Changing Codes

& Grid Connection

by John Wiles

The final connection between a utility-interactive photovoltaic (PV) system and the electrical utility grid is an area of importance to PV system designers and installers. Due to the varying sizes of PV systems and configurations of existing service-entrance equipment, these connections vary significantly among PV systems. Differences in Section 690.64 of the 2005 and 2008 editions of the *National Electrical Code (NEC)* make these variations even more complex.

Load-Side Connections

Section 690.64(B) establishes the load side (of the main service disconnect) connection requirements for the utility-interactive inverter output. The key to understanding this section is to carefully read 690.64(B)(2) and note that the ratings of overcurrent devices *supplying* a bus bar or conductor must be added so that the sum of these ratings does not exceed the rating of the bus bar or conductor. The ratings of overcurrent devices supplying loads are *not* counted. Also note that the overcurrent device (normally a circuit breaker) *rating* is used in this calculation—*not* the current flowing through the circuit. Overcurrent devices to be counted are the main breaker and all breakers backfed from utility-interactive PV inverters. This equation expresses this ratings requirement:

PV + Main ≤ Bus or Conductor

In the *2005 NEC*, this requirement applies only to commercial (nonresidential) PV installations. Here's an example: Say the site has a 400 A main service panel with a 400 A main breaker. In this case, no PV can be added to the panel. In many commercial installations, this limitation forces the installer to use a supply-side connection (see "Supply-Side Connections" section).

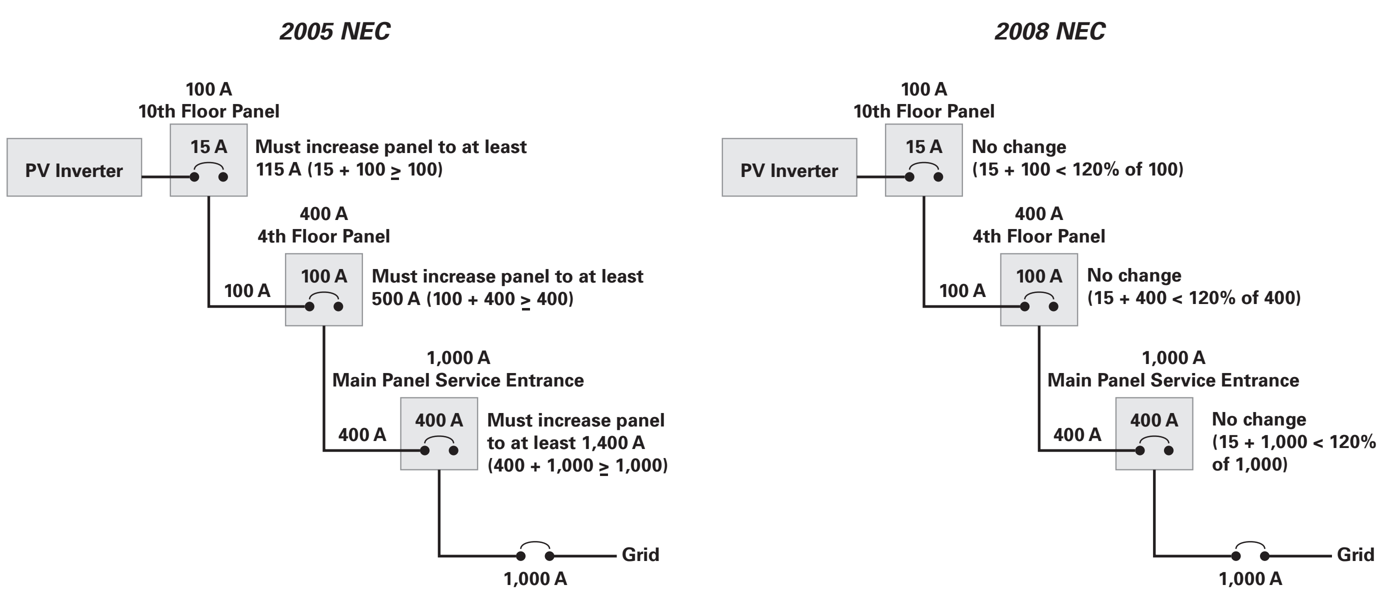
For residential installations, a 120% allowance is included. This exception makes installations somewhat easier:

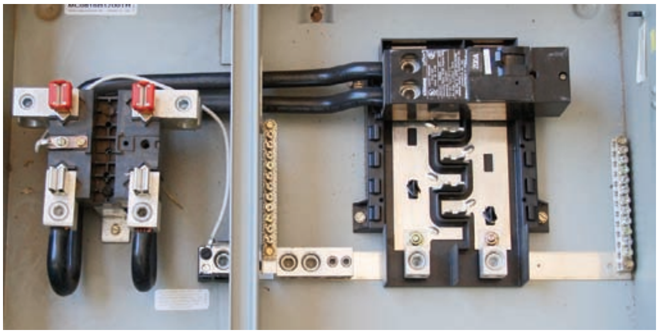
PV + Main ≤ 120% Bus or 120% Conductor

In this residential example, a 200 A mains panel with a 200 A main breaker could have up to 40 A of backfed PV breakers connected.

Section 690.64 was rewritten in the *2008 NEC* to apply the 120% allowance to commercial installations—but only

Requirements for Commercial Grid-Tied PV Systems





Combined meter/load centers can only be tapped with permission and instructions supplied by the manufacturers.

if PV backfed breakers are mounted at the opposite end of the bus from the main breaker or feeder (Section 690.64(B)(7)). Locating breakers in this fashion prevents overloading the bus bar. If this requirement cannot be met, then the sum of the breakers will be limited to no more than the bus bar rating on commercial installations—the same as the *2005 NEC* requirement. The requirements apply to both the bus bars in a panel or load center *and* to any conductor that is fed by overcurrent devices from multiple sources. The 120% allowance remains in effect for residential installations in the *2008 NEC*.

