FAILURE DIAGNOSIS ON PHOTOVOLTAIC MODULES USING THERMOGRAPHY, ELECTROLUMINESCENCE, RGB AND I-V TECHNIQUES

Sara Gallardo-Saavedra[1*], Ángel Moretón-Fernández[2], Marta María Jiménez-Martín[2], Víctor Alonso-Gómez[1], Luis Hernández-Callejo[1], Óscar Martínez-Sacristán[2], Miguel Ángel González-Rebollo[2], José Ignacio Morales-Aragonés[1]

[1] Universidad de Valladolid (UVa), School of Forestry, Agronomic and Bioenergy Industry Engineering (EIFAB), Campus Duques de Soria, 42004 Soria (Spain); *sara.gallardo@uva.es
[2]GdS-Optronlab, Dept. Física de la Materia Condensada, Universidad de Valladolid (UVa), Paseo de Belén, 19, 47011 Valladolid (Spain)

ABSTRACT

Different techniques can be used to detect and quantify PV modules anomalies, as visual inspections, electrical tests like the I-V curve test, thermography or electroluminescence (EL). Each of these techniques has some advantages and disadvantages, and based on them, PV plants operators usually apply only one or two of these techniques within the Operation and Maintenance (O&M) activities. Additionally, the results provided by each of them are usually studied separately, by different research groups. However, these methods can provide complementary results, glimpsing interesting information about the PV site state. The main strength of the research performed is the simultaneous study of all these inspection techniques, studying the correlation between them.

- **Keywords:** *photovoltaic inspection, faults diagnosis, photovoltaic thermography, photovoltaic electroluminescence, IV curve.*

INTRODUCTION

Visual inspection is efficient, cheap and quick, but only reveals some of the failures: bubbles, delamination, yellowing and browning in the front of the module, broken cells… I-V curve (current versus voltage curve) provides important information about the electrical performance of the system and its main parameters, revealing degradation, mismatched modules, cracked cells, improper resistance, shadings or bypass diodes malfunction [1], but it can not be performed in common operation. Thermography is not intrusive, and possible thermographic defects detected in a PV module are: cell hotspot, overheated bypass circuit, junction box, connection or whole module [2]. Can be performed with aerial cameras. Finally, EL can be used in manufacturing process, shipped to a lab after unmounting the modules from the site or on the field, with an structure or specific tripod or also by means of EL cameras mounted on UAVs. The high resolution of the EL images enables resolving some defects more precisely than in IR images [3]. Each of these techniques has some advantages and disadvantages and provides complementary results, analysed in this research.

METHODOLOGY

Figure 1: PV field of the Campus Duques de Soria (a), temperature and humidity controlled chamber at the EIFAB in Soria (b) and EL and IR imaging capturing system used in the temperature and humidity controlled chamber ©

