10 keys *to* PASSING INSPECTION

For PV Installers, EPCs and Solar Business Owners

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installation CHALLENGES

Every PV installation presents challenges. One of those is passing inspection. We've put together this guide to help you better understand changing NEC codes and save time and money on every project.

Keep in mind that you should consult with your local inspectors to understand how codes are interpreted in your region.

#1 DC Cabling

Let's start with the infrastructure that carries solar energy from panels to people.

Understanding the system should be easy. To make that happen, PV source, output and inverter circuits must be identified at all points of termination, connection and splices.

DC CABLING REGULATIONS

- DC (>30 volts) wire must be "not readily accessible" or in conduit
- When routed inside a building, cables must be in metal raceway or metal-clad (MC) cable
- Raceways must be labeled "WARNING: Photovoltaic Power Source"

TIP

The wire color code for 2014 is:

Red = Positive
Black = Negative
White or Grey = Grounded

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#2 DC Voltage

You do a lot of math when you work with solar installations.

For example, the NEC requires you to calculate "derating" and correction factors, since the environment affects how they perform.

Why? You need to ensure that systems operate as designed and are safe for first responders, and that inverters don't go into an overvoltage fault mode and shut down.

DERATING CODE STEPS

- ✓ Calculate correct Voc (voltage open circuit) for coldest expected ambient temperature
- ✓ Check Voc at warmest expected ambient temperature to verify inverter operation (not code requirement)
- ✓ Ensure that all equipment is rated for corrected maximum voltage, including:
  - Cables
  - Disconnects
  - Overcurrent Devices

TIP

Remember, at lower temperatures, PV modules' voltage increases; at higher temperatures, PV modules' voltage falls.

ACTIVITY

Let's work through the formula relevant to 690.7, assuming a PV system with 13 modules in a string and Open Circuit Voltage of 36.9 V. The system is located in Minnesota, with a coldest expected ambient temperature of -16°C.

You have two options:

1. Use NEC Table 690
2. Use manufacturer's information, the preferred calculation.

CALCULATING DERATING

Option 1:

36.9 volts
(Open circuit voltage Voc)
X 1.18 (from Table 690)
= 43.54 volts

43.54 volts X 13 modules
= 566.02 volts

Option 2:

25°C (standard test conditions)
- (-16°C (avg. cold ambient temp)) = 41°C

41 X .36% (temperature coefficient Voc)
= 14.76% (△increase by +14.76%)

36.9 volts (open circuit voltage Voc)
X 1.1476 = 42.35 volts
42.35 volts X 13 modules = 550.55 volts

ELECTRICAL CHARACTERISTICS

Maximum Power (Pmax)*	230W
Tolerance of Pmax	+10% / -5%
Type of Cell	Polycrystalline silicon
Cell Configuration	60 in series
Open Circuit Voltage (Voc)	36.9 V
Maximum Power Voltage (Vpm)	29.3 V
Short Circuit Current (Isc)	8.45 A
Maximum Power Current (Ipm)	7.85 A
Module Efficiency (%)	14.1%
Maximum System (DC) Voltage	600 V
Series Fuse Rating	15 A
NOCT	47.5°C
Temperature Coefficient (Pmax)	-0.485% / °C
Temperature Coefficient (Voc)	-0.36% / °C
Temperature Coefficient (Isc)	-0.053% / °C

*Illumination of 1kW/m2 (1 sun) at special distribution of AM 1.5 (ASTM E892 global spectral irradiance) at a cell temperature of 25 °C

TIP

The standard test conditions (25°C) are fixed so solar panels can be accurately compared and rated against each other.

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690.8 (wires);
690.9 (OCPD)
(2014)

#3 DC Ampacity

NEC 690.8 is written to specify PV circuit sizing and current calculations. The results are the maximum PV source-circuit current that the “home runs” carry.

690.9 deals with proper location and sizing of the overcurrent protection device (OCPD or fuse).

DC AMPACITY CODE STEPS

- ✓ Multiply Isc X 1.25 for “edge of cloud” effect (690.8(A))
- ✓ Multiply (A) X 1.25 for continuous operations rating (690.8(B))
- ✓ Wiring sized at larger of:
  (A) or
  (B) Total incluing conditions of use
- ✓ OCPD sized using (B); round up to next standard size

TIP

There are two steps. First, calculate the edge of cloud effect along with the adjustment for continuous operation; second, use the result to size the fuse.

ACTIVITY

Now, let's work through the math relevant to 690.8.

With this calculation, you determine the conductor ampacity (ampere capacity), so you can select the right overcurrent protective devices.

