Optimize Your PV with Module-Level Power Electronics

Guy Lichtenstern, Product Manager

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SolarEdge in Numbers

9.6GW
of our systems shipped worldwide

30.9M
power optimizers shipped

1.3M
inverters shipped

Over **750,000** monitored systems around the world

Presence in **25** countries

1,398 employees

140 awarded patents and **194** additional patent applications

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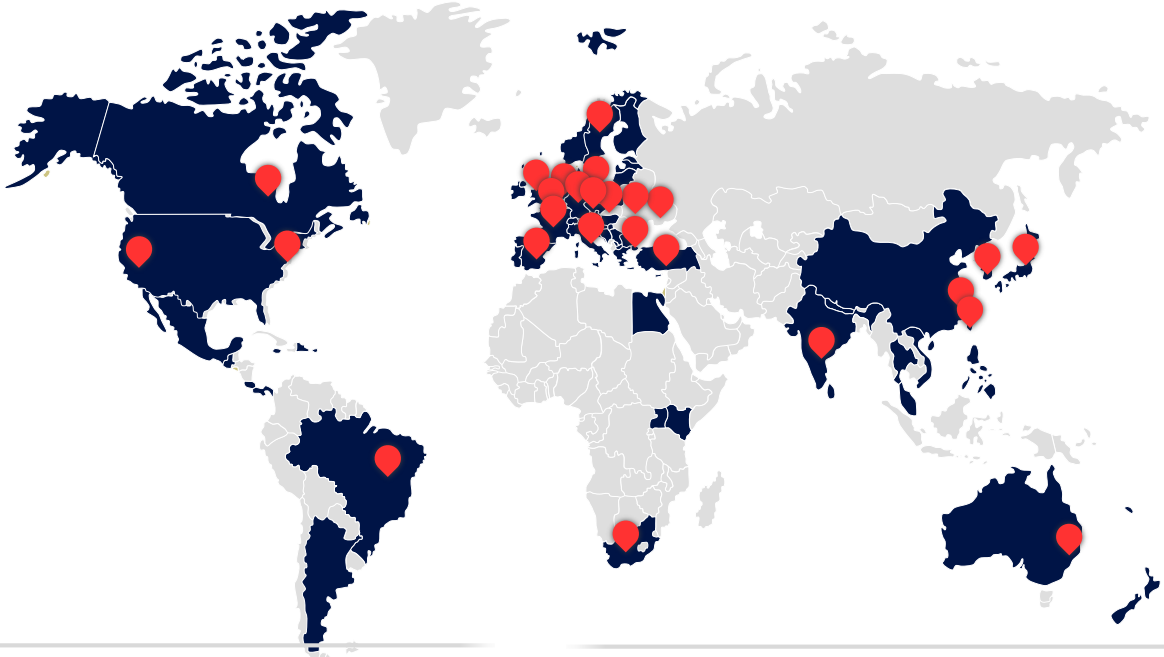
Established Global Reach



Presence in **25 countries**

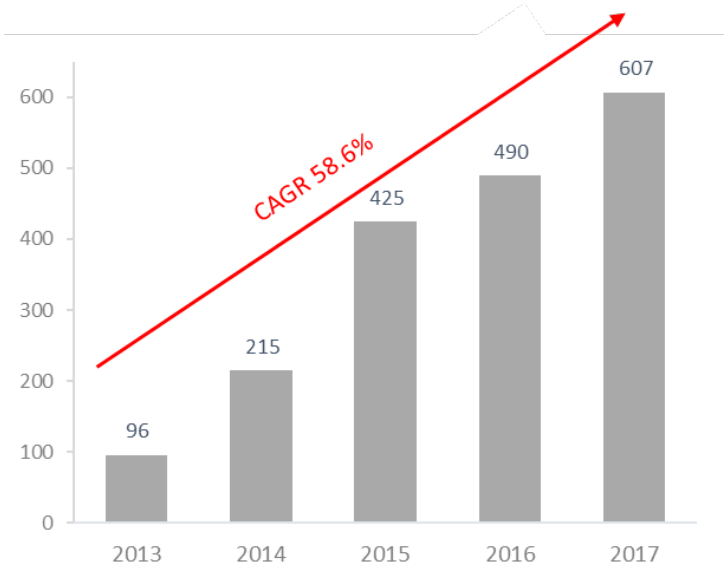
Regional service centers

Over 20,000 installers

Systems installed in **133 countries**

Revenue Growth

(CY Ending Dec 31, USD millions)



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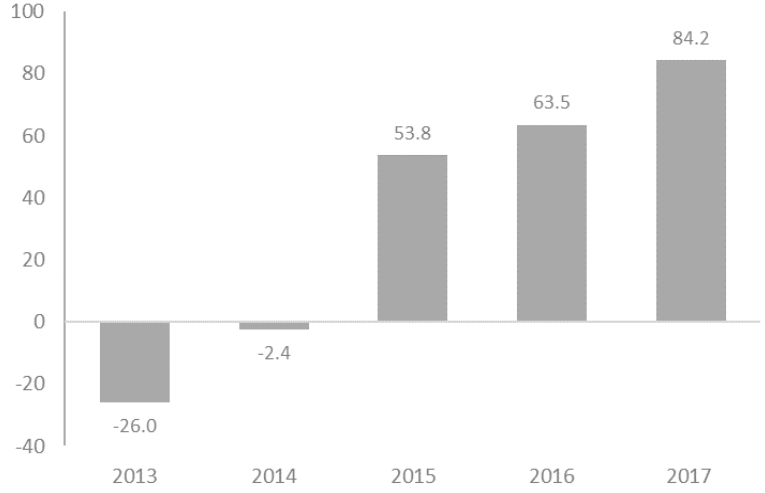
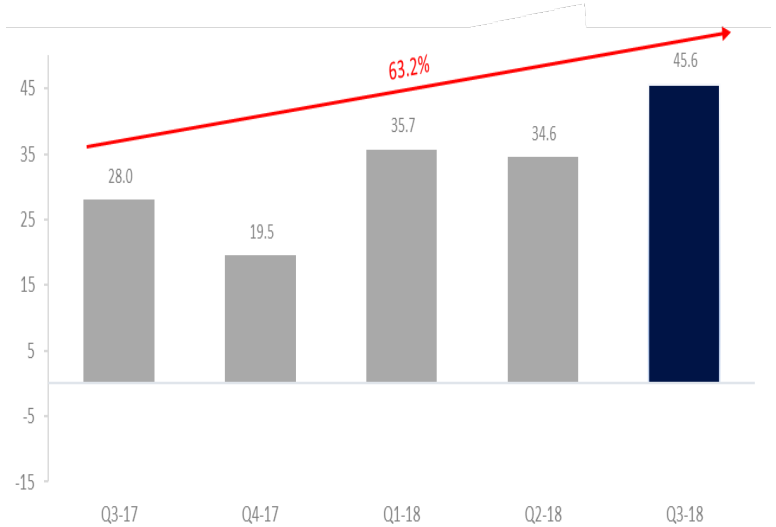
Net Profitability

(CY Ending Dec 31, USD millions)





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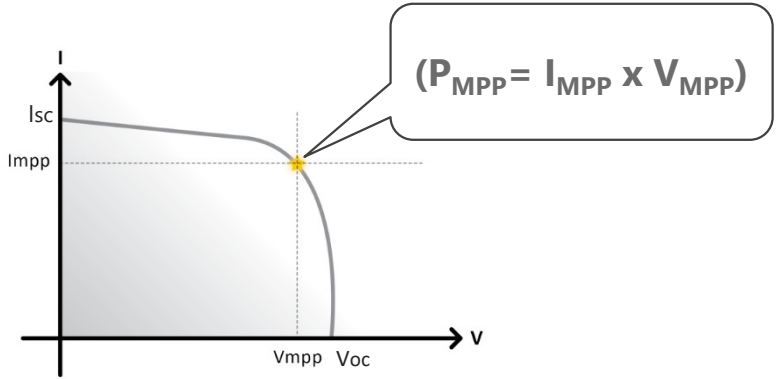
Limitations of Traditional PV Systems

