



What is Power Optimizer ?



How Does Optimizer Work in PV System ?



Long String Design with Power Optimizer



Easy installation Verification and Safe Operating



Optimizer Pairing with Inverter



Module Performance Monitoring in Physical View

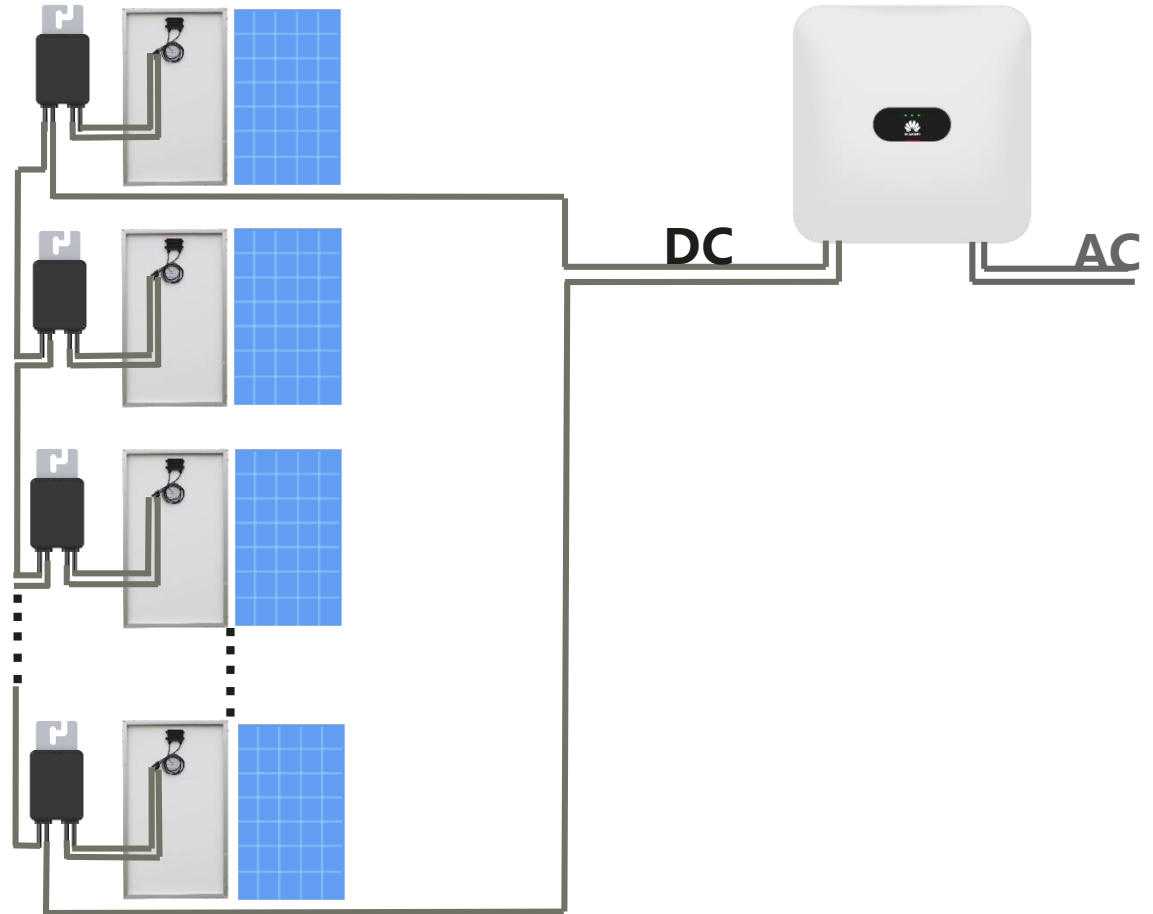
Introduction of Power Optimizer



Power Optimizer

A power optimizer is a DC/DC power electronics device attached to PV module to:

1. Capture the maximum power point of PV module
2. Shutdown module voltage to a safe voltage
3. Enable module level monitoring

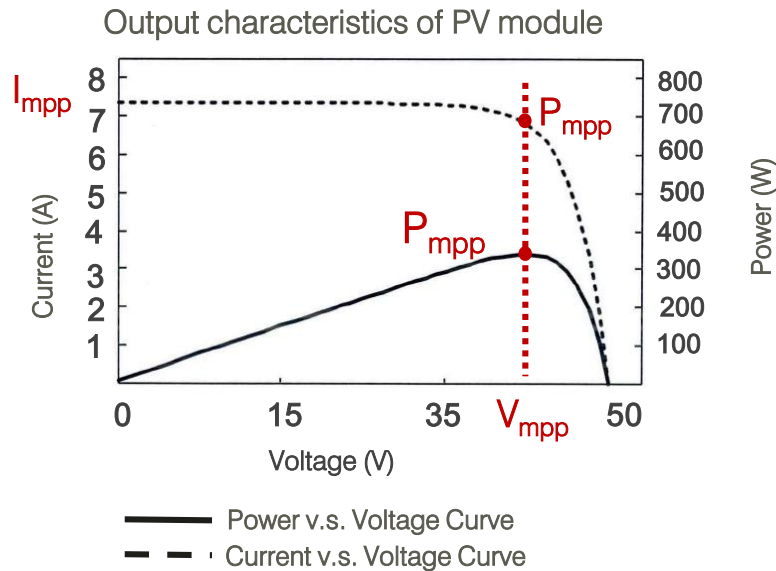


1. PV module output connect to the input of power optimizer
2. Power optimizer output connects in series to the input of inverter

Basic Function of Power Optimizer

1. Module-level Power Optimization

Power optimizer harvests the maximum power (P_{mpp}) of module onto which it is attached

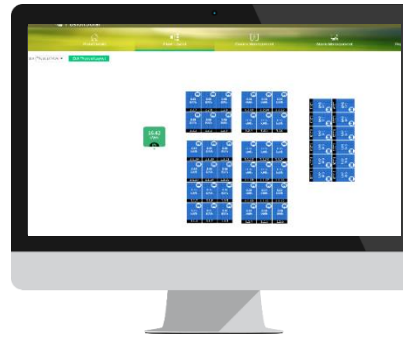


2. Module-level Voltage Shutdown



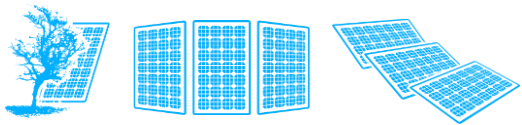
- Power optimizer could adjust to output a safety voltage whenever output is open or the connected inverter is shutdown.
- In this case, DC wires are de-energized to safe voltage level for personnel installation, O&M and firefighters.

3. Module-level Physical Viewing



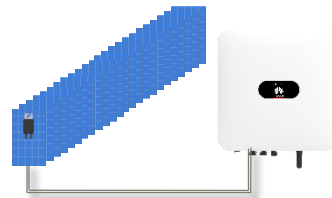
- More precise module operating information can be monitored via physical view in management system
- Pin-point alert of module operating for remote diagnosis and easier fault location.

4. Flexible Design



Modules affected by shading, multiple orientations can be connected in one string with power optimizer attached

5. Long String



Optimizer make possible longer string to

- Increase DC/AC oversizing
- Save BoS (Balance of System) cost



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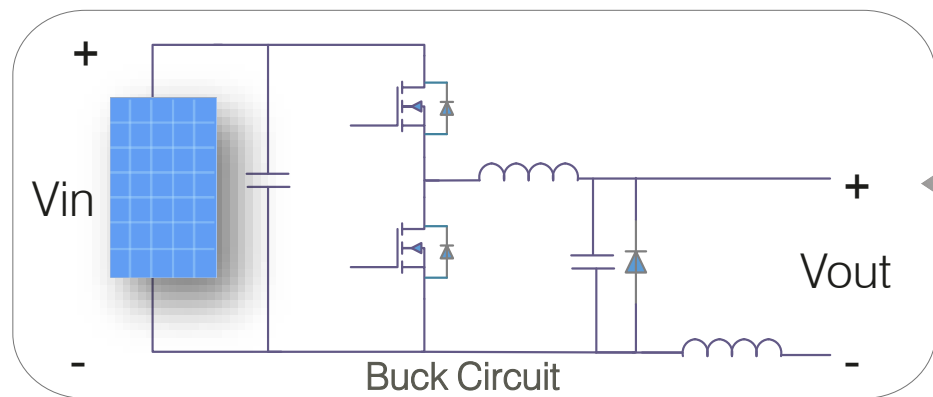


Optimizer Pairing with Inverter



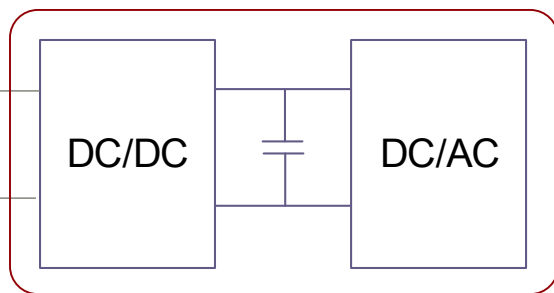
Module Performance Monitoring in Physical View

