Photovoltaic and 2005 NEC

Analysis of Changes

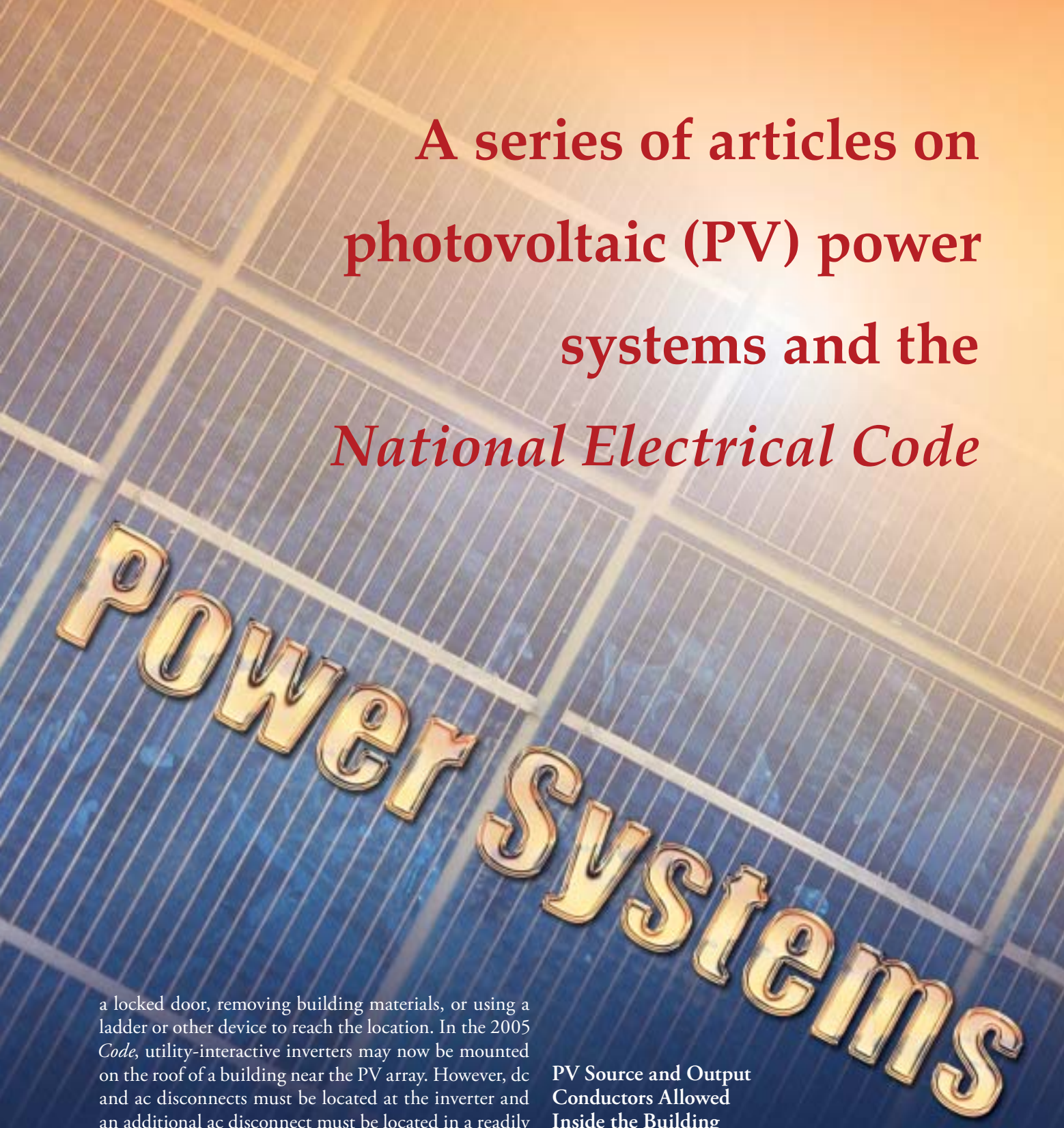
by John Wiles

The 2005 *NEC* has been published and Article 690 has some changes that will benefit the Photovoltaic (PV) Power Industry and electrical inspectors by making the *Code* easier to understand and by allowing modified installation procedures. As jurisdictions adopt the *Code* (some as early as January 1, 2005—others possibly not for years), the new requirements may be applied. These requirements and other significant changes will be covered in this article.

