

Connector Failures: Codes & Standards Opportunities and Solutions

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Powering the Solar+ Decade



Common Issues



- **Product integrity issues**
 - Melted, discolored, or cracked casings
 - Uneven or inadequate surface contact
 - Early or unexpected material degradation
- **Environmental impacts**
 - Soiling, corrosion, or foreign particles between contacts causing high resistance
 - Moisture or water ingress
 - Early or unexpected material degradation
- **Installation practice errors**
 - Loose or disconnected connectors
 - Improperly installed connectors (incompatible)
 - Lack of technical-based training (just doing instead of learn + doing)
 - Use of incorrect tools impacting the material integrity

Standards Opportunities / Solutions

- Explore creating a universal product design standard to prevent compatibility-related issues
- Standardize installation, workmanship, and inspection practices and processes in ANSI accredited standards.
 - SEIA 201 (Residential and Small Commercial)
 - SEIA 251 (Large Commercial and Industrial)
 - TBA SEIA XXX (Utility-scale / Large-scale)
- Industry-wide effort to offer consistent training programs
 - SEIA/NREL will collaborate on a nation-wide plan to educate on (future ANSI) SEIA PV and ESS installation, training, inspection, and maintenance standards
 - SEIA 202 – Residential and Small Commercial
 - SEIA 252 – Small Commercial and Industrial
 - SEIA 301 – O&M Technician Training
 - SEIA 501 – Environmental Health and Safety



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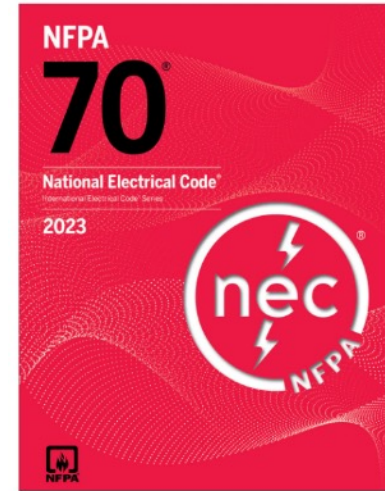
PV Connectors: *NEC & UL Safety Standards*



PV Connectors & NEC

National Electrical Code (2023 NEC)

- PV modules & connectors must be listed (690.4(B); 690.15(B)(1))
- Manufacturer's instructions must be followed (110.3(B))
- Specific requirements for intermatatability when connectors are not of the identical type and brand (690.33(C); UL 6703)
- The installation of equipment, associated wiring, and interconnections shall be performed only by qualified persons (690.4(C))



Qualified Person.

One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training to recognize and avoid the hazards involved. (CMP-1)

Informational Note: See NFPA 70E-2021, *Standard for Electrical Safety in the Workplace*, for electrical safety training requirements.

ENHANCED CONTENT

Collapse ✕

Section 110.6(A) of NFPA 70E[®], *Standard for Electrical Safety in the Workplace[®]*, 2021 edition, provides training requirements for qualified and unqualified persons who might be exposed to electrical hazards.

Listed.

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. (CMP-1)

Informational Note: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. Use of the system employed by the listing organization allows the authority having jurisdiction to identify a listed product.

PV Connector Standards

PV Module Safety Standard UL 61730-1 & 2

- Requires connector compliance with UL 6703 or UL 62852
- Edition 3:
 - connector type will be required on label;
 - clarification to instruction requirements that “MC4 compatible” is not sufficient to describe intermatability / compatibility with different connectors.

PV Connector Standards UL 6703 & UL 62852

- UL 6703: Connectors ...are to be of the same brand, *unless multiple product manufacturers are submitting under the same evaluation for the purpose of proving intermatability.*
- UL 62852: intermatability not covered

Test	Sample Requirements
Water Spray Sequence	
Dielectric Voltage Withstand - as received Leakage Current Water Spray Dielectric Voltage Withstand following Water Spray Leakage Current following Water Spray	3 assemblies, mated
Temperature Cycling Sequence	
Dielectric Voltage Withstand - as received Leakage Current - as received Temperature Cycling Dielectric Voltage Withstand following Temperature Cycling Leakage Current following Temperature Cycling Wet Insulation Resistance following Temperature Cycling	3 assemblies, mated
Humidity Cycling Sequence	
Dielectric Voltage Withstand - as received Leakage Current - as received Humidity Cycling Leakage Current following Humidity Cycling Wet Insulation Resistance following Humidity Cycling	3 assemblies, mated
Additional tests to UL 1703	
Wet Insulation Resistance - as received	3 assemblies, mated
Impact ^h	3 assemblies, mated
Low Temperature Impact ^h	3 assemblies, mated
Additional tests to UL 746C	
Crush Resistance	3 assemblies, mated
Mold Stress-Relief Distortion followed by Strain Relief	6 assemblies, mated
Additional tests to UL 486A-486B	
Current Cycling ^g **	4 assemblies, max wire size/amp rating, mated
Static Heating Sequence ^g	4 assemblies, max wire size/amp rating, mated
Mechanical Sequence ^g	4 assemblies, min wire size not mated
Dielectric Voltage Withstand ^l	24 assemblies, max and min - 6 assemblies and mated as received - 6 assemblies aged then assembled and mated - 6 assemblies mated, conditioned, then tested - 6 assemblies mated ^c
Stress Corrosion (for current-carrying parts containing more than 15% zinc)	3 assemblies, max wire size, not mated
Additional tests to UL 486C	
Spring-action clamp sequence ^g	6 of each combination of connector and test conductor(s)
- Conditioning - Temperature - Dielectric withstand	

Safety Standards / NEC - Changes Needed?

NEC updates?

- equipment listing, “qualified workers” already required -> look at safety standards and SEIA worker training

Safety standards updates?

- Universal connector – incompatibility for small systems only
- Other issues - safety standards or NEC might help address
- **Root cause analyses of failures** needed, account for installation & field history (exposure during construction, opened under load, climate etc.)
- Modification to tests in standards? Need more data.
- Increase number of samples tested in safety standard?
- Add production line tests?
- Increase quarterly or annual reliability tests on connector assemblies from factory?



SEIA's List of Common Issues

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Installation practice errors

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Thank you

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Safety. Science. Transformation.™