IV Curve & MPP

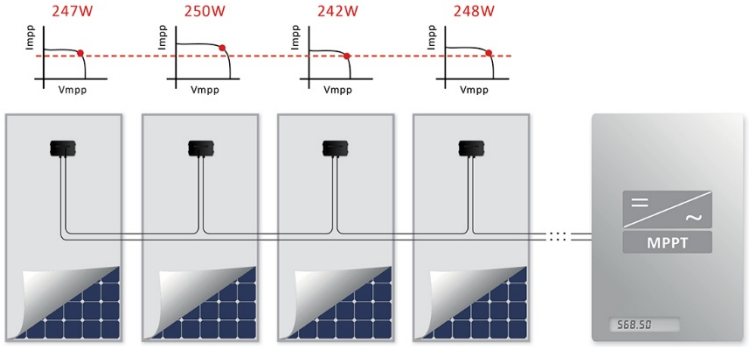
- Each module has a unique IV curve and reaches maximum power at a specific current and voltage
- The maximum power point is abbreviated MPP
- Module IV curve depends on the individual electrical properties of the module and the ambient conditions (irradiance, temperature)



Modules with different IV curves = module mismatch

Module Mismatch Causes Power Loss

- Traditional inverters perform MPPT (Maximum Power Point Tracking) for the entire string
- Due to the module mismatch, weaker modules impact the output of the entire string by reducing the output of the other modules or by being bypassed
- All modules in the same string operate at the same current, regardless of their individual MPP



Module mismatch ➡ Power losses

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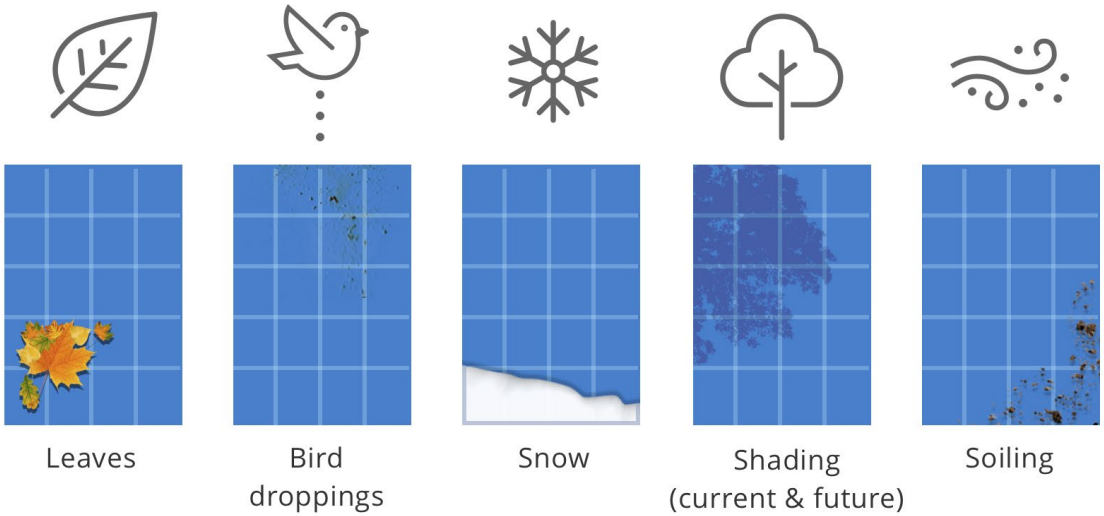
Sources for Module Mismatch

- The performance of each module depends internal and external factors
  - Raw materials and manufacturing
  - Environmental conditions:



- Mismatch from all the above grows constantly, increasing power lost each year

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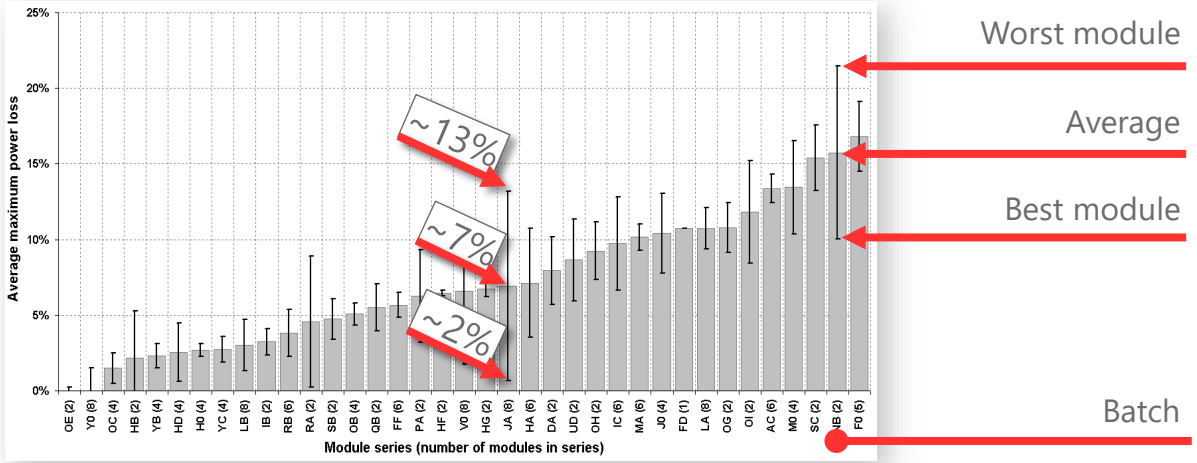
Uneven Module Aging

- Module performance degrades 20% over 20 years
- However, each module will age at a different rate
- With SolarEdge, each module produces the maximum energy without affecting the performance of other modules



Source: A. Skoczek et. al., "The results of performance measurements of field-aged c-Si photovoltaic modules", Prog. Photovolt: Res. Appl. 2009; 17:227–240

How SolarEdge Overcomes Limitations of Traditional PV Systems

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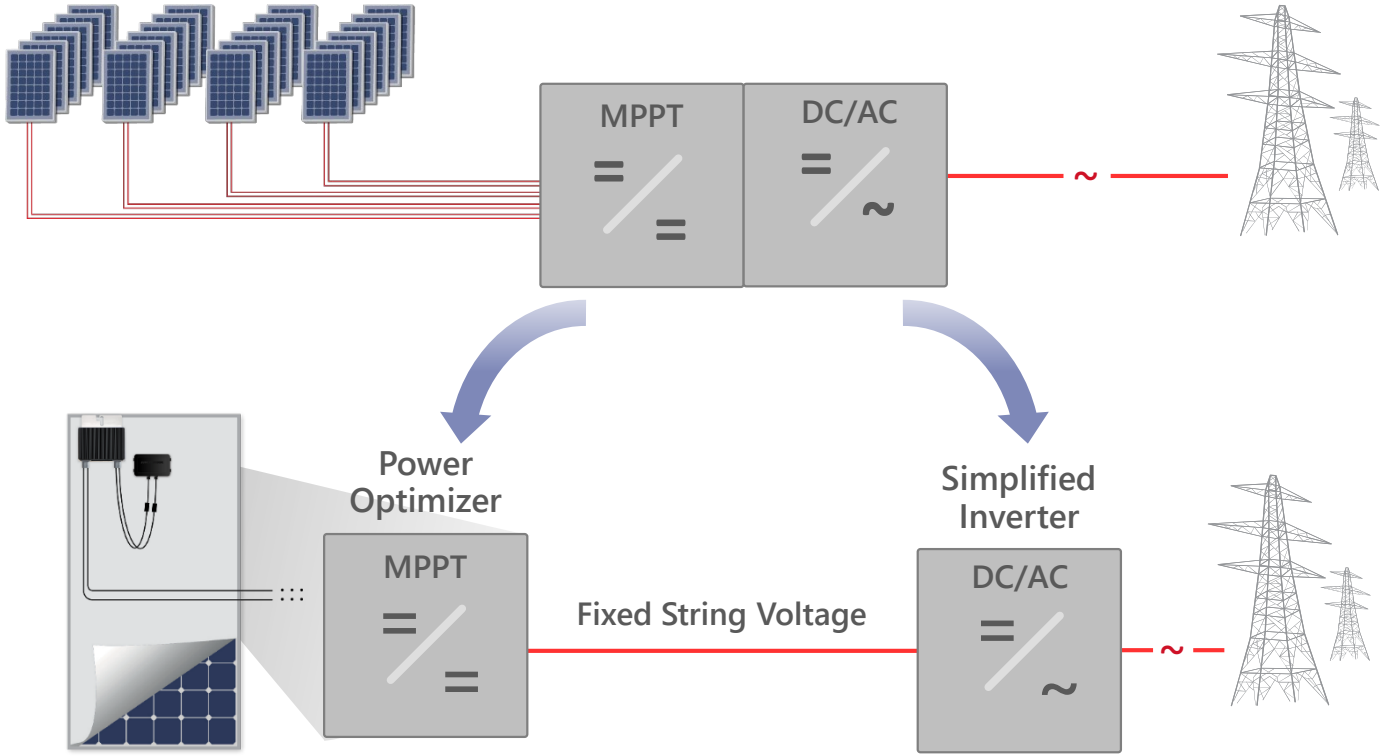
Splitting Inverter Functionality