Optional Inverter Locations

The intent of the 2002 *NEC* was to have utility-interactive inverters mounted in readily accessible locations. However, these devices are relatively robust, require little maintenance, and generally are constructed with outdoor enclosures. Section 690.14(D), new to the 2005 *NEC*, allows utility-interactive inverters to be mounted in areas that are not readily accessible. A readily accessible area is one that can be approached without opening

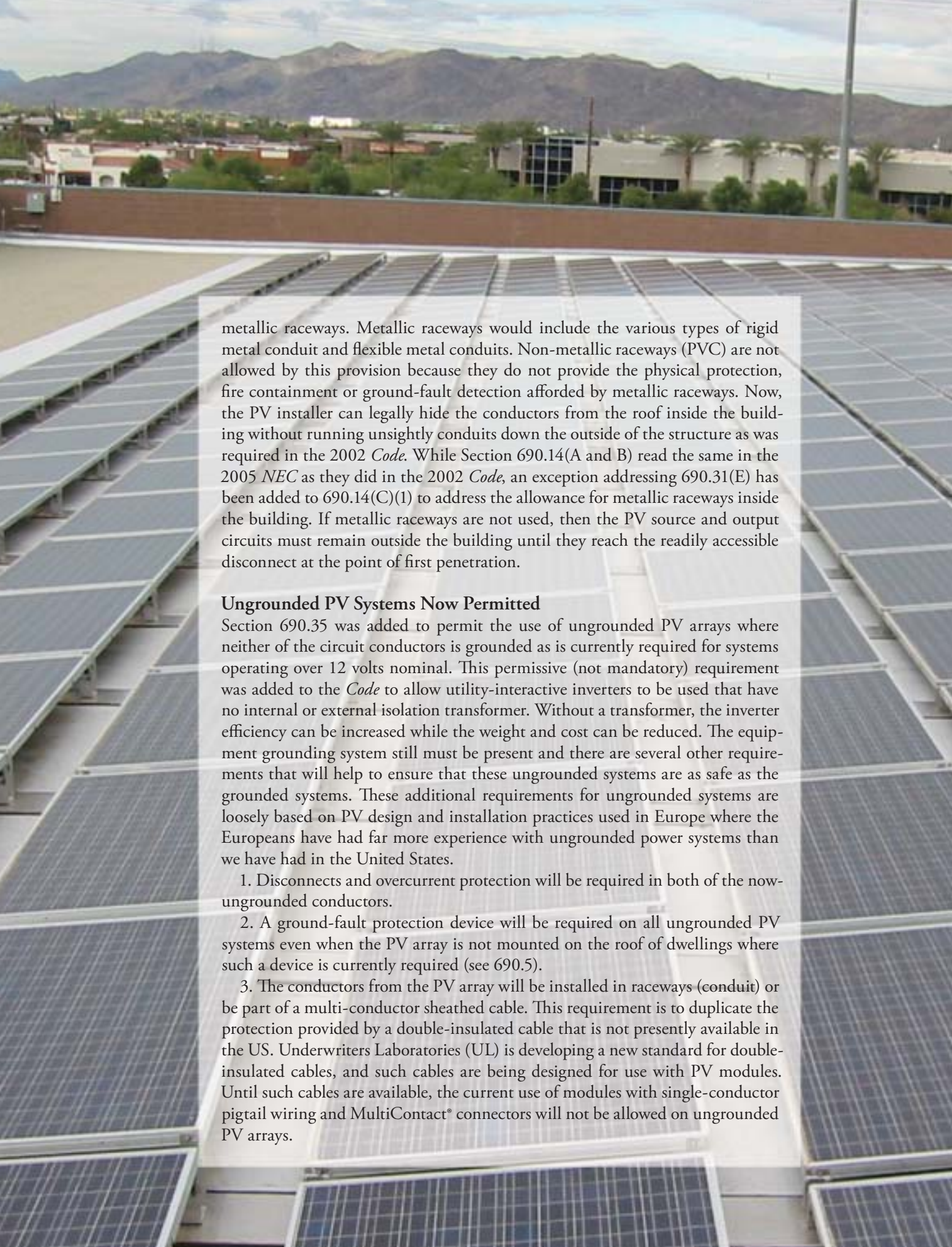
A series of articles on photovoltaic (PV) power systems and the *National Electrical Code*



