Building America Case Study

# Photovoltaic Systems with Module-Level Power Electronics

## PROJECT INFORMATION

**Building Component:** PV system

**Application:** New and/or retrofit; Single and/or multifamily

**Applicable Climate Zones:** All

## PERFORMANCE DATA

Recovery of PV system energy losses due to partial shading of modules: 20%–35%

Recovery of PV system energy losses due to orientation mismatch of PV modules: ~100%

Direct current (DC) power optimizers and microinverters (together known as module-level power electronics, or MLPE) are one of the fastest growing market segments in the solar industry. According to GTM Research* in *The Global PV Inverter Landscape 2015,* more than 55% of all residential photovoltaic (PV) installations in the United States used some form of MLPE in 2014.

**DC power optimizers.** Attached to or integrated in the junction box of a PV module, a DC power optimizer is designed to increase the power yield of the module before it sends an optimized DC voltage to the central inverter of a conventional PV system. A DC optimizer is technically a DC-DC converter that also performs maximum power point tracking (MPPT) at the module. DC power optimizers provide system benefits including improved performance under shading or other mismatch conditions, low-voltage safety under emergency disconnect conditions, and relaxed design constraints for the PV installer.

**Microinverters.** A microinverter performs the same basic function as a central (or string) PV system inverter—converting DC into alternating current (AC)—but it does the conversion at the PV module. Similar to the DC power optimizer, microinverters allow the output of each PV module to be unaffected by the other modules in the system. This is in contrast to a conventional PV system in which the modules are connected in strings and then wired to a central inverter. (See schematics on the next page.) While multiple input string inverters can also provide some reduced mismatch loss, microinverters can improve overall system AC output when a PV system must be mounted on more than one roof plane or when the PV modules are unevenly shaded. Microinverters may also employ some of the same optimization and MPPT circuitry that DC power optimizers use to increase overall PV system output.

While first costs of MLPE-equipped PV systems tend to be higher than a comparable central inverter PV system, most modern MLPE products also include Web-based monitoring that allows system owners and technicians to remotely assess system performance and health at the module level.

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*GTM Research. 2015. The Global PV Inverter Landscape 2015. greentechmedia.com/research/report/the-global-pv-inverter-landscape-2015.

## DESCRIPTION

DC power optimizer that attaches to the frame or back of a PV module and is wired to the junction box terminals


Microinverter that attaches to the frame or back of a PV module and is wired to the junction box terminals

For more information see

Deline, C., Marion, B, Granata, J., and Gonzalez, S. 2010. *A Performance and Economic Analysis of Distributed Power Electronics in Photovoltaic Systems.* *www.nrel.gov/docs/fy11osti/50003.pdf*.

MacAlpine, S., and Deline. 2015. *Modeling Microinverters and DC Power Optimizers in PVWatts.* NREL. *www.nrel.gov/docs/fy15osti/63463.pdf*.

Images courtesy of APS America, SolarEdge, and SMA America, respectively.

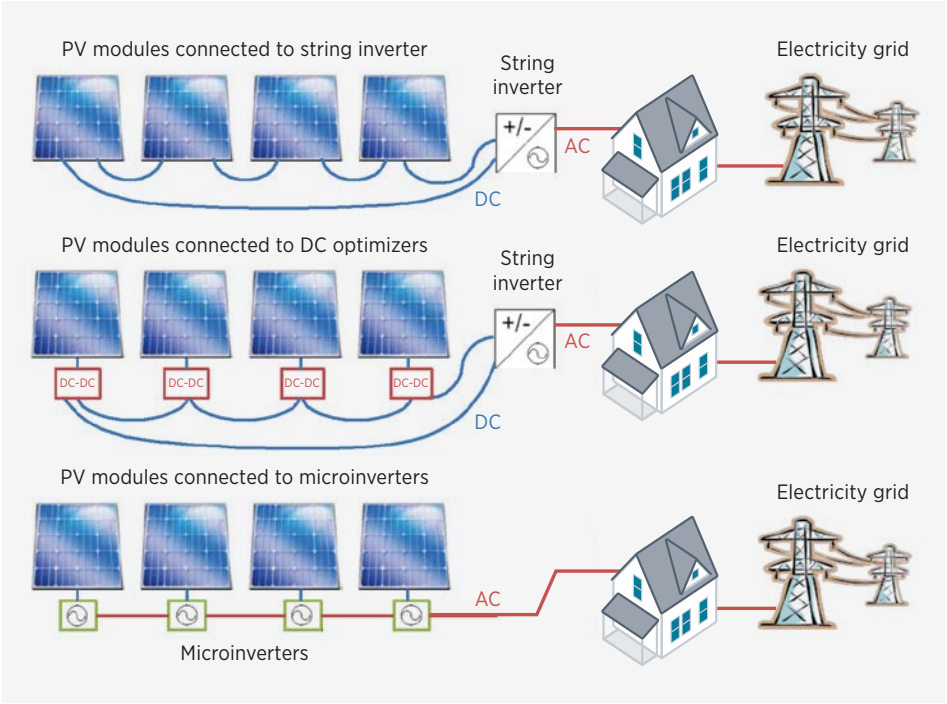


Figure 1. Schematic of conventional PV system (top); DC optimizer-equipped PV system (middle); and microinverter-equipped PV system (bottom)

## Lessons Learned

- MLPE such as DC power optimizers and microinverters can reduce the impact of shading losses, multiple roof planes, and module mismatch on PV system performance.
- MLPE can also help meet recent National Electrical Code (NEC) requirements for rapid shutdown of energized PV circuits.
- Accurately estimating the performance of MLPE-equipped PV systems requires some minor adjustments in the default values that are used in common PV modeling programs.
- MLPE technologies (in conjunction with optional communication gateways) can allow for module-level performance monitoring and diagnostics.
- Warranties for MLPE products are typically longer than conventional central or string inverters.

## Looking Ahead

Some PV module manufacturers have begun to investigate submodule-level power electronics in which the DC optimization circuitry is embedded in the PV module. MPPT can then be performed on each cell string within the PV module. Future NEC code cycles may incorporate enhanced safety disconnect requirements to further accelerate the adoption of MLPE solutions.

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