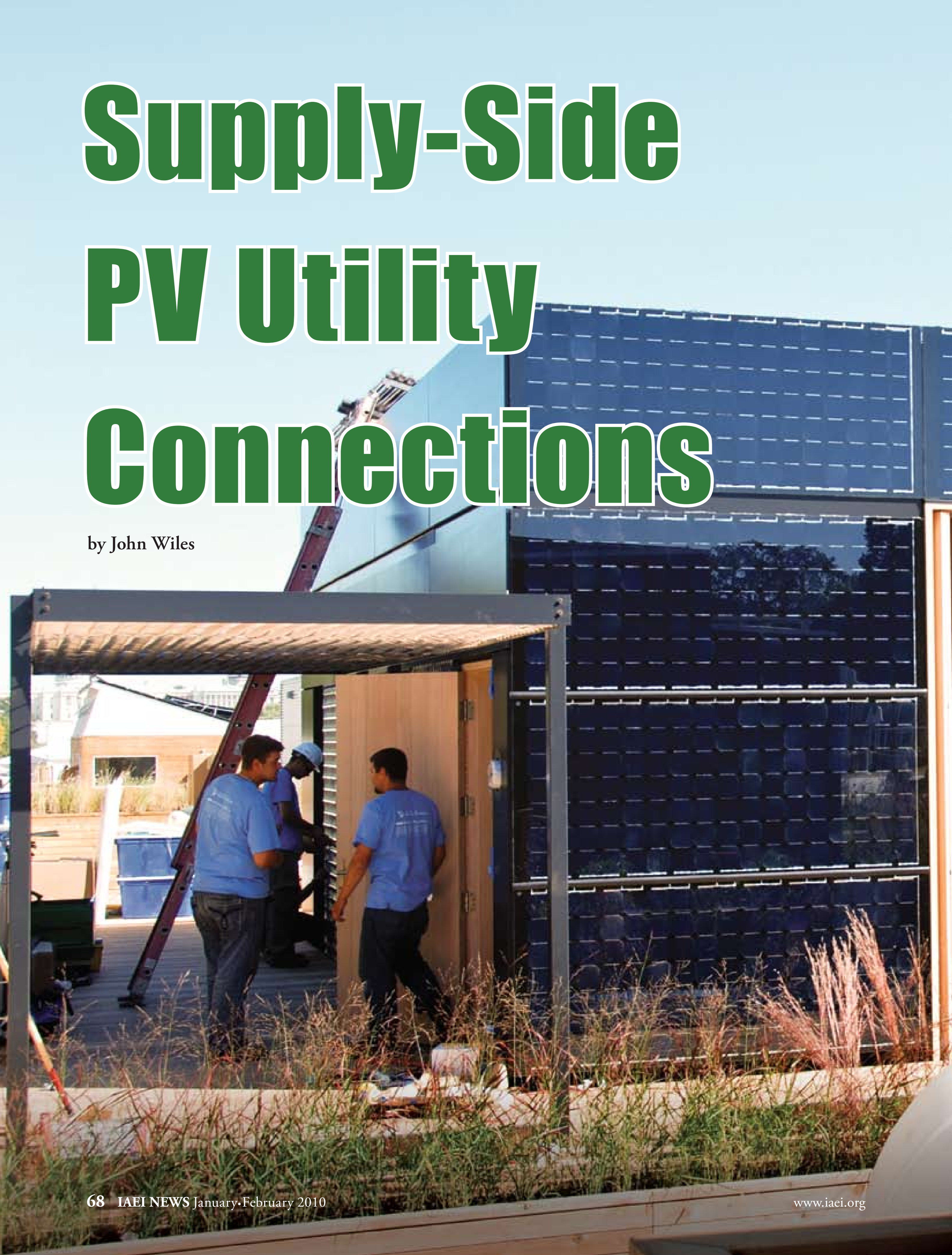
Supply-Side PV Utility Connections

by John Wiles



Many larger PV systems cannot meet the requirements for a load-side (of the service disconnect) connection to the premises wiring system and a supply-side connection must be considered.

