UNDERSTANDING POTENTIAL-INDUCED DEGRADATION (PID) OF PHOTOVOLTAIC (PV) MODULES

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UNIVERSITY OF YORK, UK

PEARL PV'S TRAINING SCHOOL ON THE **POTENTIAL OF MONITORING TOOLS AND ADVANCED OPERATION AND MAINTENANCE PRACTICE FOR SECURITY AND PREDICTABILITY OF PV PERFORMANCE**

CONTENTS

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- **May. 2018 – August 2021:** Lecturer/Senior Lecturer in Electronics and Control Engineering, School of Computing and Engineering, University of Huddersfield.
- **Jan. 2016 – Dec. 2016:** Research Assistant, project title: “PV output power enhancement using new intelligent PV configurations”. School of Electronic and Electrical Engineering, Leeds University.

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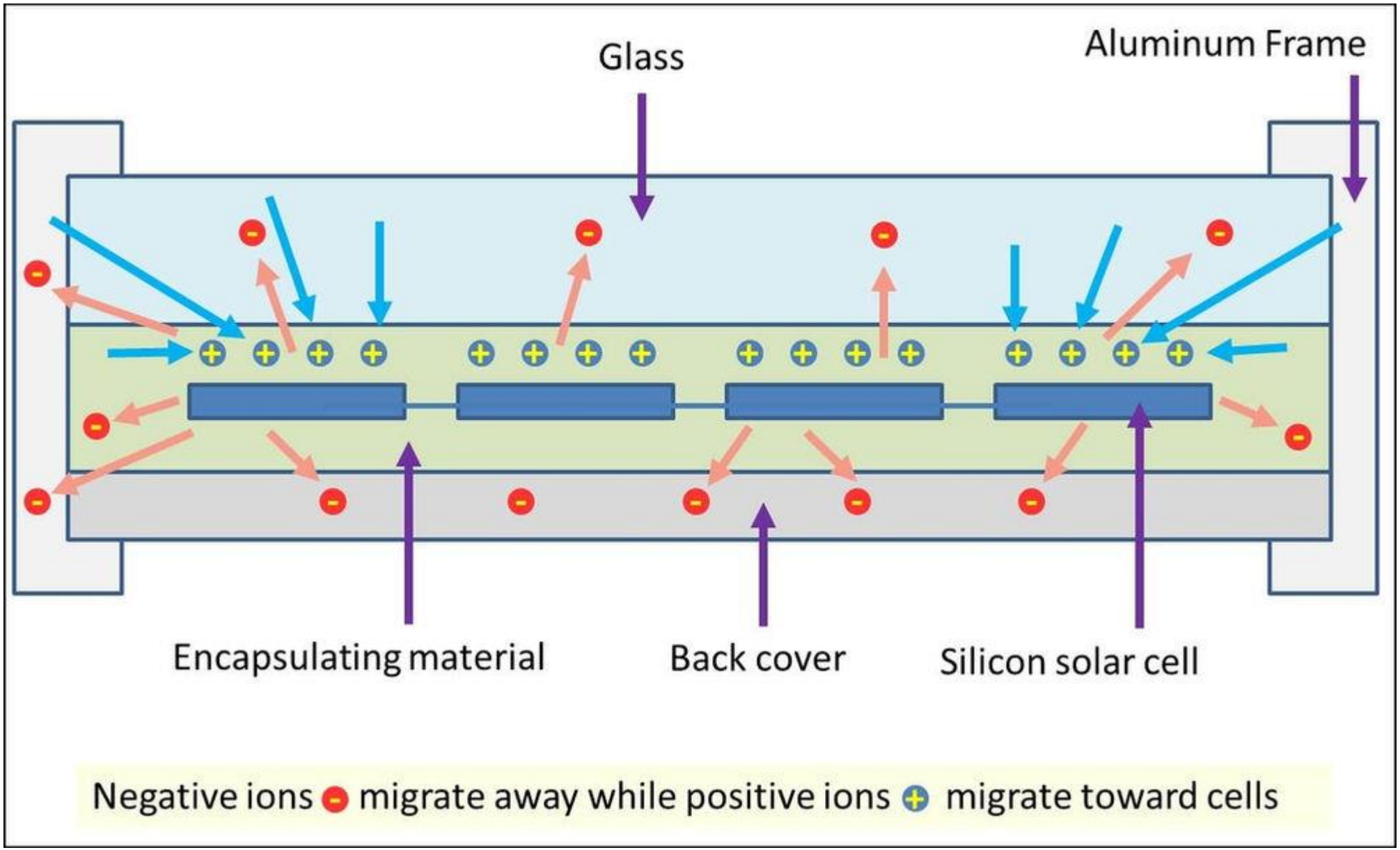
WHAT IS PID?

PID stands for potential induced degradation.

PID occurs because of minor, unwanted currents between the semiconductor on the one side, and the glass, **anti-reflective coating (ARC)**, the frame, and the mounting on the other side.

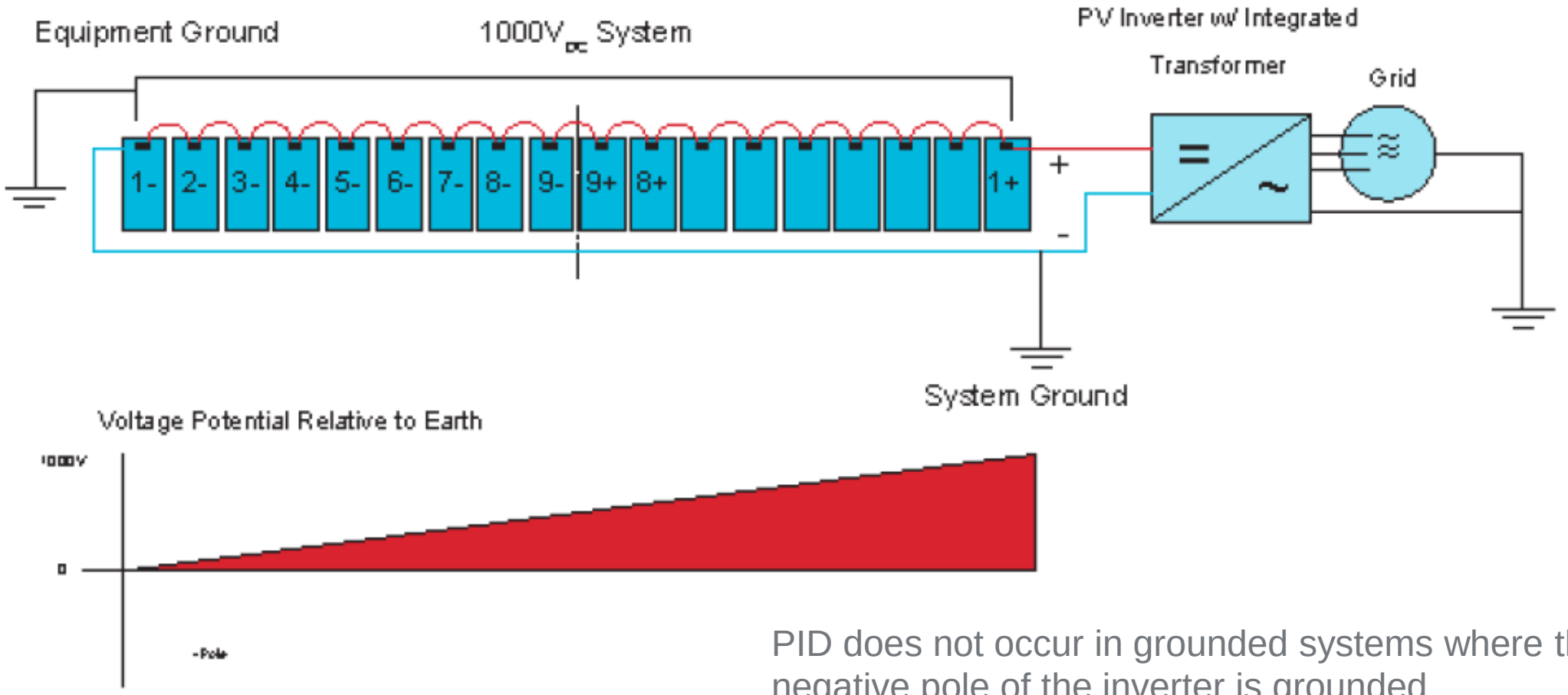
The degradation in performance is associated with migration of **sodium ions**, from the glass plate through the encapsulation (commonly: EVA) and the Anti-Reflective Coating (ARC) to the cell.



higher negative potential

sodium ions?

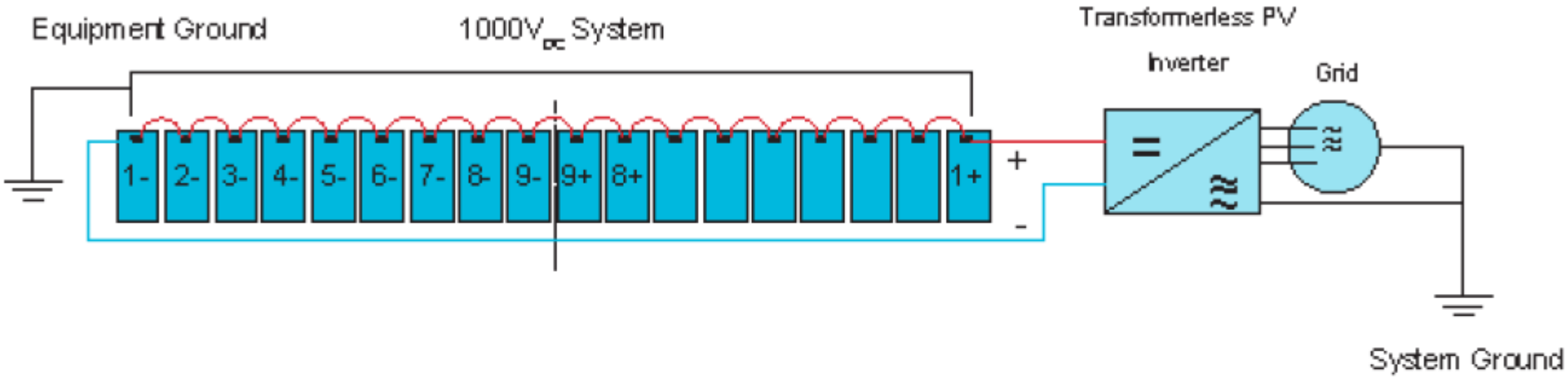
What is PID in Solar (PV) Panels? (vigdu.com)

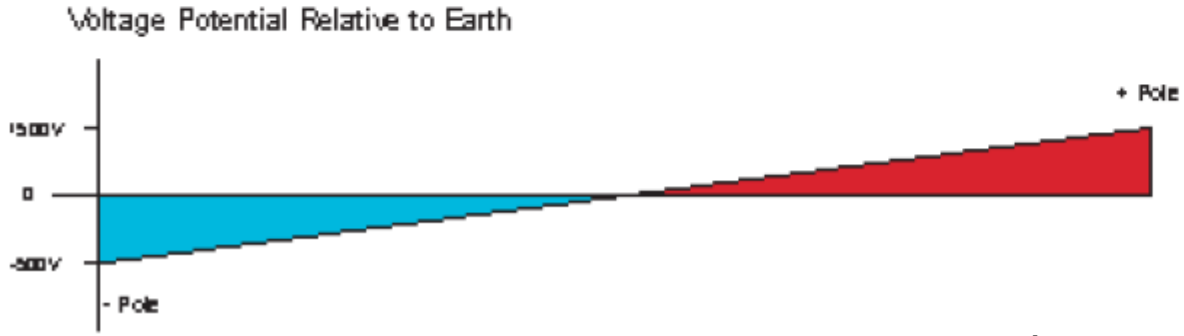


PID does not occur in grounded systems where the negative pole of the inverter is grounded

PID & INVERTER

[What is PID and how can you reduce solar power loss? – HSB Equipment Connection Blog]





In the case of an ungrounded system the PID effect is most severe in the modules with the highest negative potential

