SEERSTEMS

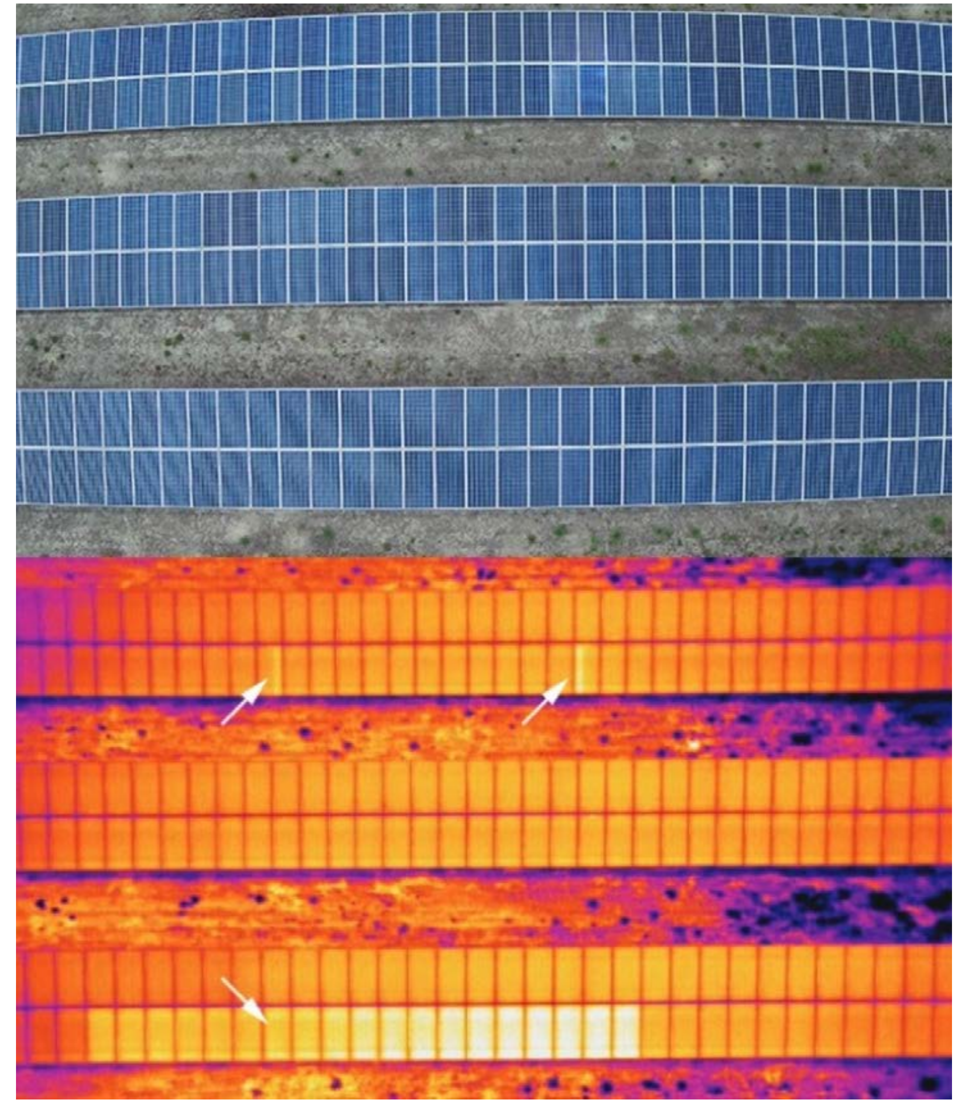
ROBÓTICA Y SISTEMAS S.L.

VISUALBOT *SOLAR*

IA PARA DETECCIÓN DE DEFECTOS EN IMÁGNES TERMOGRÁFICAS

¿QUÉ ES VISUALBOT *Solar*?

