

Testing Protocol/Procedure

Thermograph of the modules

The purpose of an infrared (IR) camera inspection is to detect unusual temperature variations in operating PV modules in the field. Such temperature variations may indicate problems within the modules and/or array, such as reverse-bias cells, solder bond failure, bad quality of cells, crack in the cells, high internal series resistance and other conditions that lead to localized high operating temperature.

The modules which are connected to the load/inverter which is under working condition is selected and thermographed for any hotspots. Module temperature should be relatively uniform, with no areas of significant temperature difference. However, it is to be expected that the module will be hotter around the junction box compared to the rest as the heat is not conducted as well to the surrounding environment. It is also normal for the PV modules to see a temperature gradient at the edges and supports.

Error type	Example	Appears in the thermal image as
Manufacturing defect	Impurities and gas pockets	A 'hot spot' or 'cold spot'
	Cracks in cells	Cell heating, form mainly elongated
Damage	Cracks	Cell heating, form mainly elongated
	Cracks in cells	A portion of a cell appears hotter
Temporary shadowing	Pollution	Hot spots
	Bird droppings	
	Humidity	
Defective bypass diode (causes short circuits and reduces circuit protection)	N.A.	A 'patchwork pattern'
Faulty interconnections	Module or string of modules not connected	A module or a string of modules is consistently hotter

(Source: ZAE Bayern e.V, "Überprüfung der Qualität von Photovoltaik- Modulen mittels Infrarot-Aufnahmen" ["Quality testing in photovoltaic modules using infrared imaging"], 2007)