PID & INVERTER

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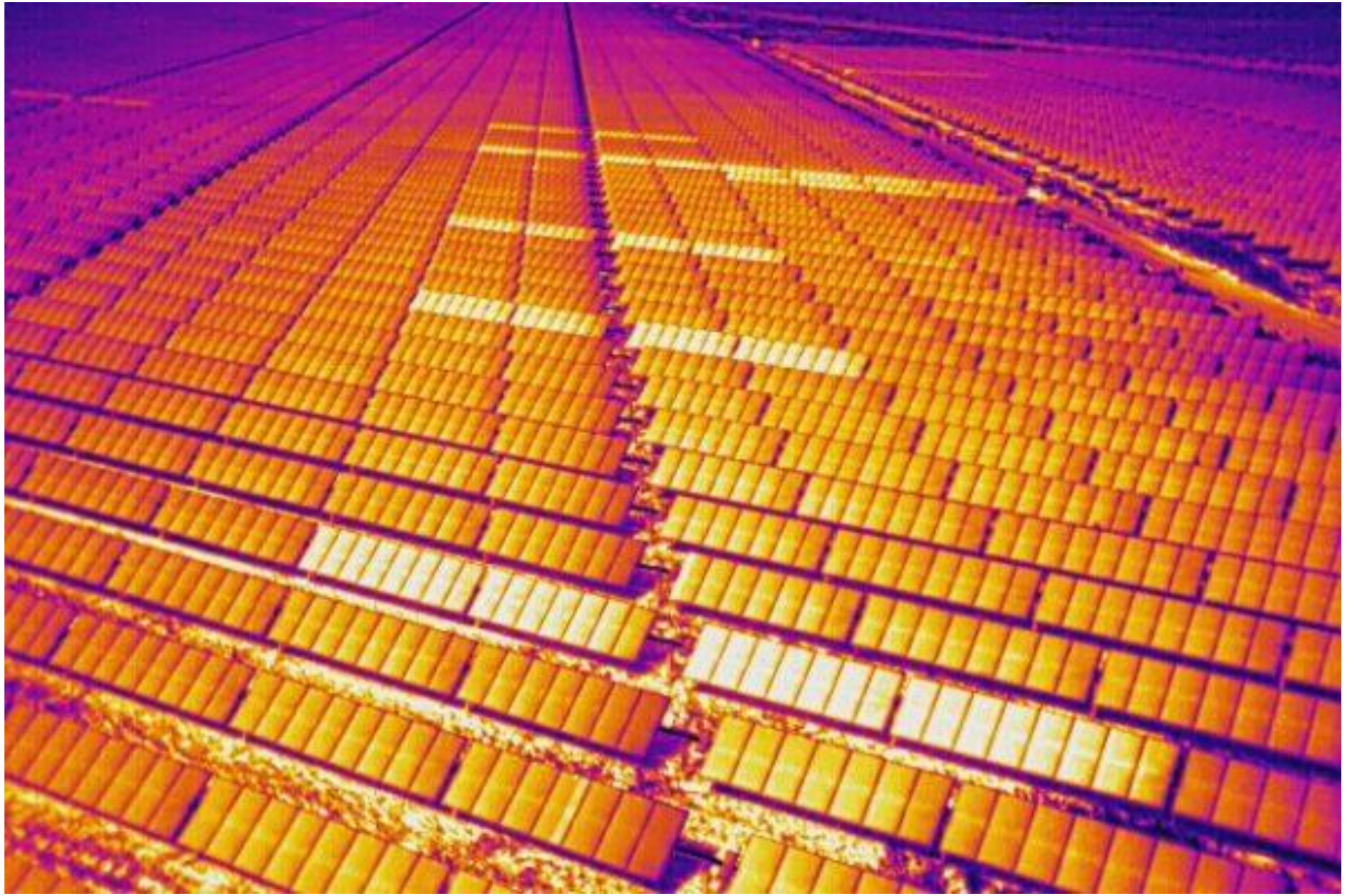
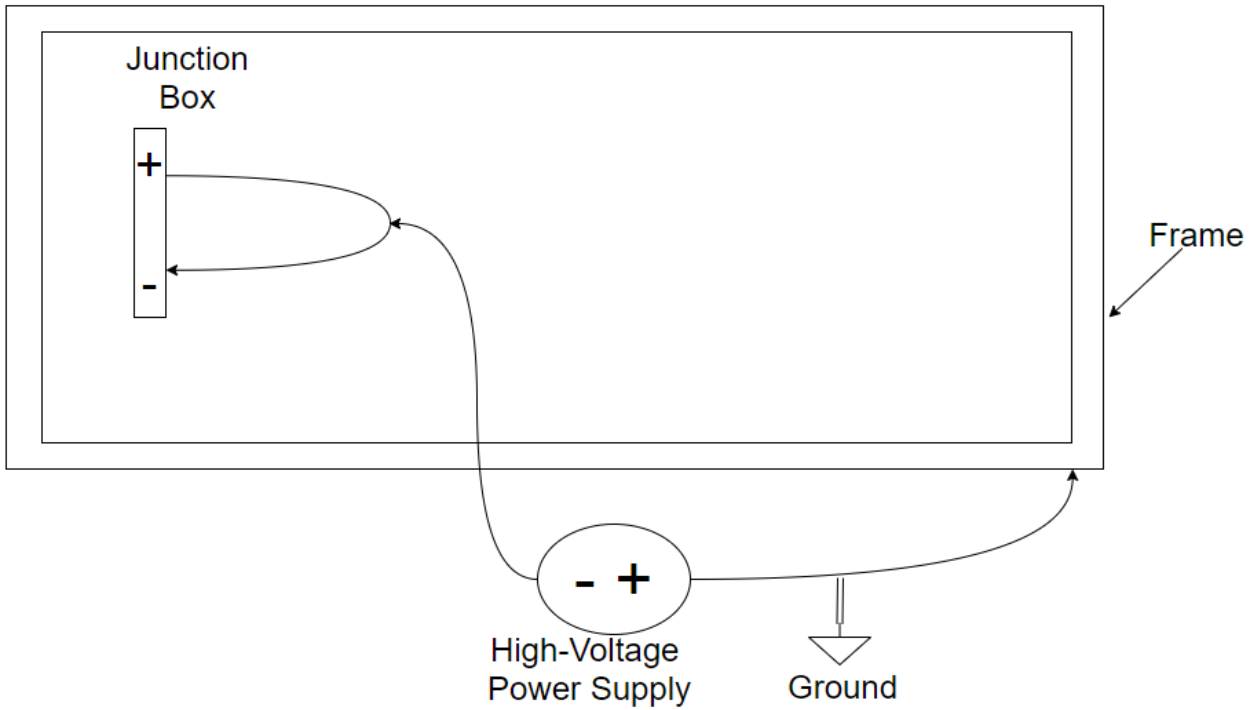


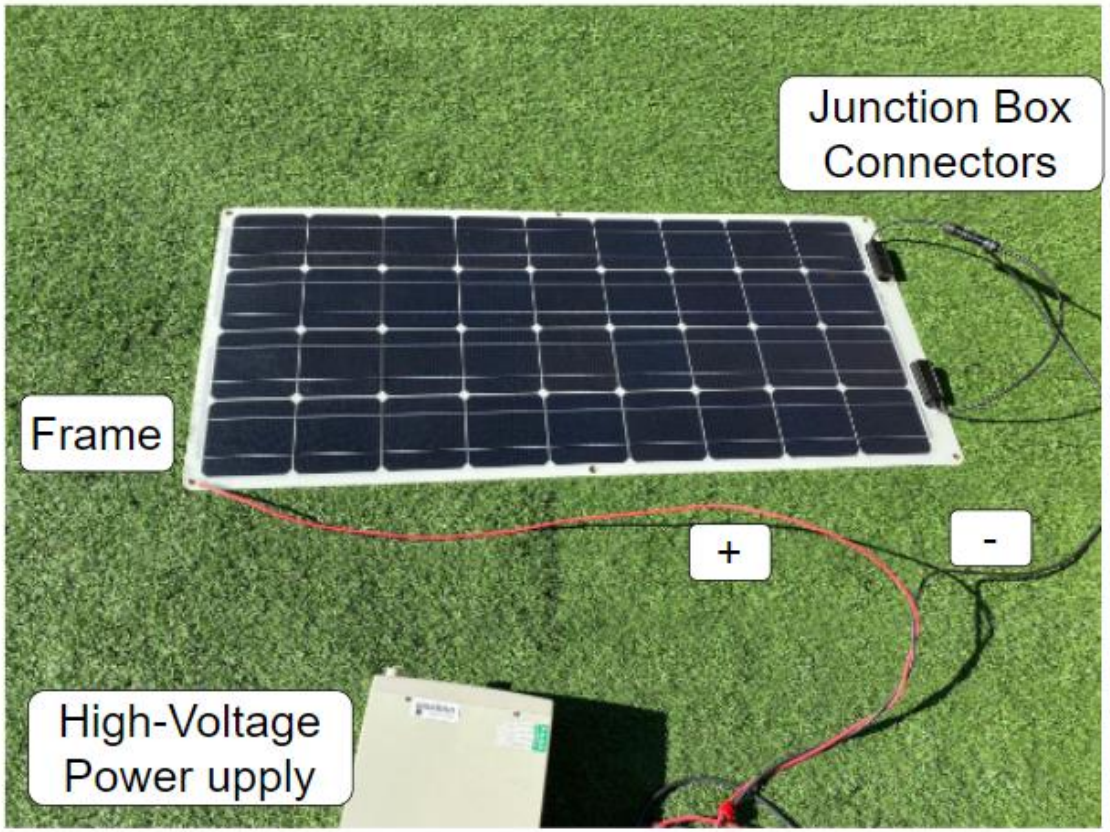
PID EFFECT

TESTING PROCEDURE - INDOOR

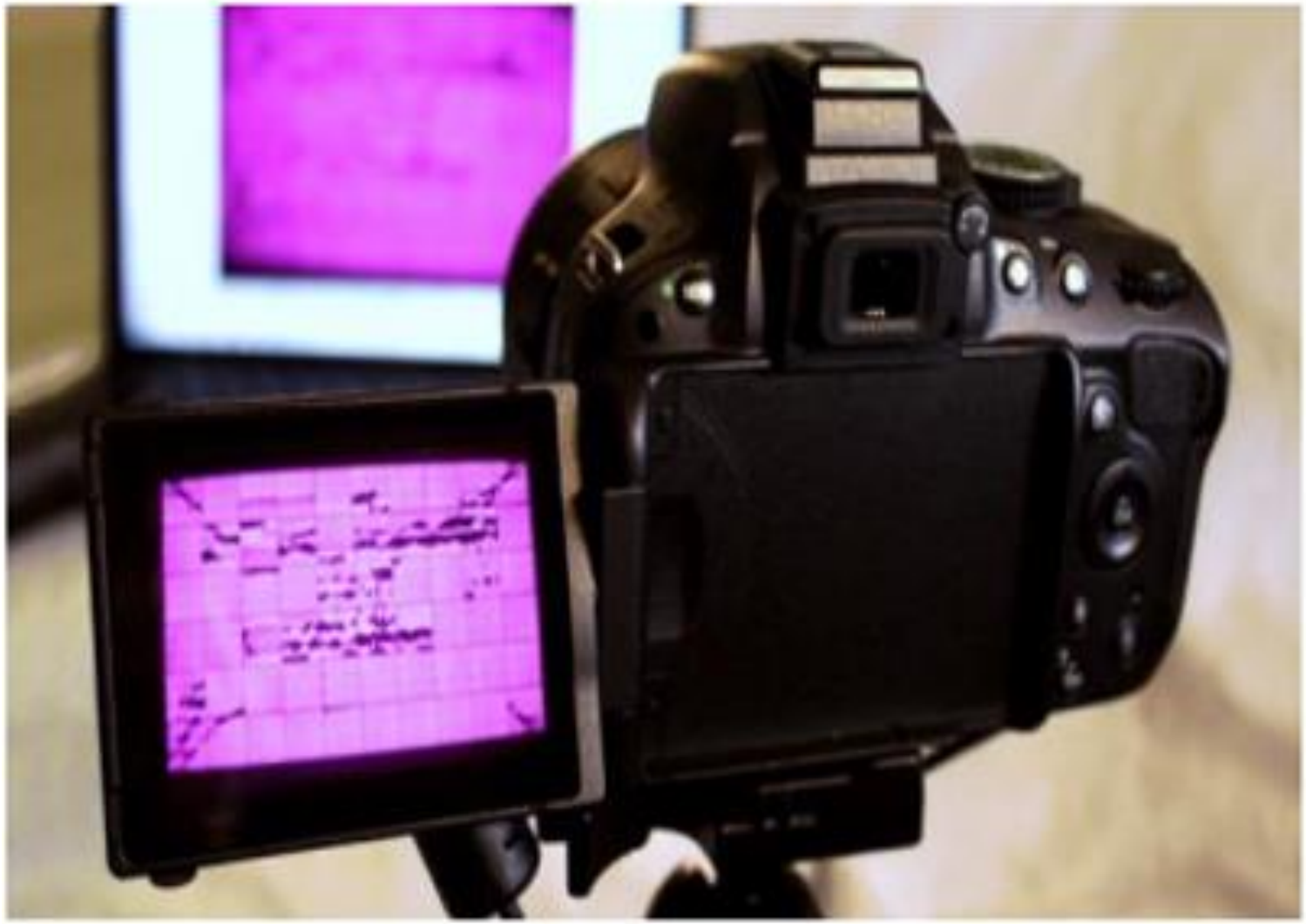
80% relative humidity, 85°C and biased with a voltage of -1000 V, for 96 hours