a locked door, removing building materials, or using a ladder or other device to reach the location. In the 2005 *Code*, utility-interactive inverters may now be mounted on the roof of a building near the PV array. However, dc and ac disconnects must be located at the inverter and an additional ac disconnect must be located in a readily accessible location as required by 690.14(A)–(C), usually at ground level. These disconnects are *Code* requirements and may not satisfy any utility requirements for a readily accessible, visible-blade, lockable ac disconnect for the PV system. These disconnect requirements were covered in the article on PV systems in the March/April 2004 issue of the *IAEI News*.

PV Source and Output Conductors Allowed Inside the Building

Section 690.14 generally requires that PV source and output conductors remain outside a building until they reach a readily accessible disconnect at the point of first penetration. Section 690.31(E) now permits conductors from the PV array on the roof of a building to be run inside the building before reaching the first readily accessible disconnect if those conductors are installed in



metallic raceways. Metallic raceways would include the various types of rigid metal conduit and flexible metal conduits. Non-metallic raceways (PVC) are not allowed by this provision because they do not provide the physical protection, fire containment or ground-fault detection afforded by metallic raceways. Now, the PV installer can legally hide the conductors from the roof inside the building without running unsightly conduits down the outside of the structure as was required in the 2002 *Code*. While Section 690.14(A and B) read the same in the 2005 *NEC* as they did in the 2002 *Code*, an exception addressing 690.31(E) has been added to 690.14(C)(1) to address the allowance for metallic raceways inside the building. If metallic raceways are not used, then the PV source and output circuits must remain outside the building until they reach the readily accessible disconnect at the point of first penetration.

Ungrounded PV Systems Now Permitted

Section 690.35 was added to permit the use of ungrounded PV arrays where neither of the circuit conductors is grounded as is currently required for systems operating over 12 volts nominal. This permissive (not mandatory) requirement was added to the *Code* to allow utility-interactive inverters to be used that have no internal or external isolation transformer. Without a transformer, the inverter efficiency can be increased while the weight and cost can be reduced. The equipment grounding system still must be present and there are several other requirements that will help to ensure that these ungrounded systems are as safe as the grounded systems. These additional requirements for ungrounded systems are loosely based on PV design and installation practices used in Europe where the Europeans have had far more experience with ungrounded power systems than we have had in the United States.

1. Disconnects and overcurrent protection will be required in both of the now-ungrounded conductors.

2. A ground-fault protection device will be required on all ungrounded PV systems even when the PV array is not mounted on the roof of dwellings where such a device is currently required (see 690.5).

3. The conductors from the PV array will be installed in raceways (conduit) or be part of a multi-conductor sheathed cable. This requirement is to duplicate the protection provided by a double-insulated cable that is not presently available in the US. Underwriters Laboratories (UL) is developing a new standard for double-insulated cables, and such cables are being designed for use with PV modules. Until such cables are available, the current use of modules with single-conductor pigtail wiring and MultiContact® connectors will not be allowed on ungrounded PV arrays.

4. Because many people think that ungrounded PV systems are inherently safer than grounded systems, a warning label will be required at all points where the ungrounded conductors are terminated. Labels with the following warning will have to be attached by the installer at points like junction boxes and disconnects where the conductors are attached to terminals that may require service.

WARNING
ELECTRIC SHOCK HAZARD. THE DIRECT CURRENT CIRCUIT CONDUCTORS OF THIS PHOTOVOLTAIC POWER SYSTEM ARE UNGROUNDED BUT MAY BE ENERGIZED WITH RESPECT TO GROUND DUE TO LEAKAGE PATHS AND/OR GROUND FAULTS.

5. Inverters or charge controllers used in ungrounded systems must be specifically listed for that purpose by Underwriters Laboratories or other acceptable testing and listing agencies like ETL or CSA.

Installers and inspectors should note that most of the currently-available PV equipment intended for use on 12 to 48-volt PV systems is designed to be used only on grounded PV systems and would generally not meet the requirements listed above for ungrounded PV systems. This equipment frequently has overcurrent devices and disconnects installed in only one of the current-carrying conductors and the other current-carrying conductors are frequently connected to a common bus without overcurrent protection. Also, most 12 to 48-volt PV systems will continue to use inverters that have transformers to obtain the necessary 120-volt ac output voltage from the lower dc input voltage.