Optimizer Operation Mode: Buck / Bypass Mode



Buck Mode
 $V_{out} < V_{in}$

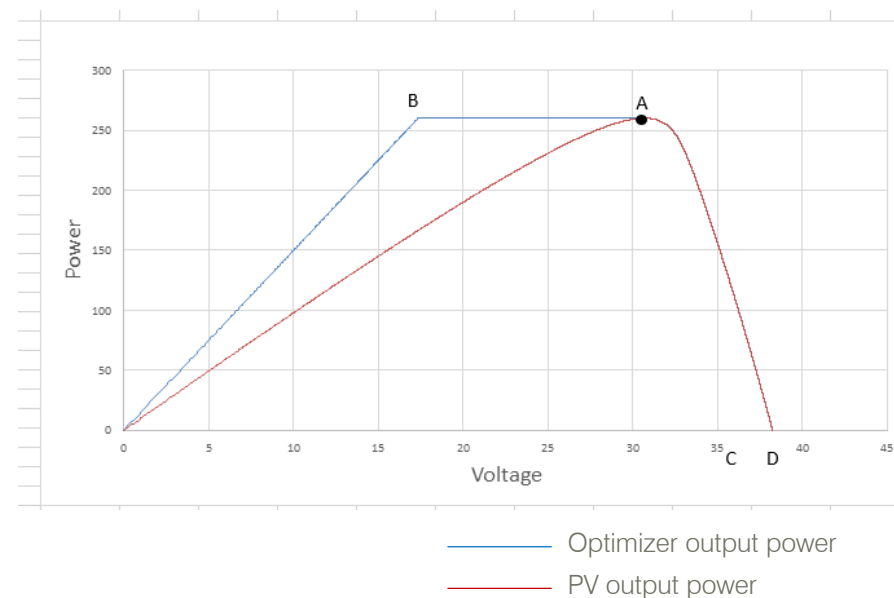
Bypass Mode
 $V_{out} \approx V_{in}$



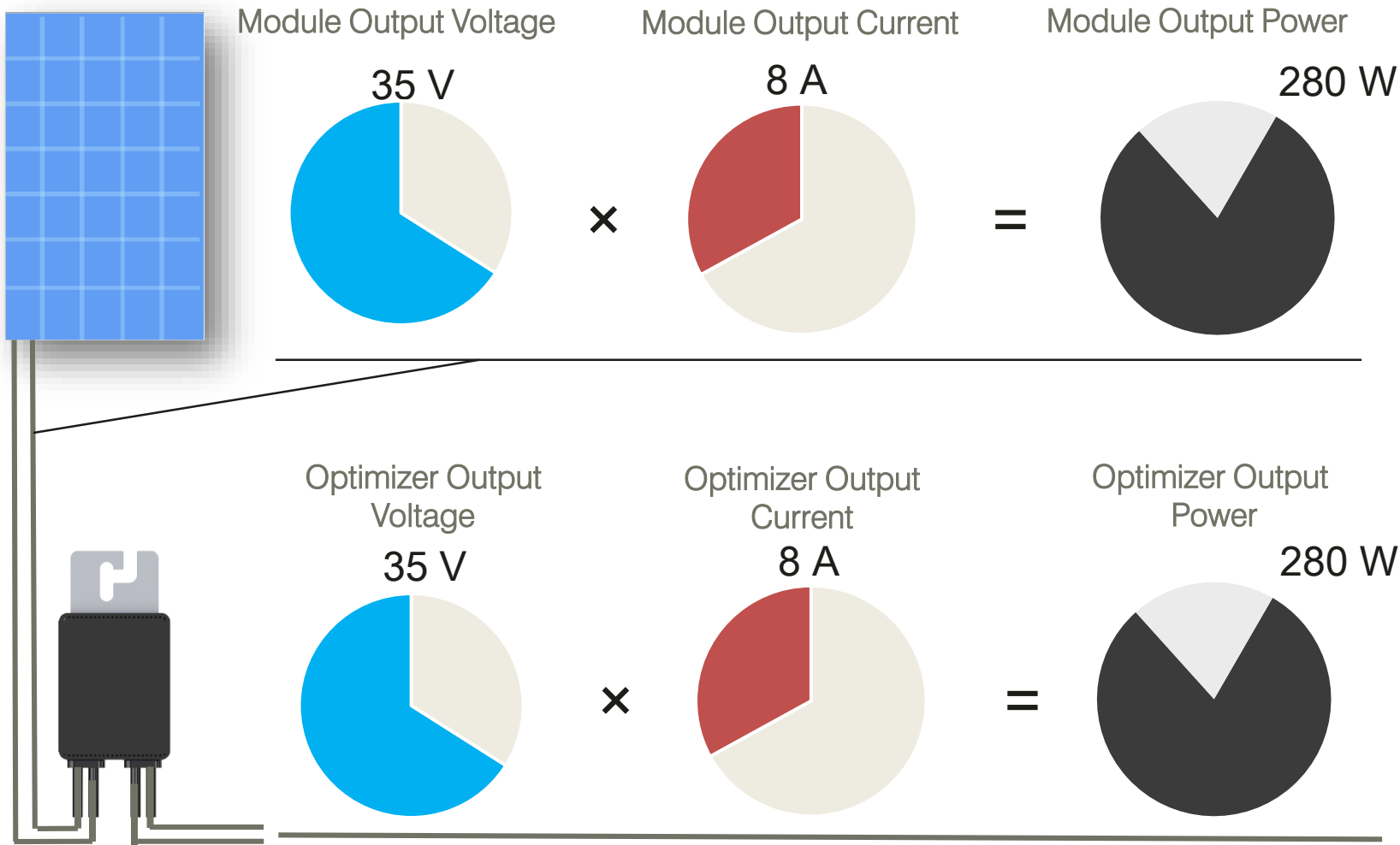
Two Stage Inverter

Optimizer in buck circuit steps down voltage (while stepping up current) from its input to its output.

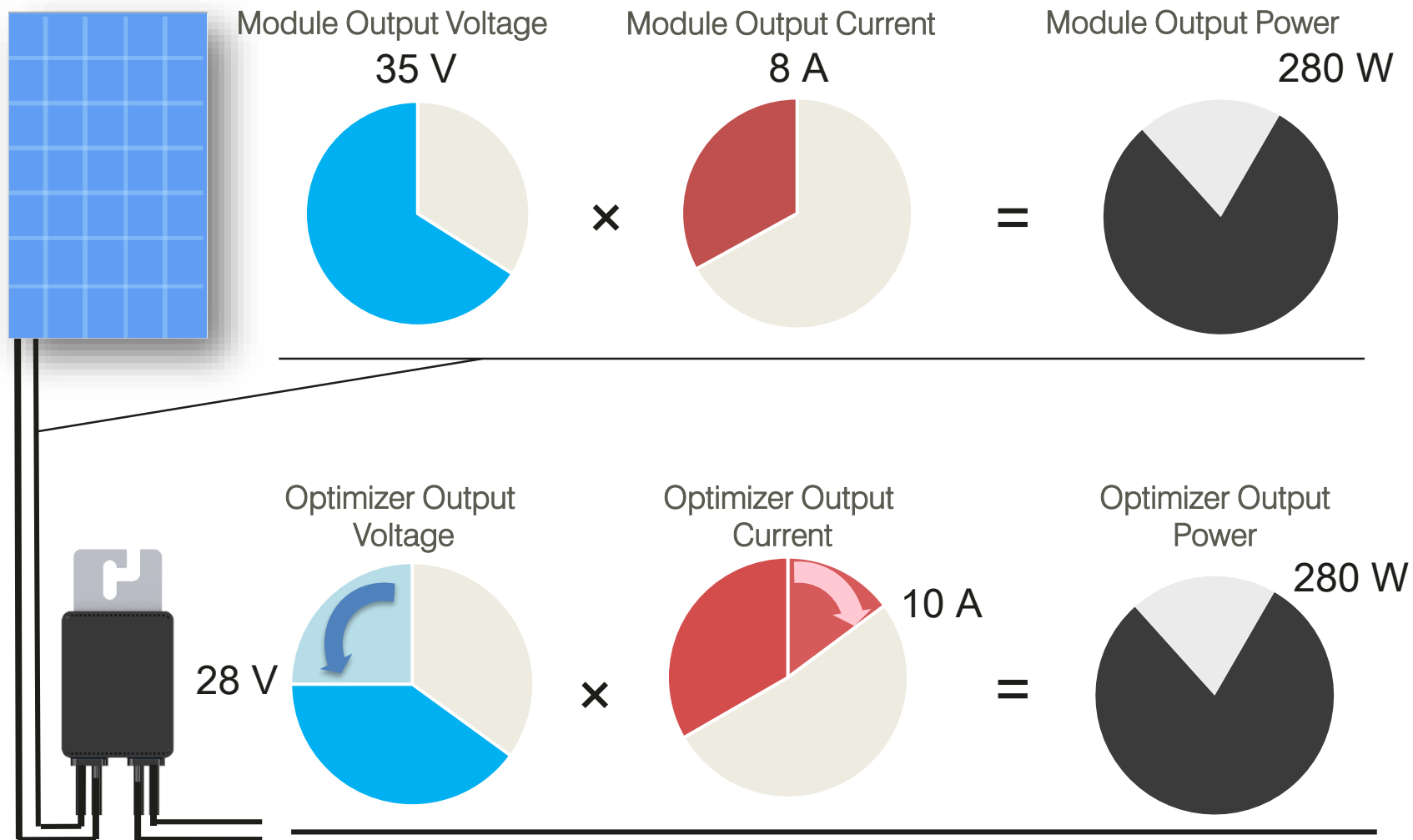
It interacts with two stage inverter while tracking maximum power point of PV module.