PV Module


Junction
Box
+
-
Frame
- +
High-Voltage
Power Supply
Ground


Junction Box
Connectors
Frame
+
-
High-Voltage
Power upply

ELECTROLUMINESCENCE (EL) IMAGING



MONOCRYSTALLINE SILICON PHOTOVOLTAIC – CASE STUDY

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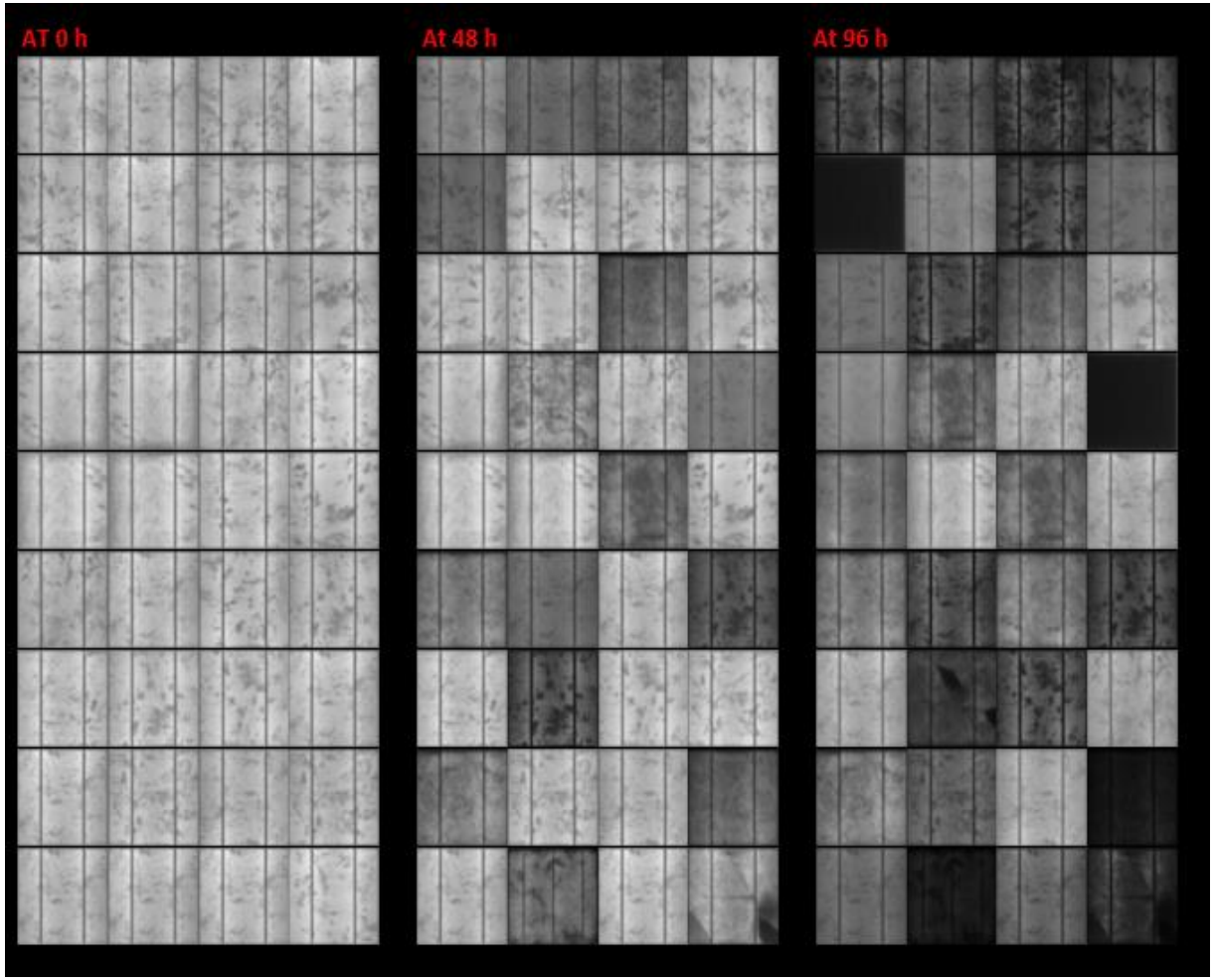

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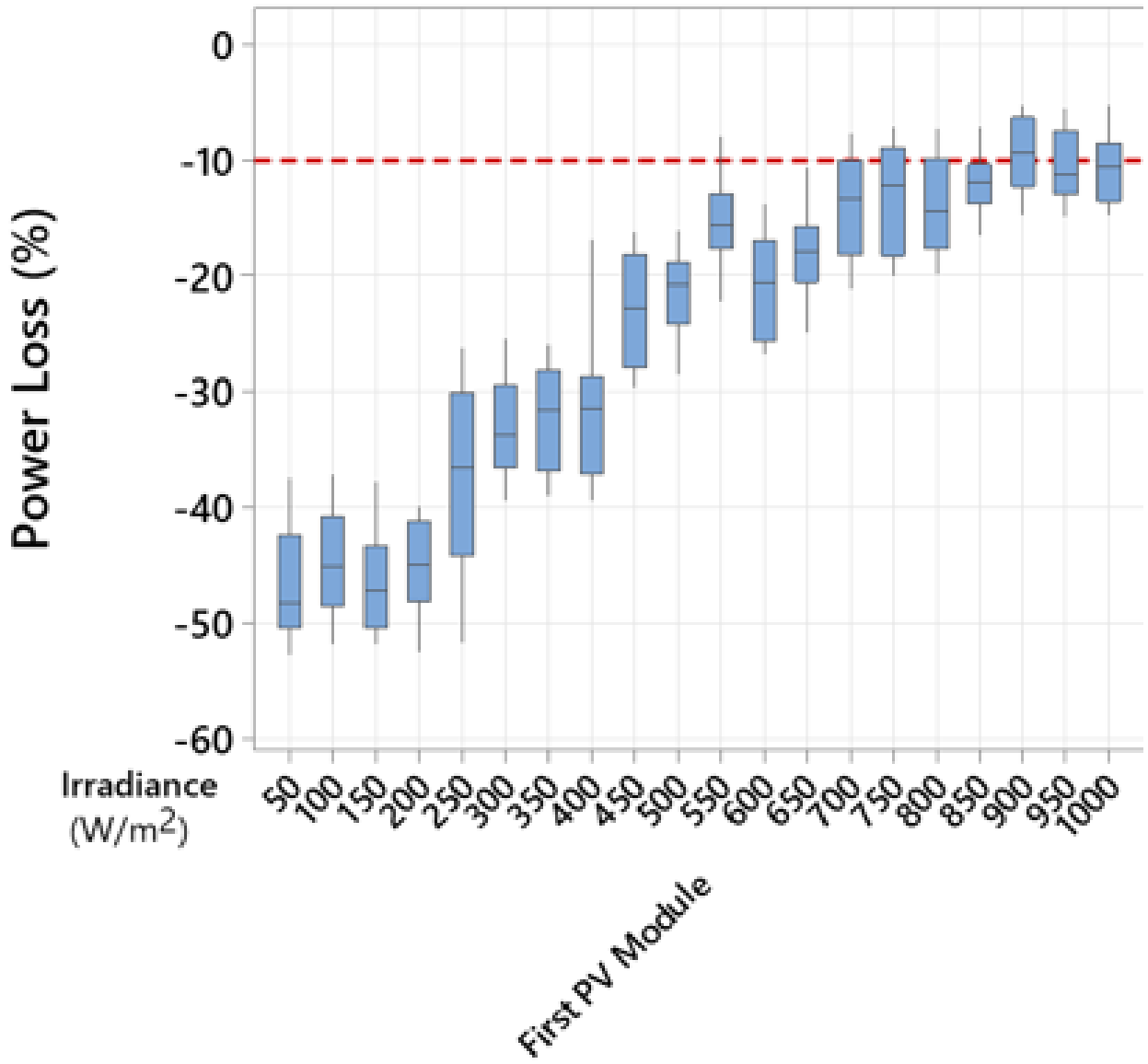

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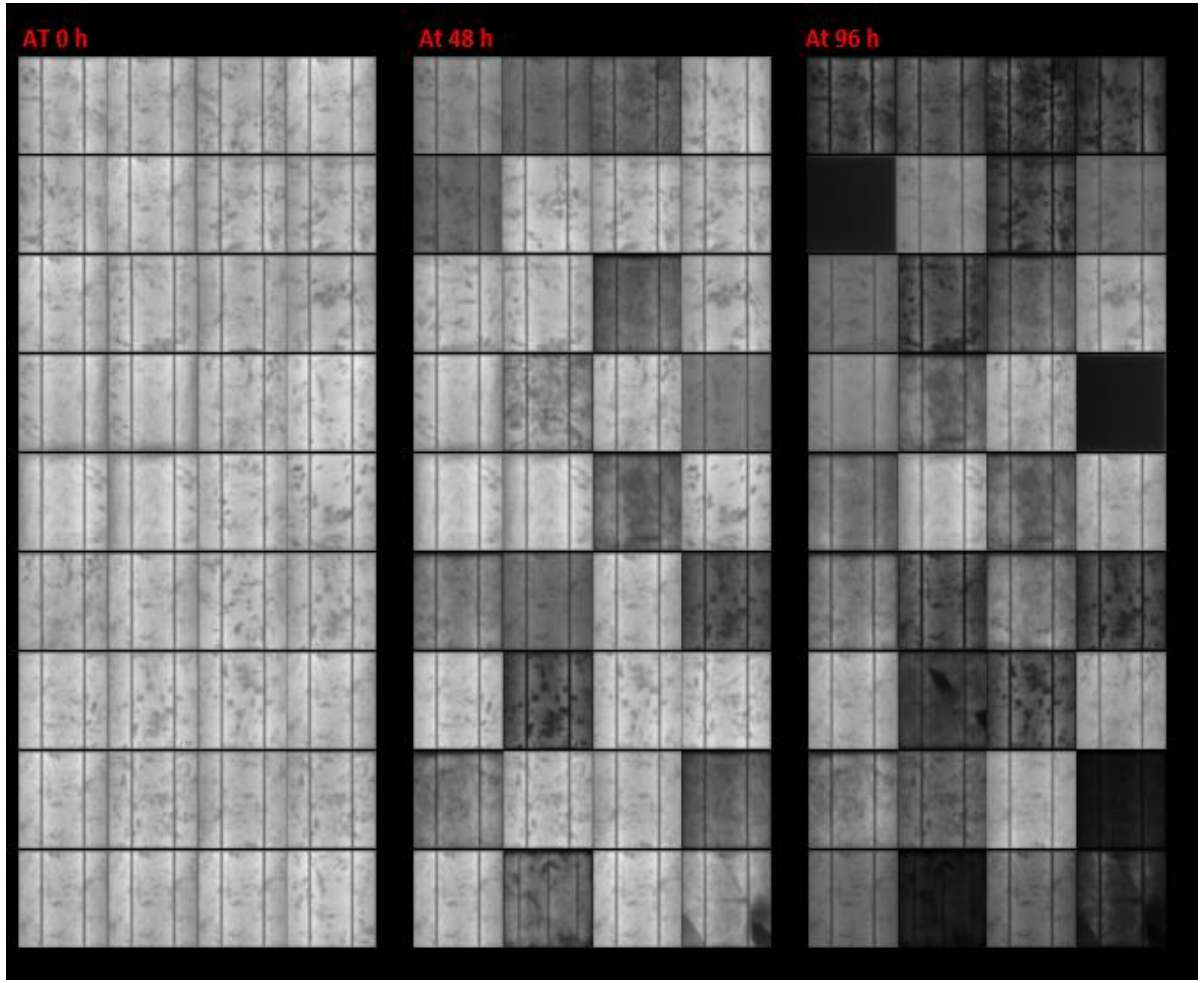