Code Considerations

The supply-side connection (also known as a service-entrance tap) is allowed by the *National Electrical Code (NEC)* and is addressed in a number of sections in the *Code*.

Section 690.64(A) {moving to 705.12(A) in the *2008-2011 NEC*} allows a supply (utility) side connection as permitted in 230.82(6). Section 230.82(6) indicates that solar photovoltaic equipment is permitted to be connected to the supply side of the service disconnect.

It is evident that the connection of a utility-interactive PV inverter to the supply-side of a service disconnect is essentially connecting a second service-entrance disconnect to the existing service and many, if not all, of the rules for service-entrance equipment must be followed. Many years ago, the National Fire Protection Association (NFPA) made an informal interpretation that these supply-side taps were essentially a second service entrance on the building or structure and should be treated as such.

Section 240.21(D) allows the service conductors to be tapped and refers to 230.91. In general, the other "Tap Rules" of Section 240 do not apply because they were not developed to address two sources of power in a tap circuit, nor were they developed to assure safe operation when one source is an unprotected utility power source.

Section 230.91 requires that the service overcurrent device be co-located with the service disconnect. A circuit breaker or a fused disconnect would meet these requirements. See photo 1. A utility-accessible, visible break, lockable (open) fused disconnect (aka safety switch) used as the new PV service disconnect may also meet utility requirements for an external PV ac discon-

Photo 1. A breaker as a supply-side tap. But is it *Code* legal?

Photo 2. Utility-required ac disconnects. Could have been combined into one.

nect in areas where utilities require such an additional disconnect. See photo 2.

Section 230.71 specifies that the service disconnecting means for each set of service-entrance conductors shall be a combination of no more than six switches and sets of circuit breakers mounted in a single enclosure or in a group of enclosures. The PV system may be counted as a separate service (230.2) and could have up to six disconnects of its own.

Location and Directory

Section 230.70(A) establishes the location requirements for the service disconnect. Section 705.10 requires that a directory be placed at each service equipment location, showing the location of all power sources for a building. See photo 3. Locating the PV ac disconnect adjacent to or near the existing service disconnect may facilitate the installation, inspection, and operation of the system. See photo 4.

Size Matters

Obviously the size of the new PV service disconnect is important. It will normally be sized at 125% of the rated output current from the PV inverter(s). But in small systems, a question arises; how small can it be? Section 230.79 addresses the rating issue. Some inspectors have looked at 230.79(A) and say that it can be as low as 15 amps if that value is at or above the rating of the inverter output circuit. The connection of other allowed loads at this level is common.

I would suggest caution here, since the tap is to service-entrance conductors rated at 100 amps and above. The typical 15-amp circuit breaker with 10,000 amps of interrupt capability, in this application, may not be able to withstand the available fault current, since it is not protected and coordinated with any main breaker typically rated at 22,000 amps. Of course, Section 110.9 should be followed and fault current calculated. Also

Photo 3. Directory for PV system

a service entrance rated 30-amp fused disconnect with 15-amp fuses could be used.

Another consideration is the size of the service-entrance conductors, the new tap conductors, and the size of the terminals on available switchgear rated at 30 or 60 amps. The added conductors between the existing service-entrance conductors and the new service disconnect will be subjected to available fault currents and will have no protection except that provided by the fuse on the primary of the utility transformer. Making them as large as possible, with an upper limit of the size of the existing service-entrance conductors would seem prudent, but small disconnects will not accept very large conductors.

For these reasons, I suggest that Section 230.79(D) be used as the requirement for the smallest service disconnect for PV inverter supply-side taps. Section 230.79(D) requires that the disconnect have a minimum rating of 60 amps. This would apply to a service-entrance rated circuit breaker or fused disconnect.

Section 230.42 generally requires that the service-entrance conductors be sized at 125% of the continuous loads (all currents in a PV system are worst-case continuous). The actual rating should be based on 125% of the rated output current for the utility-interactive PV inverter as required by 690.8. The service tap conductors must have a 60-amp minimum rating from 230.79(D). Temperature and conduit fill factors must be applied.

