



# Connectors as ac Disconnects in PV Applications: Interpreting NEC Requirements

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## Introduction

Disagreements have arisen around the use of connectors as ac disconnects in PV applications. This paper summarizes and discusses relevant National Electric Code (NEC) requirements and proposes solutions to ambiguities in the 2008 NEC.

We will discuss the ac disconnect requirements as they apply to microinverters, quoting applicable sections of the code, and highlighting (in yellow) language that was added to the 2008 code. The word "code" refers to the 2008 National Electric Code, NFPA70. Each section is followed by a discussion of the NEC's intent, including our interpretation of specific points relating to the ac disconnect requirements.

Please note: this discussion is about the **ac** disconnect requirement ONLY.

## Code Sections

**690.13** – "Means shall be provided to disconnect all current-carrying conductors of a photovoltaic power source from all other conductors in a building or other structure."

Discussion: This section states that there must be a way to disconnect the photovoltaic power source, to ensure personnel safety while the equipment is being serviced. Section 690.13 does not relate to emergency disconnect. Its intent is to ensure that PV system wiring cannot be energized from other power sources (including the utility) during servicing, and that the PV system cannot energize other wiring systems.

**690.14** -- Additional Provisions. Photovoltaic disconnecting means shall comply with 690.14(A) through (D).

- (A) Disconnecting Means. The disconnecting means shall not be required to be suitable as service equipment and shall comply with 690.17.
- (B) Equipment. Equipment such as photovoltaic source circuit isolating switches, overcurrent devices, and blocking diodes shall be permitted on the photovoltaic side of the photovoltaic disconnecting means.



(C) Requirements for Disconnecting Means. Means shall be provided to disconnect all conductors in a building or other structure from the photovoltaic system conductors.

(1) Location. The photovoltaic disconnecting means shall be installed at a readily accessible location either on the outside of a building or structure or inside nearest the point of entrance of the system conductors.

Exception: Installations that comply with 690.31(E) shall be permitted to have the disconnecting means located remote from the point of entry of the system conductors.

(D) Utility-Interactive Inverters Mounted in Not-Readily-Accessible Locations. Utility-interactive inverters shall be permitted to be mounted on roofs or other exterior areas that are not readily accessible. These installations shall comply with (1) through (4):

(1) A direct-current photovoltaic disconnecting means shall be mounted within sight of or in the inverter.

(2) An alternating-current disconnecting means shall be mounted within sight of or in the inverter.

The requirements in 690.14(D)(1) and (D)(2) provide for servicing disconnects at the inverter.

(3) The alternating-current output conductors from the inverter and an additional alternating-current disconnecting means for the inverter shall comply with 690.14(C)(1).(4) A plaque shall be installed in accordance with 705.10.

Discussion – Section 690.14(D) contains the most specific language in the code regarding treatment of disconnects. This section first appeared in the 2005 version of the code and allows that inverters be installed in relatively inaccessible locations. Section 690.14 broadly covers any dc or ac disconnect in a PV system. Only section 690.14(C)1 specifically applies to the ac disconnect requirement.

The exception to 690.14(C)1 does not apply to the ac disconnect; section 690.31(E) clearly states that it applies to “Direct-Current Photovoltaic Source and Output Circuits Inside a Building.” The comment after (D)(2), above, simply clarifies that the reason for the additional means-of-disconnect requirement is to allow for servicing the inverter. Article 440.14 includes a similar provision for air conditioning equipment on rooftops, requiring that the disconnects for servicing the equipment must be within sight of the equipment.

The NEC requires another, readily accessible disconnect 690.14(D)(4), in addition to the not-readily-accessible disconnects. The readily accessible disconnect could be a dedicated branch breaker in a distribution panel, for example. The additional disconnect would be rated for load-break operation. The not-readily-accessible disconnect is for service purposes and would be used by qualified service personnel only. Paragraph 690.14(D)3 allows the dedicated branch circuit breaker to serve as the current-interrupting (load-break) disconnect required in 690.17(4).



**690.17 -- Switch or Circuit Breaker.**

The disconnecting means for ungrounded conductors shall consist of a manually operable switch(es) or circuit breaker(s) complying with all of the following requirements:

- (1) Located where readily accessible
- (2) Externally operable without exposing the operator to contact with live parts
- (3) Plainly indicating whether in the open or closed position
- (4) Having an interrupting rating sufficient for the nominal circuit voltage and the current that is available at the line terminals of the equipment.