Splitting Inverter Functionality



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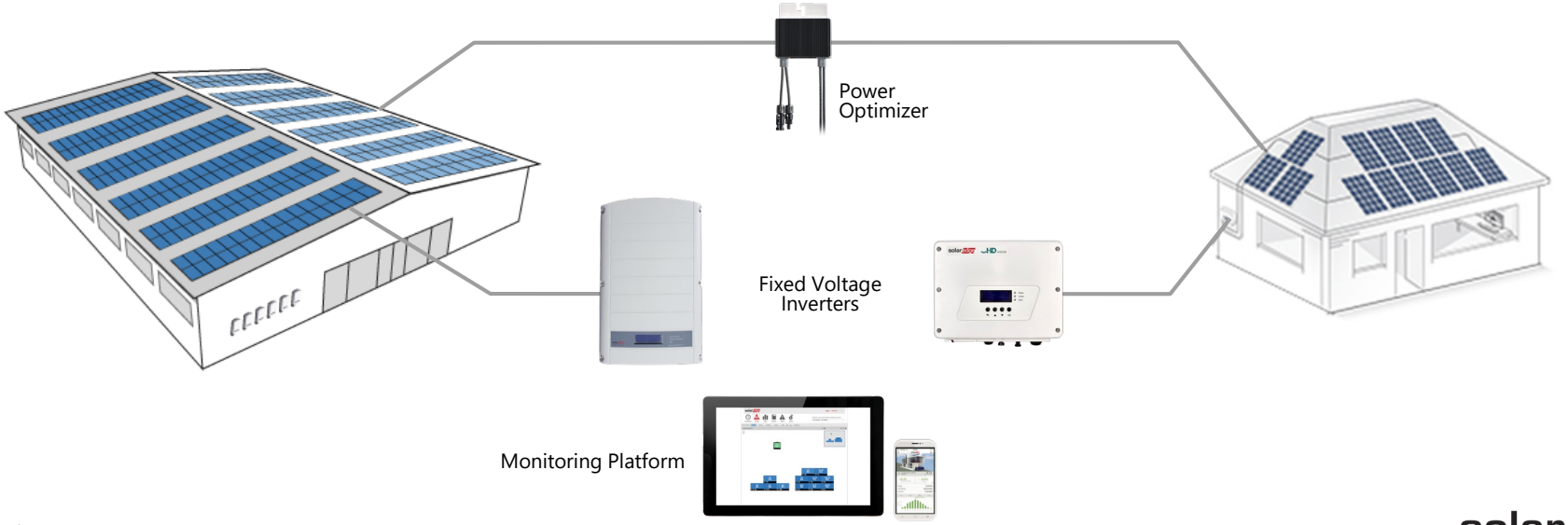
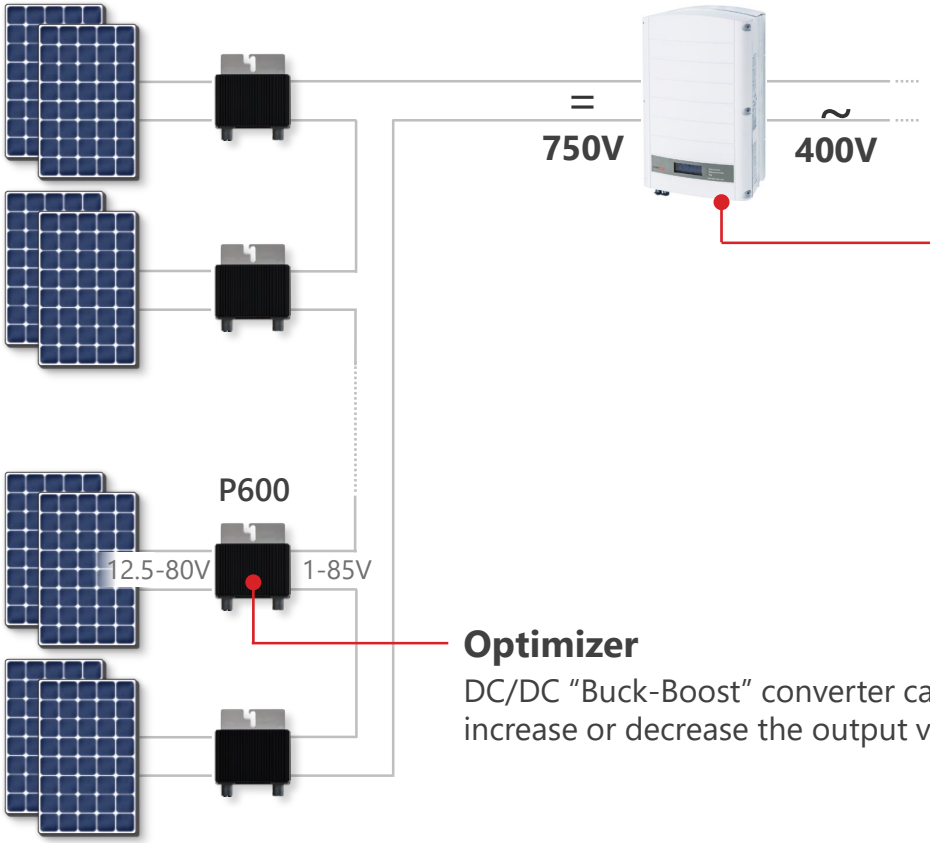
The SolarEdge Solution

- Split the traditional inverter functionality into two:
  - The power optimizer to maximize energy production for each module
  - A simplified inverter only responsible for DC -AC inversion and grid management



System Topology



Inverter (DC/AC)

