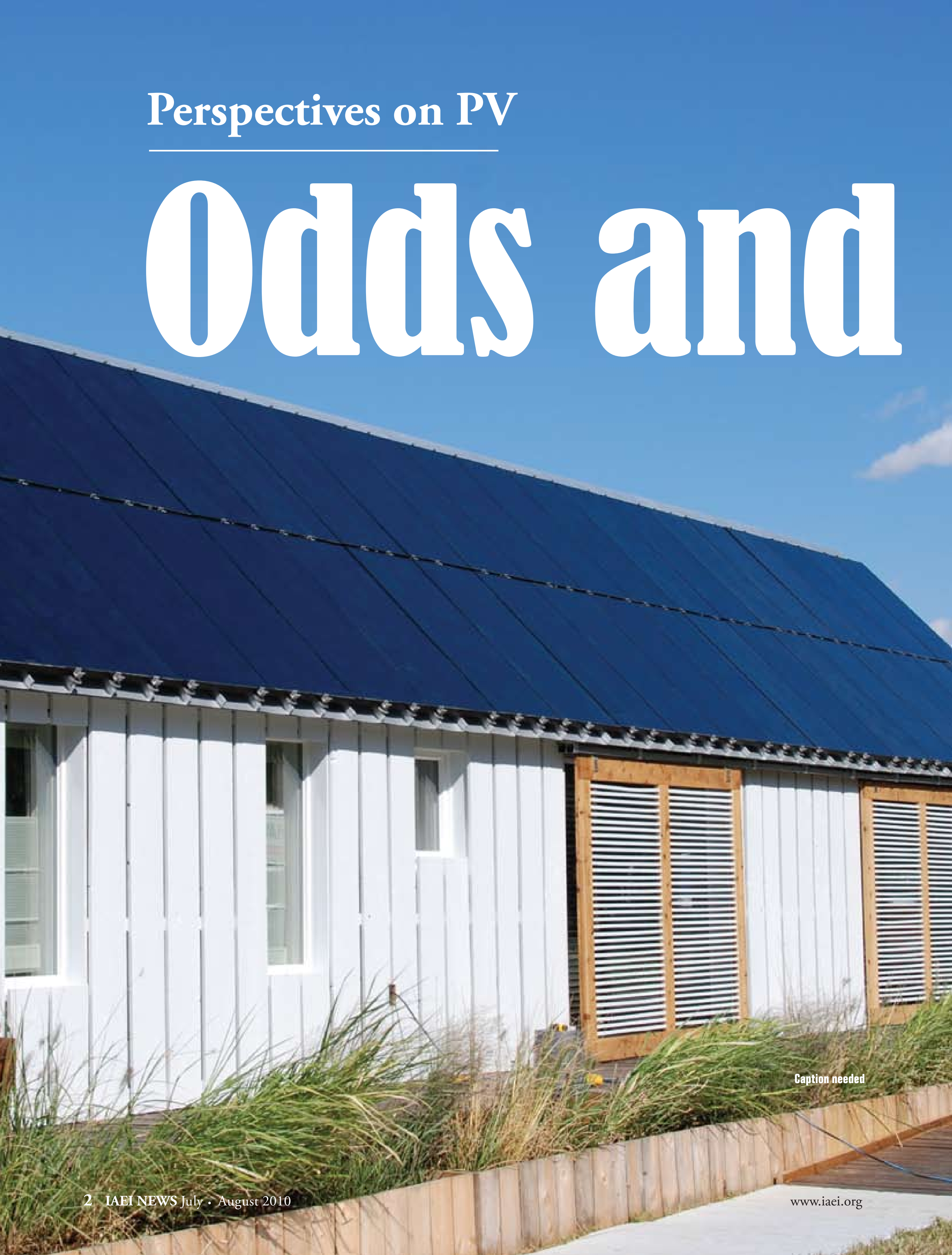
Perspectives on PV

Odds and



Caption needed

Ends

In the course of daily business, I get some questions repeated many times. I try to address these areas of common and frequent interest in this series of articles, but there are always a few that need clarification or repeating.

