

---

## 4-307 Log #2652

---

### NEC Article 690.41

#### *Table of Contents*

#### *I ROP Text*

#### *II Working Group Commentary*

#### *III Proposed Language Change*

**I ROP Text:** *The following text is verbatim from the ROP document.*

---

4-307 Log #2652 NEC-P04 **Final Action: Accept**  
**(690.41)**

**TCC Action:** The Correlating Committee **directs that the panel rewrite this section as multiple sentences for clarity.**

**This action will be considered as a public comment.**

**Submitter:** William F. Brooks, Brooks Engineering

**Recommendation:** Revise text to read as follows:

**690.41 System Grounding.**

For a photovoltaic power source, systems shall comply with 690.35 or one conductor of a 2-wire system with a photovoltaic system voltage over 50 volts but not greater than 300 volts and the reference (center tap) conductor of a bipolar system shall be solidly grounded or shall use other methods that accomplish equivalent system protection in accordance with 250.4(A) and that utilize equipment listed and identified for the use.

Exception: Systems complying with 690.35.

**Substantiation:** This proposal is to limit the use of solidly grounded systems to only those below 300 volts to be consistent with 250.162. Conventional wisdom believed that all systems above 50 volts would be safer if grounded, but field practice has shown that higher voltage systems become much more dangerous when grounded, particularly above 300 volts—the majority of systems now being installed in the U.S. Recent fires have also shown that grounding of systems has created critical blindspots in ground-fault detection systems allowing grounded conductor faults to persist undetected setting up the circumstances for a full array short circuit condition under an ungrounded conductor fault. These faults can flow over 1000 amps in large 500 kW PV arrays. As 600Vdc PV arrays continue to proliferate, 1000Vdc systems are also being installed. These systems, if allowed to be grounded at the recommendation of the NEC, will result in even more significant fires and electrocution hazards. The fault detection schemes required by ungrounded PV arrays substantially improve both fire and life safety. It should be noted that 690 has been in conflict with article 250.162 and it turns out that article 250 is correct and should be followed above 300Vdc. Since the provisions of 690.35 provide guidelines on how to install ungrounded systems properly, it is straightforward to make this a requirement of all systems greater than 300Vdc. The exception is unnecessary since the section is now written in as a positive provision, eliminating the need for the exception which is consistent with the direction in the style manual.

**Panel Meeting Action: Accept**

**Panel Statement:** The panel recognizes that a “,” should be inserted between “690.35” and “or”.

**Number Eligible to Vote: 13**

**Ballot Results:** Affirmative: 12 Negative: 1

**Explanation of Negative:**

ROGERS, J.: This proposal as written is too restrictive and actually prohibits the design and installation of a grounded PV system operating over 300 volts.

Section 690.35 already permits this, it should also be permissible to design and install a grounded system at voltages over 300 if deemed necessary to do such.

**Comment on Affirmative:**

---

**4-307 Log #2652**

---

**NEC Article 690.41**

BOWER, W.: This is new language and is using the term photovoltaic in the sentence. The final should read:

For a PV power source, systems shall comply with 690.35 or “one conductor of a 2-wire system with a PV system voltage over 50 volts dc, but not greater than 300 volts dc and the reference (center tap) conductor of a bipolar system shall be solidly grounded” or shall use other methods that accomplish equivalent system protection in accordance with 250.4(A) and that utilize equipment listed and identified for the use.

Exception: Systems complying with 690.35.”

Note: This proposal is more relevant given the fact that the NEC is redefining low voltage as 1000Volt or less. Products that require resistive grounding for depolarization would still be allowed. Solid grounded systems would not be allowed above 300Volts dc as a result of this proposal.

End

=====

---

4-307 Log #2652

---

**NEC Article 690.41**

**II Working Group (WG) Commentary**

The ROP proposed language in question will eliminate grounded monopole PV arrays for systems operating over 300VDC. Several members of the working group are strongly opposed to such a requirement and are recommending the language be modified. We agree that 690.41 should be modified to positively and directly allow for ungrounded systems instead of grant it through an exception. However, we also agree with Jim Rogers in that requiring all systems above 300VDC to be ungrounded is far too restrictive and unjustified. Additionally, we support the TCC's request to rewrite this section to improve clarity. Thus, our comments and proposed modifications aim to address all of these goals.

The accepted modification was motivated by the fires caused by the inadequate ground fault protection used in most PV Systems today. We share the concern about the current ground fault protection, particularly for ground faults on grounded conductors, and strongly support language proposed in PV Industry Forum's comments to proposal 4-219, which will ensure that this problem is resolved. These modifications will allow for grounded systems to operate as safely as ungrounded systems throughout their design life. The notion that ungrounded systems are universally superior is false; ungrounded systems still require appropriately design ground fault protection to operate safely as well, which was also addressed by the PV Industry Forum's comments to proposal 4-302. Also, Proposal 4-212 removes a key exception from 690.5 that has allowed systems (other than dwellings) to be grounded without GF protection. By closing this loophole, the safety of grounded PV Systems has been further improved in the 2014 NEC. The only remaining exception in place is for narrowly defined systems (1 to 2 string pole/ground mount systems isolated from buildings).

