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Case study

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Determination of Potential-induced Degradation (PID) Using Aerial Thermography

Abstract

In recent years, potential-induced degradation (PID) has been one of the most detrimental problems for Photovoltaic (PV) modules operating in the field. It degrades the power output of PV modules and reduces the performance ratio (PR) of solar plants. Here we present a case study, which confirms that PV modules affected by PID can be identified from a thermographic inspection performed by *Above*. The patterns identified and diagnosis of PID were validated using electroluminescence (EL) and current-voltage (I-V) curve measurement.

Introduction

A typical PV system architecture consists of strings of modules connected in series to generate a high voltage. The frames of the PV modules are grounded for safety reasons, which causes a potential difference between the cells and the outer part of the modules [1]. PID occurs when this potential difference leads to a leakage current between the silicon semiconductor of the PV cell and other materials of the module. This involves the migration of positive ions, e.g. Na+, from the outer part of the module to the semiconductor, or of negative ions away from the semiconductor to the outer part of the module (Figure 1.a). Factors that can influence the degree of PID at the module level include the encapsulation material, anti-reflective coating on cells and the structural design of the modules (e.g. frame construction). At the system level, inverters generally do not provide a functional ground (true ground), while the frames of the modules are grounded. Hence, a high potential difference between the frame and cells in the PV array is left floating (Figure 1.b), which initiates the PID-related degradation at either the positive or negative end of the string. It is also known that environmental factors such as temperature and humidity have a strong effect on the rate of PID-related module power degradation [2].

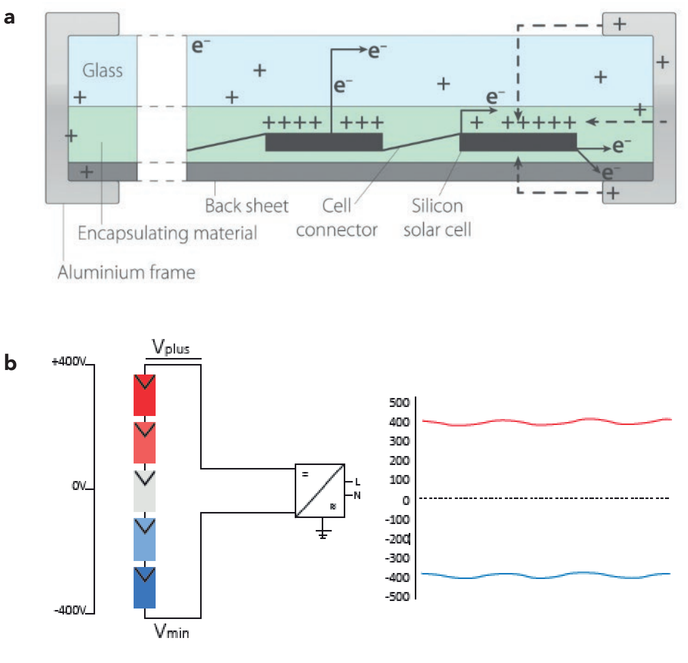

Figure 1. a, Movement of charged particles causing leakage current from the silicon semiconductor to frame of the module and **b**, the representation of floating system voltage influencing PID [3]

Methodology

We used our IEC 62446-3 compliant aerial thermographic inspection service to carry out a health check across a 5MW solar site in the UK. We analysed the thermographic data using our SolarGain Inspection Hub and observed evidence of possible PID on a number of modules. Sets of PV modules were selected for further ground-based testing. EL imaging and I-V curve measurements using a flash solar simulator were performed to validate and confirm the degradation of the modules. EL images were then retrospectively compared to the original thermographic images of the modules.

Results and Discussion

The position of the inspected modules in the string and the corresponding thermal images are shown in Figure 2. It can be clearly seen that modules 1, 3, 4, 5 and 6 exhibit multiple cells which are considerably hotter (more yellow) than other cells/modules, and that the affected modules are located at the end of a string. This so-called 'string-end heating pattern' (SEHP) is highly suggestive of PID. However, it is unusual and interesting, that module 2 is unaffected, as SEHP/PID does not typically skip modules. Slight power degradation (~3%) and darker cells at the bottom of the module suggests that module 2 was more PID-resistant than others, possibly due to differences in the materials used. However, it is likely that it will degrade further over time.

1	2	3	4	5	6	7	8	9	10	11
22	21	20	19	18	17	16	15	14	13	12

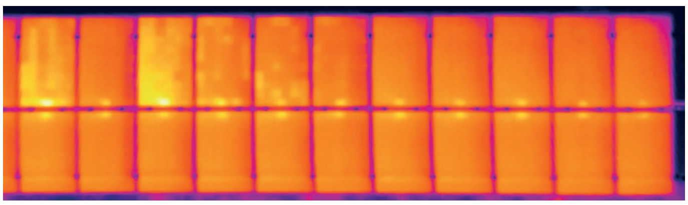

Figure 2. Schematic showing module numbering (top). Thermal imagery of a 22-module string from an aerial inspection by *Above* (bottom: more yellow denotes hotter module surface)

EL imaging and power measurement using a flash tester are reliable and effective (but costly and time-consuming) methods to investigate module degradation in the field. These methods usually require demounting and remounting of modules for measurements. Figure 3 shows the EL images and I-V curves of the six modules with corresponding power degradation. Figure 4 shows a direct comparison between EL (c) and thermographic imagery (a and b), which was captured by a UAV at 20 meters above the string, during daylight hours. The colour palette of the thermographic images has been adjusted in 4.b, so that white represents cold (normal) and black represents hot (anomalous) cells. There is a remarkable correlation between the pattern of anomalous cells in the thermographic (4.b) and EL (4.c) images.

