SUPSI University of Applied Sciences and Arts of Southern Switzerland

TESTING

HOT SPOT ENDURANCE TEST

Background and Why the Test Matters

The Hot Spot Endurance Test (HSP) evaluates the ability of photovoltaic (PV) modules to withstand reverse-bias hot spot heating without compromising safety or reliability.

A Hot Spot occurs when the operating current of a module exceeds the reduced short-circuit current of a shaded, damaged, or mismatched cell. The affected cell is forced into reverse bias, dissipating electrical power as heat. In conventional modules, depending on environmental conditions, hot spot temperatures may reach 130–150 °C or higher. Module design and material selection strongly influence the resulting impact.

Prolonged hot spots may lead to: encapsulant discolouration, solder bond fatigue or melting, metallization corrosion, backsheet damage, glass cracking, bypass diode failure and increased fire risk under extreme conditions (particularly if a bypass diode fails in open-circuit).

Test Procedure

The Hot Spot Test at SUPSI PVLab consists of three main steps:

Step 1. Selection of the most critical cells
Step 2. Identification of the worst-case shading condition for each cell
Step 3. Exposure to steady-state irradiance

Step 1 and **Step 2** are generally performed in accordance with **IEC 61215-2:2022, MQT 09.1**. When applicable, more pragmatic approaches are employed in these steps to reduce effort and testing time. In **Step 3**, the module under test is exposed to controlled irradiance and temperature conditions in accordance with IEC test requirements:

- Short-circuited
- Exposed to 1000 ± 100 W/m² irradiance (for monofacial modules)
- Maintained at a module temperature of 55 ± 15 °C
- Exposed to these conditions for 1 hour (extendable to 5 hours if the temperature is still rising)

However, field data indicate that the standard conditions may underestimate stress in certain applications, particularly in:

- Building-Attached PV (BAPV), Building-Integrated PV (BIPV) and Vehicle-Integrated PV (VIPV)
- Installations subject to frequent partial shading

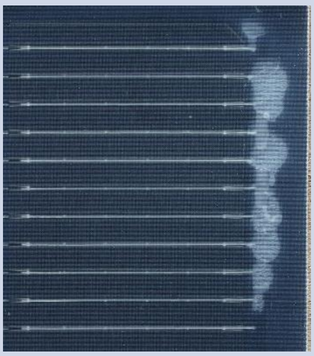
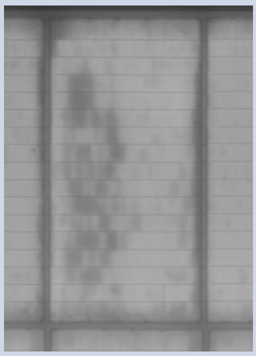
Therefore, **SUPSI PVLab** applies **the application-oriented test conditions**, as outlined in the table below, to better represent realistic operating scenarios while ensuring practical test execution [1]. The selected parameters are based on representative use cases; extreme operating conditions (i.e. diode failure) are not considered, as the goal is to replicate realistic worst-case environmental scenarios.

Application-Oriented Hot Spot Endurance Test Conditions:

Estimated or Expected Critical Operating Conditions		Application Type			Testing Condition (Module temperature & Test duration)
T_{98} (98th percentile module temperature) (IEC TC 63126:2025)	Recurrent Partial Shading	Open-rack	BAPV / BIPV – Façade	BAPV / BIPV – Roof / VIPV	
$T_{98} \leq 70$ °C	No	✓	✓	✓	55 °C and 1-5 hours
	Yes	✓*	✓	✓	55 °C and 15 hours
70 °C $< T_{98} \leq 80$ °C	No	-	-	✓	75 °C and 1-5 hours
	Yes	-	-	✓	75 °C and 15 hours
80 °C $< T_{98} \leq 90$ °C	No	-	-	✓	85 °C and 1-5 hours
	Yes	-	-	✓	85 °C and 15 hours

*: Open-rack systems under recurrent shading typically indicate non-optimized system design.

Example:

	Module – 1	Module – 2
Application type	BIPV – façade	BIPV – insulated roof
Test duration	10 hours	15 hours
Average module temperature during the test	50 °C	75 °C
Average hot spot temperature during the test	151°C	179°C
Visual / Electroluminescence Findings	 	

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Key Takeaways

- Most qualified modules meet IEC hot spot requirements without catastrophic failure.
- In real outdoor conditions, modules can still develop issues under partial shading, even if they pass the standard IEC hot spot endurance test, as observed in the partial shading induced degradation case study.
- Extended testing can reveal early degradation mechanisms not detected under standard tests, including delamination and metallization damage.
- Electrical performance loss is often limited, but early degradation indicators can be identified through visual, electroluminescence or material analysis. Rare cases of reduced insulation resistance may indicate potential safety risks.