Optimizer Bypass Operating Mode



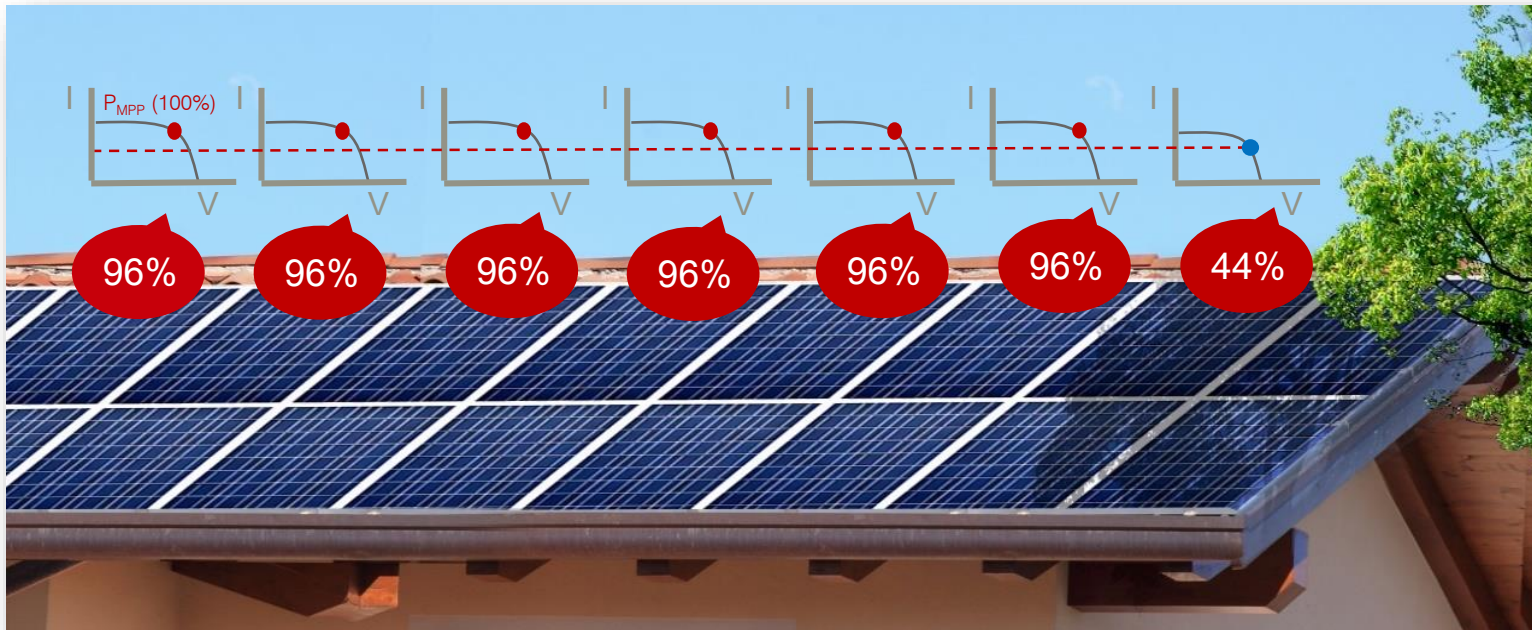
Optimizer Buck Operating Mode



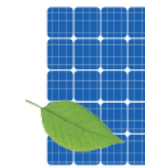
Without Optimizer : String Power Loss Caused By Mismatch

String Inverter tracks the maximum power point of whole string

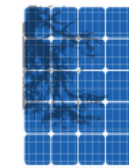
- Modules connected in the same string operate at the same current.
- Affected module's operating point shifts with current decreasing, which leads to output power reduction of the whole string.



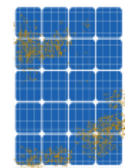
Common factors to cause power mismatch of PV module