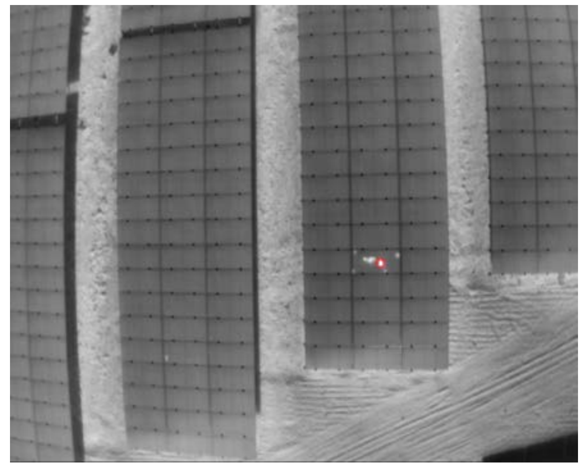
VISUALBOT *Solar* es un **software basado en AI** que permite **detectar defectos en paneles fotovoltaicos** de forma automatizada con una precisión superior al 97%

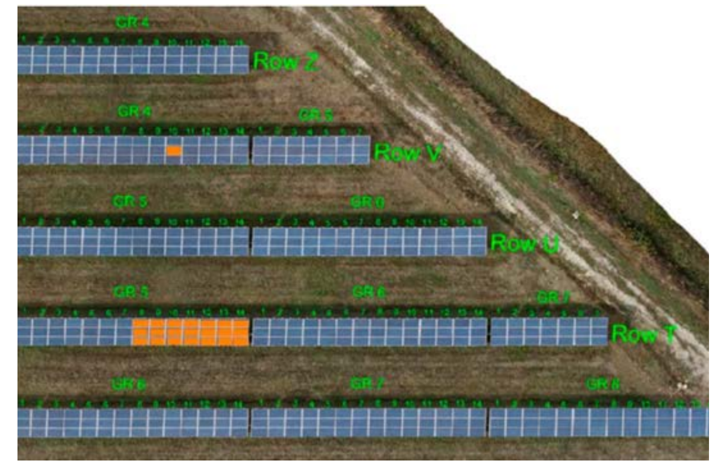


¿CÓMO FUNCIONA?

VISUALBOT *Solar* evalúa cada imagen termográfica de acuerdo con los criterios recogidos en el **estándar IEC TS 62446-3**, procesando en minutos las miles de imágenes de inspección termográfica que se generan durante la inspección de un parque fotovoltaico de grandes dimensiones.

FLUJO DE TRABAJO





1

Captura de imágenes termográficas georreferenciadas a través de dron aéreo

2

Procesamiento de las imágenes con **VISUALBOT *Solar***

3

Emisión del **Informe de Inspección**, Ortofotografía y listado de paneles dañados

ANOMALÍAS TÉRMICAS DETECTADAS

VISUALBOT *Solar* es capaz de **detectar las 12 tipologías de defectos** en paneles fotovoltaicos recogidos en **IEC TS 62446-3**

El software clasifica además los defectos atendiendo su CoA

IEC

IEC TS 62446-3

Edition 1.0 2017-06

TECHNICAL SPECIFICATION

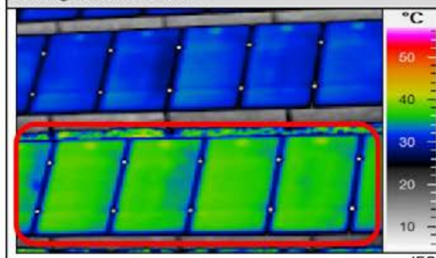
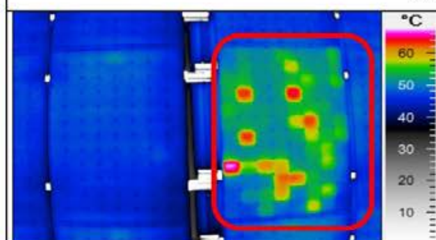
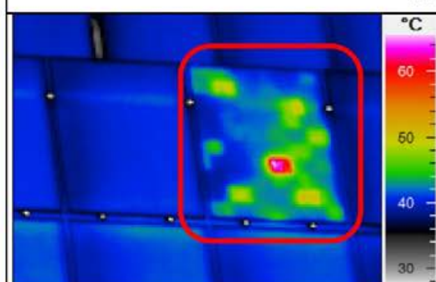
7.3.2 Classes of abnormalities (CoA)

For the allocation into classes of abnormalities (CoA), the specific patterns and measured temperatures have to be compared with the examples of thermographic images and differences in temperature shown in Annex C. Table 4 introduces three classes of abnormalies and their follow up action. This is important since there might be imminent danger (electric shock or fire) to peronal and property.