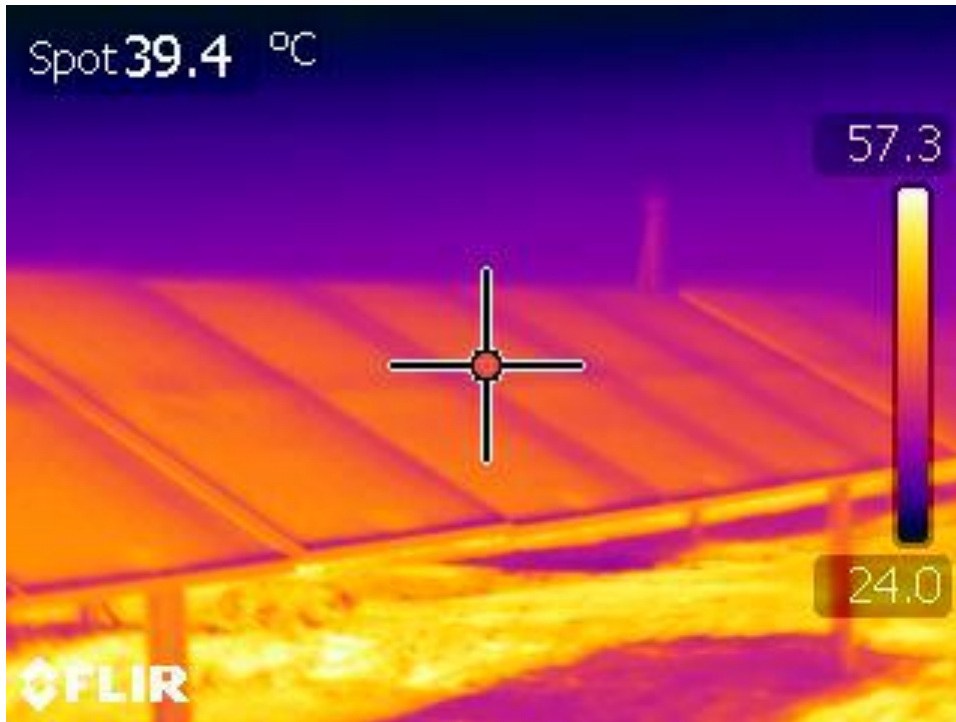


Fig 1: Modules without any hotspots

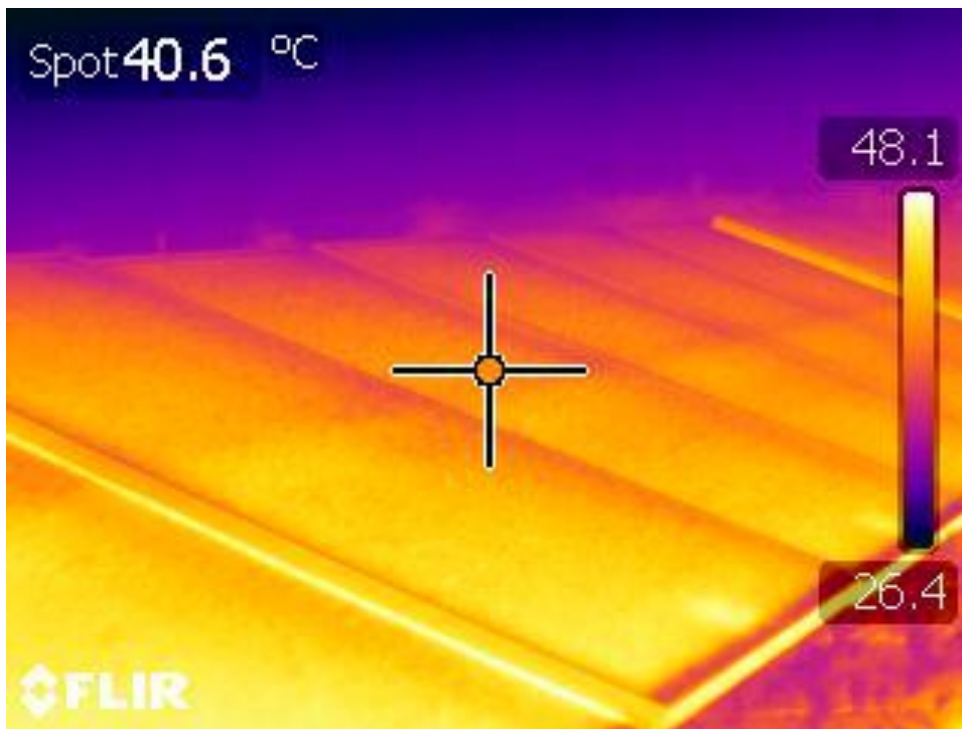


Fig 2: Modules without any hotspots

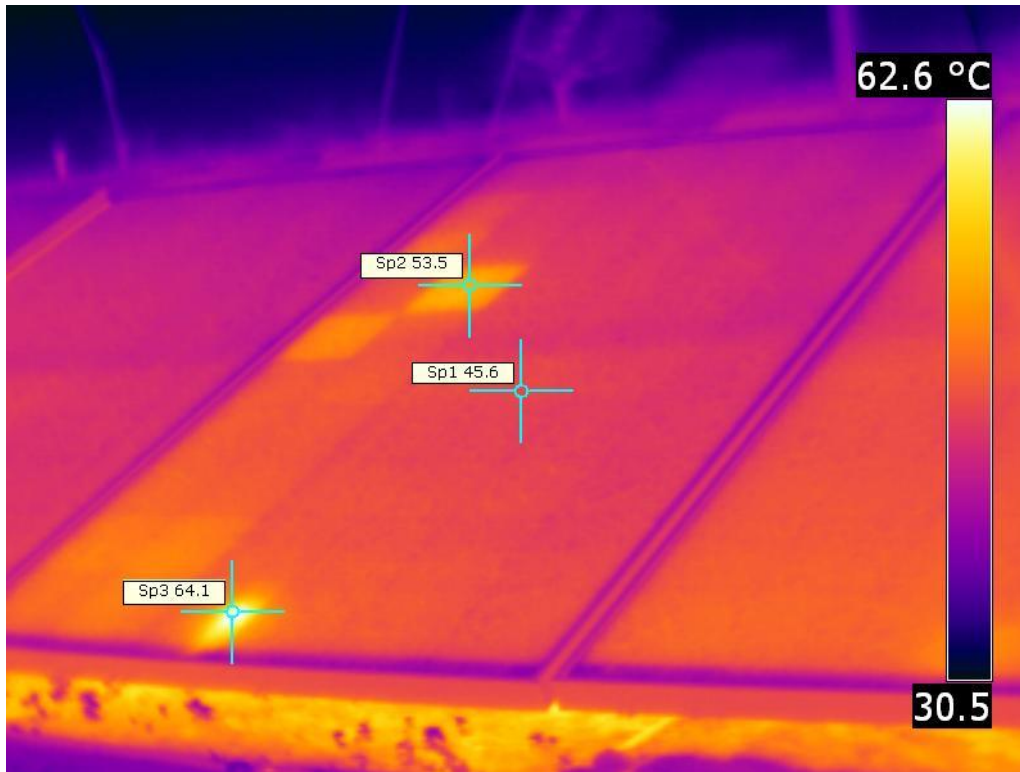


Fig 3: Module with hot spot

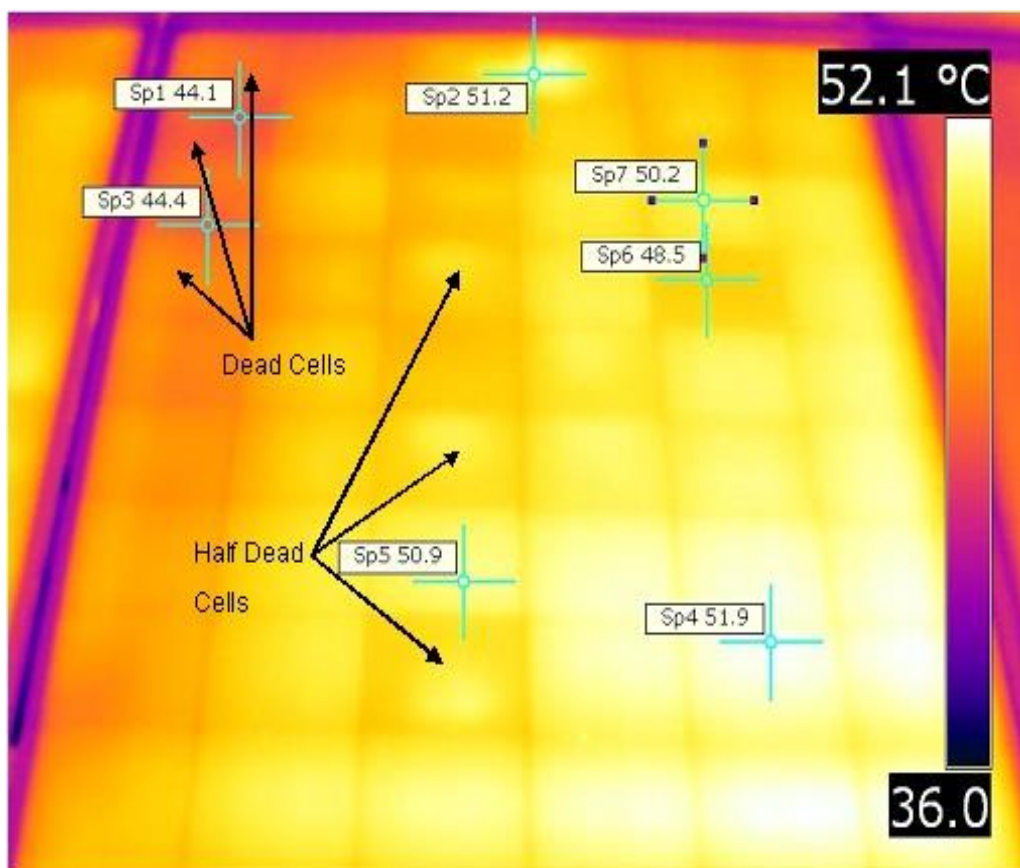


Fig 4: PID Effected modules

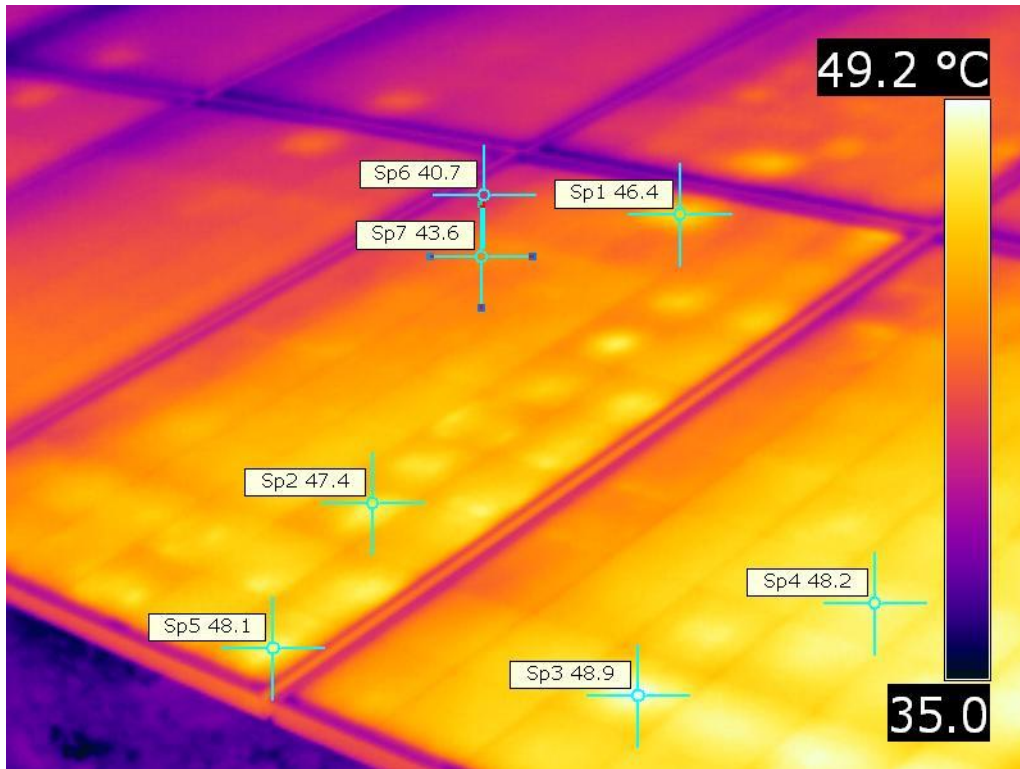


Fig 5: PID Effected modules

