC arc fault detection and interruption device is required by UL 1699B and IEC 63027.

DC AFCI works well in lab. However, it may not work well because of heavy signal noises and complicated scenarios in different PV power plants.

Traditionally, only arc current / voltage frequency domain is used to detect arc fault which is not enough for complicated scenarios on site. To address this issue, AI technology may be used for more accurate arc fault detection.



DC string level disconnection

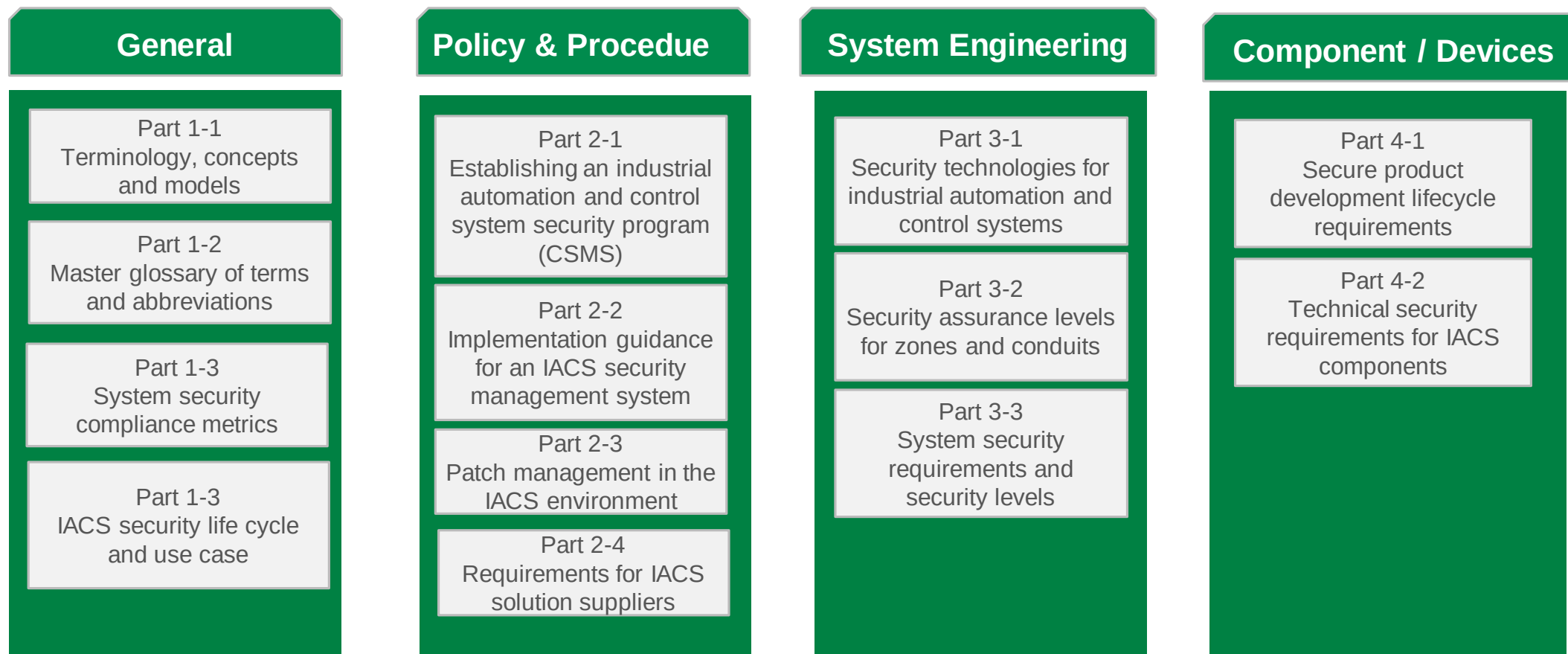


DC disconnection is required by many safety standards to disconnect DC power in any emergency. DC disconnection is also used by manufacturers for protection of DC fault.