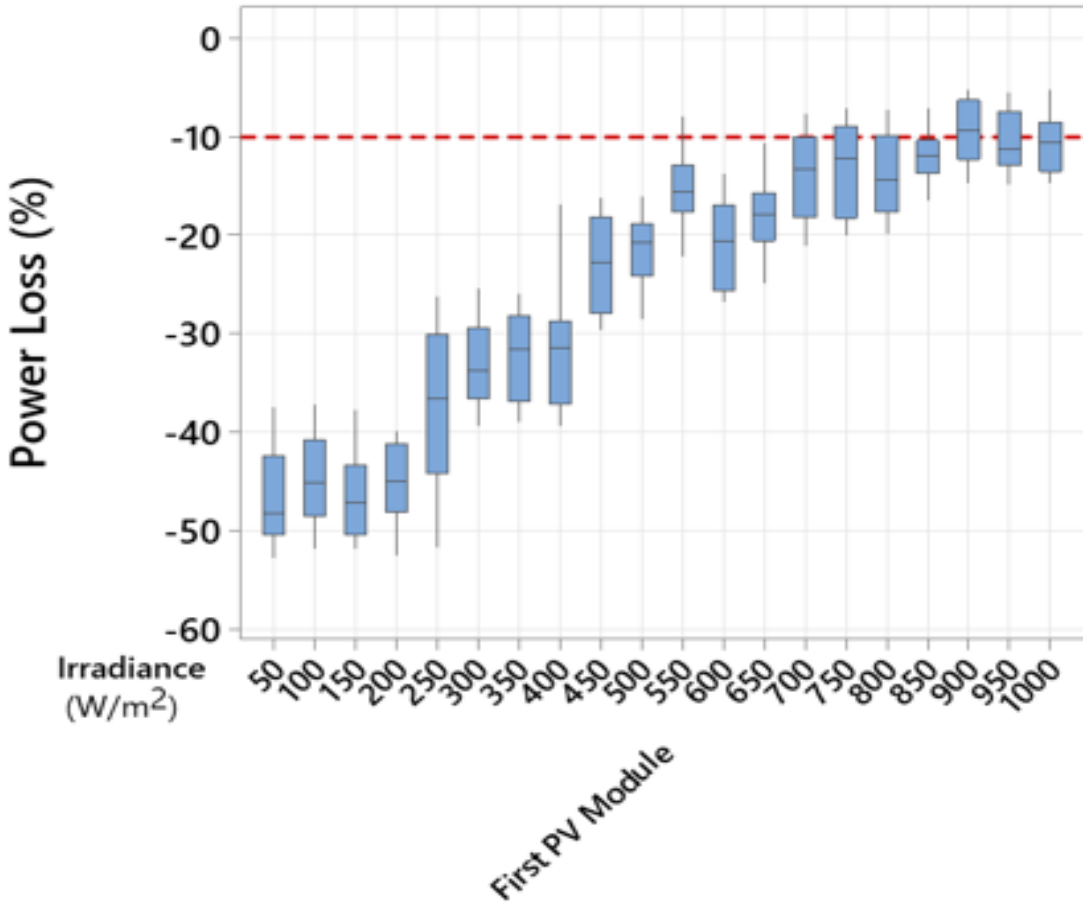

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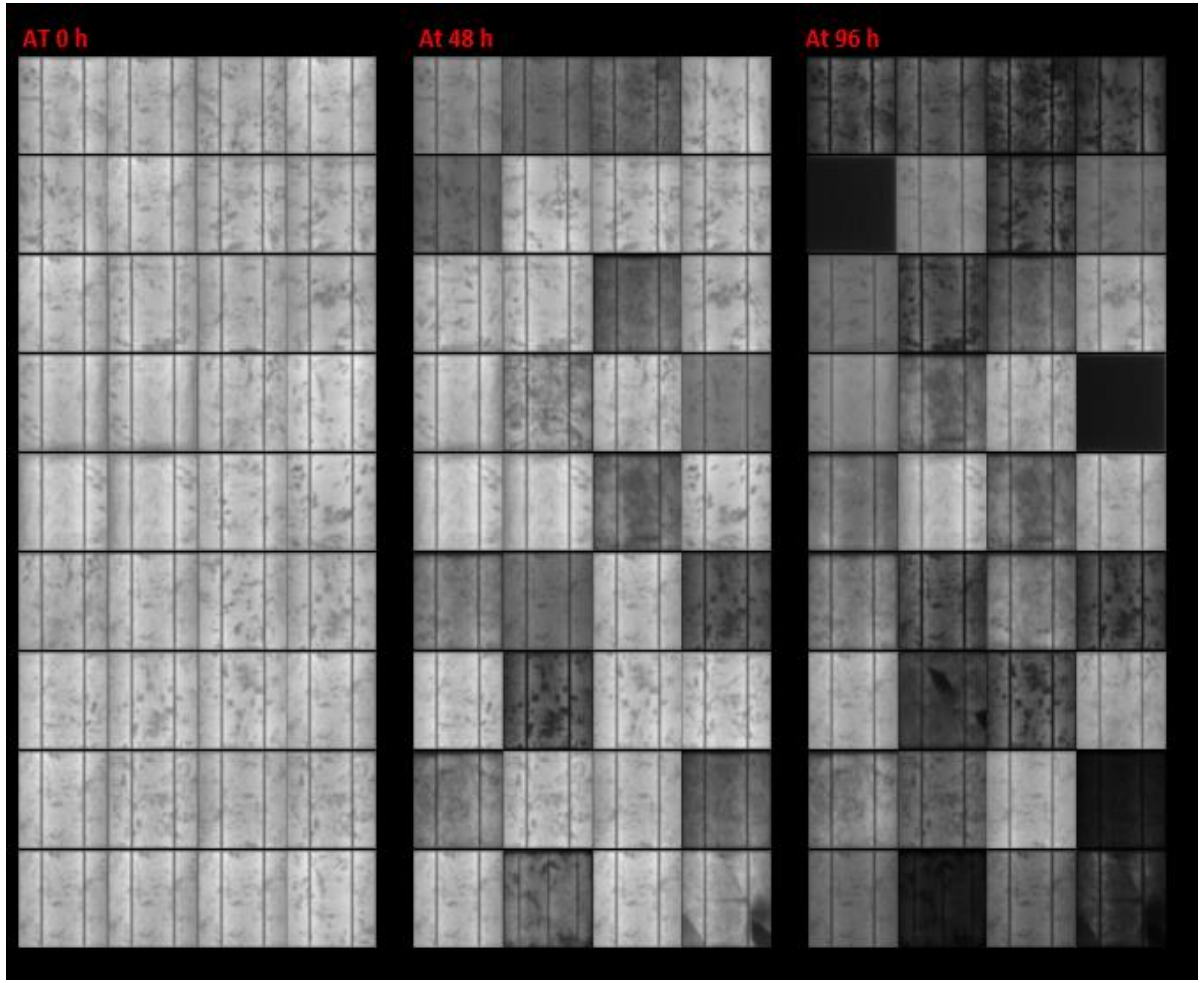
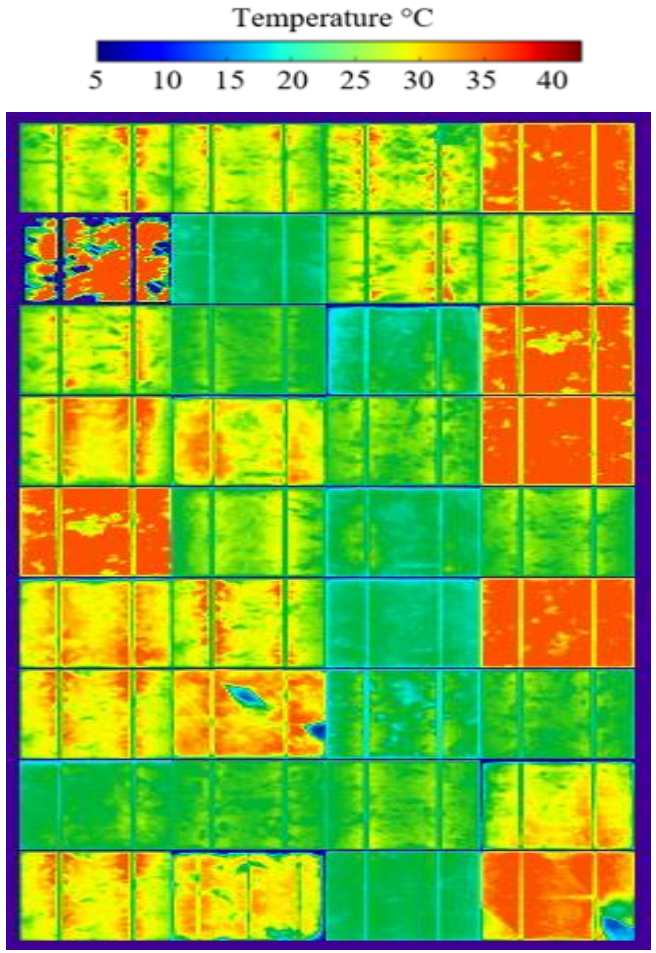
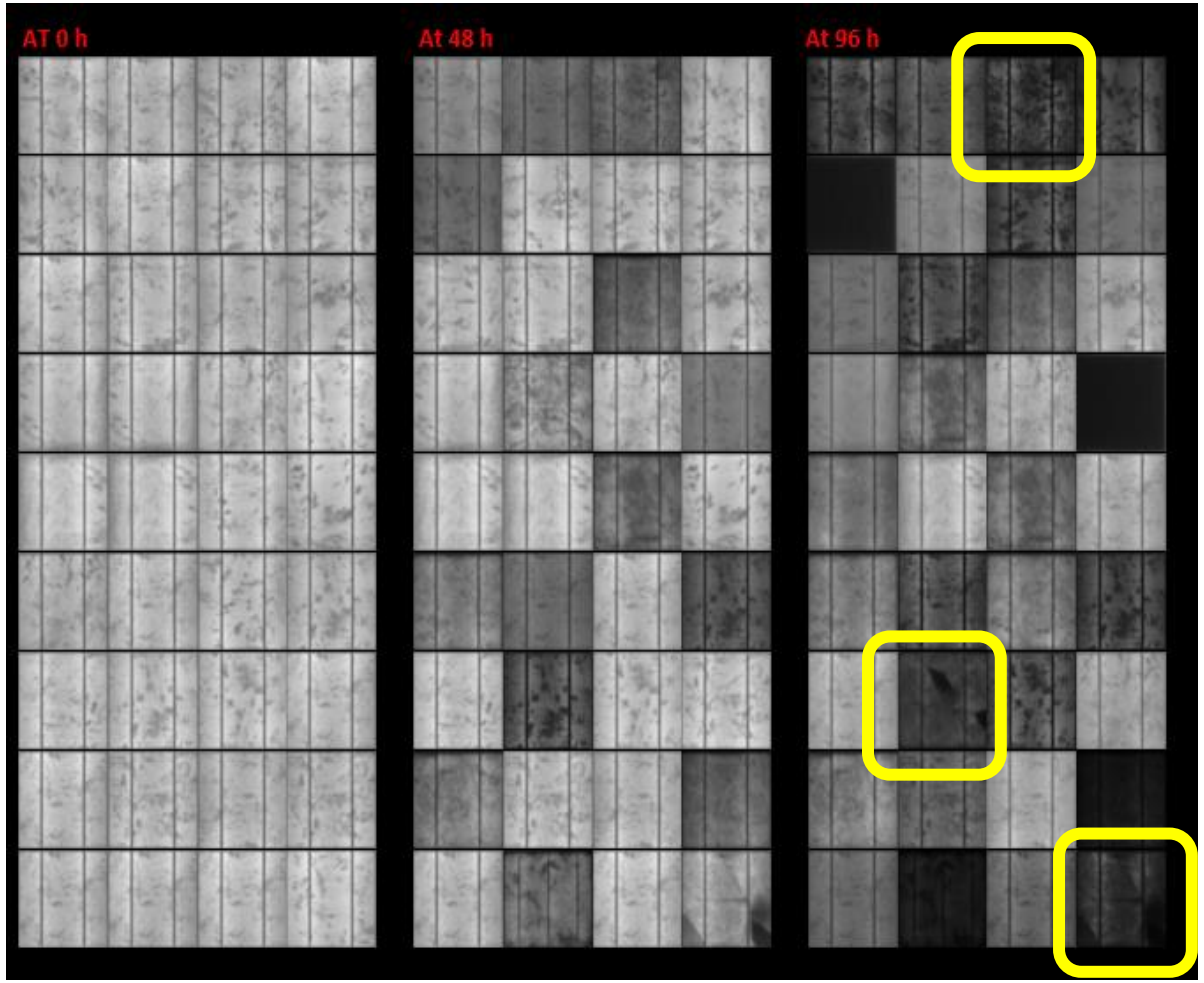
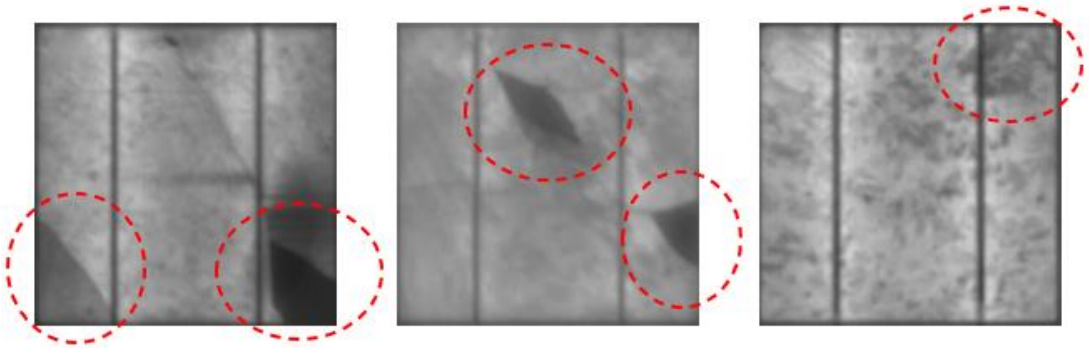




approximate increase in temperature from 25°C to 45°C.

