PV Performance
Separating Fact from Fiction

White Paper

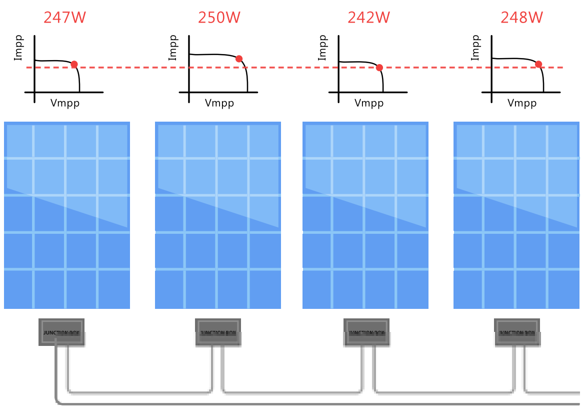
Performance is Everything

There are many external factors that can affect a PV system's performance, including solar irradiation, module and ambient temperatures, solar incidence angle, module ageing rates, shading, and manufacturing tolerance. However, the amount of impact will depend on the inverter.

This is because all of these factors cause each module in a string to have different Maximum Power Points (MPPs), which leads to module-level mismatch. In a traditional string inverter system, this module-level mismatch results in a decrease of PV generation because the weaker module brings down the production of the other modules in the same string.

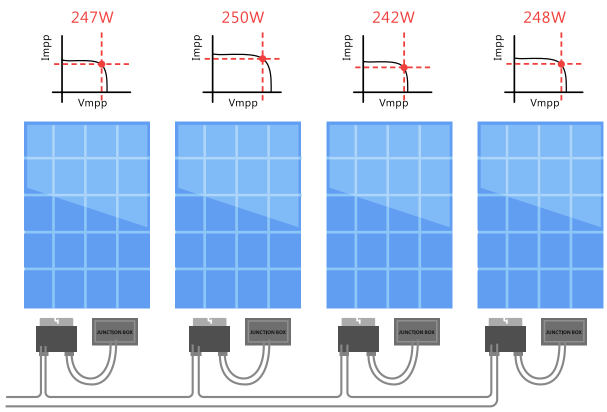
In contrast, the SolarEdge DC optimized system allows each module to produce at its maximum power point, irrelevant of the other modules in the same string. This approach to energy management eliminates power losses caused by module mismatch, meaning that the entire system can have increased solar production.

Traditional string inverter



- MPPT per string – all modules operate at same current, regardless of their individual MPP
- Weak modules reduce the performance of all modules in the string or are bypassed
- Power losses due to module mismatch

SolarEdge DC optimized system solution



- Module-level MPPT – current & voltage adjusted at the module level
- Maximum power produced and tracked from each module individually
- 2% more energy in completely unshaded systems

Optimization of Power Generation

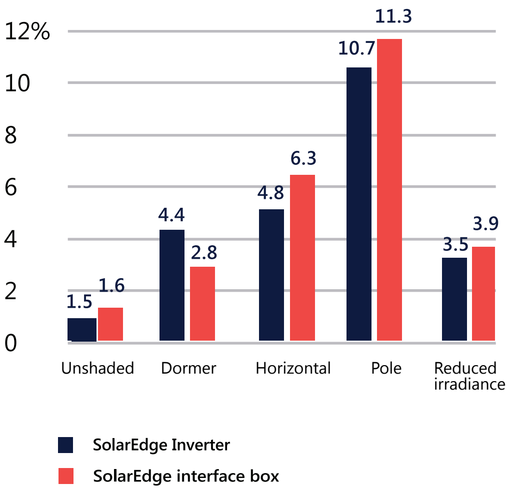
Numerous studies by reputable, objective, and professional organizations throughout the years have demonstrated the value of power optimizers and the increased energy production that they provide.

Photon Magazine commissioned an independent study in which SolarEdge power optimizers were tested in shaded, as well as unshaded conditions at its laboratory.[2] These results were compared to a reference system with a standard string inverter. The lab simulated four different, real-life shading conditions which can typically be found in residential and commercial PV installations: horizontal shading, a dormer window, a pole, and soling.

With no shading at all, SolarEdge power optimizers increased the energy yield by 1.5% - 1.7%. In the shaded scenario with a single-string configuration, the energy gain peaked at 34% in the presence of horizontal shading and 9.7% with a pole. With a two-string configuration the maximum energy gain was 11.3% and 6.3% in the presence of a pole and dormer window, respectively.