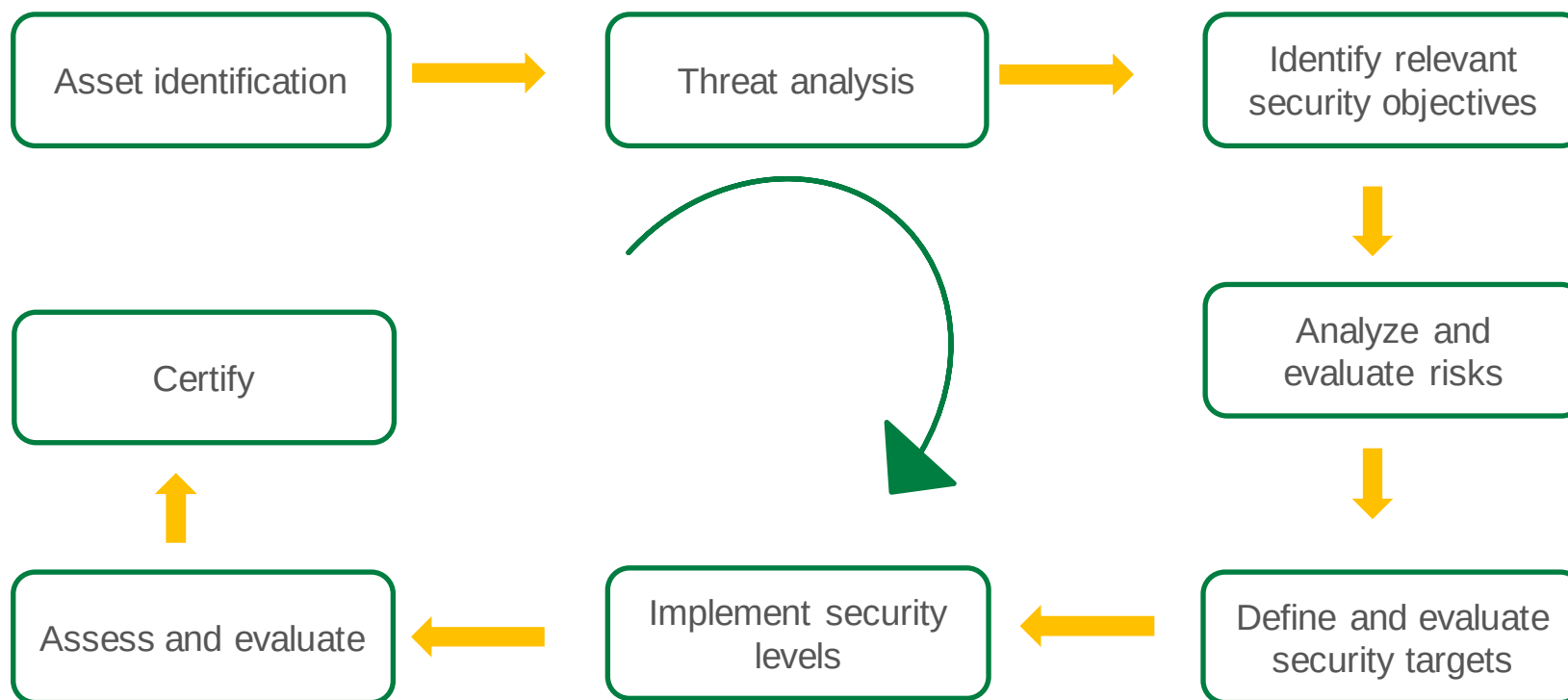
However, if only single PV string gets fault, it is not necessary to disconnect all input power of a PV inverter. A string level disconnect device with more intelligent detection technology may help save power in a PV power plant.

Furthermore, traditional electromagnetic release or thermal release of overcurrent protection can only act when the overcurrent is much higher than rated current. An electronic release with intelligent detection will catch and protect slight change of current even voltage.