Despite our concerns about universally requiring ungrounded systems, they are preferred for some PV system designs. For this reason, we propose that it be clearly listed as a positively approved System Grounding option in 690.41. Furthermore, it is the WG's understanding that the intent of proposal was not necessarily to prohibit grounding of all systems over 300V entirely. Ward Bower's comment on the affirmative stated that resistively grounded systems would be allowed. While resistively grounded systems have historically been indirectly approved under the reference to 250.4(A) in 690.41, we are proposing to improve the clarity of this by explicitly stating it in 690.41 as an approved System Grounding Option. To ensure that the grounding configuration does not negatively interact with the ground fault protection requirements for PV systems, we also proposed a direct linkage to 690.5 for this grounding configuration. With the new language proposed in the PV Industry Forum Comment for 690.5, this will require the use of a listed Ground Fault Protection Device suitable for a PV system that is impedance grounded. To be clear, the UL standard for PV Ground Fault Protection will define requirements for the GFP appropriate for this grounding configuration.

Lastly, recent discussions with CMP 4 representatives and the PV Industry Forum indicated that the use of the term "solidly grounded" could be interpreted to prohibit the use of ground fault protection devices in the ground bond, i.e. a hard wire ONLY and no fuse, breaker or contactor interrupting device. As result, we propose to drop the use of the term "solidly" in 690.41. Based on all of these comments, we believe that 690.41 should be rewritten as proposed in this

---

**4-307 Log #2652**

---

**NEC Article 690.41**

comment to clarify the requirements and to ensure that effective and safe grounding approaches are not unnecessarily prohibited by code. The proposed revision is further supported by the points below.

**1. Fire Safety -Addressing the Ground Fault “Blind Spot”**

The WG acknowledges that an unprotected condition can exist when the grounded conductor of an intentionally grounded system becomes faulted to ground *and* a fault to ground occurs on the ungrounded conductor. This condition is being addressed by the proposed language revision to ROP 690.5 “Ground Fault (GF) Protection”. The proposed revised language will require that the system be capable of detecting ground faults on both ungrounded and grounded conductors on the DC side of the PV system and that the device be listed for use in PV systems. It is anticipated that the inverter standard will be amended to address the new requirements. These code and standards changes will effectively eliminate the “Blind Spot” hazard.

**2. PV Modules Requiring Grounding**

The WG identified at least one major manufacturer of c-Si PV modules that requires one of the poles to be grounded for proper operation. This particular manufacturer is one of the world leaders in the industry. Eliminating the option to have grounded systems of any voltage would place a severe economic hardship on their sales in the US market.

**3. Addressing Conformity to Art 250.162**

The WG believes there is little commonality of intent and purpose connecting 250.162 and Article 690. The proposal’s substantiation suggests that 250.162 requires systems over 300V to be ungrounded but this is not the case. It requires systems that are 300V or less to be grounded, but is silent regarding systems over 300V. An exception allowing ungrounded industrial systems under 300V with ground fault detection is included (to allow critical DC processes to continue operating with a fault condition) but its purpose is contrary to the rationale for ungrounded PV systems. Furthermore, the vast majority of PV system architectures operating above 50 V also operate above 300V. Without a strong tie to 250.162, the choice of 300V is arbitrary and without practical meaning for the PV industry.

The WG suggests that attempting to conform Art 690 to Art 250.162 should not be cause to override the arguments expressed herein as this is more of an administrative concern rather than one of personnel and/or fire safety.

**4. Impedance Grounding**

The WG suggests that the use of impedance grounded systems be specifically allowed in this article. In fact, there are inverter technologies that currently employ such a method. The Code allows this method for other applications. Requiring these systems to employ

---

**4-307 Log #2652**

---

**NEC Article 690.41**

ground fault detection by referencing back to article 690.5 should satisfy the original intent by referencing 250.4(A).

**5. Other Economic Considerations**

An ungrounded system requires twice the number of overcurrent devices as compared to an ungrounded system. This is one of the reasons that some system designers prefer to specify grounded systems.

**COMMENTS BY WILES**

Resistance and impedance grounding methods and devices are not well defined in the code. Would a 1ohm connection be acceptable? Would a 1 megaohm connection be acceptable? Grounded for what purpose and at what current/power levels? Grounding impedances used in AC systems are very large power resistors/inductors capable of handling large currents (thousands of amps). Is this what we are referring to?

