Disconnect, Disconnect, Where For Art Thou?

by John Wiles

The requirements and necessity for, and the location of disconnects in a photovoltaic (PV) power system are always of great interest. While PV equipment manufacturers, designers, installers, and electrical inspectors are all interested in getting safe PV systems, there are usually some "friendly" discussions on the whys and hows of disconnects needed to achieve those ends. The following information may shed a little light on those sometimes elusive disconnect requirements and how they can be addressed.

Photo 1. Small system dc PV disconnect

Disconnects defined

Article 100 in the *NEC* defines *disconnecting means* as a device or devices that could be used to disconnect circuits. Switches, circuit breakers, screw terminals, and bolted connections fall under that definition (see 690.17).

Why are they needed?

PV disconnects are generally required on both small (photo 1) and large (photo 2) systems for two reasons. The first reason is to disconnect the external power source conductors from the circuits in the building or structure (690.13, 230.70). A common disconnect of this type is the ac service-entrance disconnect for a house. On a PV system, the main PV dc disconnect falls into this category if the PV dc conductors penetrate the house. Although batteries are not power generators, they can source energy, so a battery disconnect might also fall into this category.

Secondly, disconnects are required to remove power from a device that needs maintenance. I could use the word "service" instead of "maintenance," but I am trying to make these articles clearer than the *Code*. Of course, all of the main-power disconnects could be opened to remove all power from a building, but disconnects associated with equipment that must be maintained provide a degree of safety without shutting down the entire electrical system for maintenance on a single piece of equipment (see 690.15).

Disconnects for PV systems, let me count the ways

A main dc PV disconnect is required where the PV dc circuits from the PV array enter the building (690.13, 690.14).

A main ac PV disconnect is required where the dc PV circuits do not enter the building, but the ac output of the inverter does. No, you won't find this one explicitly listed in 690, but see figures 1 through 4 (690.13, 690.14).

A dc inverter maintenance disconnect is required and more than one may be required if the system has batteries (690.15).

A battery disconnect is normally required on stand-alone PV systems with batteries or utility-interactive PV systems with battery backup.

An ac inverter maintenance disconnect is required for utility interactive inverters (690.15).

Stand-alone inverters with generator inputs may also require a generator disconnect at the inverter input (690.15).

Charge controller input and output disconnects are required for maintenance on systems with batteries (690.15).

Systems with backup generators will normally require a generator disconnect both outside at the generator location (point of entry power disconnect) and inside near the inverter and other power processing equipment (maintenance disconnect).

The ac point of connection will require a disconnect on utility-interactive systems [690.64(B)(1)].

Many utilities will require a lockable open, visible blade ac disconnect for the PV system, and this disconnect will usually be located near the utility revenue meter.

Where art thou?

Utility personnel and emergency responders such as fire fighters like to know where the main-power disconnects are located. The general *NEC* requirements for these disconnects are discussed below, but the local jurisdiction may have differing requirements.

Although there are two separate requirements for disconnects, in some cases a single disconnect, prop-

Photo 2. Large system dc PV disconnects

erly rated and located, may solve both requirements. In other cases, due to equipment placement and the necessity for grouping the maintenance disconnects, two or more disconnects may be needed in a single circuit (690.15).

With the introduction of PV and Article 690 into the 1984 edition of the *NEC*, the original intent of the requirements for the PV disconnect was to match them with the existing requirements for the ac service disconnect as established by Article 230. In fact, 690.14 in the *1984 NEC* referred the reader directly to Article 230 Part F. Unfortunately, most PV installers did not follow this guidance because they were not electricians familiar with installing ac service-entrance conductors and service disconnects. The PV installers frequently penetrated the roof with energized PV source and output conductors and routed these conductors to the main dc PV disconnect just about anywhere in the structure they pleased. Complaints from electricians and electrical inspectors caused the NFPA (without any help from the PV industry) to rewrite Section 690.14 in the *2002 NEC*. In this revised section (which mimics 230 Parts IV, V), the requirement was