RESULTS AND DISCUSSION

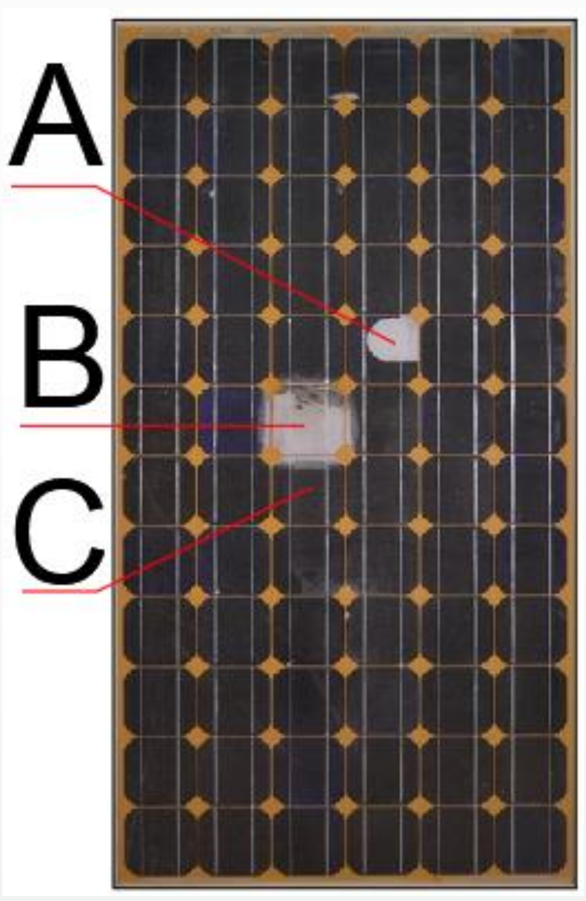


Figure 2: S-E1 module RGB appearance

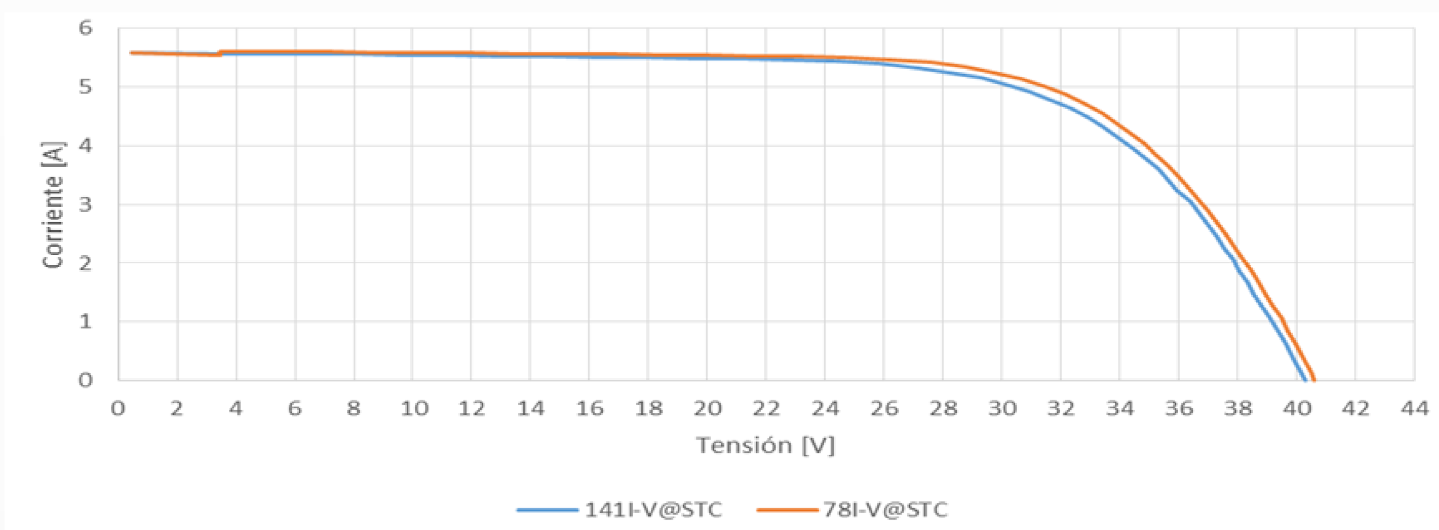
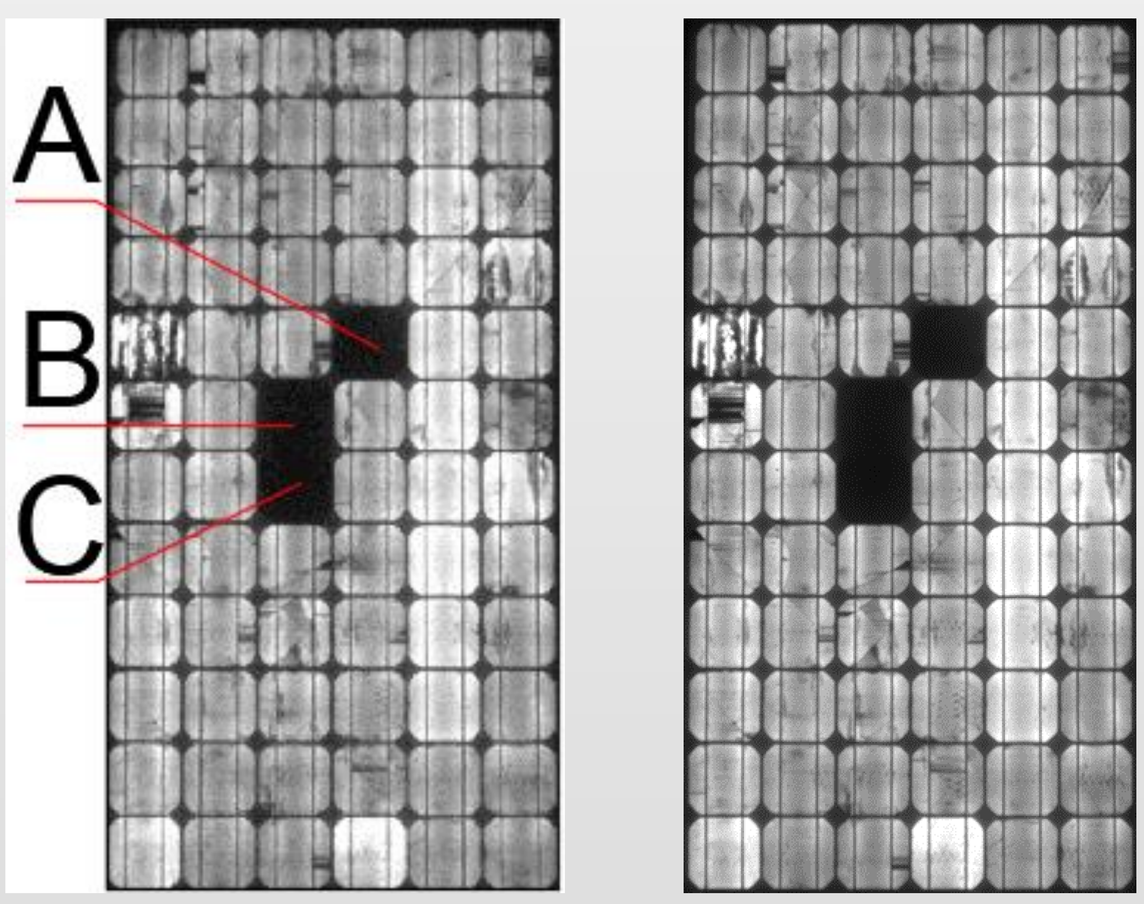