CALCULATING DC AMPACITY

Step 1: Calculate edge of cloud effect:

Multiply 8.45 A (short circuit current Isc) X 1.25 (125% possible surge) = 10.61 Amps

Step 2: Factor in continuous operation:

10.61 Amps X 1.25 (125% possible surge) = 13.26 Amps

15 Amp fuse is correct, when you round up.

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*Illumination of 1kW/m2 (1 sun) at special distribution of AM 1.5 (ASTM E892 global spectral irradiance) at a cell temperature of 25 °C

TIP

Keep in mind that 690.8 (B)(1) references Table 310.15(B)(16), which has multiple columns of allowable ampacity, arranged according to the conductor's insulation temperature rating and wire type.

690.8 (wires)

#4 AC Ampacity

Solar panels produce DC but the house and the grid use AC – you need to be able to understand both so you can “keep the lights on” and feed energy back into the grid.

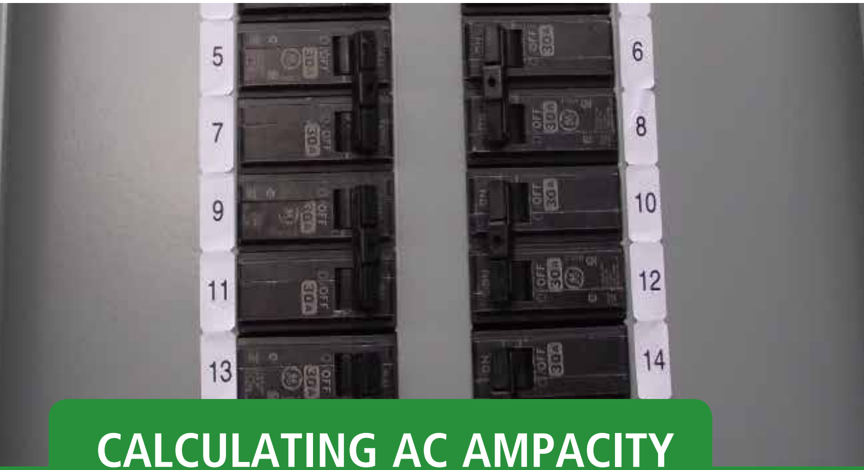
AC ampacity is based on inverter continuous output current rating from nameplate on the panel box.

- Determine whether the panel you have will pass inspection is a straight ahead calculation
- Be sure to locate backfed breakers at opposite end of panel at interconnection point
- Backfed breakers of systems that can operate as stand-alone must be secured
- Be sure to verify compliance with interconnection requirements, Art. 705.12

TIP

The rated output current is usually specified in the manual but it can be calculated by dividing the rated power by the nominal AC voltage.

690.8,
690.10(E) (panel)



CALCULATING AC AMPACITY

Service panel calculation:

1 X 20 Amp OCPD = 20 Amps

200 Amp main + 20 Amps = 220 Amps

Busbar calculation:

200 Amp busbar X 120% = 240 Amps

If the total:

✓ Does not exceed 100% of service size

✓ Does not exceed 120% of busbar rating

= **The panel is acceptable!**

TIP

2014 Code added more options for sizing of the panel when backfed breakers are added from an inverter.

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690.5

#5 Ground Fault Protection

Safety – that's what drives ground fault protection regulations.

In the latest code revision, any exceptions to 690.5 have been eliminated to protect anyone coming in contact with the system from shocks, and cut the risk from lightning or other power surges.

CODE CHANGES IN NEC 2014

- All grounded PV systems must have ground fault protection
- Ungrounded systems must also have ground fault protection or other system that meets the requirements in 690.35
- Labels are required at the location of the ground-fault indicator or on the inverter

690.11

#6 Arc Fault Circuit Protection

Where there's power, there's potential for fire. Arc fault protection helps prevent grass fires when you are using ground-mounted panels, and building fires with roof-top installations.

TIP

In NEC 2014, arc fault circuit protection requirements were expanded to all PV systems with a maximum system voltage ≥80 Vdc, regardless of location.

CODE CHANGES IN NEC 2014

- DC PV systems operating at greater than 80 volts must have listed AFCI DC protection

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#7 Rapid System Shutdown

690.12 is written to make sure that first responders can shut down solar systems when seconds count.

According to John Wiles, Senior Research Engineer at the Southwest Technology Development Institute, "The rapid shutdown requirements in 690.12 will have significant and far-reaching impacts on PV system designs and the design of PV equipment."*

PHOTOVOLTAIC SYSTEM EQUIPPED WITH RAPID SHUTDOWN

CODE CHANGES IN NEC 2014

- ✔ A rapid system shutdown mechanism is required on all PV systems installed on buildings with DC conductors more than 5 feet inside a building or more than 10 feet from the array
- ✔ Identification needs to include a reflective label

* http://solarprofessional.com/articles/design-installation/understanding-the-nec-2014-and-its-impact-on-pv-systems/page/0/4

TIP

Pending changes to 690.12 will require labels for a PV system component that shuts down the array, all conductors leaving the array and shutdown conductors leaving the array.