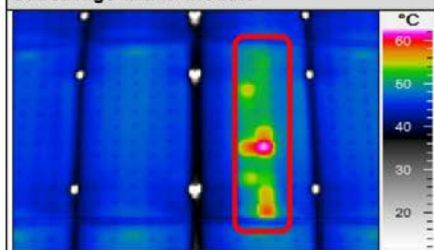
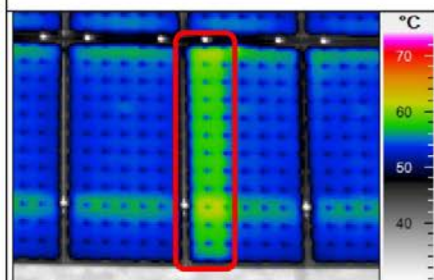
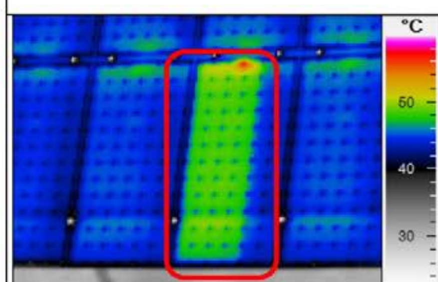
Table 4 – Allocation in classes of abnormalities

Class of Abnormality (CoA)	1 (no abnormalities – OK)	2 (thermal abnormality – tA)	3 (safety relevant thermal abnormality – dtA)
Recommendation for actions	No imminent action	Checking the cause and, if necessary, rectification in a reasonable period.	Prompt interruption of operation, checking the cause and rectification in a reasonable period.

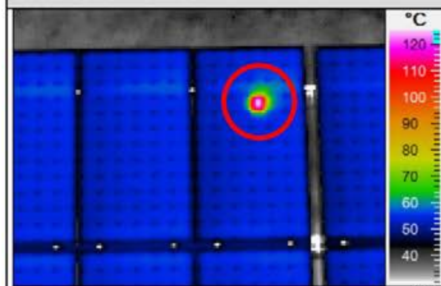
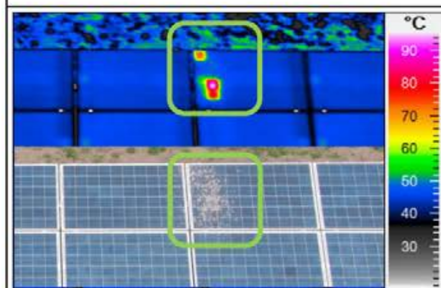
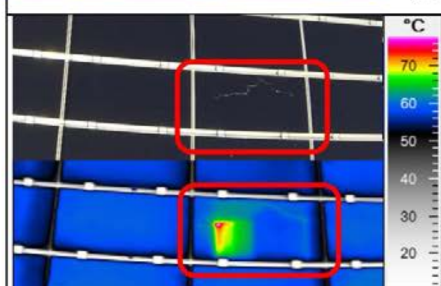
ANOMALÍAS TÉRMICAS DETECTADAS *(1 de 4)*

Example 1 – 3: Strings and modules	Category	CoA	Temperature difference to normal operating device at 1 000 W/m² (ΔT_2)	Thermal pattern, definition and additional information of abnormality
 IEC	**Modules in open circuit** **(crystalline Si and thin film)**	2	2 K to 7 K (at 15 % module- efficiency typically 4 K to 6 K)	Assessable by thermal pattern and classified as a extended area abnormality. The module surface is homogeneously heated. ΔT of the junction box is similar to operational state. Recommended: check module, state of operation of inverter, and condition of cabling, connectors, and fuses.
 IEC	**Module in short circuit** **(crystalline Si)**	2	Averaged 2 K to 7 K over module surface (at 15 % module- efficiency typically 4 K to 6 K)	Assessable by thermal pattern, visual image and classified as a extended area abnormality. Similar pattern as with broken front glass (check isolation resistance), PID, cell defects and mismatch. Recommended: check module and cabling.
 IEC	**Crystalline Si module with broken front glass** **(crystalline Si)**	3	Averaged 0 K – 7 K over module surface (at 15 % module- efficiency typically 0 K – 6 K)	Assessable by thermal pattern and visual image. Beware of high voltage as isolation resistance is lost. Similar pattern as modules in short circuit, with PID, cell defects and mismatch. Sometimes just single broken cells are heated. In the first weeks after the breakage, a module with broken glass can show almost normal thermal behaviour.

