Code Changes through the Years

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The *National Electrical Code* is the most comprehensive electrical code in the world and the most widely adopted code in the United States. Its use has resulted in generally safe and hazard-free electrical systems in the United States for 110 years. As electrical power systems, photovoltaic installations fell under *NEC* requirements from their very inception, although it wasn't until 1984 that additions to the code specifically addressed this technology.

Making Solar Electricity Safer

In the mid-1970s, Atlantic Richfield Company (Arco) and a few other companies started producing PV modules for use here on Earth. Previous to this, PV technology had been so expensive that NASA was one of the few organizations that could afford it, and they used it primarily to power satellites for communications and space investigations.

Many of the first "terrestrial" PV modules were for off-grid applications used by people in the back-to-the-land movement and for remote agricultural applications. The telecommunications and railroad industries also were early adopters of PV technology. They were interested in getting power to mountaintop repeater stations and remote railroad signals without having to deliver propane to run generators.

When the California rebate programs started in 1998, PV had recently moved onto the grid with the utility-interactive systems. Now, more than 95 percent of the PV systems being installed in the United States are utility-interactive systems. But code changes over these several decades have continued to address both off-grid and on-grid systems.

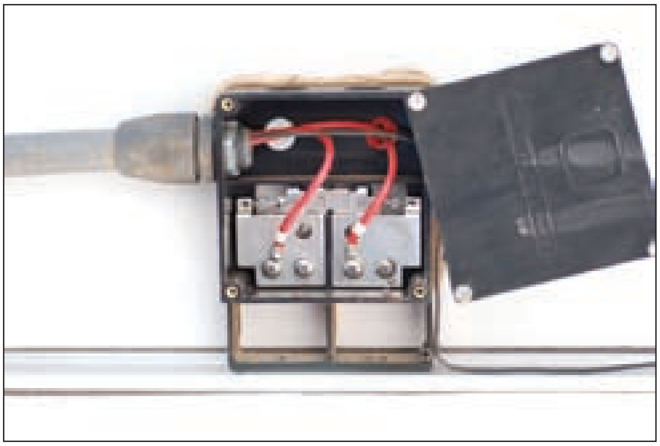
Small Changes, Bigger Results

In 1984, Article 690 was added to the *NEC* to deal specifically with PV systems. At that time, PV modules by Arco and others had single terminals for positive and negative outputs on opposite ends of the modules, a configuration that seemed to require single-conductor, exposed cables to be used. The PV industry had successfully argued that it would be a waste of money to run two-conductor jacketed cables or conduit to these widely spaced terminals (despite the fact that copper cables were relatively inexpensive then, compared to today's prices). Section 690.31 in the *1984 NEC* allowed single-conductor exposed cables to be used in PV systems. There are no other sections of the *NEC* that expressly allow exposed conductors operating up to 600 volts in the residential environment. Electrical connections that are easily pulled apart and single, exposed conductors that are readily accessible are viewed as dangerous shock hazards. As the number of installed systems operating at these voltages has greatly increased in recent years, the danger has become more widespread. The *2008 NEC* may begin to place restrictions on using these types of cables with PV.

New connections. In those early years, although the majority of PV installations were off grid, the early PV code requirements in Article 690 were written for utility-interactive systems. In the 1980s, the U.S. Department of Energy, which sponsored code-writing activities, believed that rooftop, building-integrated, utility-interactive PV systems were the future. They were right—but just 25 years early.

Over the years, due to pressure from the *NEC*, the PV industry added junction boxes and covers to limit access to module terminals, and also designed boxes that could accept conduit. Today, the majority of PV modules have factory-attached cables with Multi-Contact connectors at their ends. This easily connected wiring method makes for a time- and cost-saving installation (no conduit/no terminals), but does not necessarily result in a more robust, long-lasting installation. Direct module-to-module connections with cables protected by a raceway, such as conduit, has proved to be a very durable and safe wiring method, not only in PV systems, but in numerous other outdoor electrical systems.

Obsolete: Single exposed (top) and boxed (bottom) terminals at opposite ends of the PV module.



No longer common, but perhaps preferable: Direct wiring in conduit.