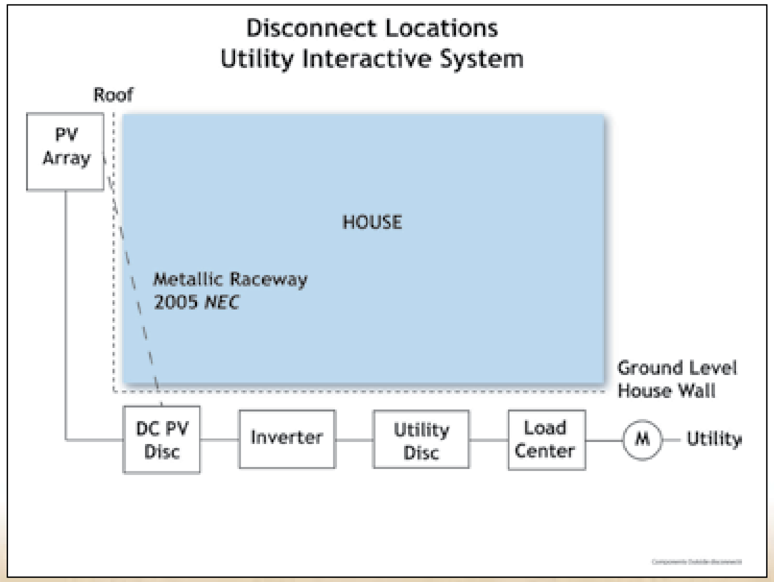

Figure 1. All components outside the building

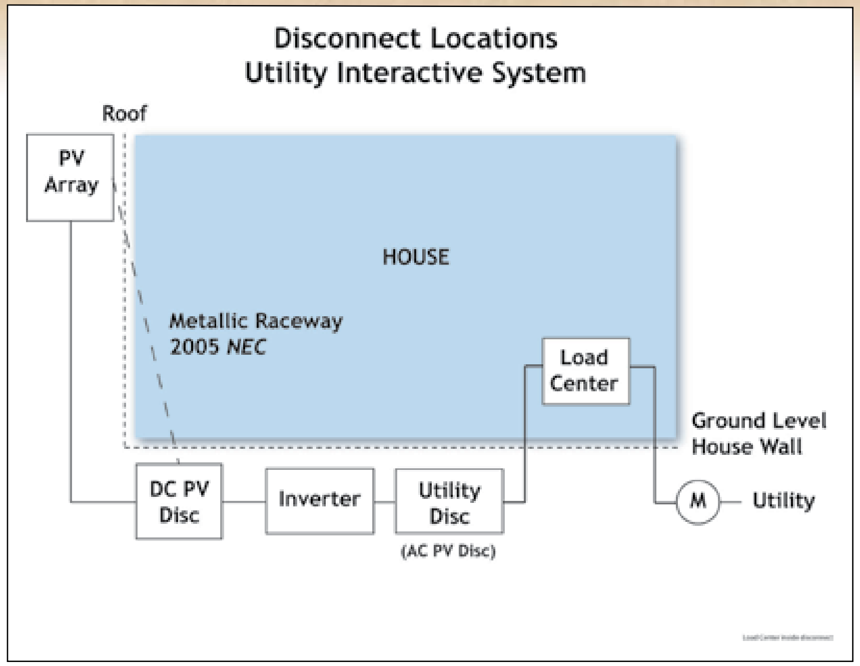

Figure 2. Main load center inside building

firmly established to install the PV disconnect in a readily accessible location at the point where the PV conductors first penetrate the structure. This requirement effectively keeps the energized PV conductors outside the structure until reaching that disconnect.

The *NEC* does not specify whether the main ac service disconnect or the main dc PV disconnect is to be located inside or outside the structure at the point of penetration of these circuits. That is left to the local jurisdiction and the requirement for locating these disconnects varies throughout the country. Figure 1 shows the simplest configuration of a utility-interactive PV system where the local jurisdiction requires all disconnects to be on the outside of the building, the ac load center is mounted on the outside of the building, and the inverter is also mounted on the outside of the building. This meets the K.I.S.S. principle.

An addition to the *2005 NEC* [690.31(E)] allows the PV source and output conductors to be routed inside the building (the dotted line in the figures) before they reach the main PV disconnect if they are installed in a metal raceway. Metal raceways include metal conduits and flexible metal conduit. Metallic cable assemblies are not allowed so the installations cannot yet use Type MC and Type AC cable assemblies—maybe in 2008?

In figure 2, the main load center is inside the building and this contains the backfed PV circuit breaker. Where the utility requires an external disconnect (usually lockable open), the utility may also allow this disconnect to be used as the grouped ac maintenance disconnect for the inverter. If the utility disconnect is not required or it cannot be used as a code-required maintenance disconnect, then a separate ac disconnect will have to be mounted in this circuit next to the inverter on the outside of the building.

In figure 3, the local jurisdiction requires that the main ac and dc power disconnects be located outside the building and the main load center containing this disconnect is also outside the building. For architectural reasons, the inverter is located inside the building. To provide for safe maintenance of the inverter, added dc and ac maintenance disconnects are needed inside the building on either side of the inverter.

While *lock-out tag-out* procedures might be used in an industrial environment to use just the external disconnects to de-energize the inverter safely, these procedures are not easily adapted in the residential or commercial environments.

Where batteries are located in a separate room or at some distance (typically, five feet or more) from the inverter and charge controllers, a disconnect is required at the battery location, and this disconnect is usually merged with an overcurrent protective device.

If a backup generator is used in the system, it is generally located outside the structure. A disconnect will be required at the generator and then again inside the building near the inverter or power distribution panel.

Contrary to the understanding of some inspectors, there is no requirement for a disconnect at the PV array [690.14(C)(5)]. Such a disconnect serves no safety purpose for the user or PV installer since the PV array is always energized when illuminated even if the disconnect were opened.

