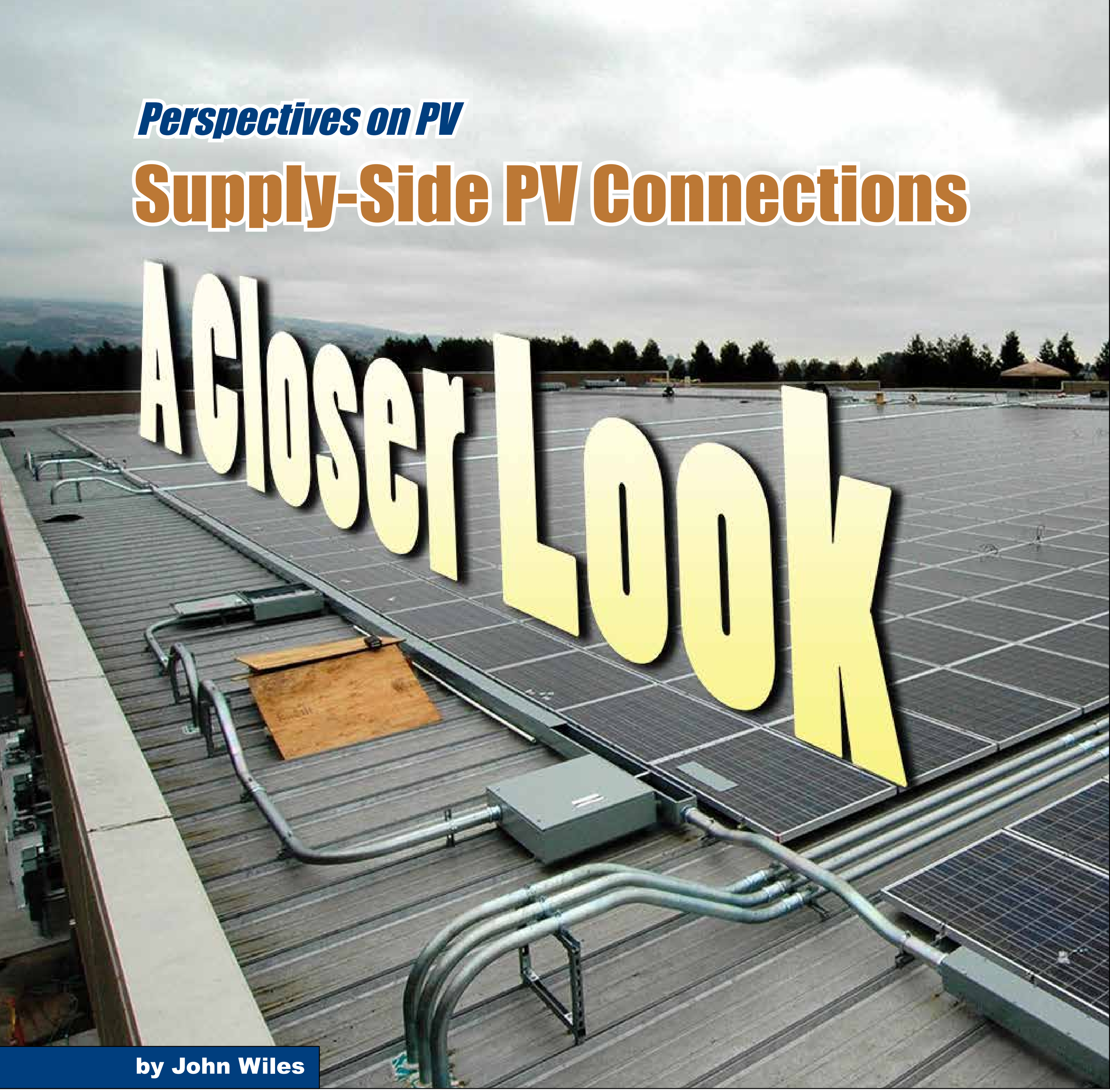
Perspectives on PV

Supply-Side PV Connections

A Closer Look



by John Wiles

Plan reviewers and inspectors throughout the country are seeing increasing numbers of supply-side connected utility interactive photovoltaic (PV) power systems [705.12(A)]. This article will examine some of the reasons for those increasing numbers of supply-side or utility-side connected systems. It will address the code requirements applicable to these systems and it will look at some of the implementations of these systems and areas in the installation that should receive additional attention. The article references *NEC*-2011.

Costs Decreasing

The cost of installing a PV power system has come down substantially in the last year or two for several reasons. There is a surplus of PV modules on the market and the cost of those modules has dropped significantly. New installation materials and tech-

niques have become available, reducing labor costs. And, financial incentives at the national, state, and local levels are still in effect in many areas.

Load-side Limitations

The size of the typical residential and small commercial PV system has been increasing because of the lower costs mentioned above, increasingly large PV modules, and inverters with higher outputs. This increased size of the PV system has made it more difficult to make a load-side utility connection [705.12(D)] because of the limitations of the 120% allowance for back feeding load centers.