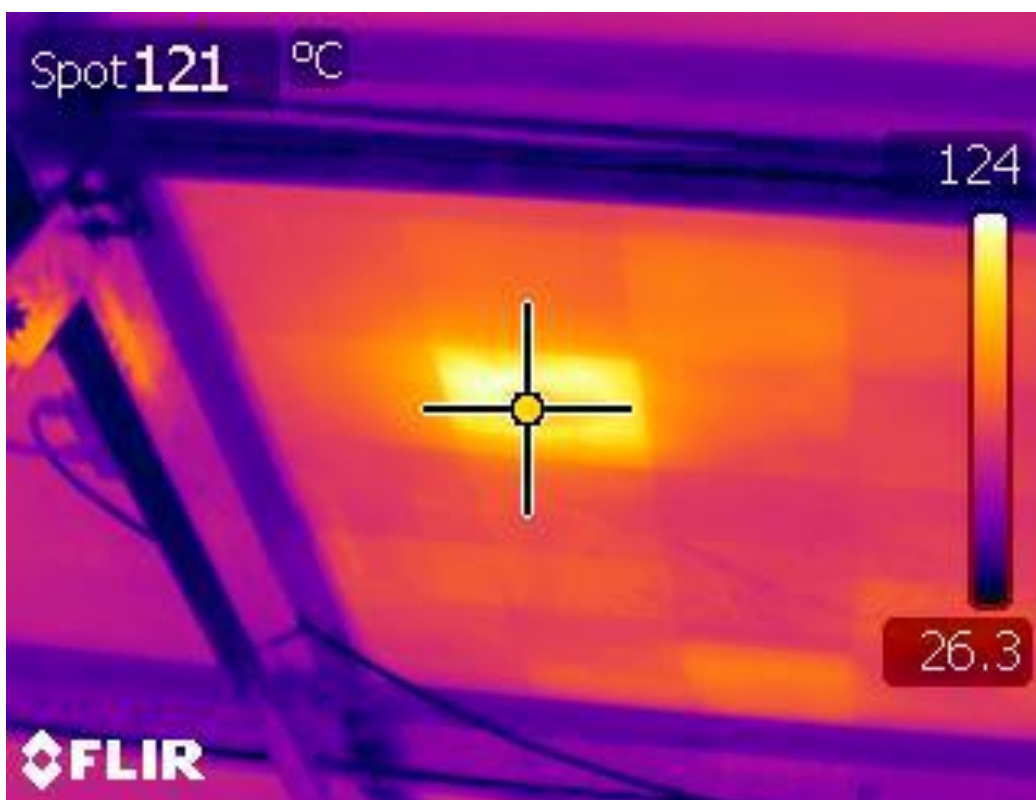


Fig 6: Hot spot module

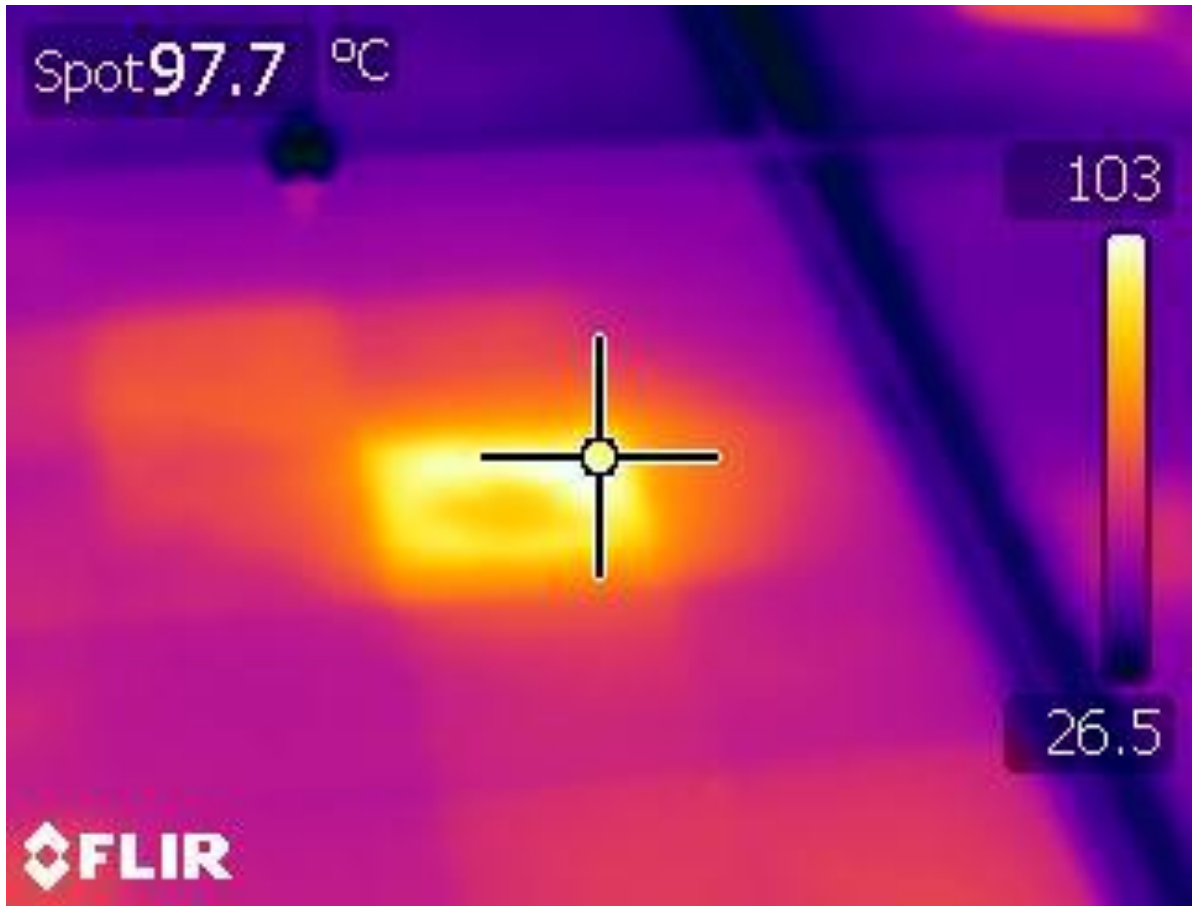


Fig 7: Hot spot module



Fig 8: Bypass diode problem module

In normal operation, temperature in all cells should be uniform as shown in fig 1 & 2. If modules have any problem, images will be like fig 3 to fig 8. Through the IR camera it is easy to find out the faulty modules and to confirm any defect, IV curve can be taken for the same module and not necessary to take IV curve of all modules/strings in the plant.

IR Scanning procedure

All modules in the plant will be scanned through IR camera. IR image will be captured for defective modules. Module serial no. and location (Row/structure No.) will be recorded in the report. The thermograph of the PV modules shows the hotspots in the module created due to bad quality of cells, crack in the cells & high internal series resistance. Stored images will be downloaded from camera and will be incorporated in the report.

Procedure for IR scanning of modules is

- Modules/ strings should be active and inverter in ON position. Imp of the string should be more than 50%
- Irradiance should be minimum of 500W/m² during scanning.