#8 Listing

You can't work effectively with the installation unless you know precisely what equipment is involved.

690.4 requires that all the equipment that comprises the system is listed and labeled, whether powering a single building, multiple buildings or other structures, such as a pole for security lighting.

CODE CHANGES IN NEC 2014

- Equipment for use in PV power systems shall be identified and listed, including:
  - Inverters
  - Photovoltaic panels
  - Charge controllers
  - Motor generators
  - Combiners
  - Etc.
- All Nationally Recognized Testing Labs (NRTLs) must test to UL Standards

WARNING: PHOTOVOLTAIC POWER SOURCE

TIP

Refer to www.UL.com for information on UL testing standards. See www.OSHA.gov for a current list of all NRTLs.

#9 Equipment Grounding

All electrical equipment is to be grounded by means of direct attachment to an equipment grounding conductor which is recognized by Section 250.118.

Fortunately, there are many options for getting that done, including using a bonding device instead of connecting all the panels together with heavy gauge bare copper wire – which is time-consuming and more expensive.

CODE CHANGES IN NEC 2014

- Exposed non-current-carrying metal parts of PV module frames, electrical equipment, and conductor enclosures shall be grounded
- Structure (racking) can be used for grounding if listed with the brand of modules used
- Devices used for equipment grounding must be listed, per 690.4.
- If the equipment grounding conductor is smaller than #6 (and you are not using a bonding device), it must be protected according to 250.120(C)

TIP

You can size equipment grounding conductors using Table 250.122. In no case can the EGC be sized smaller than a 14 AWG conductor.

690.47

#10 Grounding Electrode System

Bill Brooks, solar consultant and a member of the Code Making Panel 4 for the National Electrical Code, Article 690, clearly sums up the basis for 690.47:

*"An electrode in the vicinity of the array provides a short path to ground in the event of a lightning strike. Second, it provides a low resistance path to ground and offers additional protection for people should they come in contact with a module frame that might be inadvertently energized by a failed wiring system or damaged module."**

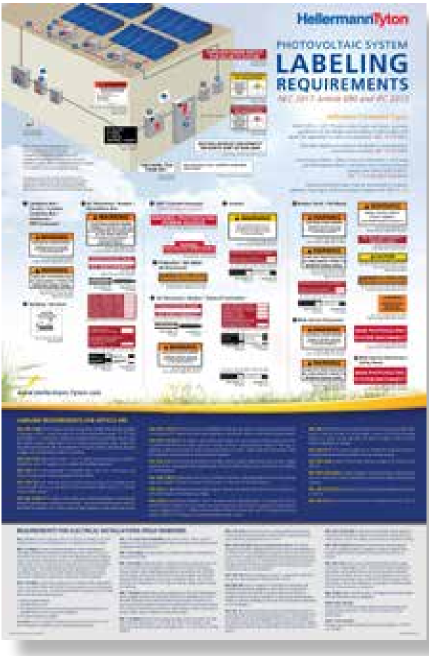
CODE CHANGES IN NEC 2014

- ✓ An AC system must have a grounding electrode system (250.50 - 250.60)
- ✓ A DC system must have a grounding electrode system (250.166 & 250.169)
- ✓ If system has both AC and DC requirements:
  - Bond DC grounding electrode system to AC grounding electrode system, GEC sized per 250.166 ***OR***
  - Install a common grounding electrode system, GEC sized per 250.166 & 250.66 ***OR***
  - Install a combined DC GEC and AC EGC, unspliced to the associated AC equipment, sized as the larger of 250.122 and 250.166

* http://solarprofessional.com/articles/design-installation/additional-electrodes-for-array-grounding

Labeling

According to engineering consultants The Cadmus Group, 70% of PV installs are improperly labeled.*



Changing codes can be the root of the problem, but missing or incomplete labels are a big issue that occurs “most of the time” in a typical installation.

There are guidelines, however, and we help you use them by putting together the poster you see here – and we’ll happily send to you.

*http://www.cadmusgroup.com/wp-content/uploads/2015/04/SolarPowerWorld_Cadmus_NECConfusion.pdfbeled

The HellermannTyton Solar Advantage

With specialized fastening and labeling solutions and industry code compliance leadership, HellermannTyton is an ideal partner for solar engineering, procurement and construction (EPC) firms, installers, electrical contractors and OEM rack manufacturers, large or small. Only HellermannTyton provides the Solar Advantage – Solar Ties, Solar E-Clips and Solar Identification products – smart, innovative solutions for the solar photovoltaic (PV) market that can't be found anywhere else.

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SOLAR E-CLIPS

SOLAR IDENTIFICATION

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- ✓ Proven solutions and products
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