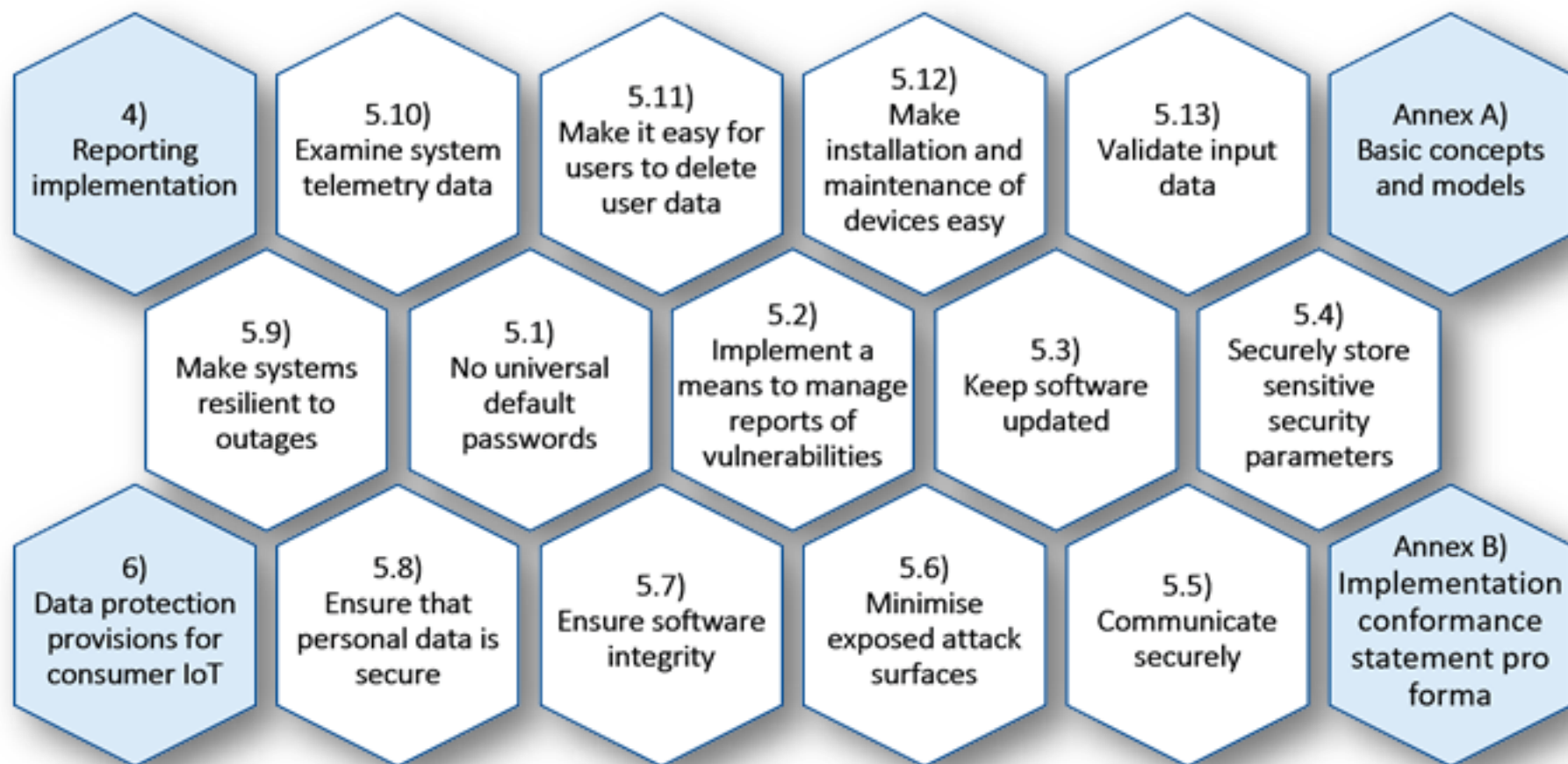
Cyber security - IEC 62443 - Structure



Cyber security - IEC 62443 – Approach



Cyber security – EN 303 645



A large, stylized green arrow graphic pointing right, composed of two overlapping shapes: a lighter green one in front and a darker green one behind it.

Thank you,
for taking care of safety.