MONOCRYSTALLINE SILICON PHOTOVOLTAIC – CASE STUDY





FIELD CASE STUDY

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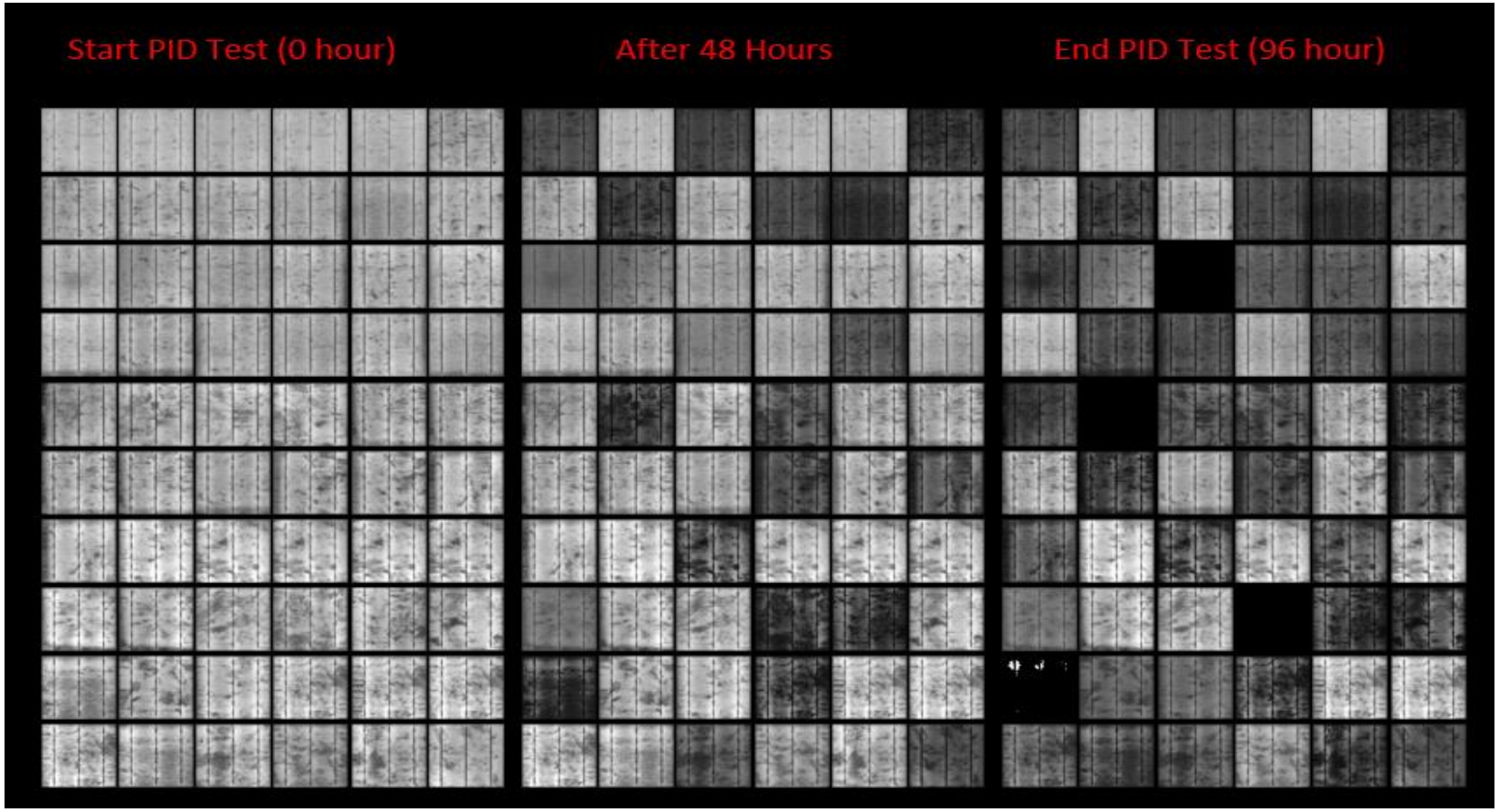

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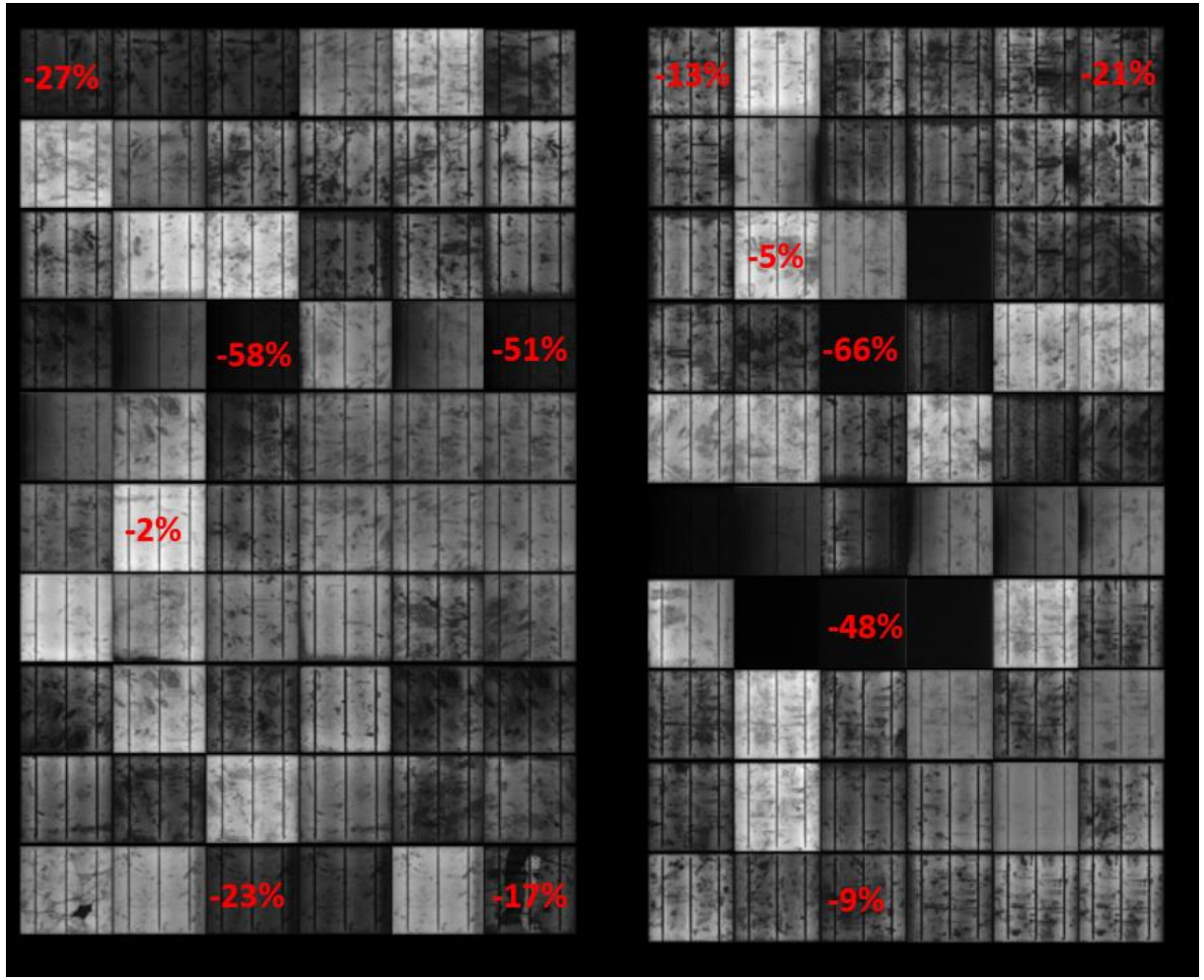

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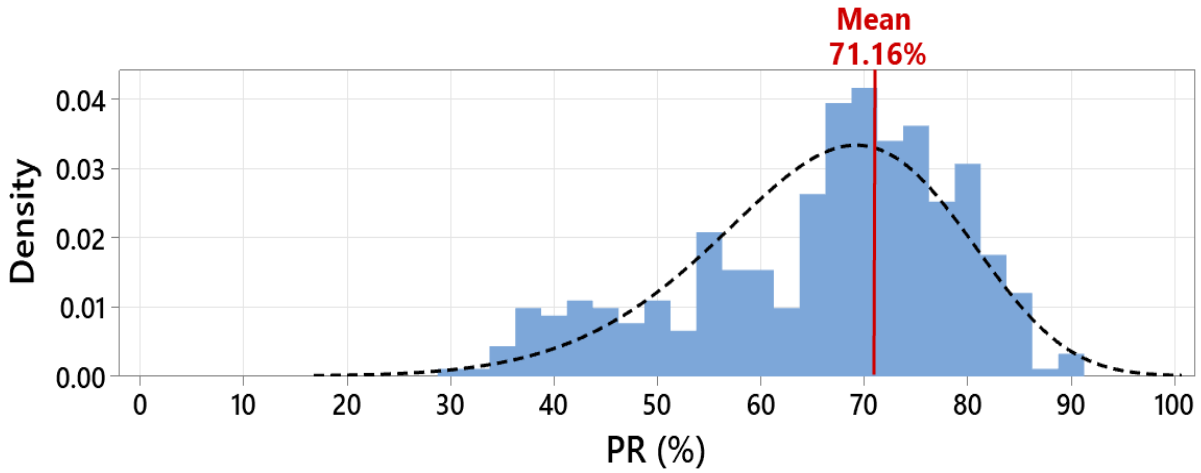
$$PR = \frac{P_{MEASURED}}{P_{STC}\,\frac{G_{poa}}{G_{ref}}\left(1+\gamma\left(T_{PV}-T_{ref}\right)\right)}$$