Inverter DC Grounding Electrode Conductor

In the "Perspectives on PV" in the September-October 2009 *IAEI News,* we covered 690.47(C) in both the 2005 and the 2008 *NEC* and discussed that since this section is permissive in both *Codes*, that either the 2008 or 2005 requirements may be applied in jurisdictions using either edition of the *NEC*. It should be clarified that the combined conductor permitted by 690.47(C) in *NEC*-2008 originates at the inverter and runs to the first grounding bar in a panel where a grounding electrode conductor (connected to a grounding electrode) is attached. It should be noted that this combined dc inverter grounding electrode conductor/ac inverter equipment-grounding conductor does not originate at the PV array. The PV array is normally grounded with an equipment grounding conductor routed with the dc circuit conductors per 690.45. Additional grounding of the PV array may be required by 690.47(D) when the array is ground mounted or mounted on a separate structure from the PV inverter.

Main AC Service Disconnect Ground-Fault Protection

NEC 230.95 requires that solidly grounded wye services with a line-to-ground voltage of 150 to 600 volts be provided with ground-fault protection. This protection is generally provided by a main disconnect consisting of a circuit breaker with an attached or included ground-fault protection device (GFPD). How should the PV designer, installer or inspector proceed where a utility-interactive PV system connection could backfeed this GFPD breaker? The answer: *With a great deal of caution.*

First, we need to know about one of those hidden-meanings, UL Standards that says if a circuit breaker *is not* marked "line" and "load," it has been evaluated for current/power flow in both directions and is suitable for backfeeding. Most of the newer, smaller molded-case circuit breakers that we deal with are not marked "line" and "load" and are suitable for backfeeding. However, in retro-fit situations we may be dealing with main disconnect circuit breakers that are 40 or 50 years old or more and may *have* "line" and "load" markings. With those markings, the breaker should not be backfed.

Let's assume that we have a main disconnect breaker that *is* suitable for backfeeding and it is also equipped with a GFPD as required by *NEC*-2008 and earlier *Codes*. Discussions with engineers at UL and with the circuit breaker manufacturers reveal that the GFPD may not have been tested for backfeeding in a method that duplicates the utility-interactive PV situation. When a ground fault trips a GFPD breaker that is being backfed by a PV inverter, both the line and load terminals may be energized at the same time for up to 2 seconds as the inverter shuts down. Many older GFPD devices could be damaged when this happens. Some of the newer GFPD breakers are not susceptible to this kind of damage, but no one seems to have a good universal answer to all GFPD breakers in all installations. So, the first hurdle is to get the design engineer at the breaker/GFPD manufacturers to provide written statements that the GFPD device will not be damaged when tripped while being backfed by a utility-interactive inverter.

Photo 1. GFP Breaker. To feed back or not.

The second hurdle is posed by meeting the Exception to 690.64(B)(3). How are the load circuits protected from ground-fault currents from the inverter? An analysis of the various impedances involved (inverter output source circuits vs. utility source circuits) to determine how currents would be shared between the inverter and the utility would not be simple. It may be possible that the inverter can source sufficient fault currents so that the GFPD does not trip. Then there is the fact that the GFPD has adjustable trip points, and the *NEC* provides no guidance on how they should be set in a non-PV installation, let alone in a PV installation. When the adjustment ranges over several hundred amps on a 1000-amp GFPD amp breaker, it is not clear how this adjustment should be made. Then if we try to put a GFPD on the output of the inverter, there is a question of how it should be connected and would it provide the desired protection?

At this point, I feel that when the existing installation has a main breaker or any breaker (or any fused disconnect) with a GFPD function, then that device should not have a utility-interactive inverter attached to any circuits that feed the load terminals of the GFPD. Supply side connections [690.64(A)] are the way to make these PV installations and avoid the issues until they are resolved.

