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PV Connector Reliability: Initial Results from Field inspections Across the US

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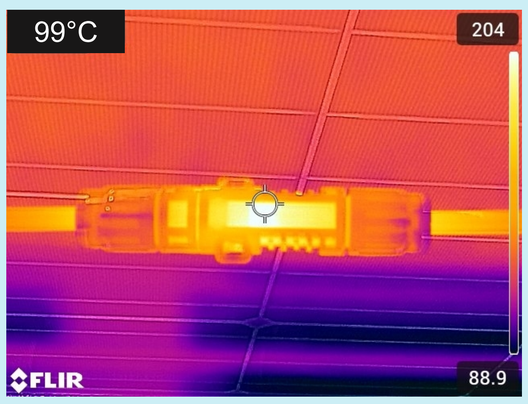
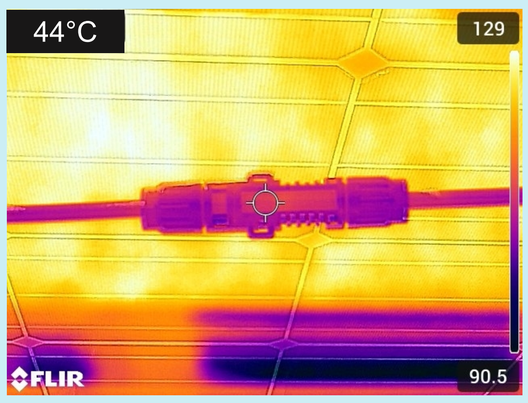
As the PV industry looks toward 50-year modules, reliability research is often focused on cell integrity and packaging materials. However, recent reports from asset owners and O&M providers suggest that connector failures are on the rise. Connectors must carry the high current output of the system with low resistive losses while providing high voltage insulation. Any degradation in performance has serious consequences. In the best case, failure causes reduced system power output and lost revenue, while in the worst case, can cause fires and catastrophic damage to the PV array and surrounding structures.

The root causes for failures have not been well-established and multiple factors are likely involved. Use of counterfeit products, cross-mating between different makes and poor manufacturing quality are often cited. Poor installation practices during construction are also to blame. Improper assembly of connectors built in the field, connector contamination prior to final stringing and incomplete mating of connectors have been observed.

Sandia, in partnership with EPRI and NREL has launched a comprehensive study of fielded connector reliability. In this three-part study, we focus on 1) onsite inspections of utility and commercial PV sites; 2) field harvesting of failed connectors and follow-on forensics analyses to identify Connector failures observed during site inspections nomic assessments to quantify associa National Mail-in Campaign





Ambient Temp: 36°C | GPOA: 1017 W/m² \ Imp: 9.2A

1. Increased Contact Resistance
- Expected ΔT < 30°C (per UL/IEC ratings)
- ”Cool connectors” imply ΔT = 8°C
- Many connectors exceed ΔT = 30°C

Observations:
- All ferrules could be loosened by hand
- Heat spread laterally into PV wire

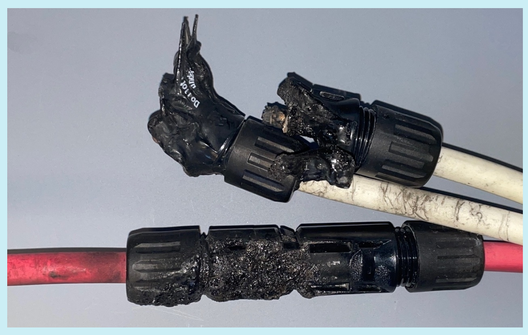
2. Seal failures at the ferrule
- Over stripping or insulation “pullout”?
- Incipient copper cable corrosion
- Water ingress into housing is inevitable

3. Housing failure
- Melting of the housing due to increased contact resistance can directly expose energized contacts and compromise the o-ring seal.

4. Catastrophic failure
- Connector housing failure, whether from improper assembly and water ingress or plastic melting can cause catastrophic arcing to nearby metallic components

MC4+MC4


QC4.10+MC4



Safe harvesting requires proper electrical training, PPE and scheduled system outages. This is often best conducted by on-site O&M personnel. Sandia has established a collection program to facilitate the safe harvesting of connectors that are then shipped to Sandia. Harvest connectors are subjected to non-destructive and destructive forensics analysis and inclusion in an anonymous but open-source database of failure types.

The mail-in program increases the scale and diversity of failure mechanisms that are identified. It facilitates correlation of failure mechanisms with climate, weather events. installation practices and other categorical factors.

Market survey of connectors in-use/available in the US

Manufacturer	Model	Manufacturer	Model
Amphenol	H4	Stäubli	MC3
	H4 Plus		MC4
	UTX		MC4-Evo 2
Bizlink Sunbolts	S418	Sunter	PV-ZH202B
Holysun	LJ-01	Taizhou Jinxiu	LJQ-1
Jinko	PV-JK00MO		LJQ-3
	PV-JK03M	TE Connectivity	Solarlok
JMTHY	PV-JM608		Solarlok PV4
Longi	PV-LR5		Solarlok PV4-S
Minghe	MH5	Tlain (Canadian Solar)	T4
QC Solar	QC4.10	Trina	TS4
Renhe Solar	05-8	Xinhui	PV-HCB40

This non-exhaustive survey identified connectors that were either readily available from resellers or encountered in the field. The market is dominated by a few well-known brands; however, module manufacturers have many options and several have adopted private label solutions. Many connectors have a similar appearance to to one another and are physically inter-mateable, increasing the risk of failure.

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https://energy.sandia.gov/pv-connectors

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