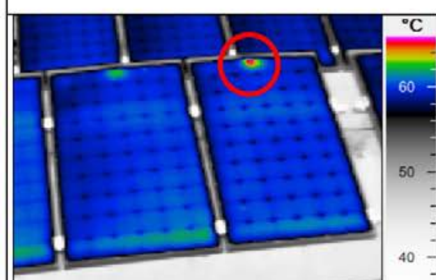
ANOMALÍAS TÉRMICAS DETECTADAS *(2 de 4)*

Example 4 – 6: Substrings within module	Category	CoA	Temperature difference to normal operating device at 1 000 W/m² (ΔT_2)	Thermal pattern, definition and additional information of abnormality
 *IEC*	**Substring in short circuit** **(crystalline Si)**	2	Averaged 2 K to 7 K higher than substring (at 15 % module- efficiency typically 4 K to 6 K)	Assessable by thermal pattern and classified as a extended area abnormality. At one or more substrings, easily mistaken for cell breakage or cell defects, Potential induced degradation (PID) or mismatch. Recommended: check module and bypass diodes for proper function under reverse biasing.
 *IEC*	**1x substring in open circuit, loss of connection within module junction box or cell connector** **(crystalline Si and thin film)**	2-3	2 K to 7 K (at 15 % module- efficiency typically 4 K to 6 K)	Assessable by thermal pattern and classified as a extended area abnormality. Part of the module surface is homogeneously heated up and heat dissipation by the bypass diode, which is operating, is visible. Temperature difference of the glass on top of the junction box containing the operating bypass diode differs with construction. Loss of contact at a cell connection might lead to a serial arc visible on the module backside surface=> CoA: 3.
 *IEC*	**2x substrings in open circuit, loss of connections within module junction box** **(crystalline Si and thin film)**	2-3	2 K to 7 K (at 15 % module- efficiency typically 4 K to 6 K)	Assessable by thermal pattern and classified as a extended area abnormality. Part of the module surface is homogeneously heated up and heat dissipation by the bypass diodes, that are operating, is visible. Temperature difference of the glass on top of the junction box differs with construction. Loss of contact at a cell connection (or failure of a bypass diode) might lead to a serial arc visible on the module backside surface=> CoA: 3.