For a small PV system, say a 2500-watt, 240-volt inverter requiring a 15-amp circuit and overcurrent protection, these requirements would appear to require a minimum 60-amp rated disconnect, with 15-amp fuses;

Photo 4. PV ac disconnect above closed service disconnect

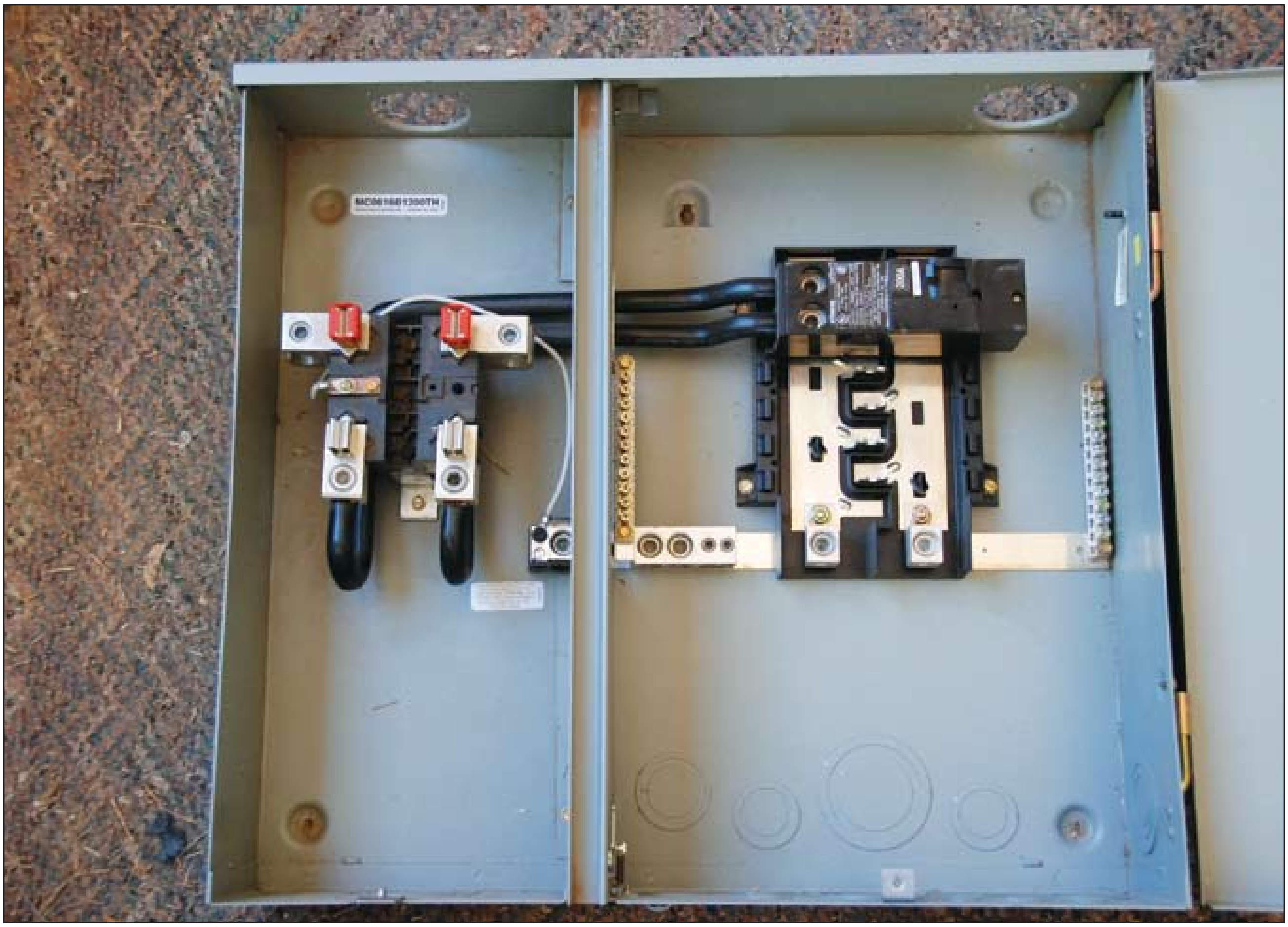


Photo 5. Meter-main combo—do not tap.