690.64(B) All the Way

The "Perspectives on PV" in the November-December 2009 issue of the *IAEI News* dealt with supply side connections and the article assumed hope for the future code in this area. Unfortunately, *NEC* 690.64(B) and 705.12(D) will be with us for a long time since it appears that proposed changes for *NEC*-2011 were rejected. This code requirement applies to any bus bar or conductor that has multiple sources of supply (utility and PV inverter outputs) with each supply protected by an overcurrent device (fuse or circuit breaker). Load breakers are not counted in this requirement. In a typical utility interactive PV system, the requirement would apply to all busbars and conductors from the service disconnect (breaker or fused disconnect) to the first dedicated overcurrent device/disconnect on the inverter output circuit. Although the number of subpanels and conductors between the service disconnect and the PV inverter output may be numerous, and the load on the building large compared with the rating of the PV system, there is always the possibility that any conductor in this path may be subjected to backfeed currents from the PV system. Each of those panel busbars and conductors between them must be sized to meet the requirements of 690.64(B)/705.12(D).

If the PV inverter output connection *cannot* be made at the very last breaker position in the most distant panel from the service disconnect as required by 690.64(B)(7), then the calculations for ampacity and busbars become more complex. Without this opposite breaker configuration, it may be possible to overload portions of the busbar or some conductors with current from both the utility and the PV system. The 120% allowance in 690.64(B)(2) cannot be applied, nor can just that first dedicated breaker connected to the PV inverter output be used in the calculations for each conductor and busbar. The designer/installer/inspector must look at each panel busbar and each conductor segment and determine which breakers are limiting current to that specific bus bar or conductor. These are usually the main breaker on the panel and the single backfed breaker in that particular panel that is handling backfed current from the possibly distant PV inverter. It is not the dedicated breaker connected directly to the inverter. Unfortunately, we have lost the 120% allowance and frequently a main breaker and the panel rating are the same. Therefore it is not possible to have breaker carrying backfed PV currents connected to this panel or conductor.

In some cases the main breaker for a panel may be reduced below the rating of the bus bar, and this can allow a backfed breaker to be connected anywhere on that panel. Load calculations determine if the breaker can be reduced. If so, then the sum of the rating of the main breaker (supplying utility power) and the rating of the backfed breaker in that panel may not exceed 100% of the bus bar rating for that panel. And, upstream panels and circuits toward the service entrance must still be analyzed to see if the 100% rule can be met. In many cases, a supply side connection is then the only option available.

Summary

Details are the meat and potatoes of the *Code*. By looking into the *Code* requirements in detail, we see how those requirements are to be implemented. Sometimes the results of these inspections are not what we expect, but the end result is safer electrical systems.

For Additional Information

If this article has raised questions, do not hesitate to contact the author by phone or e-mail. E-mail: jwiles@nmsu.edu. Phone: 575-646-6105

A color copy of the latest version (1.9) of the 150-page, *Photovoltaic Power Systems and the 2005 National Electrical Code: Suggested Practices*, written by the author, may be downloaded from this web site: http://www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html

The Southwest Technology Development Institute web site maintains a PV Systems Inspector/Installer Checklist and all copies of the previous "Perspectives on PV" articles for easy downloading. Copies of "Code Corner" written by the author and published in *Home Power Magazine* over the last 10 years are also available on this web site: http://www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html

The author makes 6–8 hour presentations on "PV Systems and the *NEC*" to groups of 60 or more inspectors, electricians, electrical contractors, and PV professionals for a very nominal cost on an as-requested basis. A schedule of future presentations can be found on the IEE/SWTDI web site.

John Wiles works at the Institute for Energy and the Environment (IEE) (formerly the Southwest Technology Development Institute) at New Mexico State University. IEE has a contract with the US Department of Energy to provide engineering support to the PV industry and to provide that industry, electrical contractors, electricians, and electrical inspectors with a focal point for Code issues related to PV systems. He serves as the secretary of the PV Industry Forum that submitted 54 proposals for the 2011 NEC. He provides draft comments to NFPA for Article 690 in the NEC Handbook. As an old solar pioneer, he lived for 16 years in a stand-alone PV-power home in suburbia with his wife, two dogs, and a cat—permitted and inspected, of course. The PV system on his home is a 5 kW (dc) utility-interactive system with a full-house battery back up.

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