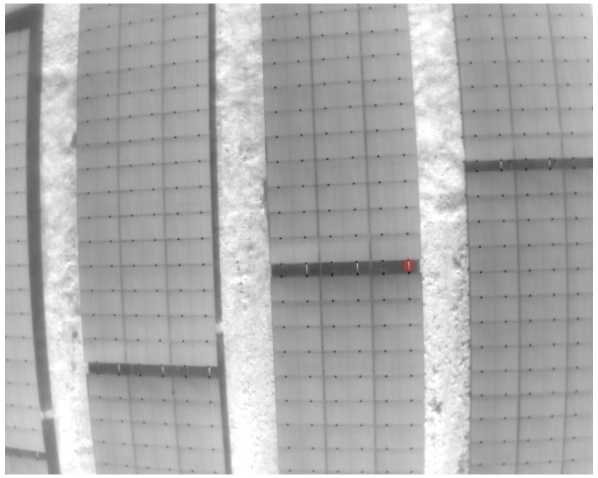
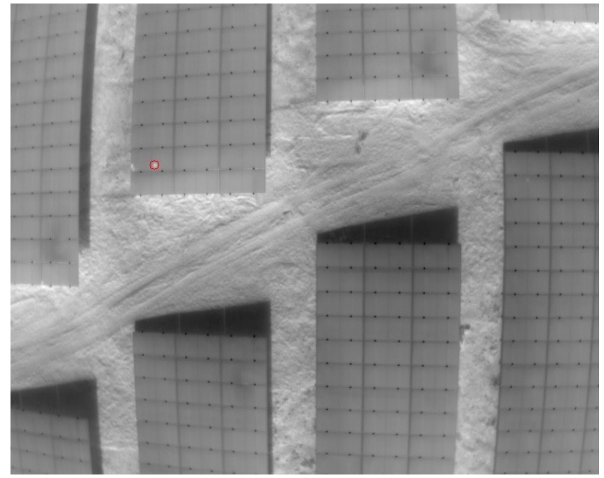
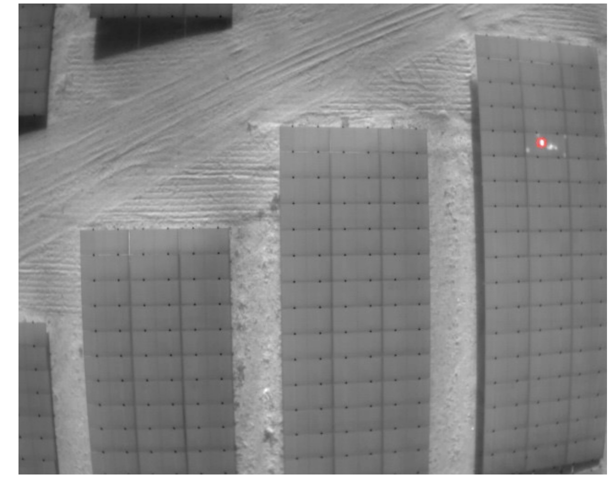
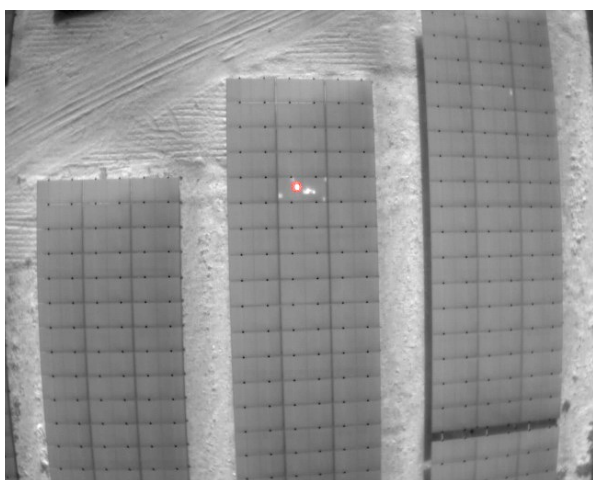
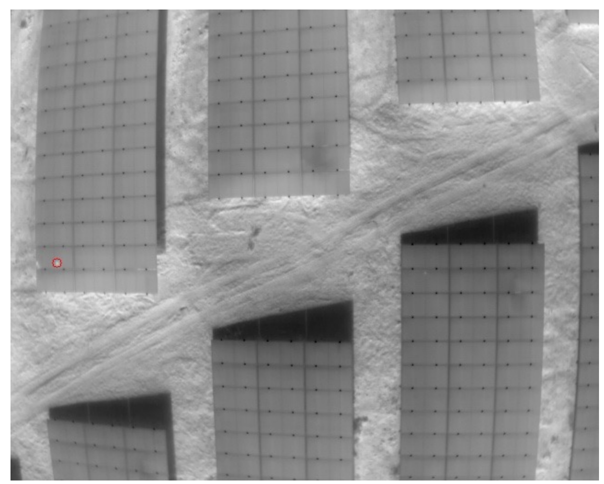
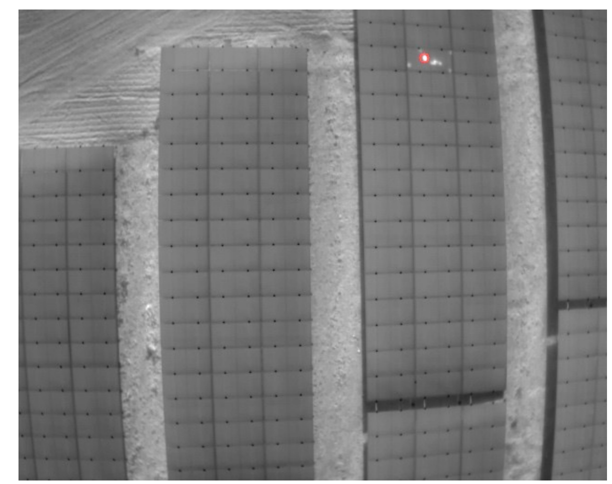
ANOMALÍAS TÉRMICAS DETECTADAS *(3 de 4)*