Fixed input/output voltage ratio for highest efficiency

Optimizer

DC/DC "Buck-Boost" converter can increase or decrease the output voltage

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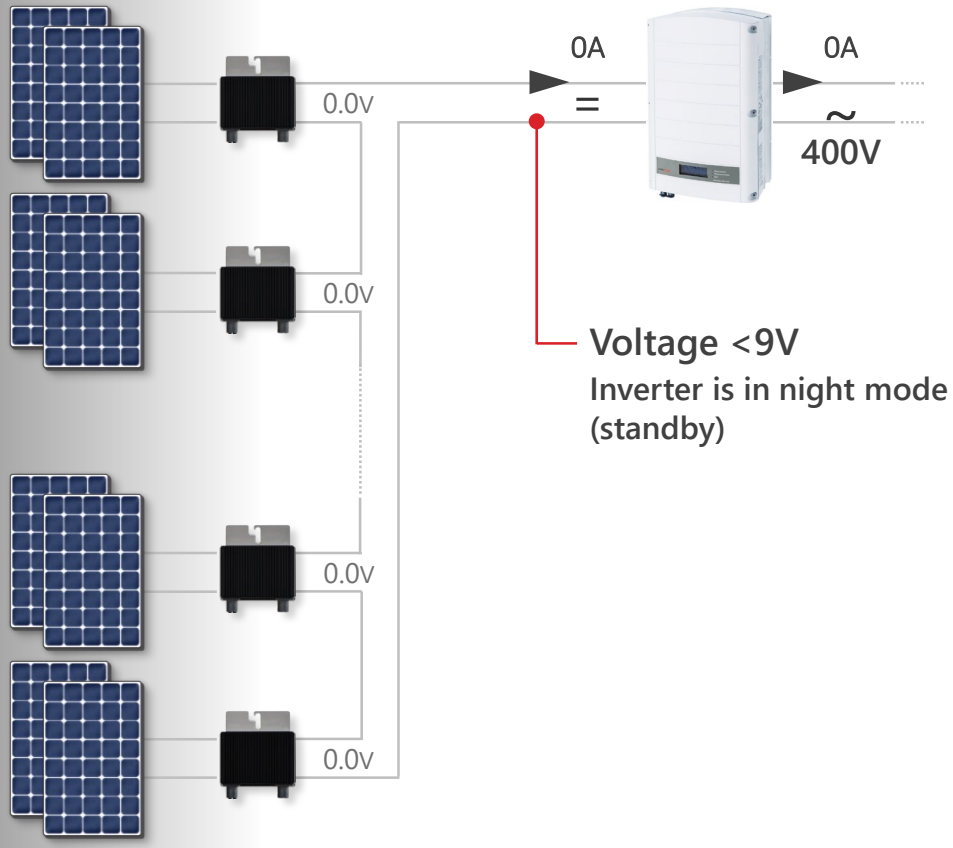
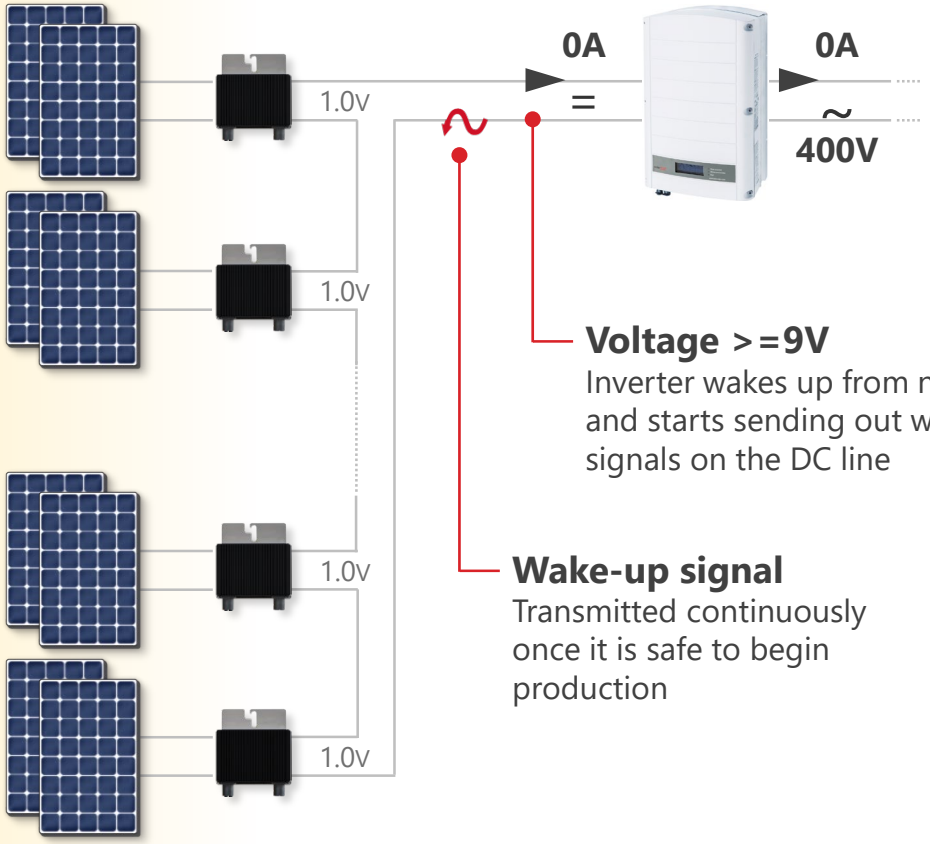
Wake-up Process



Wake-up Process



Voltage >=9V
Inverter wakes up from night mode and starts sending out wake-up signals on the DC line

Wake-up signal
Transmitted continuously once it is safe to begin production

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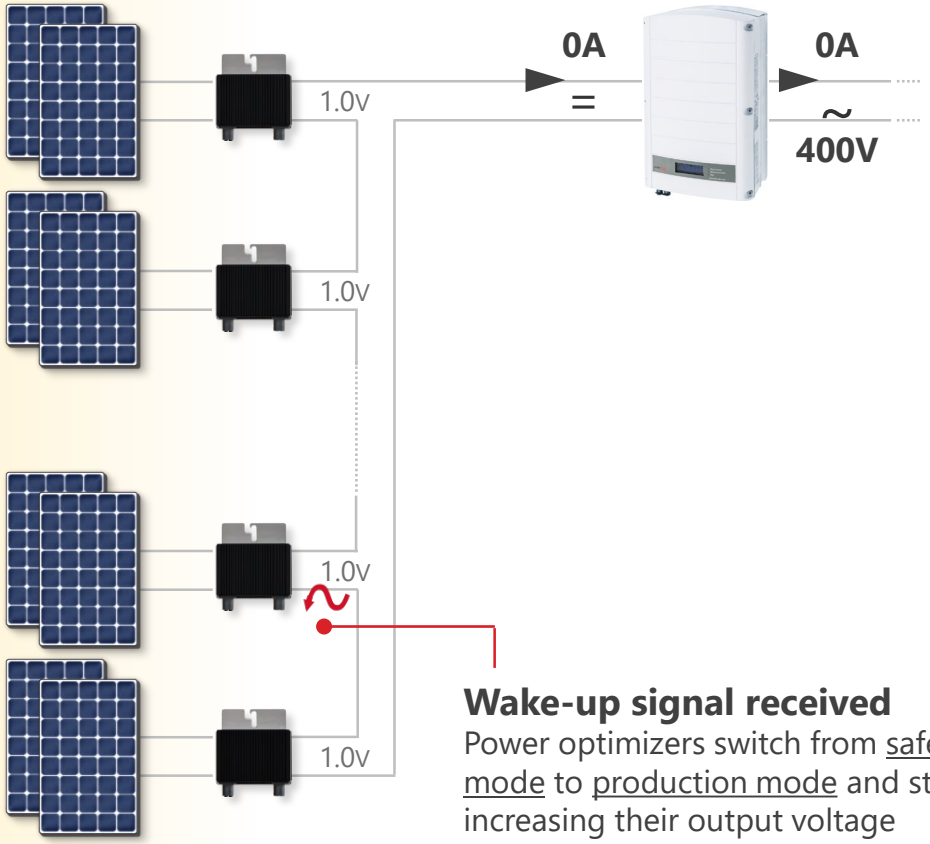
Wake-up Process



Wake-up signal received
Power optimizers switch from safety mode to production mode and start increasing their output voltage