In the illustration (opposite page), the *2005 NEC* requirements are applied to a multistory building with a PV system that requires a 15 A circuit breaker in a 100 A main lug panel on the tenth floor. This panel is fed through a 100 A breaker in a 400 A main lug panel on the fourth floor. This, in turn, is fed by a 400 A circuit breaker in the 1,000 A main distribution panel that has a 1,000 A main disconnect.

Since this is a load-side connection, 690.64(B) applies to each panel board and conductor supplied through an overcurrent device from multiple sources. To meet the requirement in the top floor's panel, it would have to be replaced with at least a 115 A panel. The feeder between the 100 A panel and the 100 A breaker would also be required to have an ampacity of at least 115 A. If that top floor panel had a 100 A main breaker (instead of a lug connection), then the feeder would need to be rated at 200 amps, since the sum of the circuit breaker ratings attached to this conductor would be 200 A (100 A breaker from the tenth floor panel + 100 A breaker from the fourth floor panel), to meet the 690.64(B)(2) equation.

At the fourth floor panel, the sum of the rating of the breakers is 100 + 400 = 500, which exceeds the panel rating of 400 amps. The panel would have to be replaced with one rated at 500 amps or more. The feeder between the fourth floor panel and the main panel would also have to be rated at 500 amps with a main lug panel. If that fourth floor panel had a 400 A main breaker, then the feeder would be required to be rated for 800 A. Now look at that 1,000 A main service panel. The sum of the rating of breakers supply is 1,400 (400 + 1,000), which is significantly larger than the 1,000 A panel rating. The existing panel needs to be replaced with at least a 1,400 A rated panel.

These requirements were established with the concept that they would help protect those buses and conductors from overloads even when the PV system was expanded, the electrical panels had excessive loads placed on them, or when the feeders were unknowingly tapped.

Under the *2008 NEC* requirements, the 120% allowance is permissible by 690.64(B)(2). In this case, the 100 A panel on the top floor is allowable because 100 + 15 = 115, which is less than the allowed 120 amps. The same equation applies to the cable when the top floor panel is a main lug panel and the feeder does not need to be changed. If the top floor panel had a 100 A main breaker, then the equation for the feeder conductors would still be 15 + 100 = 115 ≤ 120 A, and the conductor would remain unchanged. Under 690.64(B)(2) of the *2008 NEC*, only the first overcurrent device connected to the inverter output is required to be counted in subsequent equations.

At the fourth floor 400 A panel, the allowance would be 480 A (120% of 400 = 480), but the additional rule in 690.64(B)(2) requires that only the first overcurrent device connected to the inverter output be counted for subsequent equations for the first and subsequent panel boards. The equation becomes 15 + 400 ≤ 480 and no changes in the panel are required. With a main lug 400 A panel, the same equation applies to the feeder and to the main panel. Also, even if a 400 A main breaker were installed in that 400 A panel, then the cable ampacity would not need to be changed.

Even with the allowances in the *2008 NEC* for load-side connections, many systems are large enough to exceed the 120% allowance, resulting in replacing existing load centers and feeders—a costly upgrade. To avoid this scenario, installers may utilize supply-side connections, which are allowed by 690.64(A) with no changes between the *2005 NEC* and *2008 NEC* editions.

Supply-Side Connections

The supply-side connection (690.64(A)) is essentially a second service entrance on the facility that is connected on the load side of the existing meter to allow for net metering. (See "Code Corner" in *HP111* and *112* for more details on supply-side connections.)

The Section 240.21 tap rules don't apply to these service-conductor taps; these requirements were developed for a circuit with currents flowing one way from a single source protected by a single overcurrent device. The service entrance tap with a utility-interactive PV inverter may have currents flowing in *both* directions from *two* sources, with one of them (the utility) having very limited overcurrent protection.

A main-lug-only panel, with no single main breaker. Use an empty breaker position for PV system input.

Actually making the tap will depend on the type of equipment involved. Many load centers do not have adequate space to splice to the incoming service conductors. The same holds true for the limited space in meter socket enclosures. In these cases, the supply-side tap will require that a new enclosure be added between the meter and the existing load center.

Combined meter/load centers can only be tapped with permission and instructions supplied by the manufacturers. The cables and bus bars may be exposed with plenty of room for the tap, but in most cases, the manufacturer will not allow tapping because this would violate the UL listing on the device. Instead, adding a supply-side tap to this type of installation may require adding a new external meter socket and a tap enclosure before the existing meter. The existing meter is bypassed with an appropriate set of jumper bars.

Some dwellings have main-lug-only panels. There is no single main breaker feeding the panel, but up to six main breakers are allowed. Empty breaker positions can be used as supply-side connections. The basic restriction (which will be in the *2011 NEC*) that would apply to this type of main service panel is that the sum of the overcurrent devices from the PV inverter(s) should not exceed the rating of the panel bus bar or the rating of the service entrance cables.

Connections from a PV system to the utility are still somewhat complex. However, the requirements in the *2008 NEC* have allowed smaller systems to be more easily connected in the commercial environment. In either residential or commercial PV installations, the requirements of the code should be studied in some detail to ensure a safe and durable system.

Access

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Photovoltaic Power Systems and the 2005 National Electrical Code: Suggested Practices by John Wiles • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/PVnecSugPract.html

PV Systems Inspector/Installer Checklist & previous "Code Corner" articles • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html