Example 7 – 9: Local abnormalities	Category	CoA	Temperature difference to normal operating device at 1 000 W/m^2 (ΔT_2)	Thermal pattern, definition and additional information of abnormality
	**Single cell with difference in temperature** **(crystalline Si)**	a) 2 b) 3	a) 10 K – 40 K average value over the cell area b) > 40 K average value over the cell area	Assessable by thermal pattern, visual image and classified as an extended area abnormality. Difference in temperature increases with load, cell efficiency and number of cells in a substring. High temperatures mostly caused by broken cells. Might lead to irreversible damage of cell, encapsulation and bypass diodes. Recommended: Check that there is no shading or severe soiling.
	**Module with cells shaded by dirt** **(crystalline Si and thin film)**	a) 1 b) 2	a) if location with lots of rain and ΔT a few K b) if location with basically no rain and ΔT > 40 K	Assessable by thermal pattern, visual image and classified typically as an extended area abnormality. a) Normal dirt, e.g. dust or bird droppings on modules will be washed by rain. No further immediate action required. b) Cleaning of PV modules is highly recommended in near future to avoid damage of PV module
	**Thin film module with broken front glass**	3	Averaged 0 K – 7 K over module surface (at 10 % module- efficiency typically 0 K – 4 K)	Assessable by thermal pattern and visual image. Beware of dangerous voltage(s) as isolation resistance is lost. Similar pattern as modules in short circuit, with PID, cell defects and mismatch. Sometimes just single broken cells are heated. In the first weeks after the break a module with broken glass can show normal thermal behaviour.

ANOMALÍAS TÉRMICAS DETECTADAS *(4 de 4)*

Example 10 – 12 Local abnormalities; Evaluation only by experienced PV – thermographers	Category	CoA	Temperature difference to normal operating device at 1 000 W/m² (ΔT_2)	Thermal pattern, definition and additional information of abnormality
 IEC	**Transfer resistance at cross-connections of a thin film module**	2-3	>10 K	Assessable by thermal pattern, visual image and classified as a point abnormality. Difference in temperature increases with load, caused by increased contact resistance e.g. due to bad soldering. Personal review by a PV expert or thermographer level 2 or equivalent is recommended.
 IEC	**Transfer resistance at cell connections of a crystalline Si module**	2-3	>10 K	Assessable by thermal pattern, visual image and classified typically as a point abnormality. Difference in temperature increases with load, caused by increased contact resistance e.g. due to bad or no soldering. Could also be caused by a broken ribbon or a missed solder point between ribbon and cross connector. Personal review by a PV expert or thermograph level 2 or equivalent is recommended.
 IEC	**Heated module junction box** **(crystalline Si and thin film)**	2-3	≥ 3 K higher temperature compared to nearby junction box	Assessable by thermal pattern, visual image and classified typically as a point abnormality. Temperature difference increases with load caused by increased contact resistance within the junction box. Alternatively it could be caused by low resistive bypass diodes that carry a significant current although they should be biased in reverse direction. Personal review by a PV expert or thermographer level 2 or equivalent is recommended. Be aware of high voltages.

IMÁGENES PROCESADAS POR VISUALBOT

VISUALIZACIÓN DE ANOMALÍAS DETECTADAS

Anomalía 1/52

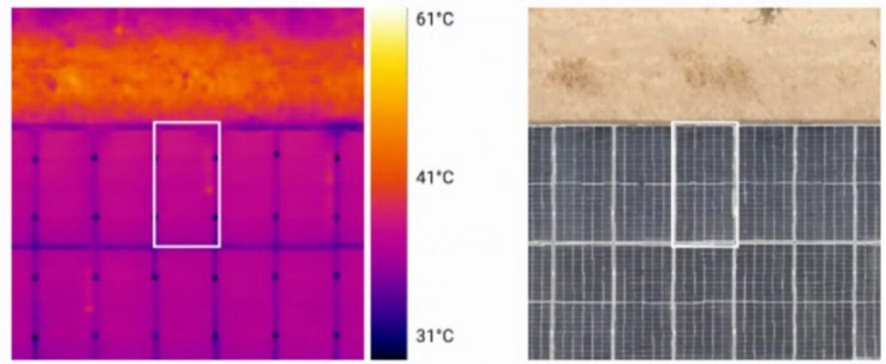
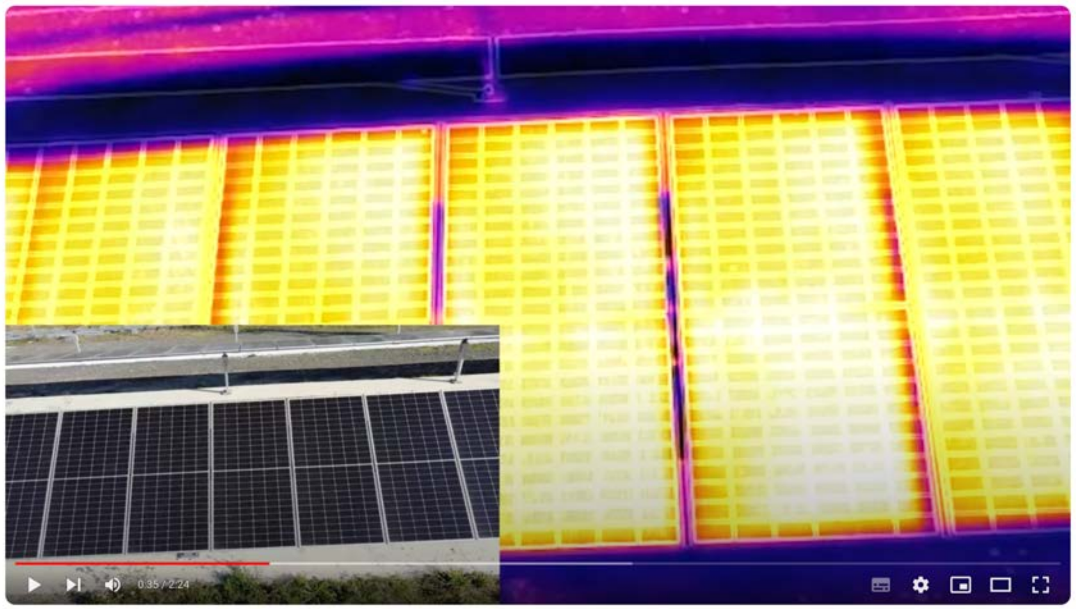