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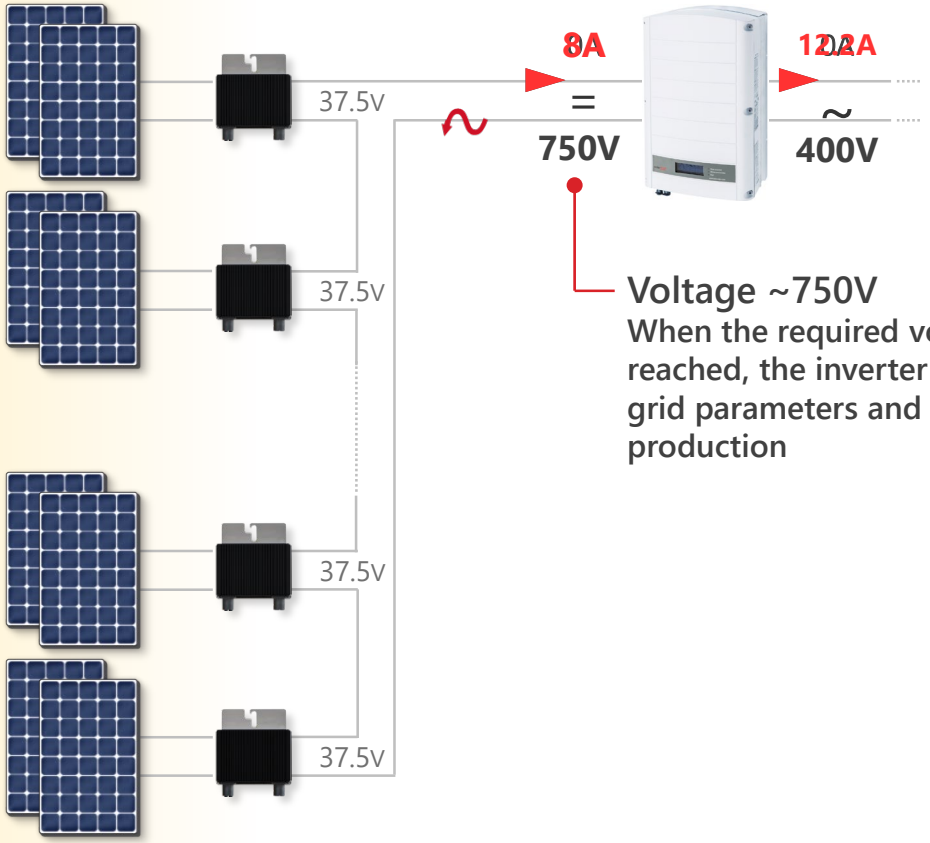
Wake-up Process



Voltage ~750V

When the required voltage is reached, the inverter checks the grid parameters and starts power production

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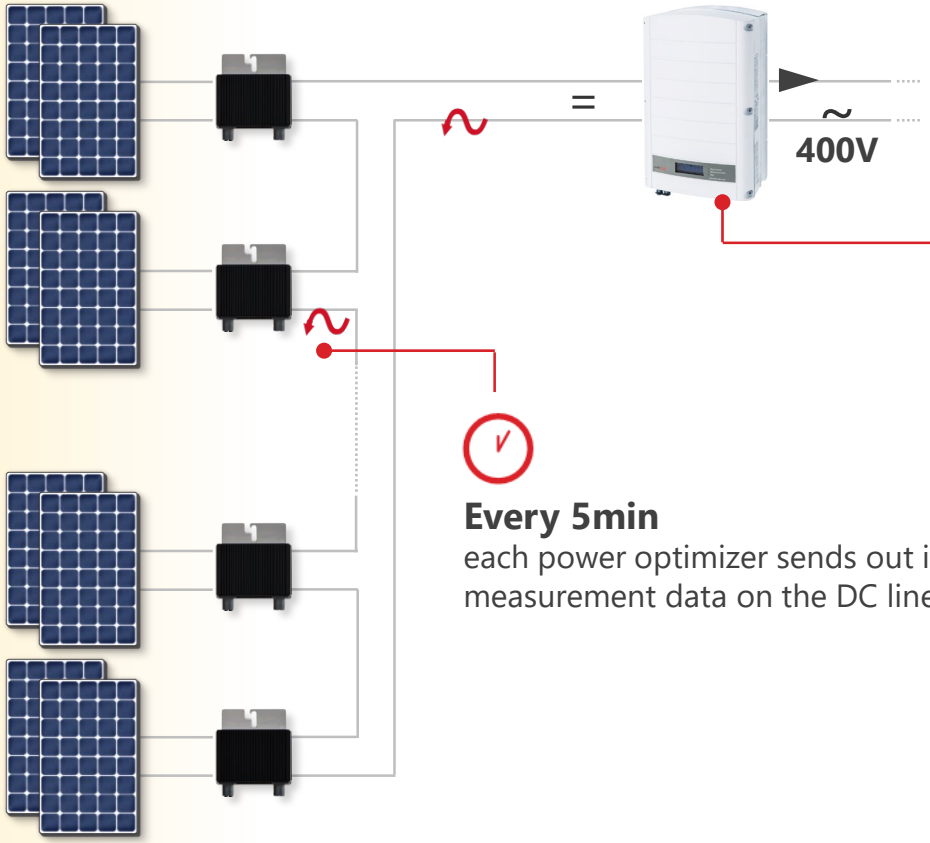
Monitoring Telemetries

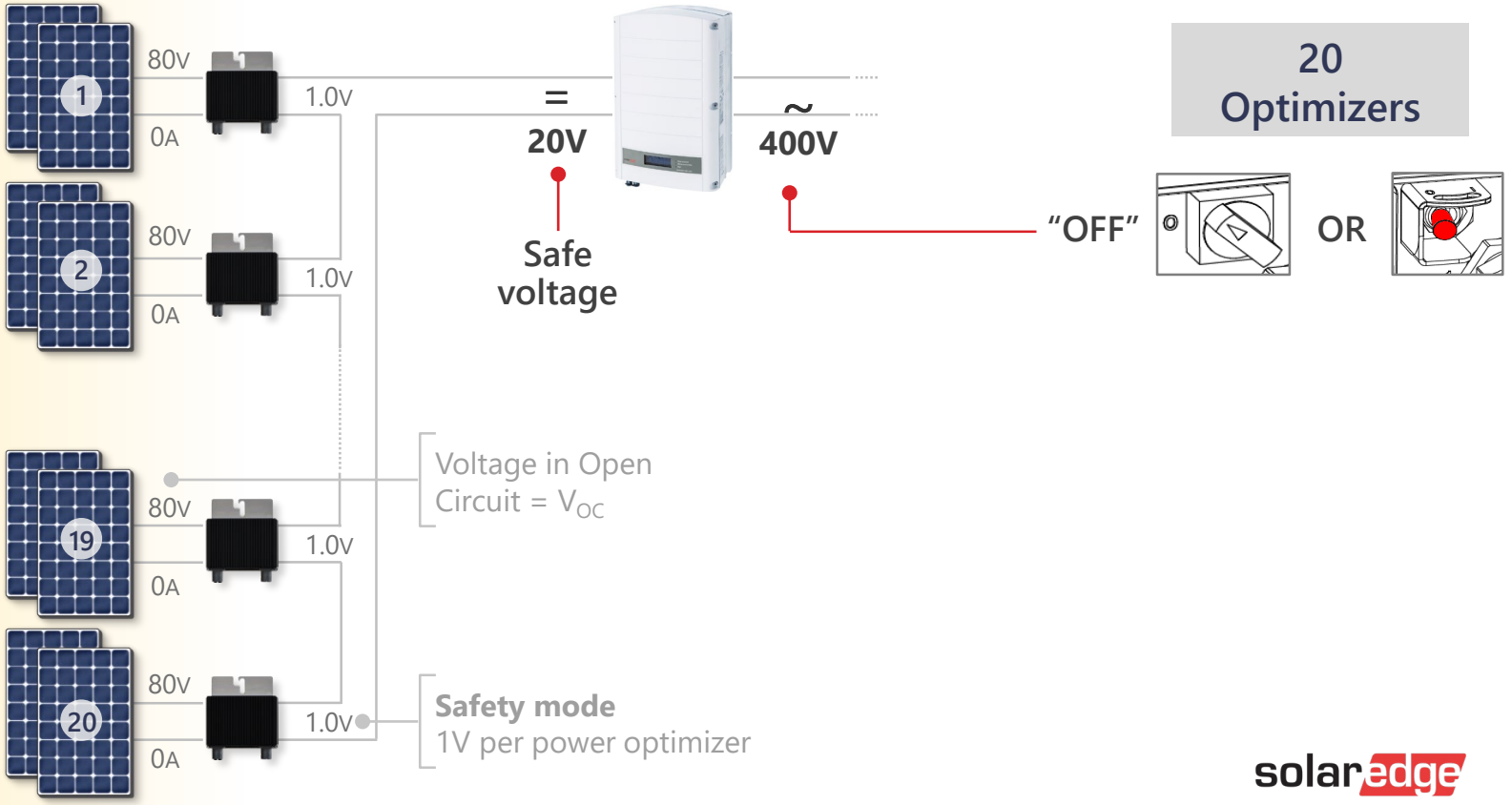


A flashing yellow LED
signalizes reception of a measurement data set. This data is forwarded to the SolarEdge monitoring platform.