With no reduction in the size of the main breaker, a 100-amp load center with the 20-amp backfed PV breaker would allow only a PV system with an inverter output rated current of 16 amps. The circuit breaker protecting the inverter output circuit has to be at least 125% of the rated inverter output current or in other terms, the rated inverter current can be no larger than 80% of the breaker rating (690.8). At 240 volts, this allows a maximum inverter rating of 3840 watts (240 x 16). Similarly, a 200-amp load center, again with no change in the main breaker, can handle only up to an inverter rated at 7680 watts.

And, since PV inverters have ratings such as 3000 W, 3500 W, 4500 W and the like, the PV output will actually be somewhat below the numbers above. Hence, the inspector community is seeing increasing numbers of supply-side connections. See photos 1 and 2.

Code requirements

Section 705.12(A) establishes the allowance for supply-side PV connections. A supply-side connection is made on the supply or utility side of the service disconnecting means for the existing building or facility. Section 705.12(A) refers to Section 230.82(6).

Of course, this section is in Chapter 2 of the Code dealing with services, and this section allows solar photovoltaic systems or interconnected electric power production sources to be connected on the supply side of the service disconnecting means.

Also pertinent is section 230.2(A)(5) that permits additional *services* including parallel power production systems as a Special Condition.

The National Fire Protection Association (NFPA) has ruled informally decades ago and again more recently that a supply-side connected PV system is an additional *service* on an existing building or facility. As a service, most of the Chapter 2 service requirements should apply to the ac circuits between the connection to the existing service and the new, added PV service disconnect.

After the circuit passes through the PV service

Photo 1. PV systems are getting larger and frequently will require supply-side connection to the utility. No, shaded modules are not good and will not get the maximum energy from the PV array.

disconnect, the electrical requirements are now on the load side of the service disconnect and the Chapter 2 service entrance requirements no longer apply. AC circuits toward the inverter from the PV service disconnect should comply with 690.8 or 705.12(D).

Service Entrance Requirements

While not attempting to address all of the requirements in Chapter 2 dealing with services, there are some requirements that are frequently overlooked in installing a supply-side connected PV system. The types, sizes and routing of the added PV "service conductors" are covered in Article 230.

It would appear that the minimum size for the added service conductors and the PV service disconnect is 60 A [230.79(D)]. The size of the PV output circuit overcurrent protection is not specified and may be lower than the 60-amp minimum rating of the PV disconnect and PV service-entrance conductors.

While the PV service minimum size is 60 amps, this does not preclude the connection of, for example, a 15-amp inverter output circuit to the 60-amp added service with the appropriate sized overcurrent protection. On the other hand, the maximum size of the supply-side connected PV inverter output would be limited to the rating of the service.

From the perspective of the existing service-entrance panel and conductors, the PV supply-side connection looks just like the existing utility service supply. The existing main overcurrent protective device protects all load-side circuits in the same manner whether or not the PV supply-side connection is present. None of the load-side code requirements [705.12(D)] apply to the new circuits between the new added PV service disconnect, the utility supply or the conductors to the existing main disconnect.

And, of course, the interrupt rating of the added PV service disconnect/overcurrent protection must be equal to or greater than the available short-circuit current from the service (110.9). Since the utility service may have been upgraded with larger transformers since the original electrical installation, the interrupt rating of the existing service equipment

Photo 2. Two inverters on a residential installation will generally indicate that a supply-side utility connection is required.

should not be relied upon as a sizing indicator for the interrupt rating of the new PV service equipment.

When the new PV service disconnecting means is *not* in the same enclosure as the existing service disconnect means, the PV circuit neutral should be bonded to ground and a grounding electrode conductor originating from the PV service disconnect location must be routed to the grounding electrode (250.24).

Even where the PV inverter connection does not have a neutral connection, the utility neutral should be routed to at least the new PV service disconnect and any PV production meter. The meter may require the neutral for proper operation.

Location of the Connection

The exact location where the supply-side connection can be made is subject to many variables. While the code says that the connection is made on the supply side of the service disconnecting means, that location can vary depending on the configuration of the service and other factors.

Utility Property or Premises Wiring?

It is assumed that the connection must be made on the premises wiring which is on the premises side of the service point (Article 100), but that service point will vary from utility to utility. In some cases, the service point is at the power pole or the underground distribution transformer. In other jurisdictions, the service point is the input or utility side of the meter base (socket); and in still other locations, the service point is the utility side of the main service disconnect. Normally, the PV supply-side connection must be made on premises wiring and not on utility-controlled wiring. Further complicating the issue is the fact that no matter where the service point is, the utility may actually do the wiring past the service point. In some jurisdictions the service point may be the service disconnect and the utility does the actual wiring all the way to that service point. In other jurisdictions, the service point may be the utility side of the meter base but the utility will still make the electrical connections all the way to the service disconnect. Another complicating factor is that even

Photo 3. Meter main combos may not have the internal conductors (or bus bars) tapped for a PV supply-side connection. Such a connection would violate the listing on the device and therefore violate *NEC* section 110.3(B).

when the service point is the service disconnect, the local electrician may be required to make the wiring between the meter base and that service disconnect.