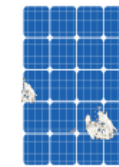
Leaves



Shading



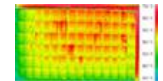
Soiling



Bird's
Dropping

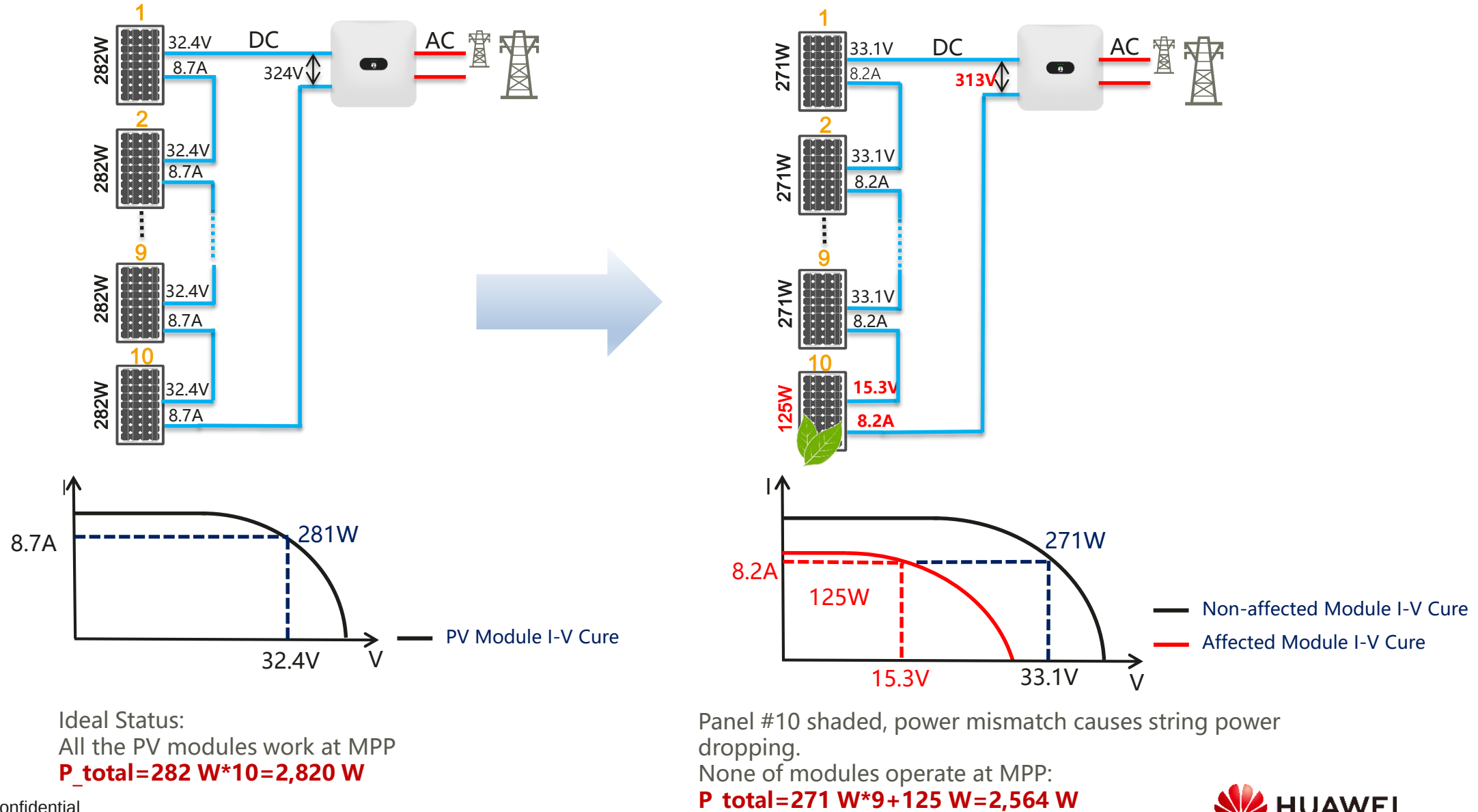


Tolerance
Mismatch



Thermal
Mismatch

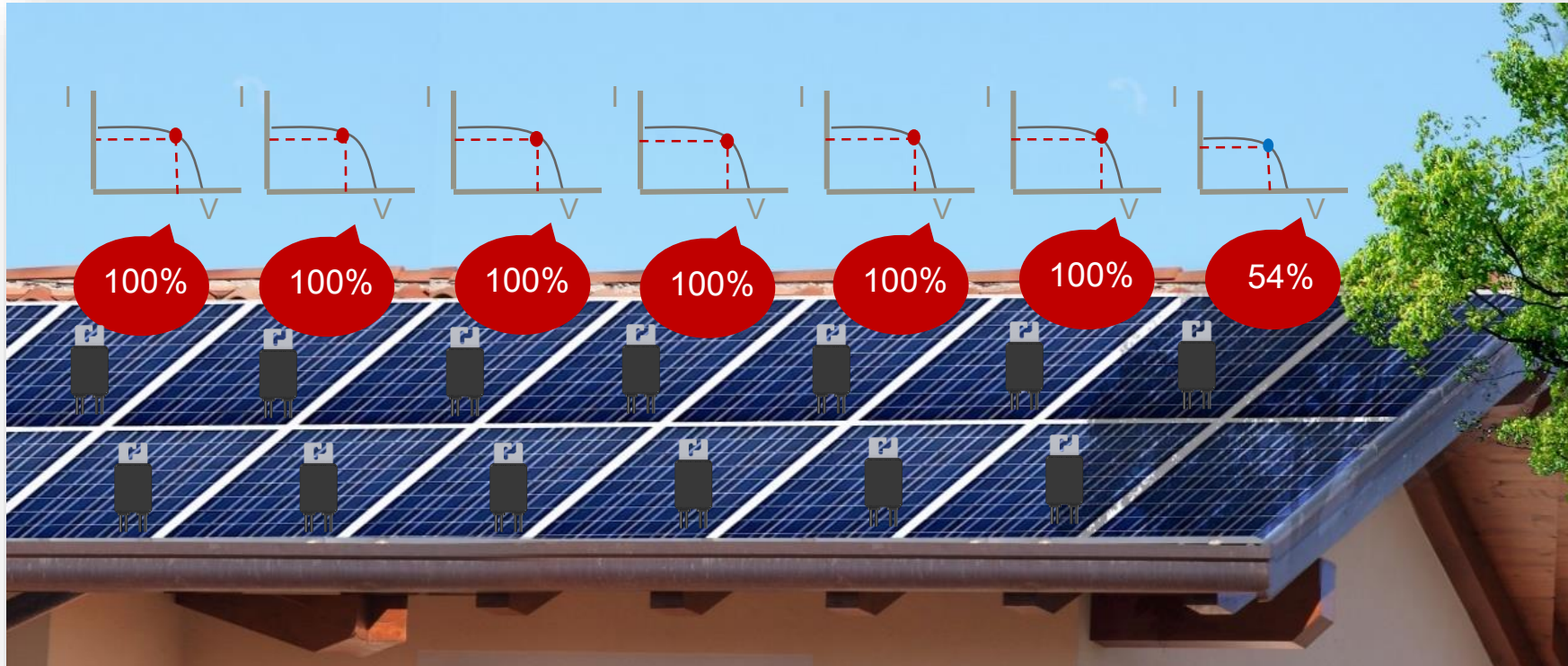
No Optimizer – Mismatch Causes Power Loss



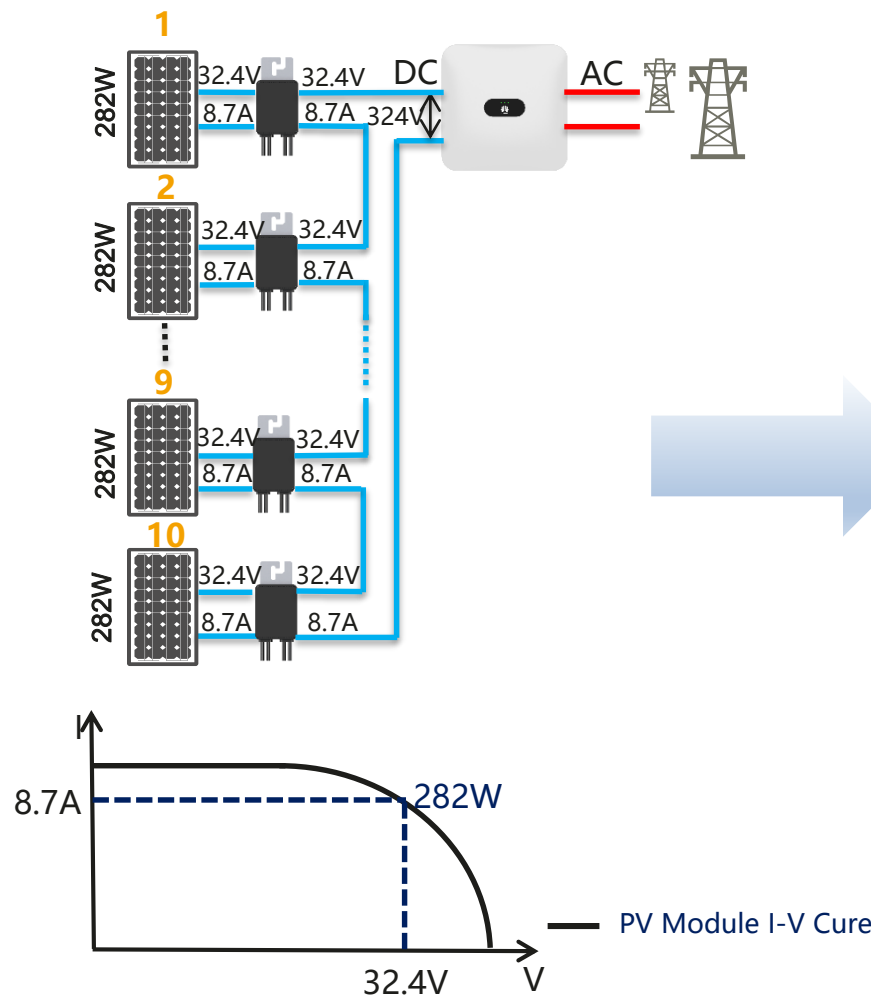
With Optimizer: Module Level MPPT to Mitigate Power Mismatch

With Power Optimizer installed to Each Module

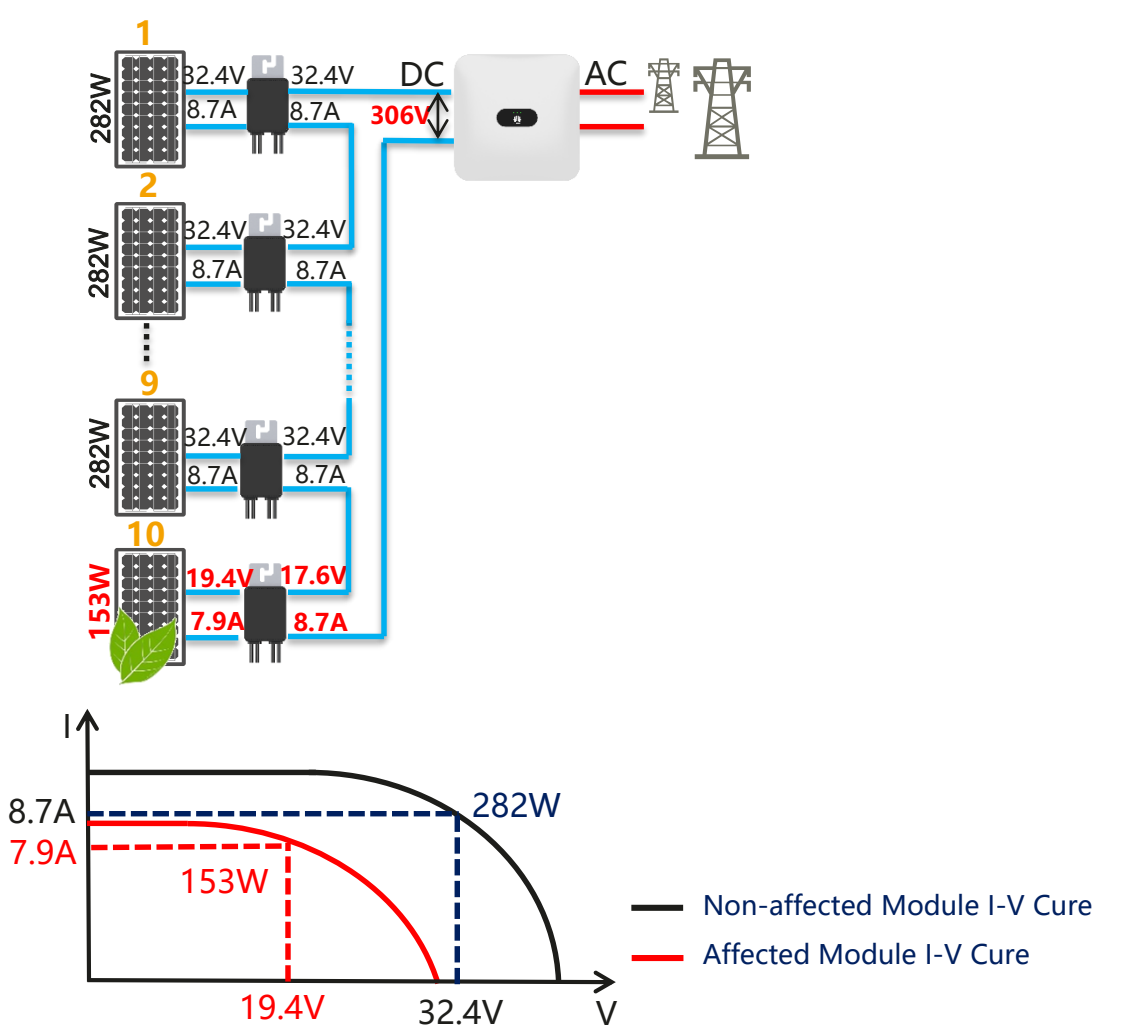
- Track the maximum power point of each PV module independently
- Underperforming modules are isolated from impacting the other modules in the string