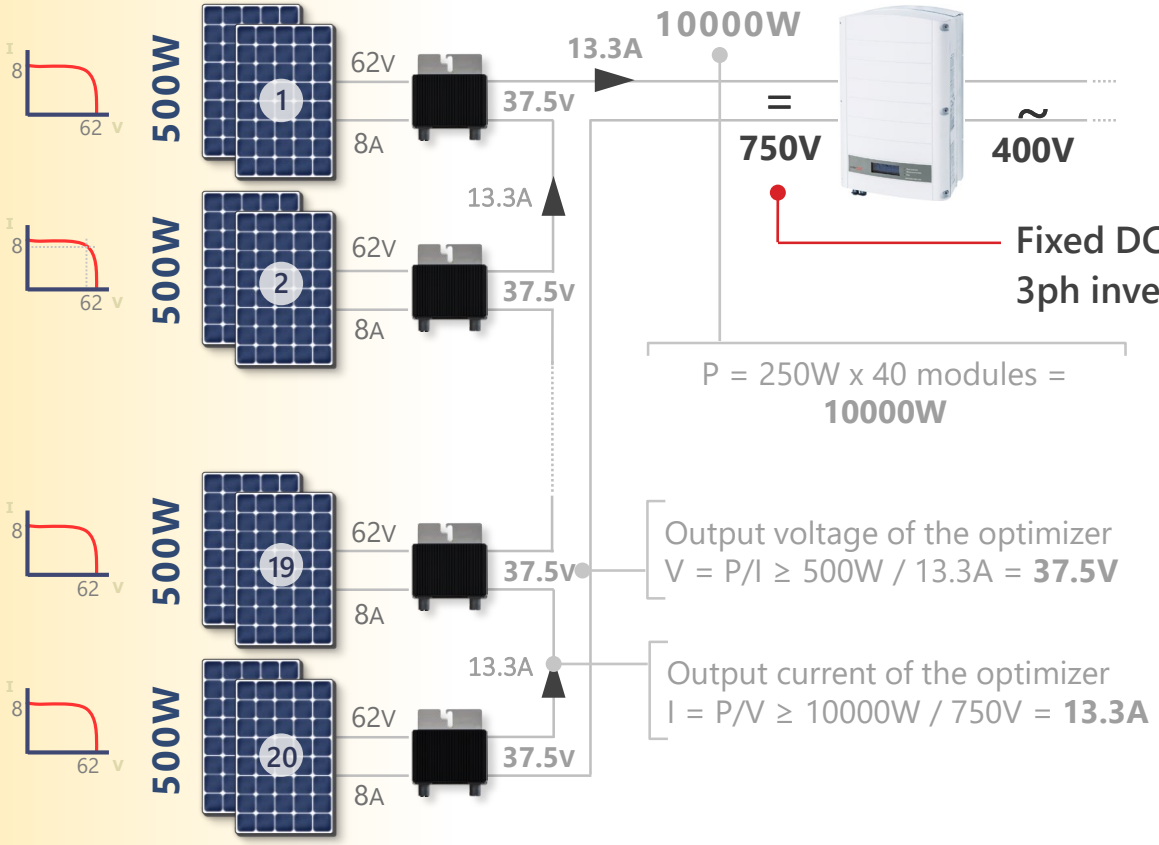
Every 5min
each power optimizer sends out its measurement data on the DC line

Concept of Operation

SolarEdge System – Safety Mode



SolarEdge System – Ideal System



20
Optimizers

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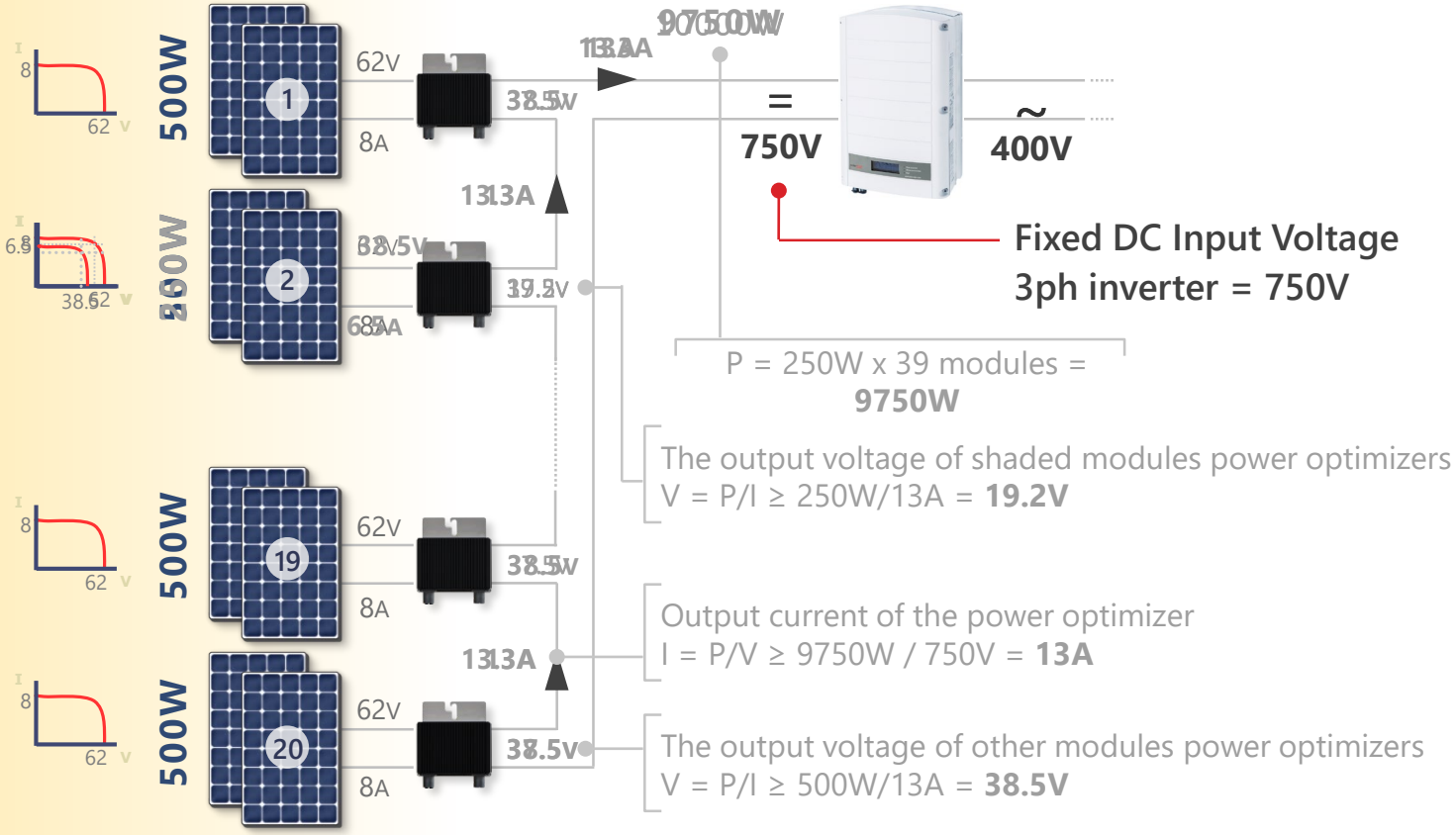
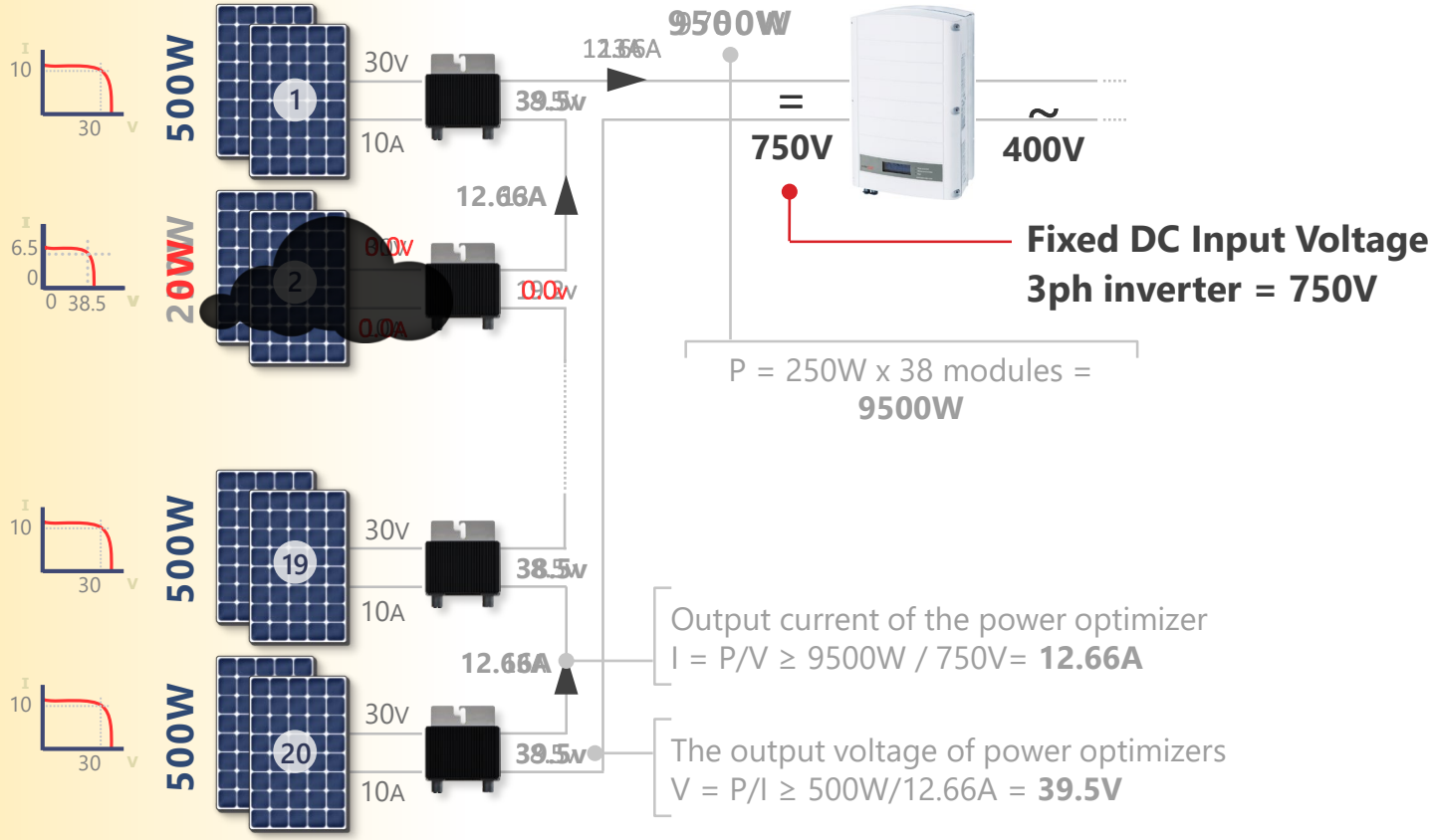
SolarEdge System – Shaded Module