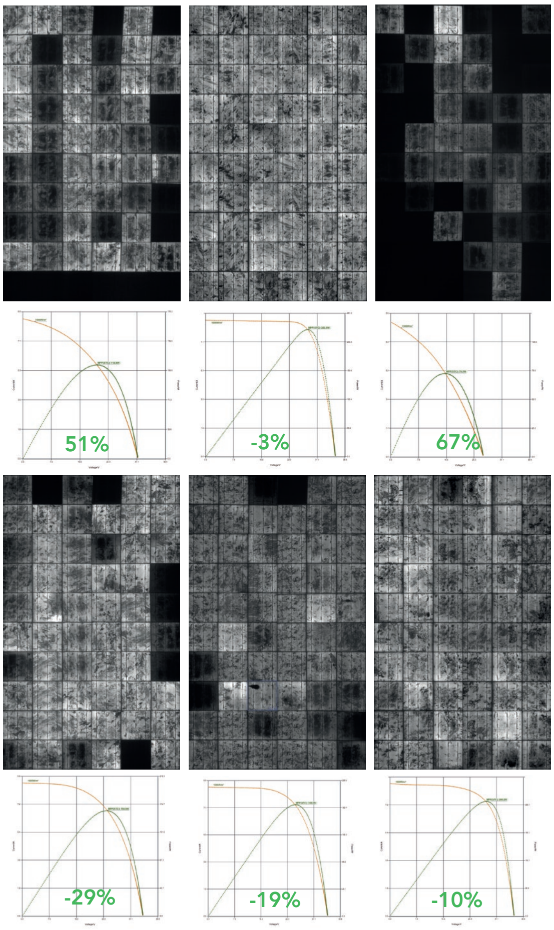

Figure 3. EL images and I-V Curves (insets below) of inspected PV modules (top row, modules 1–3; bottom row, modules 4–6)

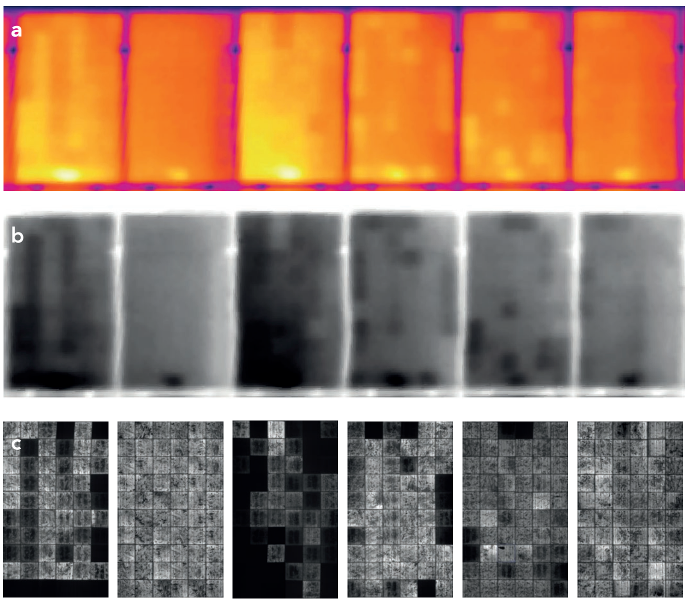

Figure 4 – Comparison between **a**, thermographic imagery (more yellow denotes hotter cells). **b**, thermographic imagery (darker colour denotes hotter cells) and **c**, EL images (darker colour denotes degraded/deactivated cell) of PID-affected PV modules.

Conclusion

It is clear from our thermographic images that the inspected PV modules have several deactivated or degraded cells. The flash power measurements confirmed the likely diagnosis of PID on selected modules, which had come to our attention during thermographic inspection a year earlier. Even though the thermal gradients detected over the surface of the modules were not high (max. 8.6°C), the degradation on the module power output was up to 67% of the rated power. The overall power loss of the entire 22-module string (based on flash power measurements of each module) was approximately 10%, which would have a significant impact on annual energy generation.

The black-and-white heat map images from the thermographic images show an extremely close correlation with the EL images. Moreover, thermographic imagery can be collected orders of magnitude faster and much more cost-effectively than EL.

Furthermore, the SolarGain Inspection Hub will soon have the capability to estimate power-losses associated with any thermal anomaly, including PID. Using our service, clients will therefore be able to both detect PID at an early stage and assess its impact on the energy yields of their assets, enabling early intervention to mitigate its potentially severe consequences.

References

[1] W. Luo et al., "Potential-induced degradation in photovoltaic modules: A critical review," Energy and Environmental Science, vol. 10, no. 1. Royal Society of Chemistry, pp. 43–68, 01-Jan-2017.

[2] J. Berghold, S. Koch, A. Böttcher, A. Ukar, M. Leers, and P. Grunow, "Potential-induced degradation (PID) and its correlation with experience in the field," Photovoltaics International, Jan-2013.

[3] S. Pingel et al., "Potential induced degradation of solar cells and panels," in IEEE 35th Photovoltaic Specialist Conference (PVSC), 2010, pp. 2817–2822.

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Above deliver cutting edge aerial inspection and data analytics solutions to the solar industry. To find out more about the solutions and software we offer, visit our website.

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