The current standard: Multi-Contact (MC) connectors.

Ground-fault, anti-fire devices. In early 1984, while the *1987 Code* was being formulated, two engineers (also journeymen electricians) from Sandia National Laboratories made a presentation to the code-makers at NFPA, showing pictures of a ground-faulted PV system in which a module had caught fire. They failed to mention that the module was an unlisted, early release, thin-film module that was never produced in any great quantities. But already on alert for anything that might pose a fire risk, the NFPA immediately called foul, worrying that electrical fires in residential attics caused by ground-faults in PV systems would be very difficult to extinguish. The PV industry was "directed" to add Section 690.5 in the *1987 NEC* requiring a ground-fault, anti-fire device in PV systems that are mounted on the roofs of dwellings. The *2008 NEC* will take this one step further and require these ground-fault protection devices on *all* PV systems, no matter where they are located. The additional requirement will be added to deal with circulating ground-fault currents that can be larger than expected and that can continue to circulate unless interrupted by the ground-fault device.

Rerouting output conductors. Through the 1980s and '90s, many off-grid PV systems still were not being inspected, nor were many "newfangled" utility-interactive PV systems. Most off-grid PV systems were out of the reach of mainstream inspection organizations, and many of the earliest utility-interactive systems were unpermitted "guerrilla" installations and, therefore, not on inspectors' radars.

From 1984 through 2001, although Section 690.14 in the *NEC* referred installers and inspectors to Article 230 for the location of the PV DC disconnect switch, most PV installers were unfamiliar with that section since it applied to AC service entrance wiring, which they did not typically deal with. The result was that, for rooftop-mounted systems, most installers ran the output conductors from the PV array through the roof at a convenient point near the array, into the attic, and then through the house to a disconnect device in any location that was most convenient. However, these conductors, which are always energized when the PV array is illuminated, pose fire hazards in attics and walls, and shock hazards for the unwary home owner who might drive a nail through them.

Inspectors, who were very familiar with Article 230 of the *NEC*, were unhappy with this unsafe practice, and sent so many complaints to the NFPA that the code writers rewrote Section 690.14 in the *2002 NEC*. This section now requires that PV source and output conductors be routed outside the house until the conductors reach the DC PV disconnect, and that the disconnect be located in a readily accessible location. Three years later, the *2005 NEC* made an allowance for using metal conduit for routing these DC PV conductors through the attic and the house. However, stay tuned—fire departments may have the last word about using these energized conductors inside the house. Even in metal conduit, these always-energized circuits (frequently hidden in walls and insulation) present a potential shock and additional fire hazard as they can be accidentally cut with the power tools used by firefighters putting out a house fire.

Grid-synchronous inverters integral to the module.

AC PV modules. In the *2002 NEC*, a new section was added and several others modified to address the introduction of new AC PV modules. These small "PV systems" consisted of a PV module (or in one case, two modules) with a utility-interactive inverter bonded directly to the back of the module. When connected according to the code requirements to a 120 VAC circuit, they were a relatively inexpensive way to get a small PV system up and running. Although a couple of brands were available, they were limited in production and are no longer available. However, there are some new AC module products that could hit the market soon.

On the horizon. The *2005 NEC* was modified to allow the use of ungrounded PV arrays and transformerless inverters in PV systems. Without a heavy and expensive transformer, these inverters are especially appealing, and have already become popular in Europe.

Through the Ages

An involved and proactive PV industry provides constant improvements and updates for each new edition of the *NEC*, ensuring that definitions are modified and added, and refining, expanding, and even deleting requirements as PV systems and equipment evolve. The result is that PV systems are becoming safer, more durable, and more reliable. And the *NEC* will help guarantee that, over their lifetimes, PV systems will achieve the maximum potential possible toward a renewable energy future for the country.

Other Questions or Comments?

If you have questions about the *NEC* or the implementation of PV systems that follow the requirements of the *NEC*, feel free to call, fax, e-mail, or write me at the location below. See the SWTDI Web site (below) for more detailed articles on these subjects. The U.S. Department of Energy sponsors my activities in this area as a support function to the PV industry under Contract DE-FC 36-05-G015149.

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