Full Optimizer System Operating



Ideal Status:
 All the PV modules work at MPP with help of Optimizer
 Optimizer then operates in bypass mode
 $P_{total} = 282\text{ W} \times 10 = 2,820\text{ W}$



Panel #10 shaded, but it operates at MPP while optimizer operates in buck mode
 Non-affected modules still operate at MPP, optimizers operate in bypass mode
 Inverter adapt input voltage to optimizer output voltage in the string
 $P_{total} = 282\text{ W} \times 9 + 153\text{ W} = 2,691\text{ W}$



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Optimizer Pairing with Inverter



Module Performance Monitoring in Physical View

Optimizer Compatibility with PV Module



JAM72S01-350/SC/1000V Temperature Coefficient	
Temperature Coefficient of Isc(α_{Isc})	+0.059% / °C
Temperature Coefficient of Voc(β_{Voc})	-0.330% / °C

JAM72S01-350/SC/1000V Specification (STC: 1000W/m², 25°C)	
Rated Max Power(Pmax) [W]	350
Open Circuit Voltage(Voc) [V]	46.89
Max Power Voltage(Vmp) [V]	38.46
Short Circuit Current(Isc) [A]	9.75
Max Power Current(Imp) [A]	9.11

Location: Germany
Minimum temperature: -9.3°C
Maximum temperature: 22.34°C

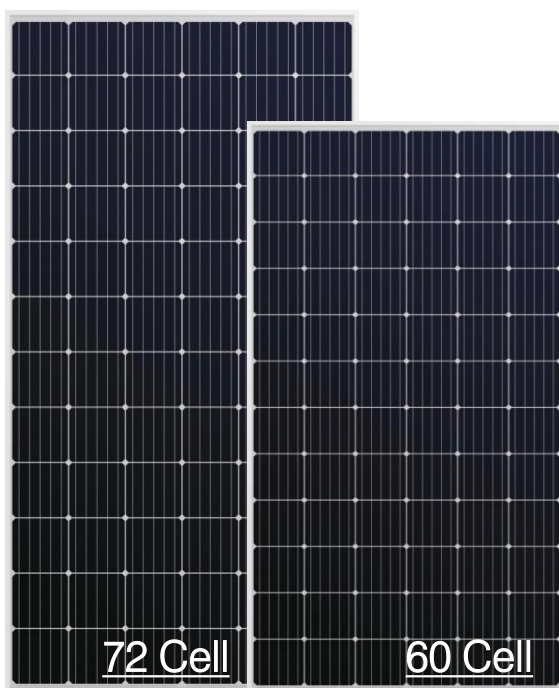
Maximum voltage at lowest temperature

$46.89V + 0.33\% \times [25^{\circ}C - (-9.3^{\circ}C)] \times 46.89V = 52.2V$
(max. voltage reached at lowest temp temperature)



SUN2000-450W-P Datasheet		
Maximum Input DC Power (W)	450	✓
Absolute maximum input voltage (V)	80	✓
Maximum Short Circuit Current (Isc)	13	✓

One Power Optimizer Fits All Application Scenarios



One SUN2000-450W-P power optimizer fits

- **All** 60 & 72 cell crystalline silicon PV modules on the market
- **All** installation scenarios
 - Optimizer 1.2m output cable suits both landscape and portrait oriented installation of PV module
 - Optimizer support both rack and PV module frame mounting
- **All** HUAWEI residential Inverter
 - SUN2000-2/3/3.68/4/4.6/5/6KTL-L1 single phase
 - SUN2000-3/4/5/6/8/10KTL-M1 three phase

Single optimizer model simplifies business operating and reduces cost of warehouse management and logistic

Long String Design with Full Optimizer

What is long string design ?

— With power optimizer, the number of modules connected in a single string is more than that of traditional string without optimizer.

Why is long string design needed ?

—Enable higher DC/AC oversizing: Max 200% DC/AC ratio.

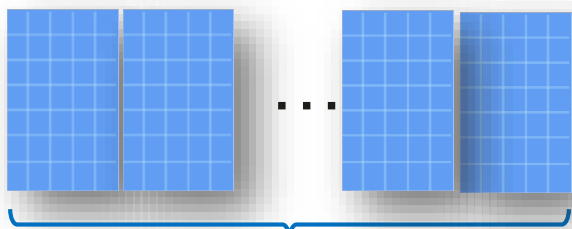


Comparison Between Normal and Long String Design

No Optimizer String Design

JAM72S01 330-350/SC/1000V Series datasheet

Maximum System Voltage 1000VDC (UL and IEC)



19 PV modules per string

Max number of PV module in the string:

$1000 \text{ Vdc} / 52.2 \text{ Vdc} \approx 19$

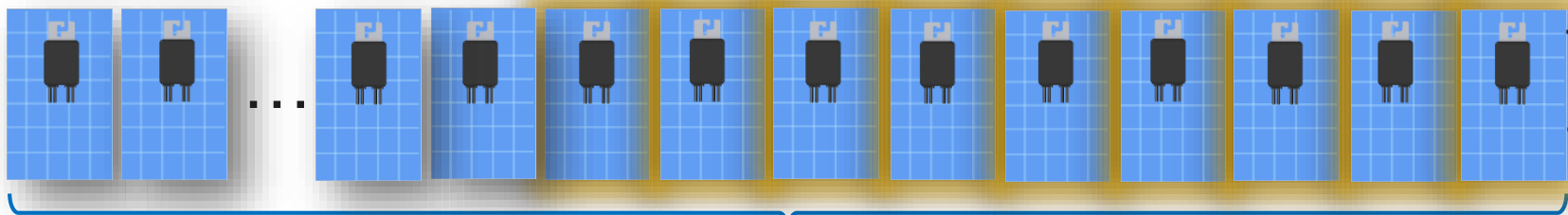
Taking JAM72S01-350/SC/1000V as example with considering temperature coefficient of Voc



Full Optimizer String Design

SUN2000-450W-P datasheet

Long String Design ²	SUN2000L-2-6KTL-L1	SUN2000-3-10KTL-M1	SUN2000-12-20KTL-M2
Minimum optimizer number per string	4	6	6
Maximum optimizer number per string	25	50	50
Maximum DC power per string	5,000 W	10,000 W	10,000 W