Grounding System Clarifications

Section 690.47(C) clarifies the requirements for grounding systems that have both ac and dc grounding requirements. Typically, all PV systems with inverters must have both the ac and the dc side of the system grounded since the internal transformer in the inverter isolates the dc grounded conductor from the ac grounded conductor. The inverter essentially creates a separately derived dc system when this isolation is considered. Normally the ac part of the PV system is grounded at the ac service disconnect (utility-interactive systems) or the ac load center (stand-alone systems) and is accomplished by the existing ac system. The *Code* allows the dc grounding electrode conductor to be routed to one or two locations: (1) to a dc grounding electrode which then must be bonded to the ac grounding electrode, or (2) directly to the ac grounding electrode where it is connected to that electrode with a separate clamp. The size of the grounding electrode conductor is determined by 250.66 (ac) and 250.166 (dc), and a bonding conductor, when used, must be sized the larger of the two. See the "Perspectives on PV" in the September/October issue of the *IAEI News* for additional details on grounding.

Backfed Breakers May Not Need To Be Clamped

The addition of Section 690.64(B)(5) takes precedence over the code requirement [in Section 408.16(F)] that all backfed circuit breakers must be clamped to the internal busbar. This revision does not require that backfed circuit breakers be clamped to the internal load center busbar where they are connected to a listed utility-interactive inverter and where all circuit breakers in the panel are secured with a front panel. Installers (and inspectors) were having a great deal of difficulty in finding load centers that had provisions for clamping backfed breakers that were not in the main breaker position. Since a backfed breaker connected to a utility-interactive inverter immediately goes dead when unplugged, the dangers associated with such breakers connected to a rotating generator (which may stay energized) do not exist. Furthermore, if an unqualified person uses a "tool" to remove the cover from a load center (thereby allowing any breaker to be removed), the main lug or main breaker terminals and the exposed bus bars may present greater hazards than an unplugged backfed breaker.

Section 690.72(B)(2)(2) clarified the requirements of diversion loads in relation to diversion charge controllers in systems with batteries. The current rating of the load must be equal to or less than the current rating of the controller (a technical requirement), the voltage rating of the diversion load must be greater than the maximum battery voltage, and the diversion load must have a power rating of 150 percent of the power rating of the PV array. These modified requirements allow the PV system designer to properly specify a diversion load that is consistent with the requirements of the diversion load controller while maintaining the required safety margins for the system.

Summary

These are the major changes for the 2005 *NEC*. It is unfortunate that some large PV markets, like California, will not immediately adopt the 2005 *NEC*. Inspectors in those regions are encouraged to review the changes in the Article 690 for 2005, and apply them judiciously

where appropriate. I encourage all PV systems designers and installers to get a copy of the 2005 *NEC* and better yet the 2005 *NEC Handbook* that has significantly expanded comments on the intent of the *Code* requirements.

The PV Industry Forum has already started formulating proposals for the 2008 *NEC* and they must be finalized before the end of November 2005. Send me your comments and suggestions on PV safety for the 2008 *NEC* and I will ensure they get the thorough review they deserve.

Inspector comments and suggestions for changes to Article 690 are particularly welcome. The "best" PV systems (safest, most durable, most reliable, highest performing) have usually resulted from a close collaboration between the PV designer, the code–familiar installer, and the electrical inspector.

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: 505-646-6105

A PV Systems Inspector/Installer Checklist will be sent via e-mail to those requesting it. A copy of the 100-page Photovoltaic Power Systems and the National Electrical *Code*: Suggested Practices, published by Sandia National Laboratories and written by the author, will be sent at no charge to those requesting a copy with their address by e-mail. The Southwest Technology Development web site (http://www.nmsu.edu/~tdi) maintains all copies of the "*Code* Corner Columns" written by the author and published in *Home Power Magazine* over the last ten years.

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.

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 30 proposals for Article 690 in the 2005 NEC. *He provides draft comments to NFPA for Article 690 in the* NEC *Handbook. As an old solar pioneer, he lives 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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