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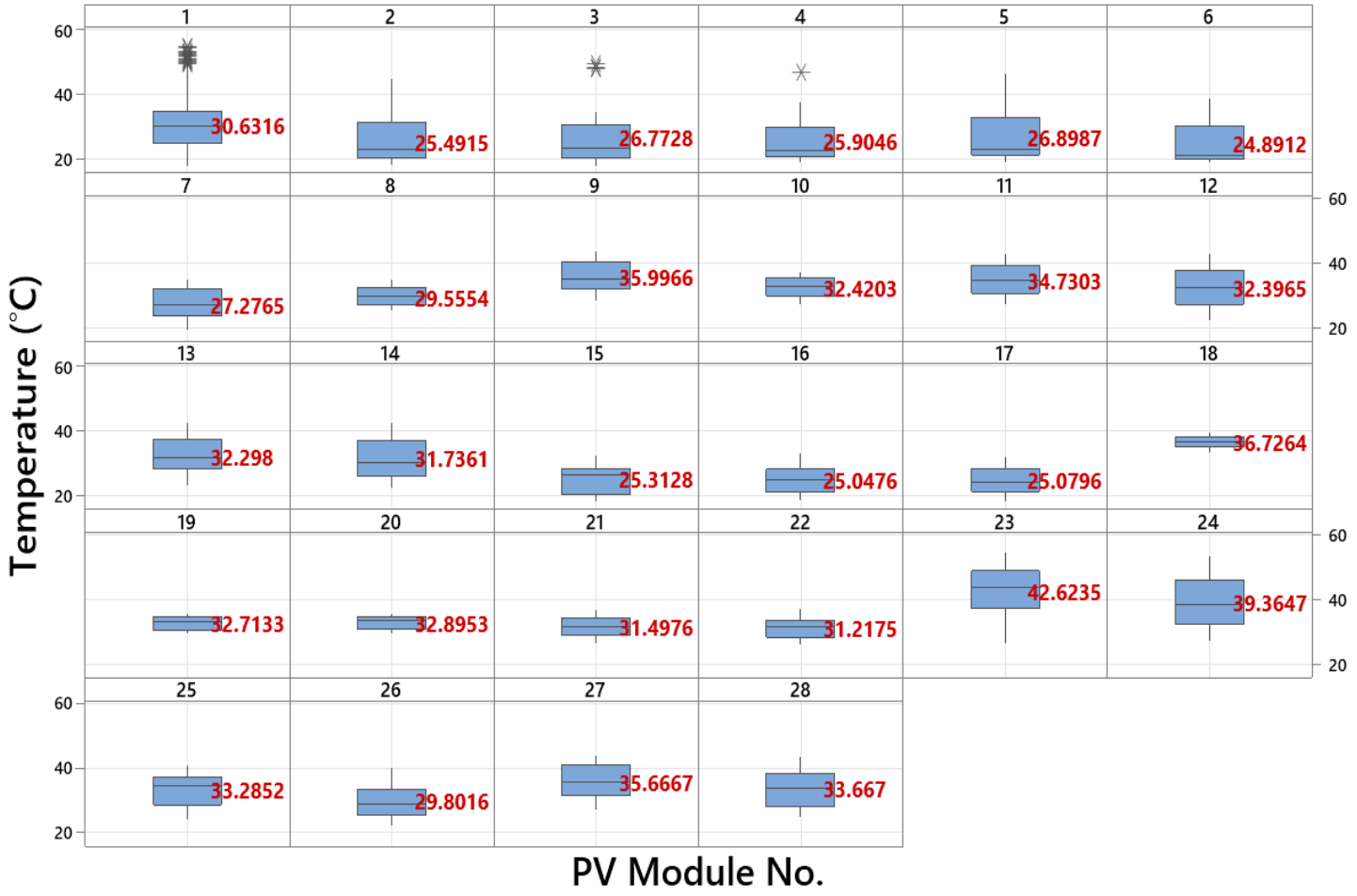
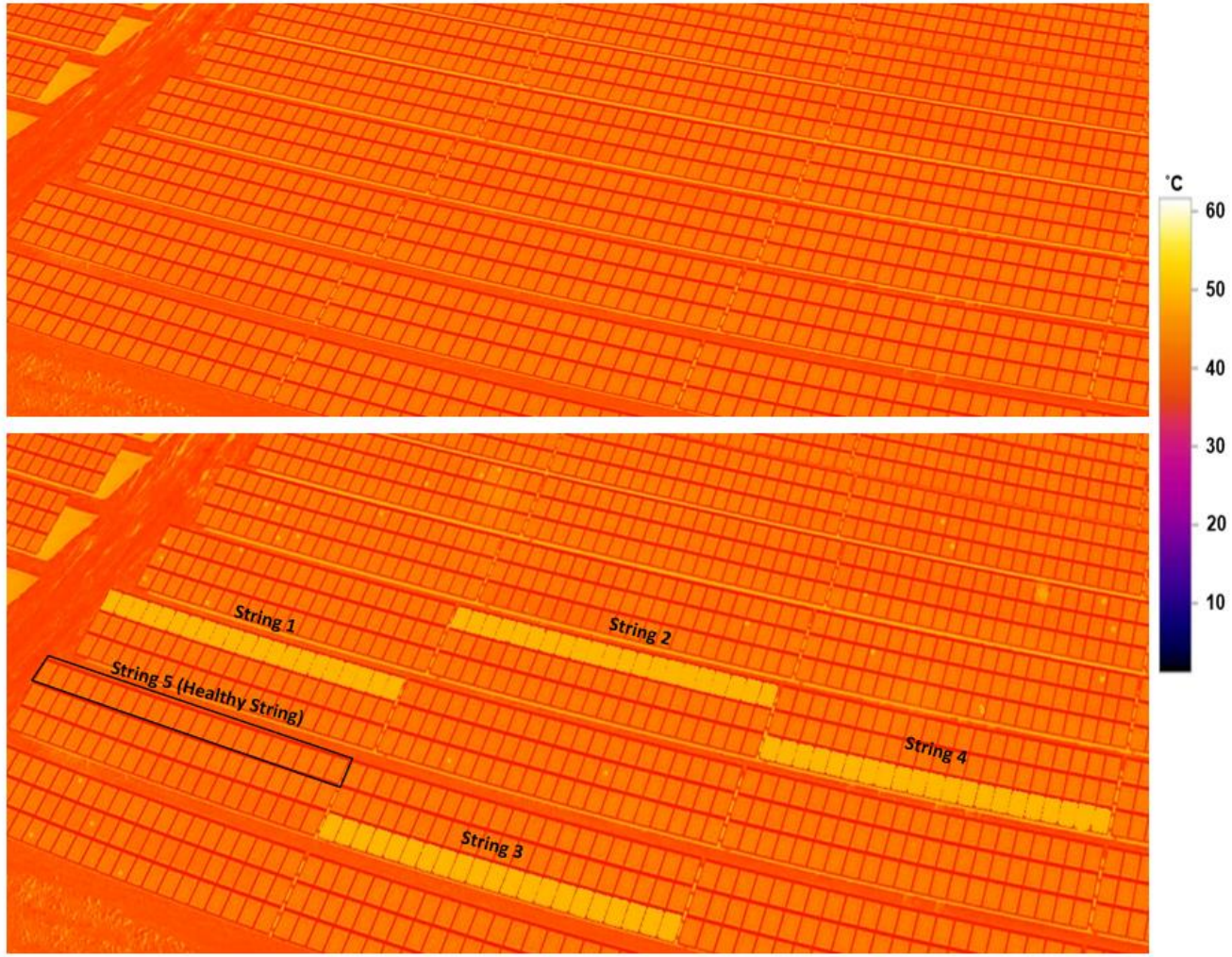


The mean value of the PV modules temperature varies between 25°C to 42°C.

INDUSTRIAL EXAMPLE

Dhimish, M., & Tyrrell, A. M. (2022). Filed Study on the Severity of Photovoltaic Potential Induced Degradation. *IEEE Open Journal of Instrumentation and Measurement.*



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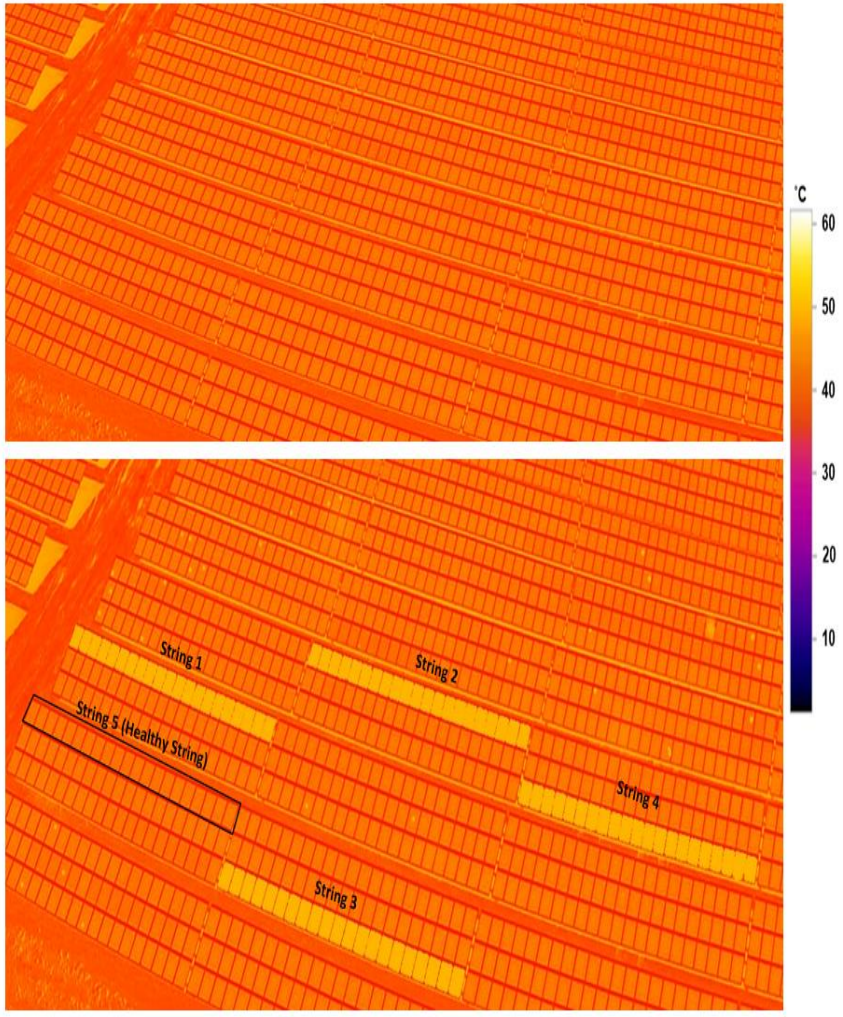

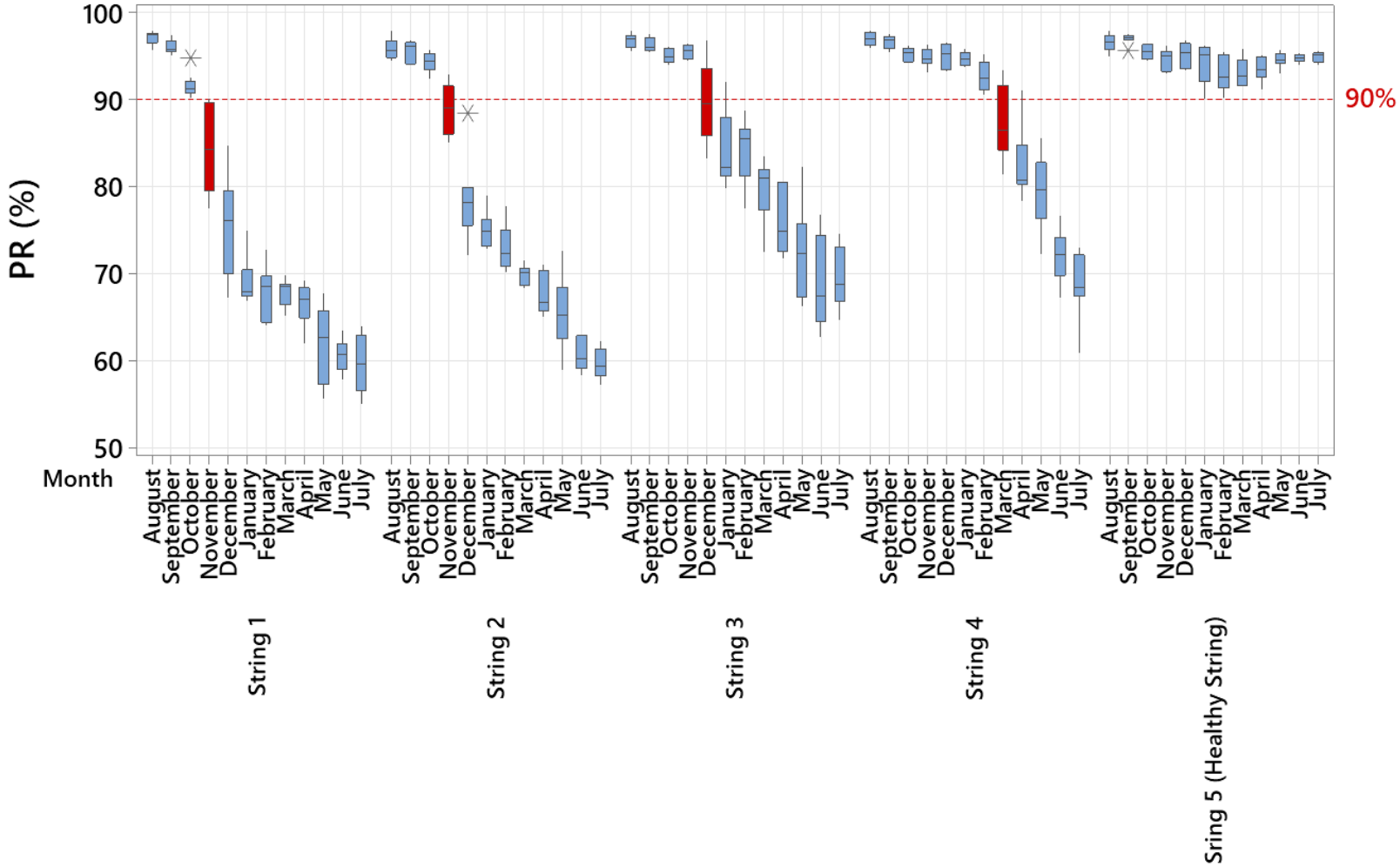

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PV String	PR (first month) (%)	PR (after 12-months) (%)	Difference (%)
1	96.5	56.6	39.9
2	94.8	58.3	36.5
3	96.1	66.9	29.2
4	96.3	68.4	27.9
5 (Healthy string)	95.7	94.4	0.3

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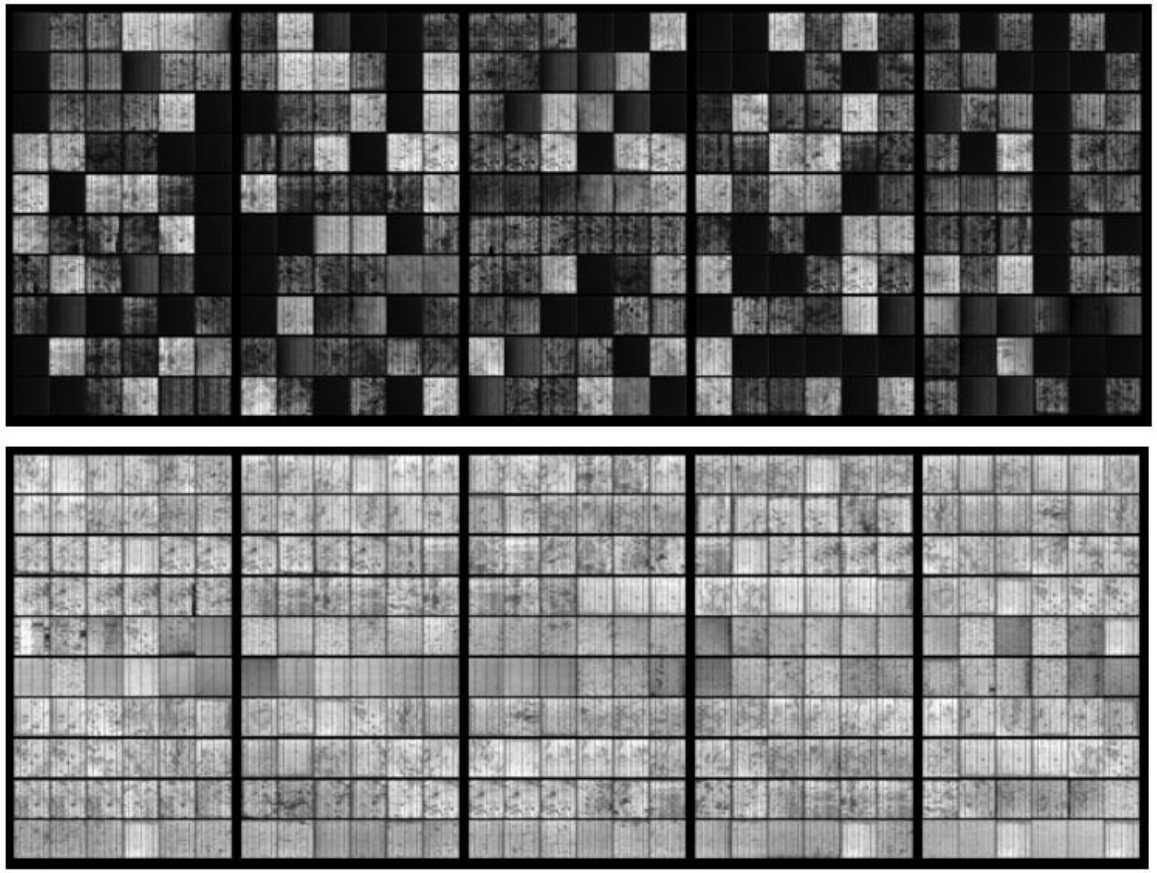

