The Ultimate Guide to PV Connector Safety

BAD CONNECTORS CAUSE PV FIRES

Solar connectors are easily overlooked when PV systems operate as expected. But when they fail, they can cause fires that jeopardize safety and property.

These incidents are more likely to occur as installed solar capacity grows and more connectors are deployed to the field, particularly in markets without a skilled solar workforce and in projects installed by new or temporary crews.

A Brief History of Connectors

- **2000** — NEC required licensed electricians to make all connections over 50 V
- **2008** — Radox and MC4 develop first push fit connectors. MC4/ Staubli dominate the market; Amphenol disrupts the industry with MC4 "compatible" Connector
- **2018** — NEC bans opening connectors under load and requires positvie locking mechanisms
- **2020** — Market is flooded with MC4-'Compatible' connectors from different suppliers
- **Future** — NEC requires BOTH parts of a connector pair must be tested together and certified to mate. Universal design standards; Better Installer Training; More Research

Connectors and Fires

- In January 2022, SunPower initiated a >$30MM USD PV connector replacement initiative due to a cracking issue in third-party products it supplied.[1]
- In the U.K., 27% of 58 fires instigated by PV systems from 2010 to 2017 were caused by connectors.[2]
- In Germany, connectors were blamed for 24% of 180 fires caused by PV systems from 1995 to 2012.[3]
- Japan's Consumer Safety Investigation Commission recommended rooftop PV system inspections in a report citing 127 fires from 2008 to 2017.[4]

Field Investigations

Utility Scale

Issue: *Connectors regularly melted and caught in fire in a 150 MW+ project in California.*

PVEL evaluated 1,500 of the nearly 100,000 field-made connectors at the site with a combination of visual inspection, infrared thermography and XCT.

Installation error was identified as the overarching root cause of connector failure:

- Critical connector installation errors were extensive, including **under- and overtorqued nuts, poor placement, improper crimping, and improperly seated contacts.**
- 40% of the connectors evaluated with XCT had installation issues, and **20% had incomplete insertion** of the contact, which suggests issues are widespread throughout the site.
- Persistent inverter nuisance tripping based on insulation resistance faults could be due to the widespread poor sealing of connectors due to under-torqued back nuts.

C&I Rooftop

More than 70% of the commercial and industrial projects inspected by HelioVolta have serious connector issues. Several trends have emerged:

- **Connectors can be difficult to locate and poor wire management is common**. Inspectors often crawl on their knees with hand-held thermal cameras.
- **Cross-mated connectors are frequently found on homerun cables.** This classic problem usually occurs because modules come with a connector type that the EPC does not have readily on-hand.
- **Poor installation practices are often to blame for failures.** Connectors may be exposed to the elements, resting on roof membranes, have a tight bend radius, or poorly torqued backnuts, among other issues.
- **Hot connectors are the most obvious indicator of underlying issues.** These connectors have higher operating temperatures than other connectors installed on-site, which indicates a higher electrical resistance.

Heliovolta developed the software application, SolarGrade, to streamline the process of identifying, documenting, and analyzing issues such as poorly made connectors on PV Inspections. The solarGrade mobile app can be used to record issues and generate reports in real-time at project sites. Find more info at SolarGrade.io and is available for Android and iOS devices.

Link to Full Paper

RE+ Poster Code

PV Connector Best Practices

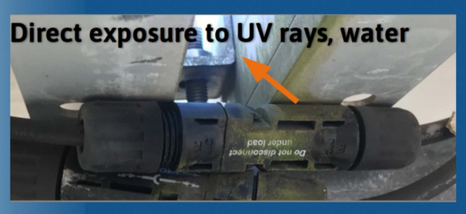
1. ***DO NOT CROSSMATE*** connectors
2. ***SPECIFY & VALIDATE*** manfuacturer, type, & authenticity
3. ***INSTALL CORRECTLY*** with manufacturer-approved tools
4. ***QA/QC INSTALLATION*** requirements in EPC contracts
5. ***INSPECT REGULARLY*** during preventative maintenance

Common PV Connector Issues

Poor or Loose Connections lead to increased resistance over time.

Over-torqued Backnuts compromise the seal and interity of the connector body.

Water and Sunlight Exposure will degrade the connector material over time.