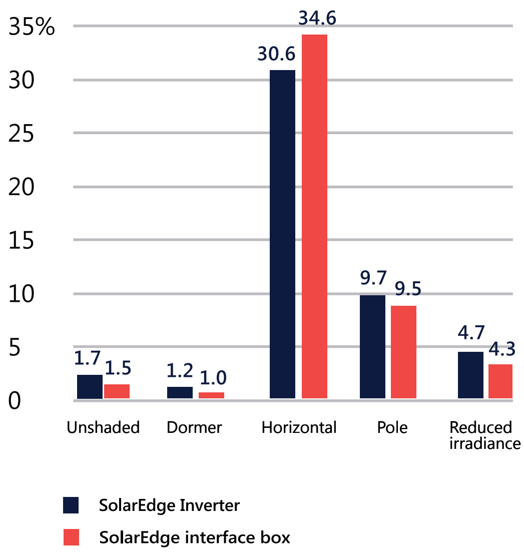
Photon also measured the efficiency of power optimizers. Measurements showed that their efficiency improved by 1% compared to the previous version. The average efficiency was measured at 98.5% and in some cases, efficiency exceeded 99%.

Additional yield produced by SolarEdge PowerBoxes-two parallel strings of seven modules each



The additional yields produced by installing PowerBoxes with systems that have comparatively short strings are rather modest. But performance is greatly improved by the devices when a system is shaded by a pole.

Additional yield produced by SolarEdge PowerBoxes-one string of 14 modules



When optimizing a long string, the differences in the results produced by varying shade conditions stand out. The gains are particularly large when there is horizontal shading.

In a standardized National Renewable Energy Laboratory (NREL) shading study, titled "Photovoltaic Shading Testbed for Module-Level Power Electronics" and conducted by PV Evolutions Lab (PVEL), it was found that the SolarEdge system outperformed both SMA inverter and Enphase microinverter systems.[3] The study simulated partial shading scenarios of typical residential rooftop PV systems, and evaluated the impact of different power conversion topologies on system performance. To calculate the percentage of shading loss that can be recovered by the device under test (DUT), a shade mitigation factor (SMF) was determined from the relative difference between total energy for the two systems (i.e. device under test compared to reference system). The equation used is as follows:

$$\text{Shade Mitigation Factor (SMF)} = \frac{E_{DUT} - E_{Ref}}{E_{unshaded} - E_{Ref}}$$

The SolarEdge system was found to harvest 1.9%, 5.0%, and 8.4% more energy than the SMA string inverter system with light, medium, and heavy shading, respectively. The SolarEdge system produced more energy than the Enphase microinverter system as well, as shown in Table 1.

NREL / PVEL SMF Results

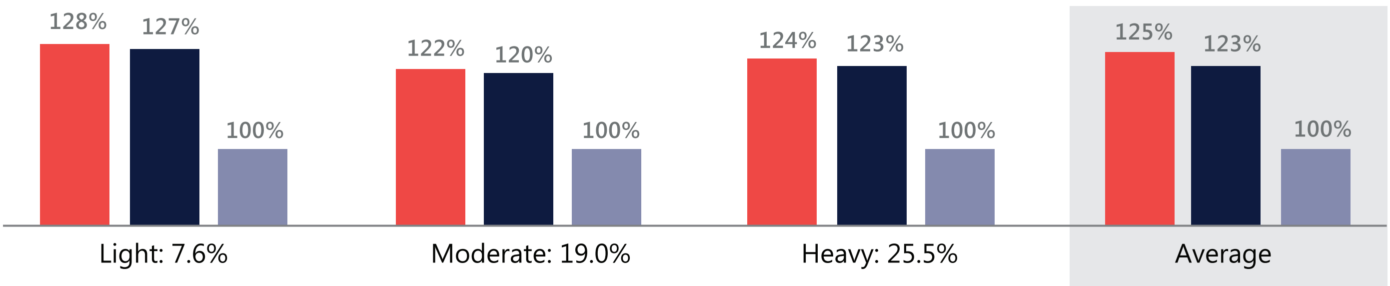


Figure 4: SolarEdge Enphase SMA

Table 1.

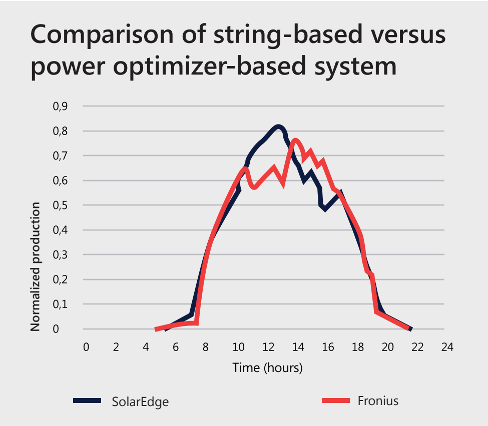
	Light	Moderate	Heavy
% of System Shaded	7.6%	19.0%	25.50%
Available Energy [kWh/M^2]	1813	1893	1784
SolarEdge Energy [kWh/M^2]	1729	1616	1439
SMA String Inverter Energy [kWh/M^2]	1697	1539	1328
Shade Mitigation Factor (SMF)	28.30%	21.90%	24.20%
Added Energy	1.9%	5%	8.4%