Exception: A connector shall be permitted to be used as an ac or a dc disconnecting means, provided that it complies with the requirements of 690.33 and is listed and identified for the use.

Discussion – The exception clearly allows the use of a connector as a disconnect.

The term “listed and identified for the use” is ambiguous. Connectors are not “listed”; they are “recognized components.” “Listed” is defined in the code as “Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.”

“Recognized components” are products that have been tested and evaluated according to established standards so that product manufacturers do not have to test every component used in every product. Recognized components become part of the listing of the end product. Their use is controlled by the end-product construction report and follow-up services performed by the listing agency at the manufacturer’s factory.

The word “identified” (“listed and identified for the use”) is often misconstrued to mean that the product has detailed markings that describe how it should be used. It actually means that the product has a mark that is authorized by an appropriate Nationally Recognized Testing Laboratory such as CSA International, UL, ETL, or TUV. These are all recognized by OSHA for PV product testing under the Nationally Recognized Testing Laboratory program.

**690.33 – Connectors**

The connectors permitted by Article 690 shall comply with 690.33(A) through (E).

- (A) Configuration. The connectors shall be polarized and shall have a configuration that is noninterchangeable with receptacles in other electrical systems on the premises.
- (B) Guarding. The connectors shall be constructed and installed so as to guard against inadvertent contact with live parts by persons.



(C) Type. The connectors shall be of the latching or locking type. **Connectors that are readily accessible and that are used in circuits operating at over 30 volts, nominal, maximum system voltage for dc circuits, or 30 volts for ac circuits, shall require a tool for opening.**

(D) Grounding Member. The grounding member shall be the first to make and the last to break contact with the mating connector.

(E) Interruption of Circuit. **Connectors shall be either (1) or (2):**

The two options provided for connectors in this requirement provide for safe disconnection of circuit connectors either by being able to be opened under load or by having a warning indicating that there can be no current (no load) on the connection prior to opening the connector.

- (1) Be rated for interrupting current without hazard to the operator.
- (2) **Be a type that requires the use of a tool to open and marked "Do Not Disconnect Under Load" or "Not for Current Interrupting."**

Connectors that can be opened or disconnected using only the hands are not acceptable.

Disconnection requiring the use of a tool implies that the connector should not be removable by hand. A "tool" could be a screwdriver, pliers, or a specialty tool designed specifically for disengaging the connector.

Discussion –

The 2008 code states that if a connector is not rated for load-break operation, then it must be a locking connector, requiring a tool to open. According to 690.17 Exception, the connector must be certified (the code says "listed" but connectors are actually "recognized components") and identified for the use. This means that the connector must be rated for the voltage, current, and environmental conditions in which it is used.

## **Application to Enphase Products**

The ac connector used on the Enphase M190 and M210 Microinverters is manufactured by Tyco Electronics. It is rated for 250vac, 30 amps, outdoor use. It has been evaluated and approved for load-break operation as part of the microinverter listing process and does not require a tool to disconnect. The 2005 National Electric Code does not require locking connectors, nor does it require that connectors need a tool to open.

By nature, a microinverter is almost always mounted in a "not readily accessible" location. Even a ground-mounted array would require the addition of a guard to enclose the wiring system. Hence, no connectors are readily accessible. A tool would generally be needed to gain access to the connectors (e.g., removing the module, or removing a guard). This could be interpreted to meet the tool requirements of 690.33(E)(2). If the jurisdiction decides that the need for a tool to gain access does not meet the intent of 690.33(E)(2), then the ac connector would require a tool to open if it cannot be opened without hazard to the operator.



In our experience, 99 percent of microinverter installations encounter no resistance to using the connector to satisfy the “within sight of” requirement under 690.14(D)(1). In the remaining 1 percent of cases, the Authority Having Jurisdiction (AHJ) requires some education, discussion, and/or review of the National Electric Code. In a few cases, the AHJ has insisted that an additional disconnect switch be placed on the roof. This is unfortunate, as it adds cost, it is one more component that can fail or succumb to environmental conditions, and it is not intended by the National Electric Code.

Proposals to the 2014 National Electric Code will be made to clarify these requirements.

As an interim measure, Enphase has done additional testing to certify that the ac connectors qualify as a “means of disconnect,” as required by the National Electric Code. This information can be found in the installation instructions for Enphase Microinverters. Please visit <http://www.enphaseenergy.com/support/downloads.cfm> for more information.