**COMMENTS by BILL BROOKS**

My point in submitting this proposal was to highlight a deficiency in the NEC as it relates to the understanding of ground-fault protection and different system configurations.

The comment that the working group developed is essentially returning the code back to the 2011 NEC, but it is actually restricting alternative methods to bi-polar systems only—I disagree with this change and I am not sure that was intended by the group. I am attaching a revised version for discussion. I combined 2 and 3 and remove the stipulation for limiting alternative grounding means to bi-polar arrays. I'm still not satisfied with the language, but it is moving in the right direction.

The substantiation is also weak as it states that grounded systems can operate as safely as ungrounded systems throughout their design life. A better way to state the same thing is to say that a grounded dc/isolated ac PV system is the same as an ungrounded dc/non-isolated ac system.

---

**4-307 Log #2652**

---

**NEC Article 690.41**

Essentially the ground fault protection for each would be nearly identical in its safety if the new 690.5 ground fault detection requirements make it into the standard.

The safest of all PV arrays is an ungrounded dc/isolated ac PV system whereby insulation resistance can be constantly monitored. The response to a ground fault for any system is under fierce debate in the IEC, but the NEC requires either the inverter to shut down or to isolate the faulted conductors in response to a ground fault.

To be clear, I have not seen a new truly bipolar array installed in over a decade.

Neither Advanced Energy nor Refusol inverters are bipolar. Advanced Energy looks like a bipolar array when it is not operating, but even then, the poles are not connected together like a typical old-school bipolar array. Refusol takes two independent circuits and connects them together as they connect through a non-isolated connection. Both of these examples are truly non-isolated arrays that receive their reference to ground through the ac transformer. The NEC does not address these specific array types in anything other than the “accomplish equivalent system protection”. By adding the requirement that only bipolar arrays can use this method, you just outlawed Advanced Energy and Refusol inverters. I don’t think that was the intent, and I certainly don’t support that language.

If we are going to go to this detail, we need to change the language. Grounded and ungrounded are fundamental misnomers. What we are ultimately discussing are different methods of ground fault protection. If we can figure out a way to change the language to more reflective of what is truly happening at the ground fault protection point, we may be able to solve this language problem.

Basically, we have the following categories for system configurations:

---

**4-307 Log #2652**

---

**NEC Article 690.41**

1. Ungrounded dc/isolated ac (GFP simply measures ground impedance—no differential current exists)
2. Grounded (zero to high impedance) dc/isolated ac (improved GFP according to new 690.5)
3. Ungrounded dc/non-isolated ac (GFP according to standard—nearly identical to new 690.5)
4. Alternative methods (e.g. bipolar-like arrays/non-isolated ac with various GFP methods—not well covered in standards—should require new 690.5 since it is non-isolated)

Standing back and looking at this list from a high level, the only difference in any of these methods is the ungrounded dc/isolated ac since differential current monitoring is not necessary. Think of it this way—we can do ground fault protection exactly the same way for ALL PV systems and simply provide an exception for ungrounded dc/isolated ac systems to not require the differential current monitoring. That is profound.

Please understand that I'm not trying to shove ungrounded systems down everyone's throat. This proposal was independent of the 690.5 proposal. Together with that proposal, we can make this much clearer. I am trying to improve and clarify the foggy understanding that the NEC currently provides on this subject.

Lastly, the substantiation does not address the fact that the current-limited nature of PV systems require much better ground fault detection and overcurrent methods than are used in conventional ac systems. PV arrays are like high-impedance ac faults—a hazard that the conventional ac electrical world does not directly address in circuits that do not have ground fault protection. That is why we must have GFP on all PV array circuits. We can't deal with the overcurrent protection problem here, but if we clarify language, perhaps we can make headway on that issue in the next code cycle.

---

4-307 Log #2652

---

**NEC Article 690.41**

**III Proposed Language Change**

The WG is recommending the following alternate language as was directed by the correlating committee. In addition to the reintroduction of grounded systems, the WG recommends allowing grounding through an impedance device (ie resistor) and presenting an enumerated listing to add clarity.

Photovoltaic systems with a maximum PV system voltage over 50 volts shall comply with one of the following:

- (1) Ungrounded and the system shall comply with 690.35 or
- (2) One conductor of a 2-wire system shall be connected to ground and the system shall comply with 690.5 or
- (3) One conductor of a 2-wire system shall be impedance grounded and the system shall comply with 690.5 or
- (4) The reference (center tap) conductor of a bipolar system shall be connected to ground and the system shall comply with 690.5 or
- (5) Biopolar systems shall use other methods that accomplish equivalent system protection in accordance with 250.4 (A) and that utilize equipment listed and identified for the use.