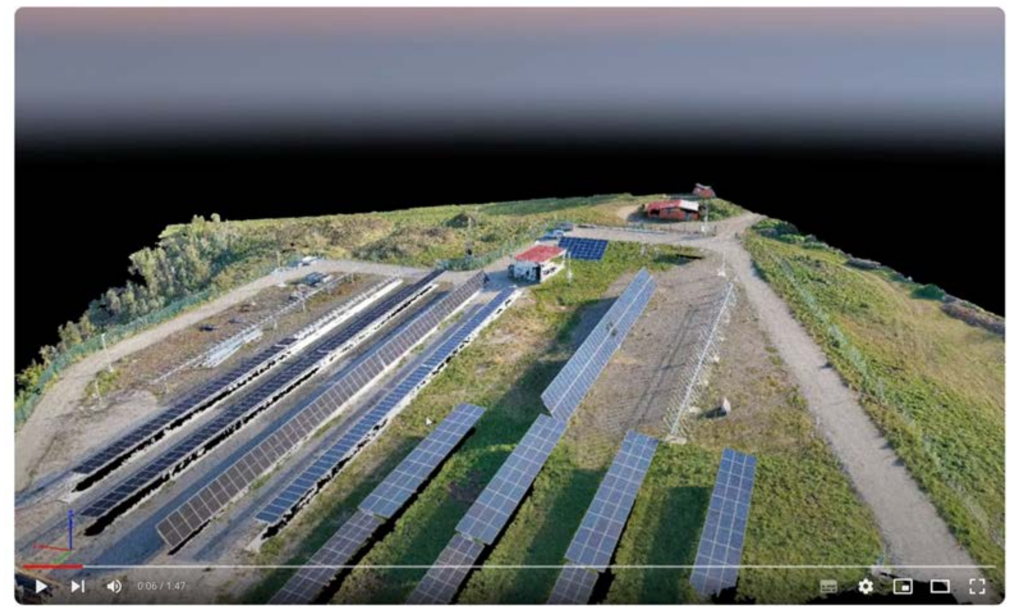
Imagen 5: Plano térmico y visual de anomalía #1

Tipo de anomalía	PID fase temprana
Causa	El módulo sufre de PID en fase temprana.
Recomendación	Revisar módulos.
Módulo	Desconocido (500 W)
Criticidad	Grave
Clase	CoA 3
Pérdidas (beta)	Medias
Temperatura máxima	44.4 ºC
Gradiente temp. Normalizado	3.1 ºC
Fecha y hora captura	2023-08-11 10:31:10
Localización	Sector: 5 / Mesa: 10 / Fila: 1 / Columna: 11
Posición GPS	link

EJEMPLOS OPERACIÓN CON DRON AÉREO



Vídeo en imagen termográfica y espectro visible



Vista 3D Nube de Puntos Parque Fotovoltaico

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