Figure 3: IV Curve of the S-E1 module in STC.

- **Visual (fig. 2):** An EVA delamination failure in the cell labelled as A, and a burn area in cell B. Apparently, cell C does not present important failures detected visually, but failure B apparently is extended in the upper area of cell C. However, these three cells are inactive, as it can be seen in the EL images (fig. 4), appearing completely black, as they do not emit. These cells are short-circuited, allowing the current passing but not producing energy.
- **IV Curve (fig. 3):** Open circuit voltage (Voc) drop of 3,45V, which correspond with the contribution of the three inactive cells in addition to other partial inactive cells. Short circuit current (Isc) does not fall, since the same current continues circulating throughout the circuit as damaged cells are short circuited.
- **EL (fig. 4):** No significant change between the IV curves shape before and after the EL test. Continuously fed short circuit current injection (72 hours) does not affect considerably the performance.



a) b)

Figure 4: First (a) and last (b) EL images of S-E1 module

- **Thermography fourth quadrant (fig. 5):** Total inactive cells remains cooler than active areas during the current injection for the EL test. Additionally, it has been observed that when there is an inactive area within a cell partially active, the active area is revealed as an overheated area.
- **Thermography ordinary operation (fig. 6):** These Failures are also revealed in operation, as hot spots working in the second quadrant. However, the delamination in A and B, produces a change in the material emissivity value responsible of covering up the hot spots, as the delaminated areas appear cooler than their actual temperature.