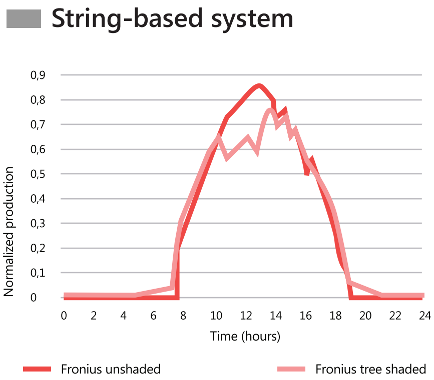
In a 2019 report, in yet another study, 'Evaluation of the performance of power optimizer-based PV systems under shading conditions'[4], the added energy provided by power optimizers was again confirmed. This study was conducted by the impartial faculty of engineering and sustainable development at the University of Gayle, and presented by Vattenfall AB and carried out at its Sweden´s largest facility – Vattenfall Älvkarleby laboratory. The research compared the production of a power optimizer-based PV system and a standard string inverter PV system under a number of different conditions, such as simulated snow cover and tree shading.

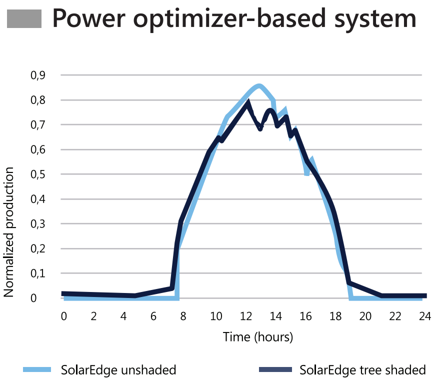
The research focuses on the shading effect on PV systems and its impact on power output. As part of the research, the gains associated with power optimizer-based PV systems under such conditions was compared to a standard string inverter system. In the study, the SolarEdge power optimizer-based PV systems demonstrated a 2% energy gain for light shade, and up to 8.5% under more severe shading, in comparison with a traditional string inverter system.

Shade from tree obstruction

In this report, it was found that the SolarEdge PV system outperformed the traditional string inverter in tree shaded conditions. With the tree centered in between the two systems at a perpendicular distance of 5 meters, the shading pattern for the string-based system was during morning hours, while the for the power optimizer-based system was during the afternoon. The experiment with obstruction shading from a 9.70 m pine tree rendered positive results, where the shading losses were reduced from 24% in the string-based system to only 9% in the power optimizer-based system. The two figures below show the normalized production of each one of the systems in comparison to the unshaded condition.

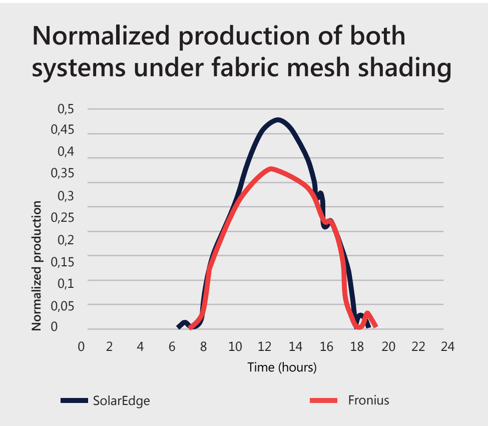


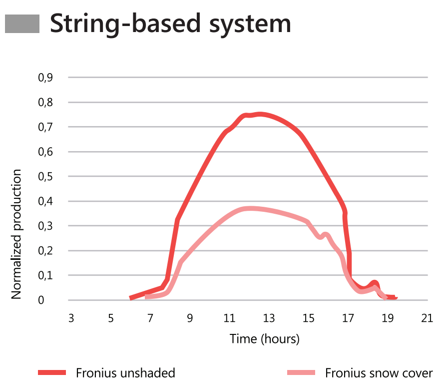


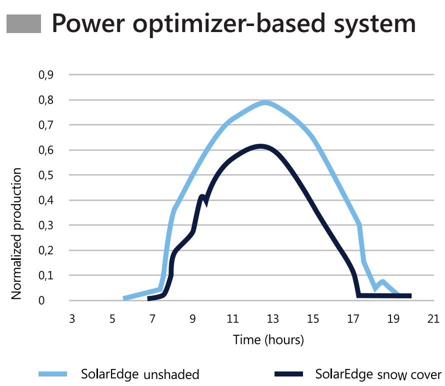


Simulated snow cover with fabric mesh

Results from its direct shading experiment using semi-transparent fabric mesh (assumed to be 50% transmittance, which is comparable to 1 cm of snow) to simulate snow are also positive for the SolarEdge system. The loss of production due to the simulated snow cover is only 29% for a SolarEdge system, whereas the traditional string inverter system has losses of 50% (see figure below). Comparing both systems, shading losses are decreased by 18% with a SolarEdge system versus a traditional string inverter system.