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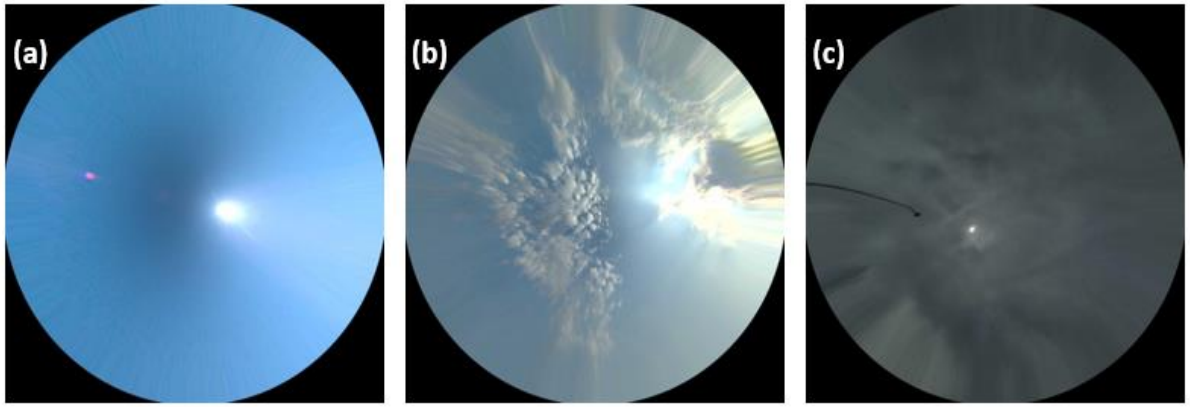

Sky image for the PV operation condition. a Clear sky. **b** Partial shading. **c** Overcasting. These images were taken using TSI 440A total sky imager. The temperature of the PV modules at these conditions is 26°C, 23°C and 19°C, respectively; and the solar radiation is 730 W/m^2, 677 W/m^2, and 408 W/m^2.

PV Modules	Environment Condition: Clear Sky (26°C, 730 W/m^2)				
	V_{OC} (V)	I_{SC} (A)	V_{MPP} (V)	I_{MPP} (A)	P_{MPP} (W)
Healthy	183.6	8.1	143.9	7.66	1102
PID	134.1	8.0	90.3	7.67	692.6
Difference* (%)	-26.9	-1.23	-37.2	+0.13	-37.15

PV Modules	Environment Condition: Partial Shading (23°C, 677 W/m^2)				
	V_{OC} (V)	I_{SC} (A)	V_{MPP} (V)	I_{MPP} (A)	P_{MPP} (W)
Healthy	183.1	8.1	145.8	7.33	1069
PID	133.6	7.9	90.9	7.49	681.0
Difference* (%)	-27.0	-2.47	-37.6	+2.18	-36.29

PV Modules	Environment Condition: Overcasting (19°C, 408 W/m^2)				
	V_{OC} (V)	I_{SC} (A)	V_{MPP} (V)	I_{MPP} (A)	P_{MPP} (W)
Healthy	181.8	8.1	155.3	5.62	872.6
PID	130.8	7.9	102.4	5.14	526.2
Difference* (%)	-28.1	-2.47	-34.06	-8.54	-39.69

*The "difference" is calculated as the following: $\left[100 - \left(\frac{PID\ electrical\ parameter}{Healthy\ electrical\ parameter} \times 100\right)\right]$. The negative sign explains how much loss in the relevant electrical parameter is induced due to the presence of PID.

PID RECOVERY

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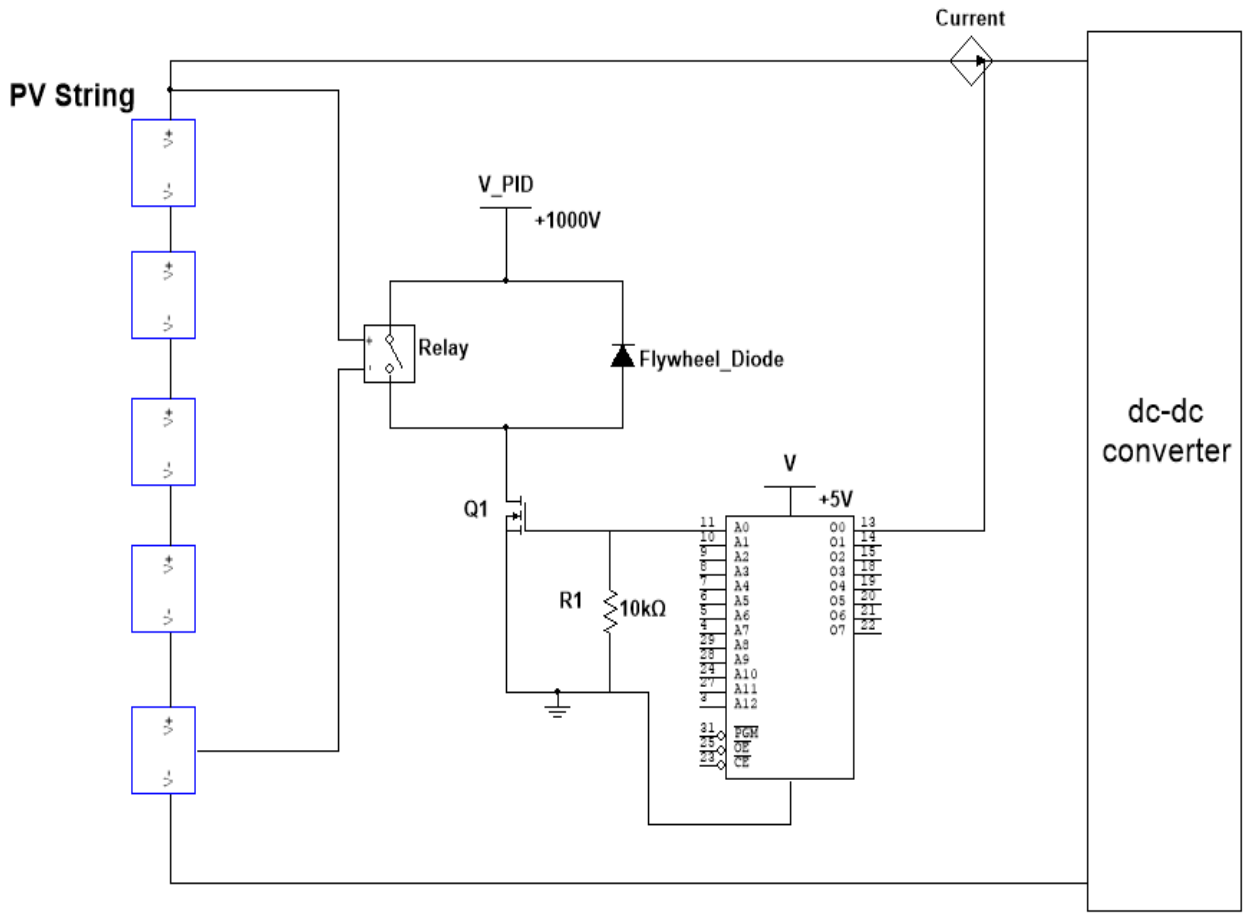
Dhimish, M., & Badran, G. (2021). Recovery of Photovoltaic Potential-Induced Degradation Utilizing Automatic Indirect Voltage Source. *IEEE Transactions on Instrumentation and Measurement*.



Automatic
Indirect
Voltage Source
+1000 V

PID RECOVERY

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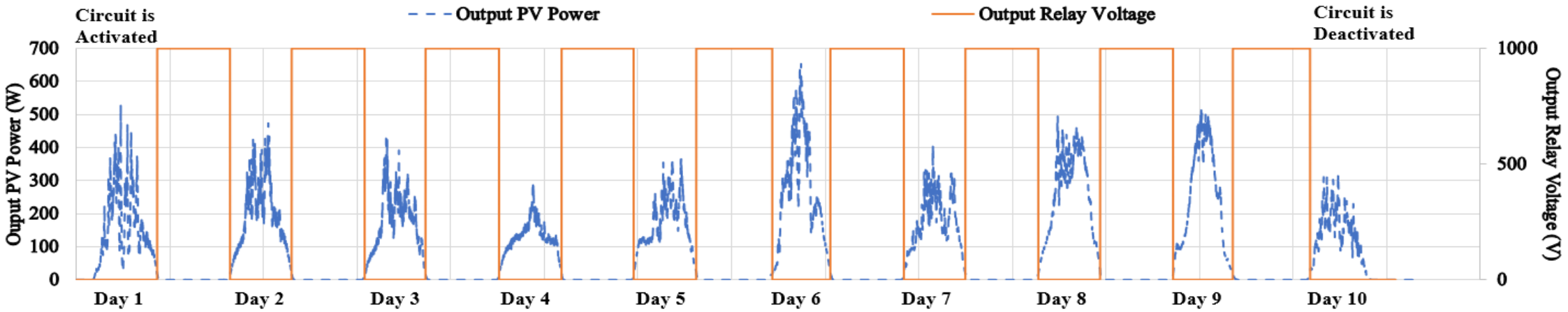

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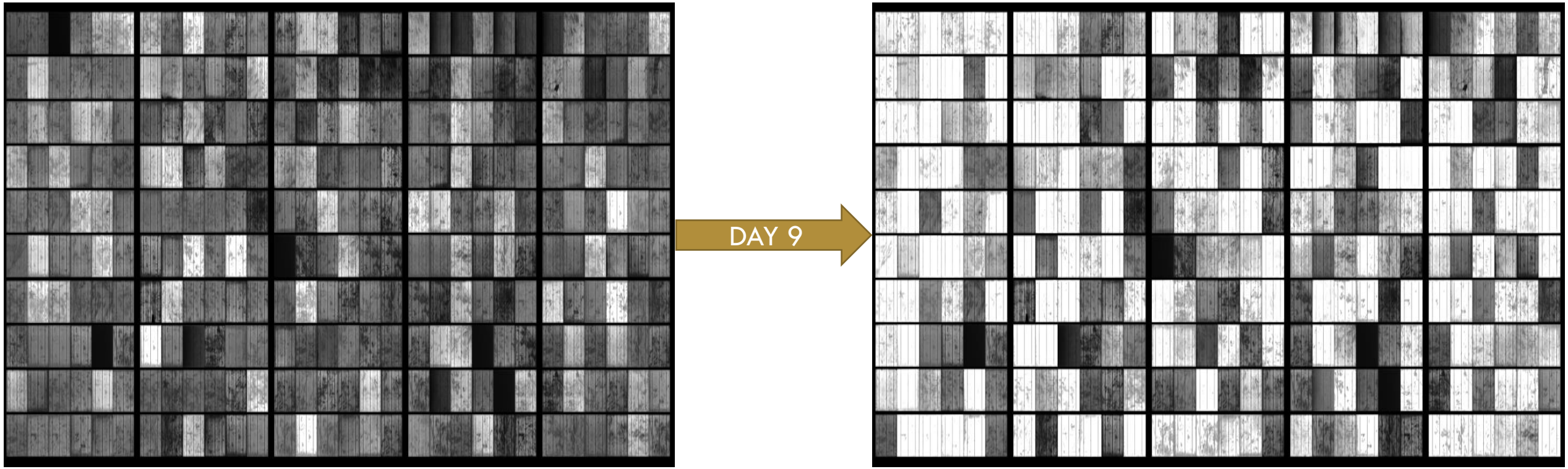