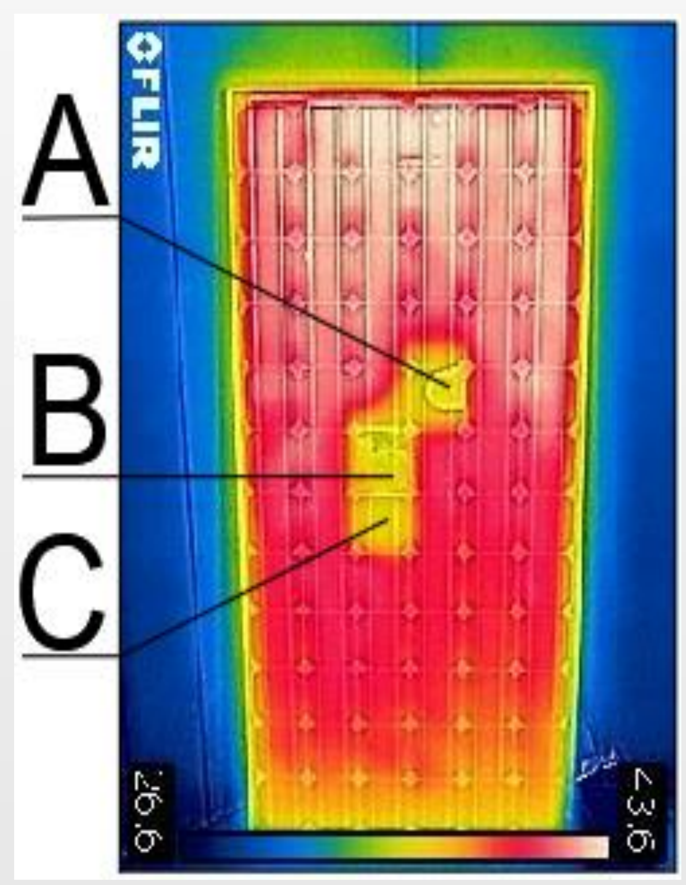


Figure 5: Thermographic image of S-E1 in the fourth quadrant during the EL test.

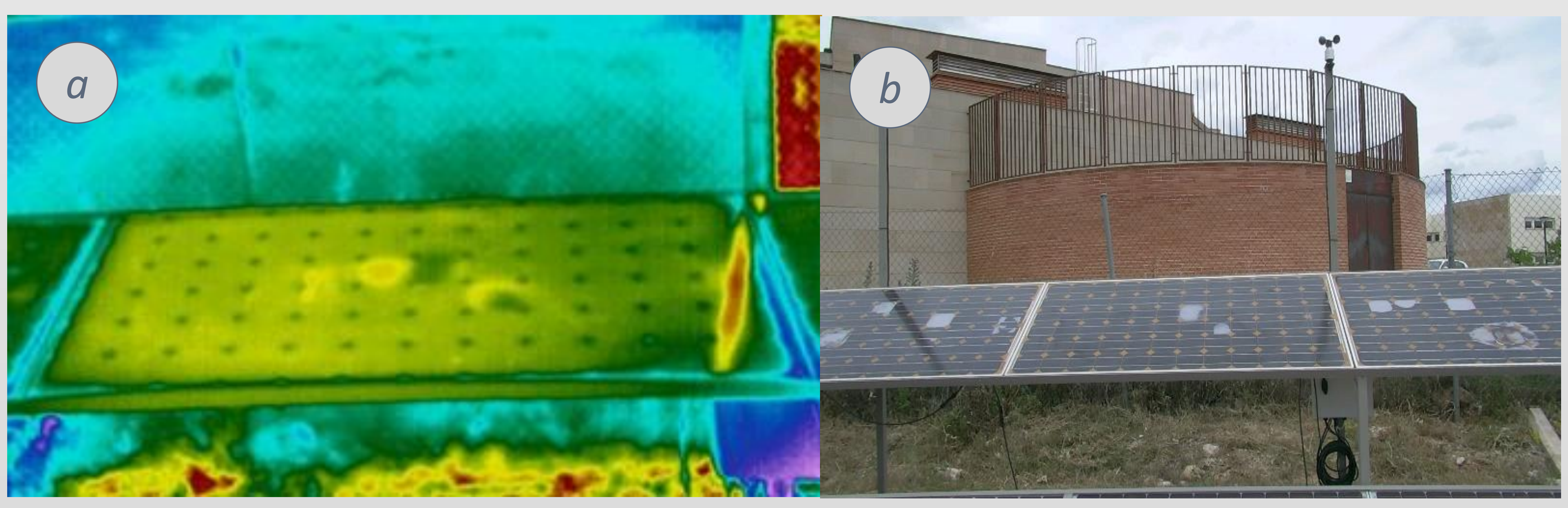


Figure 6: Thermographic (a) and visual (b) images of S-E1 outdoor in ordinary module operation.

CONCLUSIONS

- It has been seen that continuously fed short circuit current injection during 72 hours does not affect considerably the modules performance, as EL and RGB images do not reveal important changes in the module. It has been proved how EL images and thermography in the fourth quadrant have high correlation, as total inactive cells remains cooler than active areas during the current injection for the EL test. However, the similarity with thermography during ordinary operation of the modules is not direct, as some active areas appears as hot spots but they can be covering up by delamination, which causes a different emissivity value. Finally, it has been explained how total inactive cells are revealed as a Voc drop in the IV curve, maintaining the curve shape if they are not mixed with other kinds of defects.

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