Signs of overheating due to operating outside material temperature range.

Under-torqued Backnuts do not properly seal the gasket around the conductor jacket.

Insufficient Bend Radius compromises the integrity of the backnut seal and internal crimp.

Cross-threaded Backnuts can compromise the watertight seal.

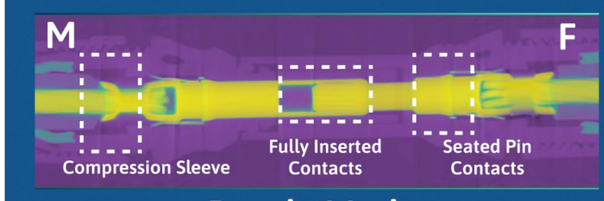
Inconsistent Install Methods are indicated by inconsistent threads at the backnut.

Crossmated Connectors are not tested together and the internal fit is usually out of manufacturer specifications.

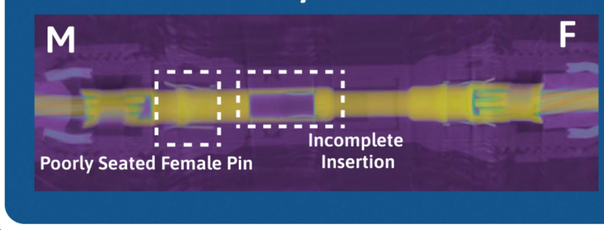
Inside a PV Connector

X-ray Computed Tomography (XCT) provides 3D images of the pin contacts within a connector. The lack of surface area contact in poorly made connectors is clearly evident.

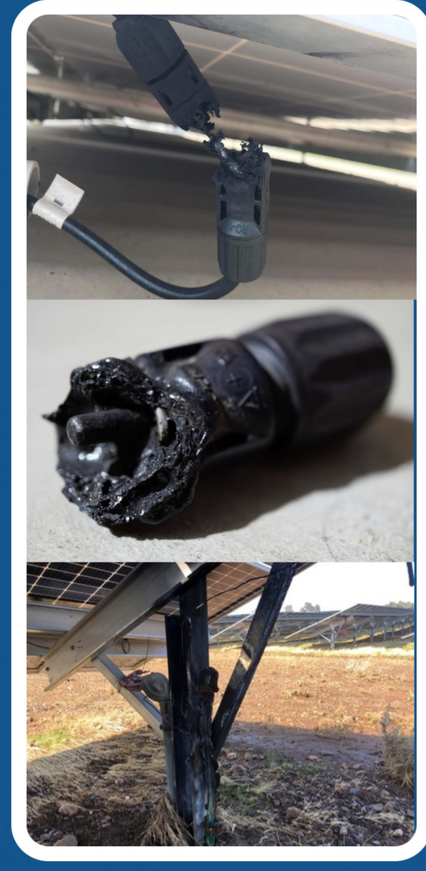
Properly Made



Poorly Made



WALL OF SHAME



The Solar Industry's Most Common Torquing Myth

It is a common misconception that the plastic wrenches used for installation slip when there is sufficient torque on the back nut. This is false. Plastic wrenches may be used to initially make the connection, but then the nut must immediately be torqued properly with the manufacturer-approved torque wrench.

Torque on the back nut cannot be checked post-commissioning. It is imperative that asset owners are confident in their installation teams and the quality of the connectors in their projects.

Heliovolta

HelioVolta is a solar and energy storage software and technical advisory services company. We developed SolarGrade, a platform that provides fast, easy-to-use software to standardize solar and energy storage inspection procedures, enables team collaboration, and generates shareable professional reports.
Our mission is to ensure that solar and storage assets fulfill their promise as responsible and reliable energy sources beyond our generation.
To learn more about HelioVolta's software and services, contact our team at **hello@solargrade.io.**

PV Evolution Labs

PV Evolution Labs (PVEL) is the leading independent lab for the downstream solar and energy storage market and a member of the Kiwa Group.
As a bankability testing pioneer, PVEL has accumulated more than a decade of measured reliability and performance data for PV and storage equipment. Our lab and field testing and technical services help mitigate risk, optimize financing and improve performance in solar and storage assets.
To learn more about PVEL's field testing services, contact PVEL's business development team at **info@pvel.com.**

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