Microinverters

& AC PV Modules

by John Wiles

Two Enphase inverters, showing their DC input connections, and AC input and output connections.

No discussion of PV systems would be complete without a look at the newest inverter technologies that installers and inspectors will encounter. These new technologies include microinverters and AC PV modules.

Microinverters

Most grid-tied inverters are "string inverters"—they operate with a string of series-connected PV modules. These inverters range in power from 700 watts up to 1 megawatt. DC maximum system voltages can be as low as about 125 volts.

Enphase's microinverter, which hit the market in 2008, is a tiny inverter—about the size of a video cassette—that is designed to work with a single PV module and operate at a maximum of about 70 VDC (for one Enphase model). The inverter is electrically connected directly to the PV module using the existing conductors and connectors attached to both the module and the inverter.

Microinverters are grid-tied inverters with DC ground-fault protection (*National Electrical Code* Section 690.5) in the current offering. Enphase's microinverter internally grounds the positive DC module conductor. That internal grounding bond (via the DC ground-fault protection circuits; *NEC* 690.5) requires that the inverter have a DC grounding electrode terminal and that the terminal be on the outside of the Enphase microinverter case. Other types and brands of microinverters may ground differently or switch to an ungrounded configuration using modules with the new "PV Cable" required by *NEC* 690.35 for such systems.

With both AC input and output connections, microinverters have been UL-listed to allow multiple inverters to be connected on the same cable and circuit. With a power output in the 175 to 210 W range (depending on the model), the rated AC output current at 240 V will range from 0.73 to 0.88 A. On 14 AWG cable with a 15 A overcurrent device, the rated current for that circuit is limited to a maximum of 12 A. This rating will allow up to 16 inverters for the 175 W version and up to 13 inverters for the 210 W version to be installed on the same AC output cable.

AC PV Modules

Take a standard DC PV module and connect a microinverter to it, fasten the microinverter to the back of the module and cover the exposed DC conductors so none of them are accessible, and secure a listing to UL1741 for a pre-assembled module/inverter device, and you have an AC PV module. At least one AC PV module is available—Akeena Solar's Andalay AC PV module. Since the DC wiring between the module and inverter is no longer accessible and has become an integral part of the product, *NEC* DC requirements no longer apply to the AC PV module.

Akeena's module has a unique frame that serves as the module mount. Because each module is connected with stainless steel threaded rods to the adjacent modules, only one equipment grounding connection is needed for the array. The AC PV module has no requirement for DC grounding electrode terminals, and the single AC equipment-grounding conductor from the module/frame rack may be all that is needed in many installations. In ground-mounted arrays, Section 690.47(D) requires an additional grounding conductor from the array frame to a grounding electrode.

DC Connections

Should the microinverter or module fail, the microinverter's DC connection to the PV module will need to be disconnected for replacement. With today's inverter designs, the maximum voltage will be about 70 V and the current may be in the 3 to 8 A range—posing risk of damage (and creating a possible safety hazard) to the connector. While some inspectors may request a costly and impractical load-break rated disconnect, the code-compliant solution is really quite simple: Covering the module with a thick blanket or other opaque material per *NEC* 690.18 will drop the DC output voltage and current (and the AC current from that inverter, but not the other inverters connected to the same cable) to near zero, allowing the module/inverter DC connectors to be opened safely. Opening this connection with the module covered will likely be safer than opening the same connectors on a module in a high-voltage string of modules. The AC PV module has no accessible DC connections, so this issue is avoided.

AC Connections

Each microinverter or AC PV module has an AC input/output cable to allow multiple parallel inverter connections. Under bright sunlight conditions, this cable may carry currents ranging from 0.7 A at 240 V from the first module/inverter in the set to as much as 12 A at 240 V through the last connector of a set with multiple devices. Servicing a single AC PV module or utility-interactive microinverter could be accomplished by covering the module to reduce the DC (and hence the AC) current to zero. However, only covering the module in question in the set would still allow current from the other modules/inverters to flow through the cable. Although inverter anti-islanding circuits minimize the hazard somewhat, since they shut down very rapidly and reduce arcing when the AC connector is opened. Opening these 240 VAC connections under load could damage the connector and pose a shock hazard.

A safer solution would be to open the AC circuit at the PV back-fed breaker in the building service entrance panel—but only if that breaker can be locked open. However, breaker lock-outs are few and far between and lock-out/tag-out procedures are often not used in residential and commercial electrical systems. *NEC* Section 690.14(D) addresses this situation and points to a solution: Installing a separate AC disconnect near the AC PV modules or microinverters meets *NEC* requirements and enhances system safety. A common 60 A, unfused, pull-out air-conditioning disconnect (less than $10) can serve as the disconnect, a place to terminate the AC output cable from a set of microinverters or AC PV modules, and a place to originate the field-installed wiring system to the AC load center in the house.

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A Word of Warning

The microinverter or AC PV module system using load-side connections, just like conventional string inverters, must be connected on a dedicated circuit per *NEC* 690.64. See recent *Code Corner* articles for details on how to properly interconnect single and multiple output circuits to the grid. They should never be connected to a circuit protected by a GFCI or AFCI, since neither of these devices has been tested or listed for back-feeding.

Since a microinverter and an AC PV module work individually, each inverter extracts the maximum power from its matched module—independent of the other module/inverter pairs in the array. The outputs of the microinverters or AC PV modules are connected in parallel rather than in series, which isolates the performance of one from another.

The outputs are at 240 VAC, with the AC output circuits acting much like AC branch circuits. When utility power is removed at any disconnect in the circuit, all the inverters go dead and do not pose the safety hazards associated with daytime, "always-energized" DC circuits, which operate at hundreds of volts between the modules and a string inverter. If a short circuit or ground fault were to occur in these AC output circuits, the dedicated branch circuit breaker would open and the circuit would be de-energized. Opening the main service disconnect or the back-fed PV breaker will de-energize those PV AC output circuits—a boon to firefighters.

Numerous microinverters and AC PV modules are being installed. They are even being sold in home improvement centers, building supply houses, and electrical supply houses—so the general public is buying them. PV installers are best equipped to design and install these devices and understand the *NEC* requirements that apply to them.

Access

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Southwest Technology Development Institute • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html • PV systems inspector/installer checklist, previous "Perspectives on PV" and *Code Corner* articles, and *Photovoltaic Power Systems & the 2005 National Electrical Code: Suggested Practices*, by John Wiles