SolarEdge System – Dead Module



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SolarEdge Design Rules

Traditional Design Guidelines

- Determine string length:
  - Calculate Voc at min. temperature and Vmpp at max. temperate
  - Using calculated Voc, Vmpp and the inverter input voltage range, calculate min/max string length
- Group modules into strings of permitted equal length
- Limited string length (number of modules)
- All strings must match
  - Same string length
  - Same orientation (tilt + azimuth)
  - Same module type
  - Shading avoidance
- Unmatched strings require multiple inverters or MPP trackers

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SolarEdge Design Rules

- Find matching inverters: single/three phase inverters
- Find matching power optimizers:
  - Check the module datasheet: pay attention to module maximum input voltage (@min temp), max input current, rated input power
  - Note that in some cases, 2 modules to 1 power optimizer is supported
  - Check that the power optimizer is compatible with the selected inverter
- Design string sizing: within min/max range, max power
  - Refer to the string design rules in the power optimizer datasheet (see example below)
  - Refer to the datasheet to check which power optimizers can be mixed in the same string

PV SYSTEM DESIGN USING A SOLAREDGE INVERTER[4]		SINGLE PHASE HD-WAVE	SINGLE PHASE	THREE PHASE	THREE PHASE FOR MV GRID	
Minimum String Length (Power Optimizers)	P300,P350,P370,P500[5]	8		16	18	
	P404,P405,P505	6		13 (12 with SE3K)	14	
Maximum String Length (Power Optimizers)		25		50	50	
Maximum Power per String		5700	5250	11250	12750	W
Parallel Strings of Different Lengths or Orientations		Yes				

[4] It is not allowed to mix P404/P405/P505 with P300/P370/P500/P600/P700/P800 in one string.
[5] The P300/P370/P500/P505 cannot be used with the SE3K three phase inverter (available in some countries; refer to E-Series inverter datasheet).

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Manually Checking Compatibility

1 Module datasheet:

Electrical data (STC: 1000W/m², 25°C)		
Power rating	P_{mpp}	265Wp
Rated voltage	V_{mpp}	30.7V
Rated current	I_{mpp}	8.67A
Open circuit voltage	V_{OC}	38.1V
Short circuit voltage	I_{SC}	9.01A

Thermal data		
Temp coeff. of I_{SC}	+0.04	%/°C
Temp coeff. of V_{OC}	-0.33	%/°C
Temp coeff. of P_{MPP}	-0.43	%/°C

2 Max voltage at lowest temperature

-30°C · -0.33 %/°C = **9.9%**
(30°C lower temp. causes 9.9% voltage increase)

38.1V + 9.9% = **41.87V**
(max. voltage reached at lowest temp temperature)

3

Calculated numbers	
V_{OC} at lowest temp	41.87V
V_{MPP} at lowest temp	33.74V
V_{MPP} at highest temp	29.18V

4 Power optimizer datasheet:

	P300
Rated Input DC Power (@STC)	300W ✓
Absolute Maximum Input Voltage (V_{oc} at lowest temperature)	48V ✓
MPPT Operating Range	8-48V ✓
Maximum Input Current (I_{SC})	10A ✓
Maximum Output Voltage	60V
Maximum Output Current	15A

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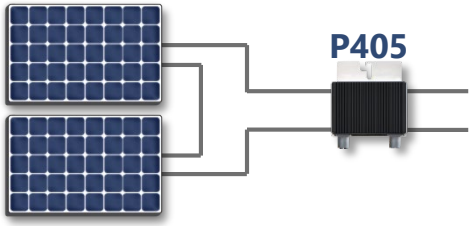
2-to-1 Serial Setup, P405 Example

- When connecting 2 modules to 1 power optimizer (P405, P600, P700, P800p, P850), make sure the combined Voc or Isc don´t exceed the power optimizer rating



Max P_{STC}	405W
Max V_{DC}	125V
Max I_{SC}	10.1A

Example 1:
Low power crystalline modules

2x 

P_{MAX}	185W
V_{OC} @ -20°C	34.4V
I_{SC}	8.4A

=

	Series ✓	Parallel ✗
P_{MAX}	370W ✓	370W ✓
V_{OC} @ -20°C	68.8V ✓	34.4V ✓
I_{SC}	8.4A ✓	16.8A ✗

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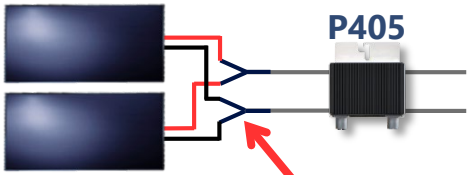
2-to-1 Parallel Setup, P405 Example

- When connecting 2 modules to 1 power optimizer (P405, P600, P700, P800p, P850), make sure the combined Voc or Isc don´t exceed the power optimizer rating