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The conclusions of the study show that the use of power optimizers in PV systems has proven to decrease losses of energy production, therefore leading to an increase in the overall system energy generation, in both shaded and unshaded scenarios.

Another field study was conducted in 2018 and commissioned by Billion Watts Technologies Co., Ltd, a distributor of SolarEdge inverter systems in Taiwan. This field trial compared the long-term power generation with different types of modules in a PV system with and without power optimizers.[5] This study used three different types of modules - lightweight, bi-facial, and high efficiency - and compared production results using power optimizer versus a standard string inverter.

In addition, the impact on the system's overall power generation under different shading conditions was analyzed and evaluated. The experiment took place in the green energy demonstration verification field of the Liu Jia Yuan District of the Industrial Technology Research Institute (ITRI), a world-leading, not-for-profit R&D organization engaging in applied research and technical services.

The daily power generation during the test period was recorded and the difference in power generation compared. To analyze the long-term power generation of the system using the power optimizers and without, a study was conducted as shown in Table 2 below. The results demonstrate that the long-term cumulative power generation of the system using power optimizers is higher than any of the three systems without.

Table 2. Long-term power generation

	Power Generation in kWh for Systems With and Without Power Optimizers					
	System 1	System 2	System 3	System 4	System 5	System 6
	Lightweight	Lightweight	Double-sided power generation	Double-sided power generation	PERC High efficiency	PERC High efficiency
	2.8kW	2.8kW	2.61kW	2.61kW	2.665kW	2.665kW
	SolarEdge	Delta	SolarEdge	Delta	SolarEdge	Delta
Energy production during the test period	1,218.25kW	1,118.28kW	1,335.57kW	1,284.50kW	1,301.83kW	1,275.86kW
	2.52%		**3.98%**		**2.04%**	

Performance under shaded and dusty conditions

The study also compared the long-term power generation of a system with SolarEdge power optimizers against that of a traditional string inverter system.

This experiment used a fine mesh gauze with a transmittance of 21.6% as a shield to cover the area of the two modules in a series. The experimental results demonstrated that when two modules are shaded in a series, the system with power optimizers delivers increased power generation compared to that of a standard string inverter system. The increase power generation ratio was 12.0% - 32.2% higher for power optimizers compared to a standard string inverter, as shown in Table 3 below.

Table 3. Power generation comparison results in kWh of partial module exposure to dust in systems with and without power optimizers

SolarEdge Generation	Delta Generation	Differences in Power Generation
(kWh)	(kWh)	%
13.6	11.0	24.1
13.6	11.3	20.2
12.7	10.2	24.1
12.0	10.1	19.4
9.2	7.7	18.3
11.3	8.5	32.2
6.7	5.8	16.8
4.0	3.6	12.0
13.7	11.3	21.4

/ Conclusion

As these numerous studies show, the value of power optimizers has been demonstrated, with replica results, by reputable, professional, and objective organizations throughout the years. These findings are based on high-quality research, that takes into account test duration, testing quantity, and real-word conditions.
In addition to the research, the market has acknowledged the value provided by MLPE, in particular power optimizers.

In less than a decade, since its first commercial shipments in 2010, SolarEdge has successfully established itself as the leading PV inverter supplier, in an extremely competitive and crowded global PV landscape. This success is built on a worldwide fleet of over 1.5 million monitored PV systems as of April 2020 and record year-on-year growth in both revenue and gross margin. Today, SolarEdge is the preferred inverter for industry-leading installers, integrators, and other energy market participants, with a vast install base of satisfied PV system owners in 130+ countries.

Sources:

[1] SolarPower Europe - Global Market Outlook for Solar Power / 2019 - 2023.

[2] Photon Labs put the SolarEdge Power Optimizers to the test, Photon Magazine.

[3] Performance of PV topologies under shaded conditions, PV Evolutions Lab (PVEL).

[4] Evaluation of the performance of optimizer-based PV systems under shading conditions, Faculty of Engineering and Sustainable Development at the University of Gävle, 2019.

[5] Solar photovoltaic system using optimizer outdoor for performance experimental test analysis report, Institute of Green Energy and Environment, 28 May 2018.

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