28 PV modules per string

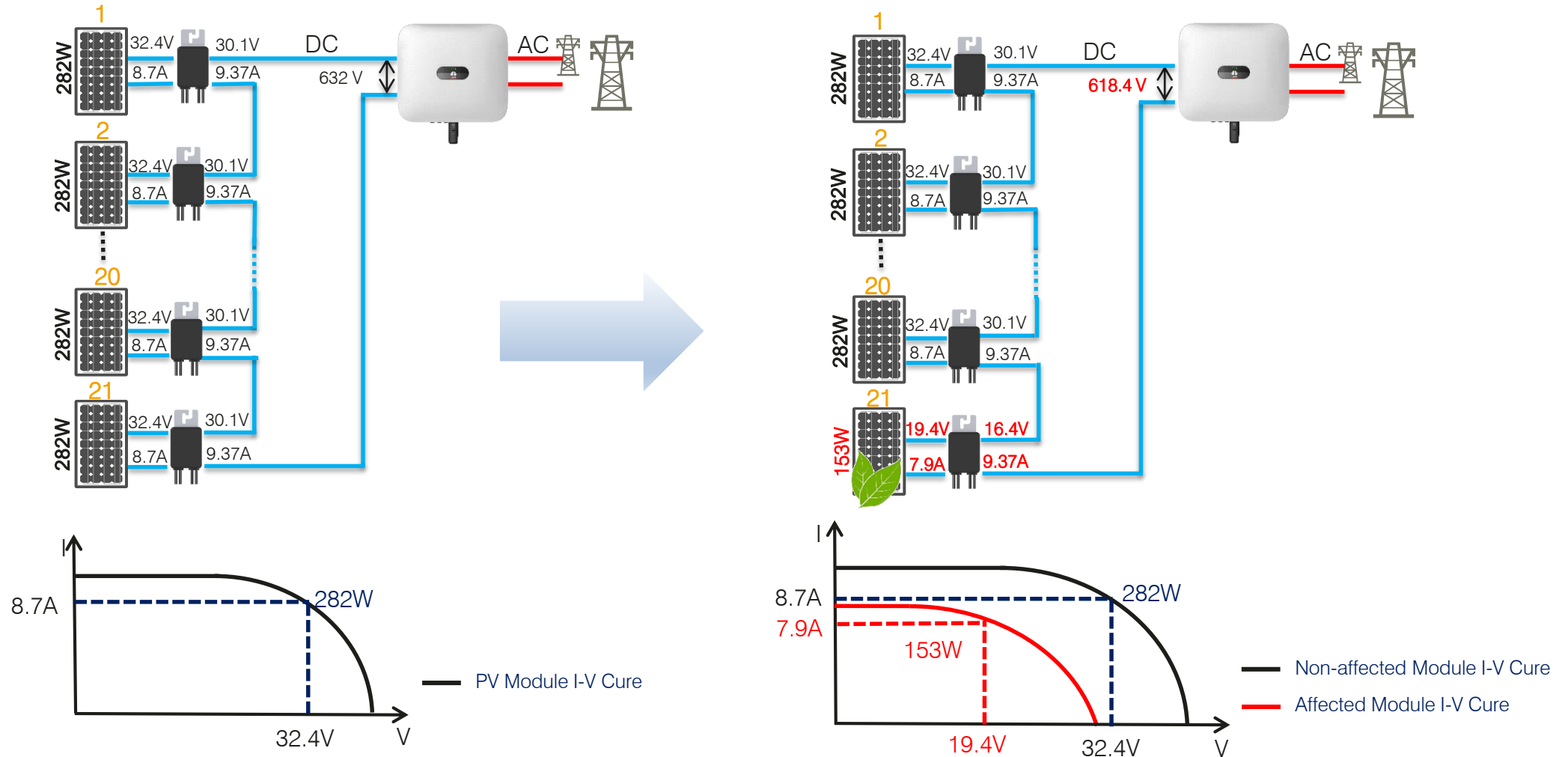
Max number of PV module in the string:

$10,000 \text{ W} / 350 \text{ W} \approx 28$

Taking JAM72S01-350/SC/1000V as example



Full Optimizer Long String System Operating

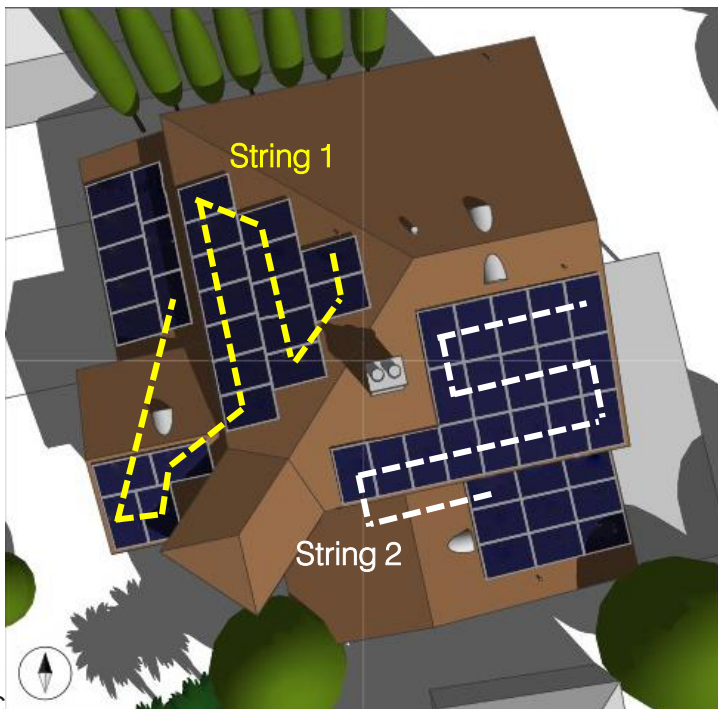


Long String Design for Higher DC/AC Oversizing

A 10KTL inverter without optimizer, max DC/AC oversizing ratio :

$$= \frac{P_{pv}}{P_{inverter}} = \frac{19 \times 350 + 19 \times 350}{10000} = 133\%$$

Traditional string length is too short to cover all modules, only 38 modules can be connected



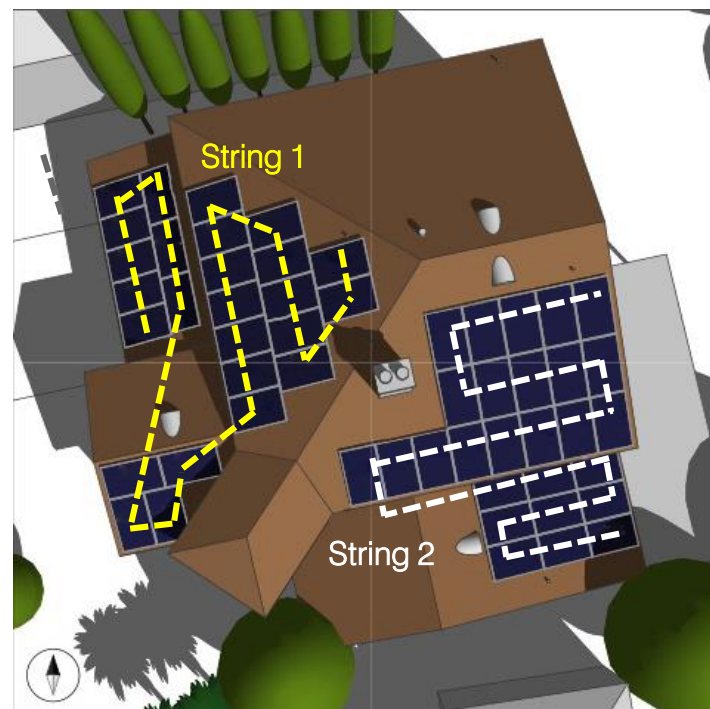
A 10KTL inverter, DC/AC oversizing ratio with long string design:

$$= \frac{P_{pv}}{P_{inverter}} = \frac{26 \times 350 + 27 \times 350}{10000} = 185\%$$

Two long string design:

String 1: 26 modules

String 2: 27 modules

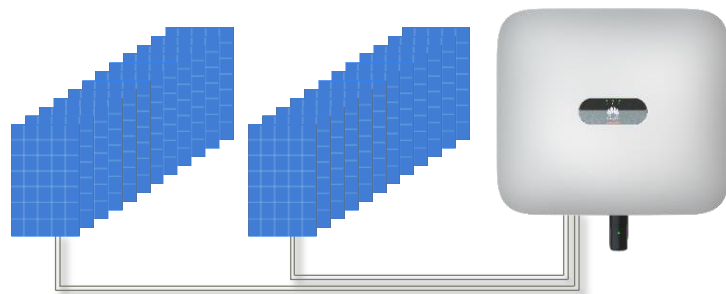


Lower BoS Cost & Flexible String Design

Lower BoS Cost

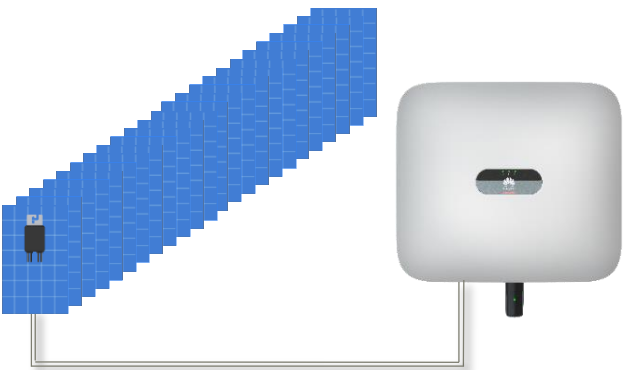
Without Optimizer

24 modules connected in two separated strings, 12 modules per string



With Optimizer

24 modules connected in a single string



Flexible String Design

Without Optimizer

Extra modules exceeding the limit of string have to be connected across rooftop with other string.