Many utilities are very protective of service wiring that they consider under their control. They nearly always lock the meter base; and in the larger installations, the service entrance section (SES) of the switchgear cannot be accessed by anyone other than the utility. Utility permission and access to these supply-side locations must be granted in order to make PV connections in these areas.

Inside the Service Equipment

There may be sufficient space to do a connection on the service-entrance conductors as they come into the service-entrance panelboard (load center) and before they reach the main breaker. There must be sufficient space in the panelboard to make these connections and this may be a workmanship judgment call by the AHJ. Note: Connections ahead of main breakers in *subpanels* that are not the service-entrance panels *are not* considered supply-side connections.

Photo 4. Large system electrical switchgear. Possible connection points must be identified and made by an approved organization and allowed by the utility.

In some parts of the country, a main-lug-only service-entrance load center is used. With no main breaker, each of the six allowable breakers in this panelboard can be considered a supply-side connection and is considered a service-entrance disconnect. If one of the six breaker positions is unused, the PV connection can be made using a breaker in that open position. The maximum circuit rating of the PV output would be limited to the lesser of the service rating, the bus bar rating in this panelboard, or the maximum size breaker that can be installed in the open position. With this type of supply-side PV connection, where the added PV disconnect is inside an existing panelboard, the existing neutral-to-ground bond for the entire panelboard accomplishes the neutral-to-ground bond for the PV service.

It should be noted that the rating of a service-entrance panelboard is not necessarily the same as the rating of the service, although they may be related. The utility determines the rating of the service and their conductor size requirements, for a given current rating, are generally not the same as those found in the *NEC*.

The Meter-Main Combo

On small residential systems, a meter-main combo panel will frequently be used. This is a single unit containing the meter base and the service disconnect (photo 3). Although there is a significant amount of room in this combo panel and the conductors are easily accessed between the meter base and the disconnect breaker, those conductors *may not* be used for connection points for the PV system. Such a connection would violate the listing on the enclosure and should never be made [110.3(B)].

Large System Switchgear

On the larger commercial electrical installations, switchgear assemblies rated at thousands of amps are used (photo 4). These switchgear assemblies are generally manufactured and installed by electrical equipment assemblers/manufacturers known as Underwriters Laboratories (UL) 508 Shops, where UL 508 is the standard governing the certification of these assembly shops and what they can and cannot do. Making a supply-side connection on bus bars that are readily accessible in these types of switchgear is a specialized task. Underwriters Laboratories has maintained for years that only the assembling/manufacturing UL 508 Shop may legally make these connections without violating the listing on the switchgear. Just because holes are available in the bus bars at the proper location, does not mean that these holes are designed for electrical connections. In all cases, for an electrical connection to be made while maintaining the listing, the holes in the bus bars must be marked as "tap points," the electrical terminal devices must be specified, and the specific instructions for making the electrical connection must be provided and followed.

A complicating factor is that even though a connection point can be identified in the switchgear and a connection can legally be made, the utility may not allow such a connection in the service entrance section (SES) of the switchgear that is under their control. Also, the location of current transformers (CTs) and potential transformers (PTs) used for metering may not allow net metering to be accomplished because the metering points are frequently connected on the load side of the main disconnect. A supply-side PV connection, even when allowed, would not allow the meters to measure the net energy flow—only the load energy.

Ahead of the Service Equipment

In general, the connection between a separated meter base and the service disconnect panelboard is a possible place to make a connection. Of course, conduit or other raceway must be broken, a junction box added, and the splice made inside the junction box. The difficulty in completing these actions depends on the physical installation.

The meter base is another potential location for the supply-side connection. Some meter bases have lugs that are listed for double connections. Several organizations and meter base manufacturers have listed meter base adapters that are installed between the meter and the base and allow the PV supply-side connection to be made at that location. However, some utilities and some jurisdictions will not allow supply-side connections to be made at the meter or in the meter base.

With a supply-side connection ahead of the service equipment, the rating of the PV circuit is essentially limited to the lesser of the rating of the service (established by the utility) or the ampacity of the conductors where premises wiring is involved.

Summary

Plan reviewers and inspectors need to be fully aware of the Code requirements for making the supply-side PV connections. These unprotected conductors from the connection point to the new PV service disconnect are to be treated as service conductors. Familiarity with utility practices and restrictions is also required to ensure that a legal connection is being made.

The author has retired from the Southwest Technology Development Institute at New Mexico State University, but is devoting about 25% of his time to PV activities in order to keep involved in writing these Perspectives on PV articles in IAEI News and to stay active in the NEC and UL Standards development. He can be reached, sometimes, at: e-mail: jwiles@nmsu.edu, Phone: 575-646-6105

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. A color copy of the latest version (1.93) 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

It should be updated to the 2008 and 2011 *NEC* before the 2014 *NEC* arrives.

CORRECTION: The Perspectives on PV article in the September-October IAEI News incorrectly stated that Section 690.7(C) of the 2014 NEC would allow PV systems up to 1000 volts on one- and two-family dwellings. Systems on one- and two-family dwellings will be limited to 600 volts with no change from past editions of the Code. The 2014 NEC will allow other structures to have PV systems up to 1000 volts.