fuse adapters would be required. Fifteen-amp conductors could be used between the inverter and the 15-amp fuses in the disconnect. Section 230.42(B) requires that the conductors between the service tap and the disconnect be rated not less than the rating of the disconnect; in this case, 60 amps.

How we would deal with the 60-amp disconnect, 15-amp over-current requirements using circuit breakers is not as straightforward. A circuit breaker rated at 60-amps would serve as a disconnect, and it could be connected in series with a 15-amp circuit breaker to meet the inverter overcurrent device requirements. In this case, the requirements of 690.64(B)(2) should be applied for the series connection. See "Perspectives on PV" in the November-December issue of the *IAEI News* for details.

Section 110.9 of the *NEC* requires that the interrupt capability of the equipment be equal to the available fault current. The interrupt rating of the new disconnect/overcurrent device should at least equal the interrupt rating of the existing service equipment. The utility service should be investigated to ensure that the available fault currents have not been increased above the rating of the existing equipment. Fused disconnects with RK-5 fuses are available with interrupt ratings up to 200,000 amps.

Section 230.43 allows a number of different service-entrance wiring systems. However, considering that the tap conductors are unprotected from faults, it is suggested that the conductors be as short as possible with the new PV service/disconnect mounted adjacent to the tap point. Making these tap conductors as large as the service-entrance conductors, while not a *Code* requirement, would also add a degree of safety. Of course, the added disconnect must be able to accept the larger conductors. Conductors installed in rigid metal conduit would provide the highest level of fault protection.

All equipment must be properly grounded per Article 250 requirements. See 250.24(B) for bonding requirements. As a service disconnect, neutral-to-ground bonding would generally be required at the new disconnect, and a grounding electrode conductor should also be added.

The actual location of the tap will depend on the configuration and location of the existing service-entrance equipment. The following connection locations have been used on various systems throughout the country.

On the smaller residential and commercial systems, there is sometimes room in the main load center to tap the service conductors just before they are connected to the existing service disconnect. In other installations, the meter socket has lugs that are listed for two conductors per lug. Of course, adding a new pull box between the meter socket and the service disconnect is always an option. Combined meter/service disconnects/load centers frequently have significant amounts of interior space where the tap *appears to be possible* between the meter socket and the service disconnect. However, tapping this internal conductor or bus bar in a listed device such as a meter-main combination would violate the listing and should not be done. See photo 5.

Where the service-entrance conductors are accessible, a new meter base (socket) could be added ahead of the combination device. A tap box would then be added between the new socket and the combination device. The meter would then be moved from the combo device to the new socket, jumper bars added to the old socket and the old socket covered.

In the larger commercial installations, the main service-entrance equipment will frequently have bus bars that have provisions for tap conductors. The tap can only be made by the organization supplying the service equipment and that is usually a UL 508 panel shop. They can tap the equipment and maintain the listing on the equipment.

In all cases, safe working practices dictate that the utility service be de-energized before any tap connections are made. Additional service-entrance disconnect requirements in Article 230 and other articles of the *NEC* will apply to this connection.

Summary

Supply-side service entrance taps are useful for larger PV systems where the conditions of the load-side tap cannot be met. These supply-side taps normally require that the power be removed from the service to ensure a safe installation.

The next "Perspectives on PV" will address the new micro inverters and ac PV modules.

Sharp-eyed inspectors will note in the last issue that the 45 -amp breaker used for the PV system will be too large for the 200- amp panel. The panel must be 225 amps or the main breaker reduced to at least 195 amps if loads allow.

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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