There are some PV installations, both residential (flat roofs) and commercial, where the inverters are mounted near the PV arrays on the roof in not-readily-accessible locations. *NEC* 690.14(D) addresses these systems and requires ac and dc disconnects at the inverters and an additional ac PV disconnect at ground level. Figure 4 shows this system where all of the equipment is outside the building.

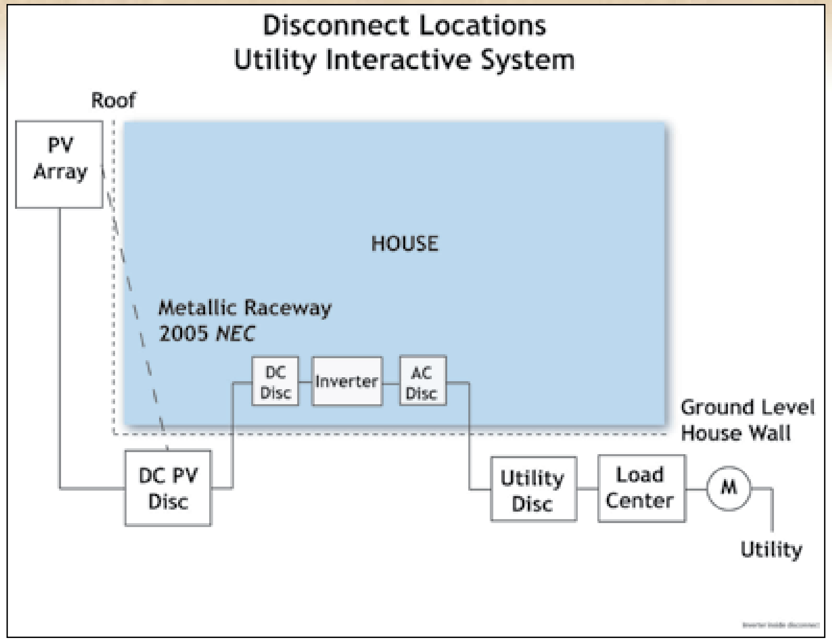

Figure 3. Inverter inside the building

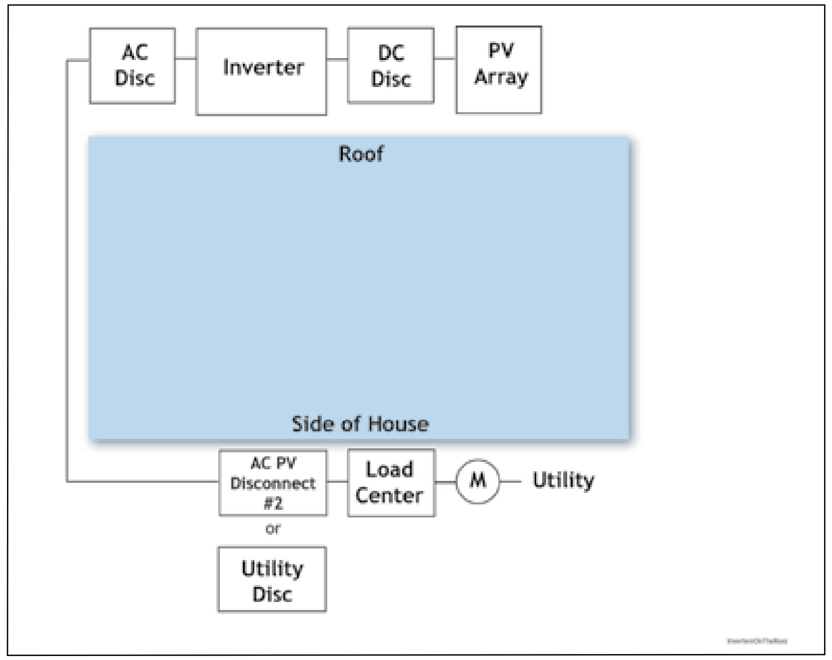

Figure 4. Inverters on the roof

For a discussion on the use of disconnects inside the inverter, see the "Perspectives on PV" in the September-October 2006 issue of *IAEI News*.

To disconnect or not to disconnect…

That is *not* the question. Disconnects are required throughout the PV system with the proper ratings and in the code-required places. As the system complexity increases with batteries, generators, and possibly wind or hydropower inputs, the number of disconnects increases. The basic disconnect requirements were in the *Code* long before PV systems arrived, and following those requirements as well as the newer requirements for PV systems will make for safe installations.

For Additional Information

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A color copy of the latest version of the 150-page, 2005 edition of the *Photovoltaic Power Systems and the National Electrical Code: Suggested Practices*, published by Sandia National Laboratories and written by the author, may be downloaded from this web site: http://www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/PVnecSugPract.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 40 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 SWTDI web site.

John Wiles works at the Southwest Technology Development Institute (SWTDI) at New Mexico State University. SWTDI 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 40+ proposals for Article 690 in the 2008 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.

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