Max P_{STC}	405W
Max V_{DC}	125V
Max I_{SC}	10.1A

Power optimizer with dual inputs, branch cables or Y-adaptors

Example 2:
Thin-film modules

2x 

P_{MAX}	145W
V_{OC} @ -20°C	121.4V
I_{SC}	2.2A

=

	Series ✗	Parallel ✓
P_{MAX}	290W ✓	290W ✓
V_{OC} @ -20°C	242.8V ✗	121.4V ✓
I_{SC}	2.2A ✓	4.4A ✓

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SolarEdge Offers Four Key Benefits

More Energy

Increased energy yield & faster return on investment through module-level MPPT

Lower O&M Cost

Full visibility of system performance & remote troubleshooting

Enhanced Safety Solution

Safety during installation, maintenance, firefighting, & other emergencies

Constraint Free Design

Maximum space utilization with minimum design time

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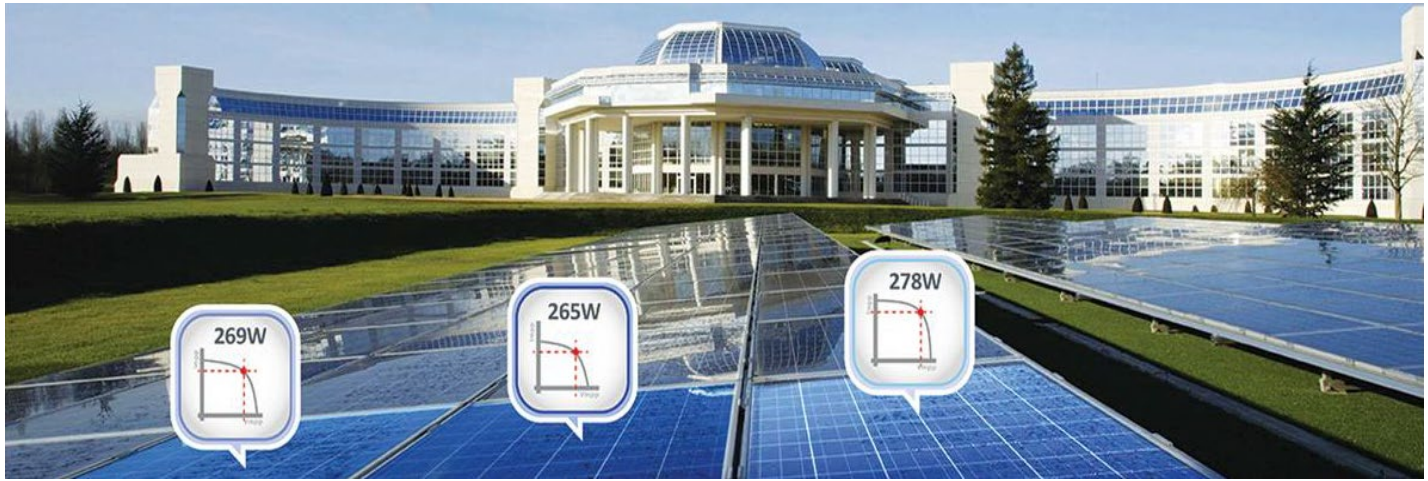
More Energy by Module-Level Optimization

- MPPT per module:
  - Maximum power from each module individually
  - Issues with individual modules isolated from impacting string



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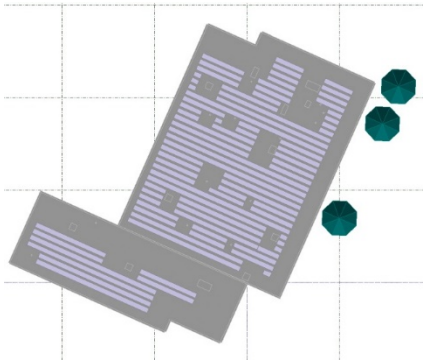
More Power by Design

Power optimizers enable installation of:

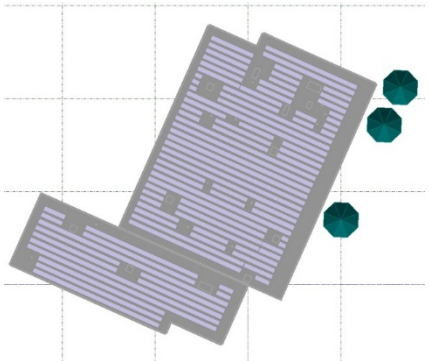
- Modules in partially shaded areas
- Strings of uneven lengths
- Strings in multiple orientations and different roof facets

More Modules on the Roof → **More Power & Revenue**

Traditional inverter: 149.5 kW DC

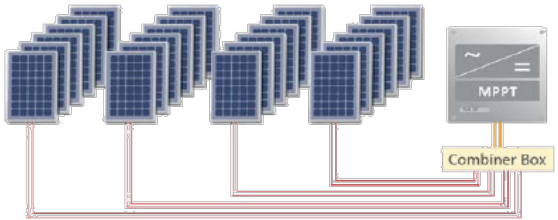


SolarEdge: 200 kW DC
34% added power

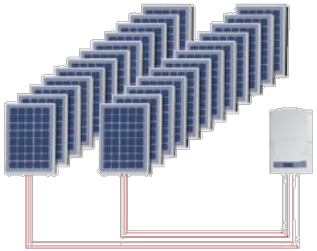


BoS Saving by Longer Strings

Double the number of modules per string → Fewer strings → Less wiring, combiner boxes, fuses, connectors, etc. → Up to 50% reduction in BoS cost



Traditional system



SolarEdge system

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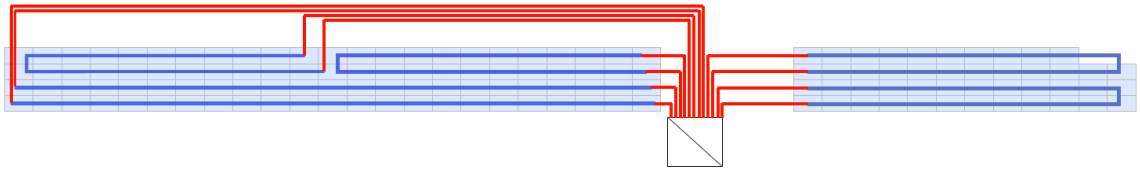
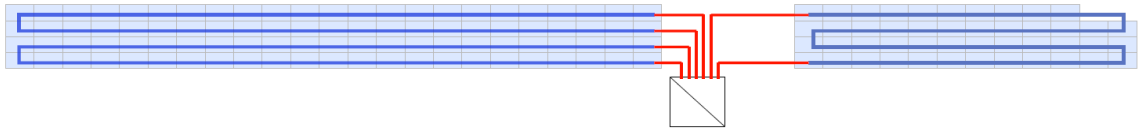
BoS Cost Saving

- Traditional 27.6kW string inverter: **4 m/kW DC**
- SolarEdge system: **0.45 m/kW DC**
- In MW-scale systems, the savings can amount to thousands of dollars

Traditional string inverter: 6 strings per inverter, 22/23 modules per string



SolarEdge: 3 strings per inverter, 44/46 modules per string



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Asset Management

- Protect your asset with full visibility into system performance & remote troubleshooting for reduced O&M costs
  - Monitoring at the module level – **free for lifetime**
  - Fault detection pinpointed on a virtual site map
  - Automatic alerts on system issues

Safe Installation and Maintenance

- Remote monitoring instead of diagnostics work at dangerous heights
- SafeDC™
  - No high VDC during installation or maintenance
  - Power optimizers and DC cables automatically shut down when inverter is off or disconnected
  - Certified in Europe as a DC disconnect according to IEC/EN 60947-1 and IEC/EN 60947-3 and to the safety standards VDE AR 2100-712 and OVE R-11-1
- Built-in protection designed to mitigate the effects of some arcing faults that may pose a risk of fire, in compliance with the UL1699B arc detection standard

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Thank You!

Cautionary Note Regarding Market Data & Industry Forecasts

This power point presentation contains market data and industry forecasts from certain third-party sources. This information is based on industry surveys and the preparer's expertise in the industry and there can be no assurance that any such market data is accurate or that any such industry forecasts will be achieved. Although we have not independently verified the accuracy of such market data and industry forecasts, we believe that the market data is reliable and that the industry forecasts are reasonable.

Version #: V.1.0