String 1: 18 modules
String 2: 18 modules



With Optimizer

Long string covers whole roof without PV cable across rooftops

String 1: 24 modules
String 2: 12 modules





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Easy installation Verification and Safe Operating

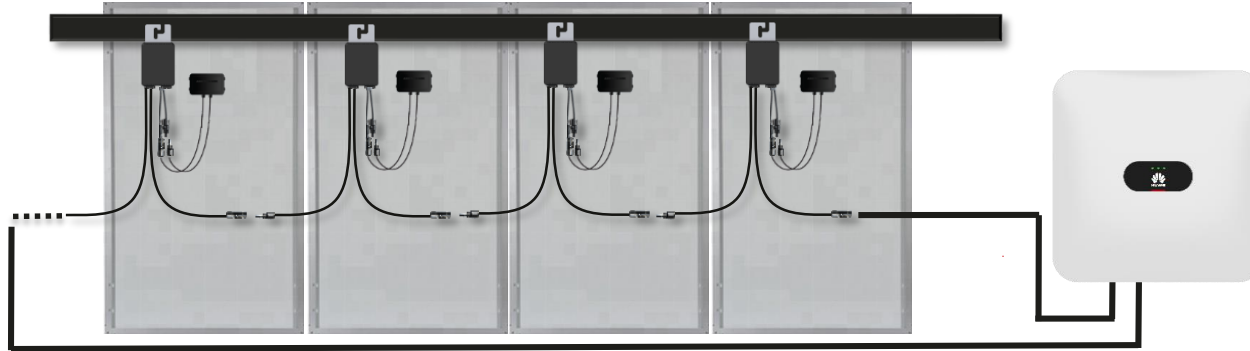


Optimizer Pairing with Inverter



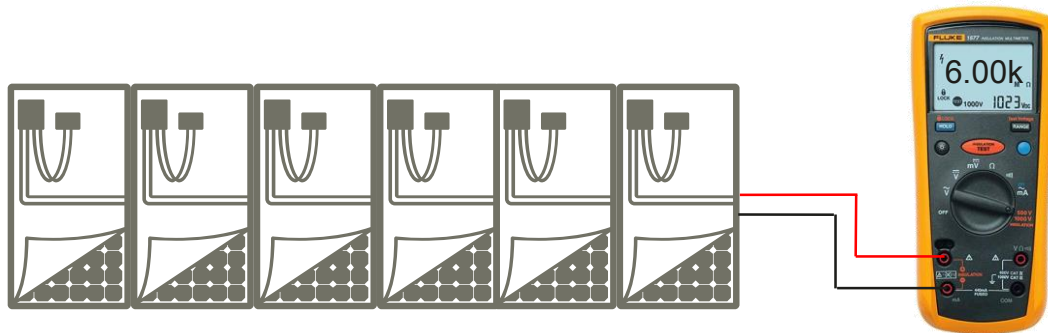
Module Performance Monitoring in Physical View

Easy installation Verification and Safe Operating



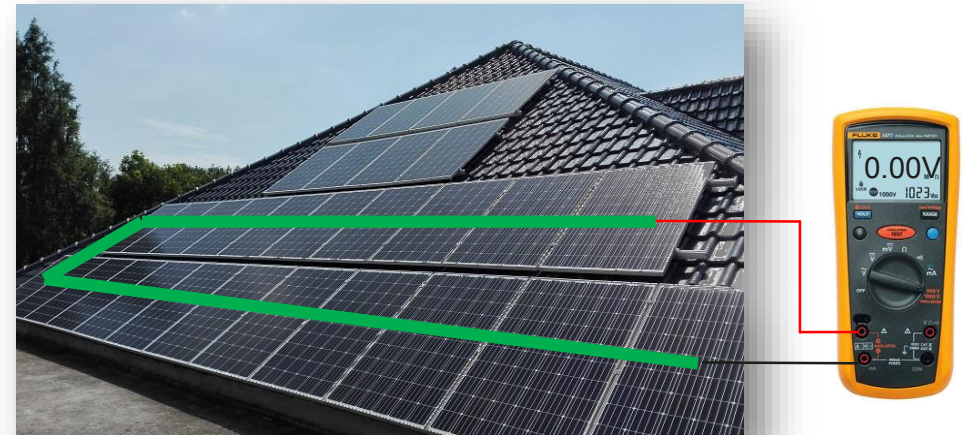
Optimizer shutdown impedance: 1K ohms

To verify optimizer installation before connecting to inverter input, check impedance of optimizer formed string, 6 optimizers equals to 6K ohms

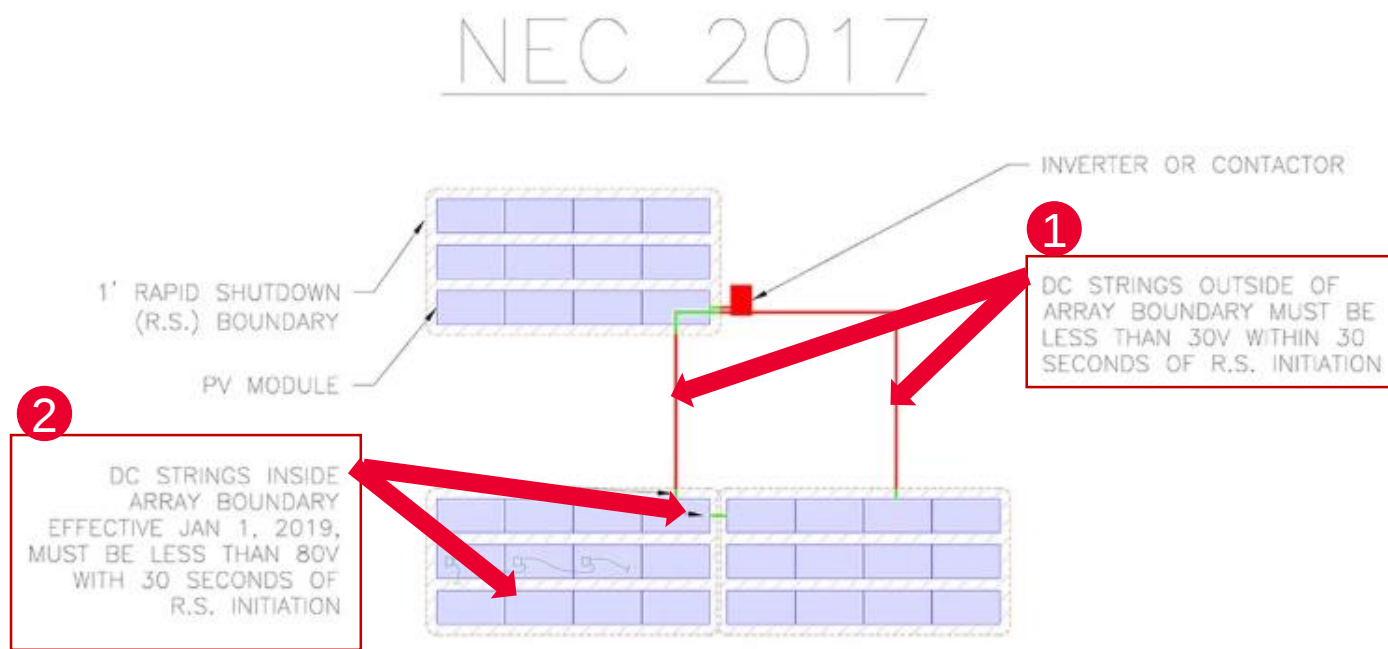


Optimizer shutdown safety voltage: 0 Vdc

When the optimizers output cable is not connected or the inverter is shutdown, each optimizers outputs 0 Vdc. (Compliant to NEC 2017)



Rapid Shutdown Interpreted of 2017 NEC 690.12



1. Outside the PV Array Boundary

Outside the Array Boundary. Controlled conductors located outside the boundary or more than 1 m (3 ft) from the point of entry inside a building shall be limited to **not more than 30 volts within 30 seconds** of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground. - NEC 2017 690.12 (A) and (B)(1)

2. Inside the PV Array Boundary

Controlled conductors located inside the boundary or not more than 1 m (3 ft) from the point of penetration of the surface of the building shall be limited to **not more than 80 volts within 30 seconds** of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground. - NEC 2017 690.12 (B)(2)

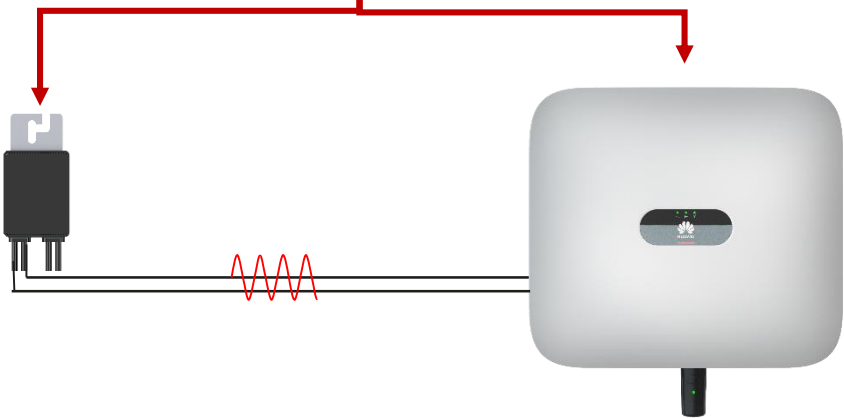
Whenever following condition is met, optimizer output a safety low voltage and PV wires are de-energized to protect personnel safety:

- House or building main switch is disconnected from the electrical grid
- The inverter is turned off
- Inverter is tripped when certain protection function is triggered.

- 
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 - Optimizer Pairing with Inverter**
 - Module Performance Monitoring in Physical View

HUAWEI HISILICON Chipset Inside Optimizer and Inverter for Faster Pairing

Pairing between optimizer and inverter is the process to establish communication between them.



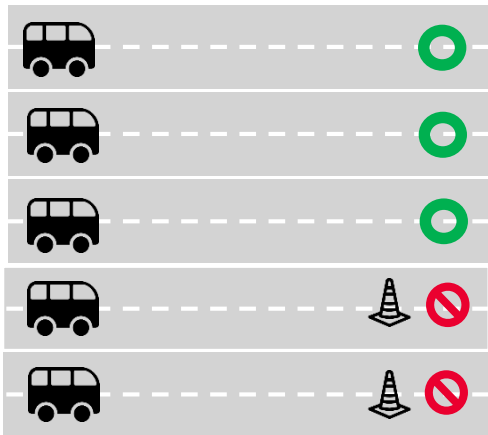
For a 10KWp typical residential system, pairing cycle-time usually takes 1.5 min

DIGITAL TURBO

Pairing through high performance DC MBUS Communication

- Orthogonal Frequency Division Modulation (OFDM) employed for high efficient communication
- Adaptive & robust to noise interference and selective attenuation for stable & reliable communication

1.5 min @ 10KW System



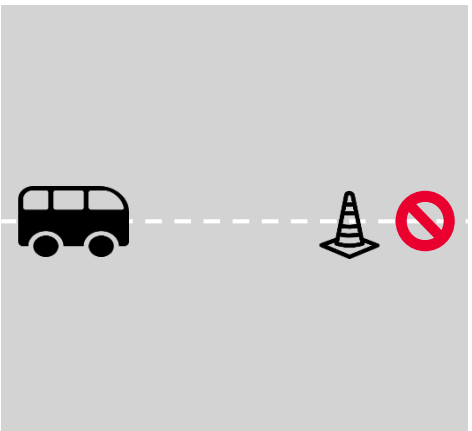
OFDM: Signal samples are transmitted concurrently with multiple orthogonal sub-channels, even certain channels are blocked, signal can still be transmitted via non-blocked channel.

Pairing through traditional power line communication

- Low efficient communication based on FSK signal modulation
- Vulnerable to noise interference and signal attenuation

V.S.

3 min @ 10KW System



FSK: Signal sample is transmitted in one channel using the entire band. If channel is blocked, signal transmitting is suspended.

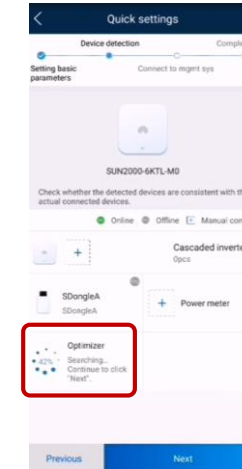


Optimizer Paring Setting



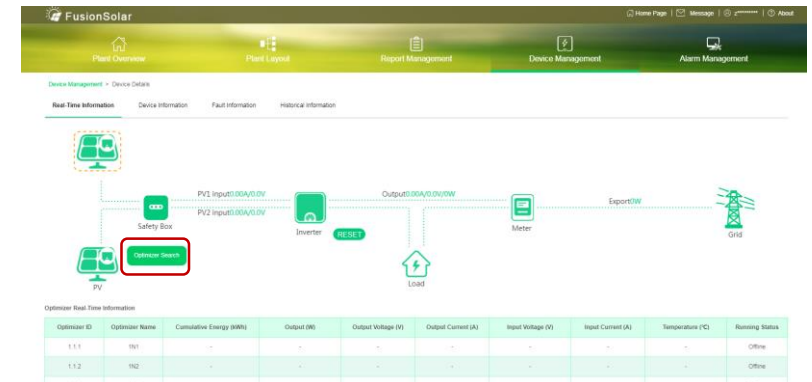
- Power optimizer paring to inverter is started when inverter is powered on.

Optimizer paring is automatically started when both inverter AC & DC is powered on. The process is shown in the second step of Quick Setting of FusionSolar



- Remote optimizer paring in FusionSolar Smart PV Management web tool

In web tool, under 'Device Management tab – Real-time Information' tab, click 'Optimizer Search' to trigger remote pairing of optimizer





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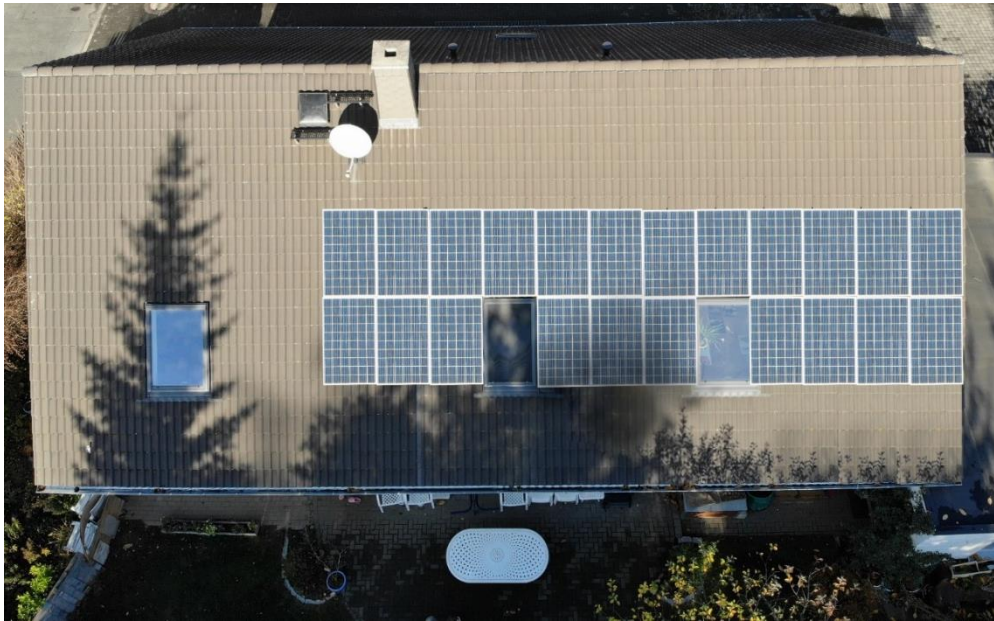


Optimizer Pairing with Inverter

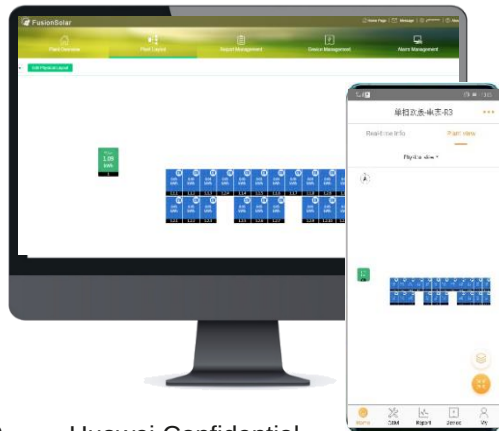


Module Performance Monitoring in Physical View

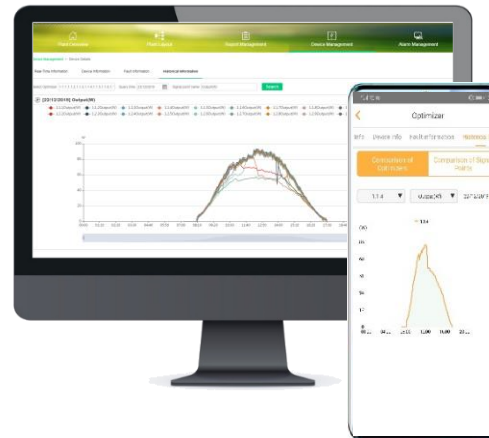
Module Performance Monitoring in Physical View



Physical Layout



Historical Data



- Physical layout view is only available to installer account users
- Real-time module performance view is under 'Plant Layout' tab of created site. Daily accumulated output energy of module is displayed and refreshes every 5 mins.
- Double click a module, following information of all modules can be monitored:

1. Real-time information

Cumulative energy, output power, output voltage, input voltage, input current are displayed in matrix.

2. Device Information

Optimizer SN and software version is displayed in matrix

3. Fault information

Fault name, status, occurred time and recovery time of each problematic optimizer is displayed in matrix

4. Historical Information

Optimizer and date can be selected to plot parameter curve of cumulative energy, output power, output voltage, output current, input voltage, input current, temperature.

5s Module Physical Layout Creating



PV module physical view is created by Image Recognition

- Step 1:** In FusionSolar app commissioning tool, click 'Device management' -> 'Physical layout design of PV modules', Click 'Camera'
- Step 2:** Take Photo of created module physical layout template pasted with optimizer QR codes and wait for detecting of optimizer QR code completion.
- Step 3:** When all QR codes have been detected, check the number of them and then click 'Confirm'.
- Step 4:** Wait for detected information uploading to inverter.
- Step 5:** Module physical view creation is completed