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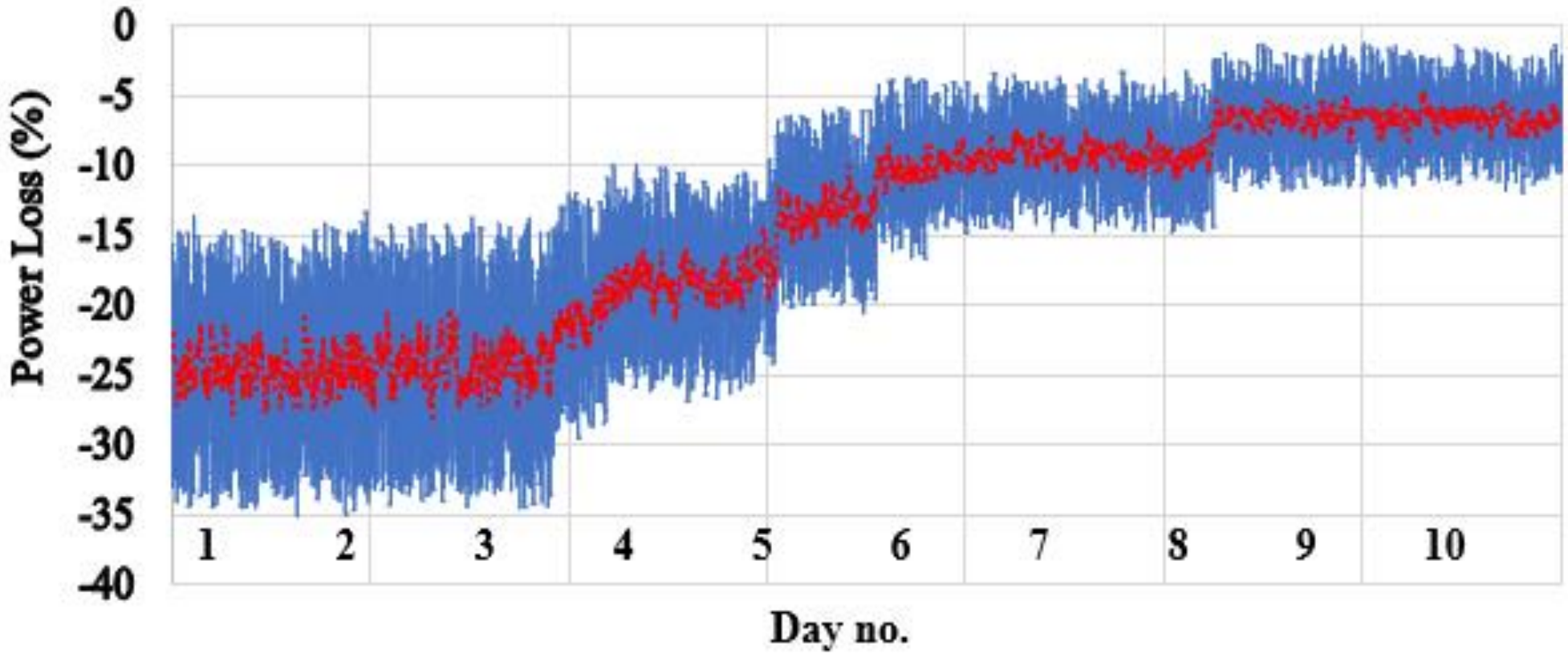

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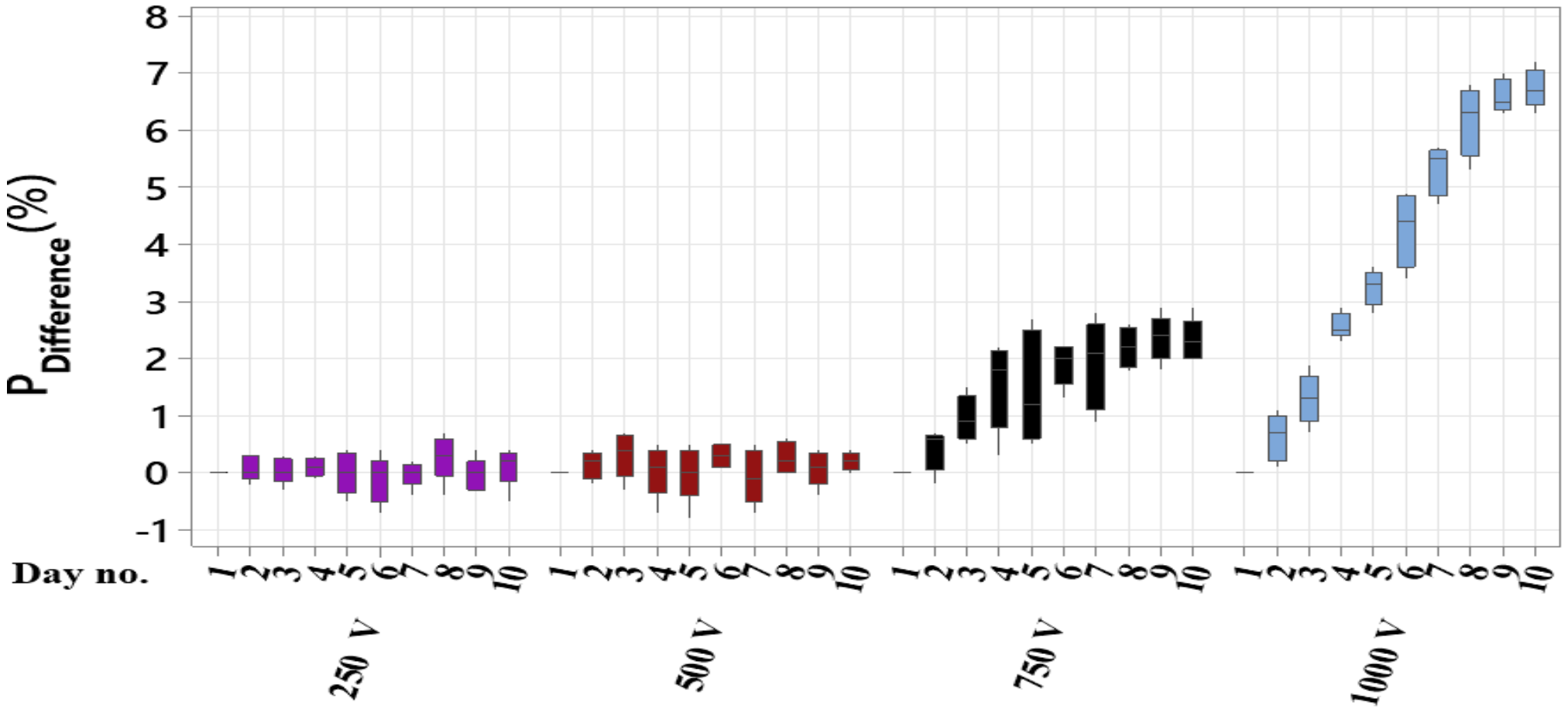

PID RECOVERY-ARC

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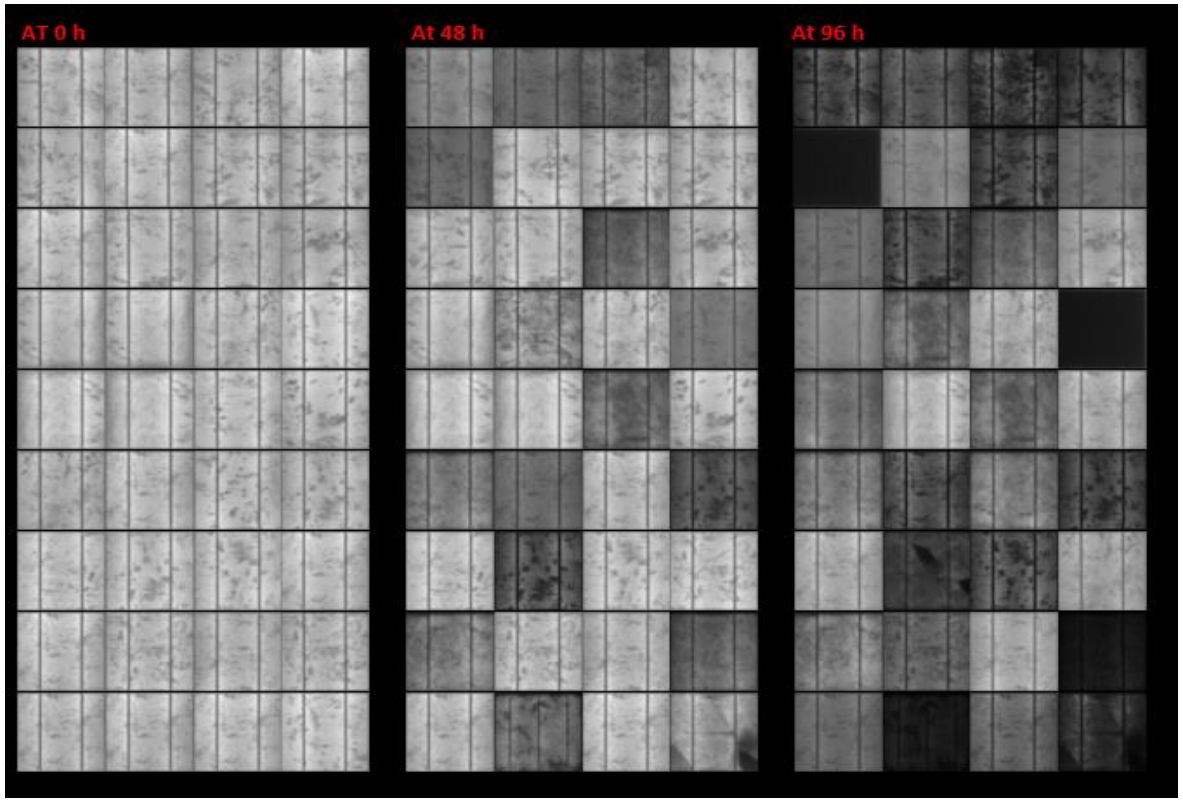
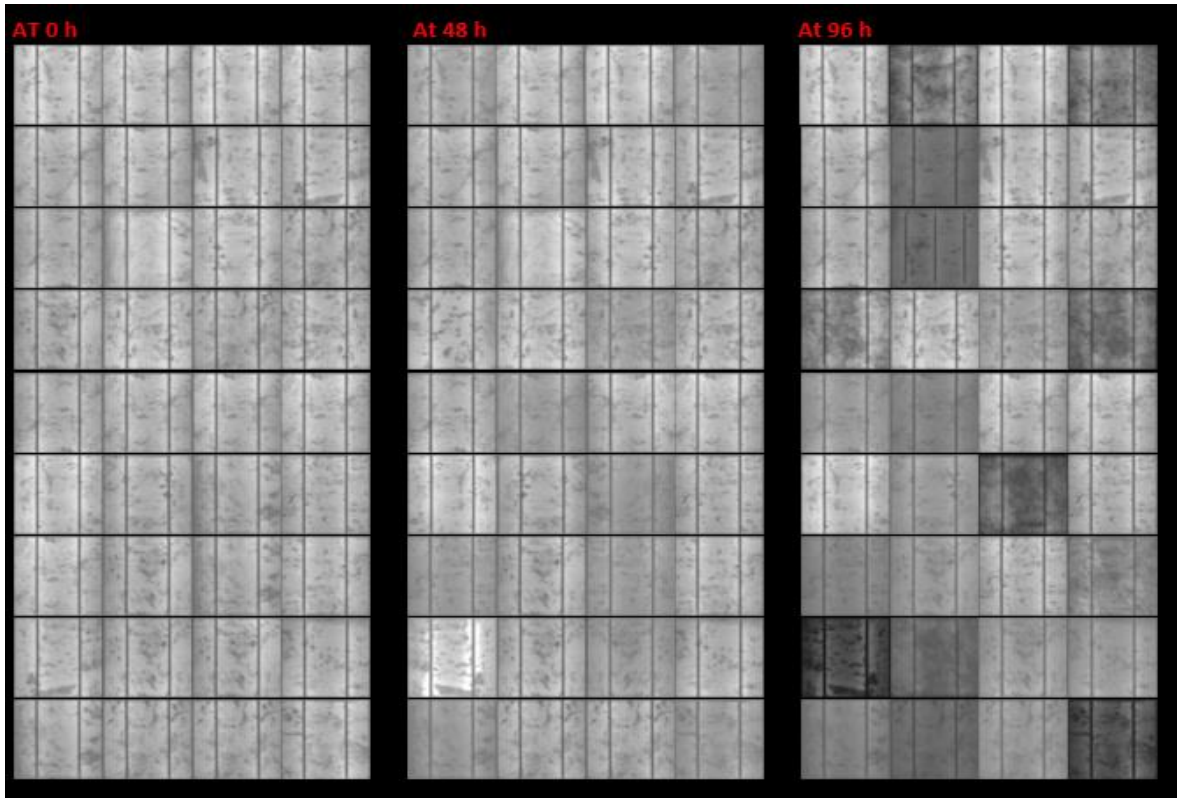


No SiO_2 thin film layer (First Module)



Contain SiO_2 thin film layer (Second Module)

PID RECOVERY-ARC

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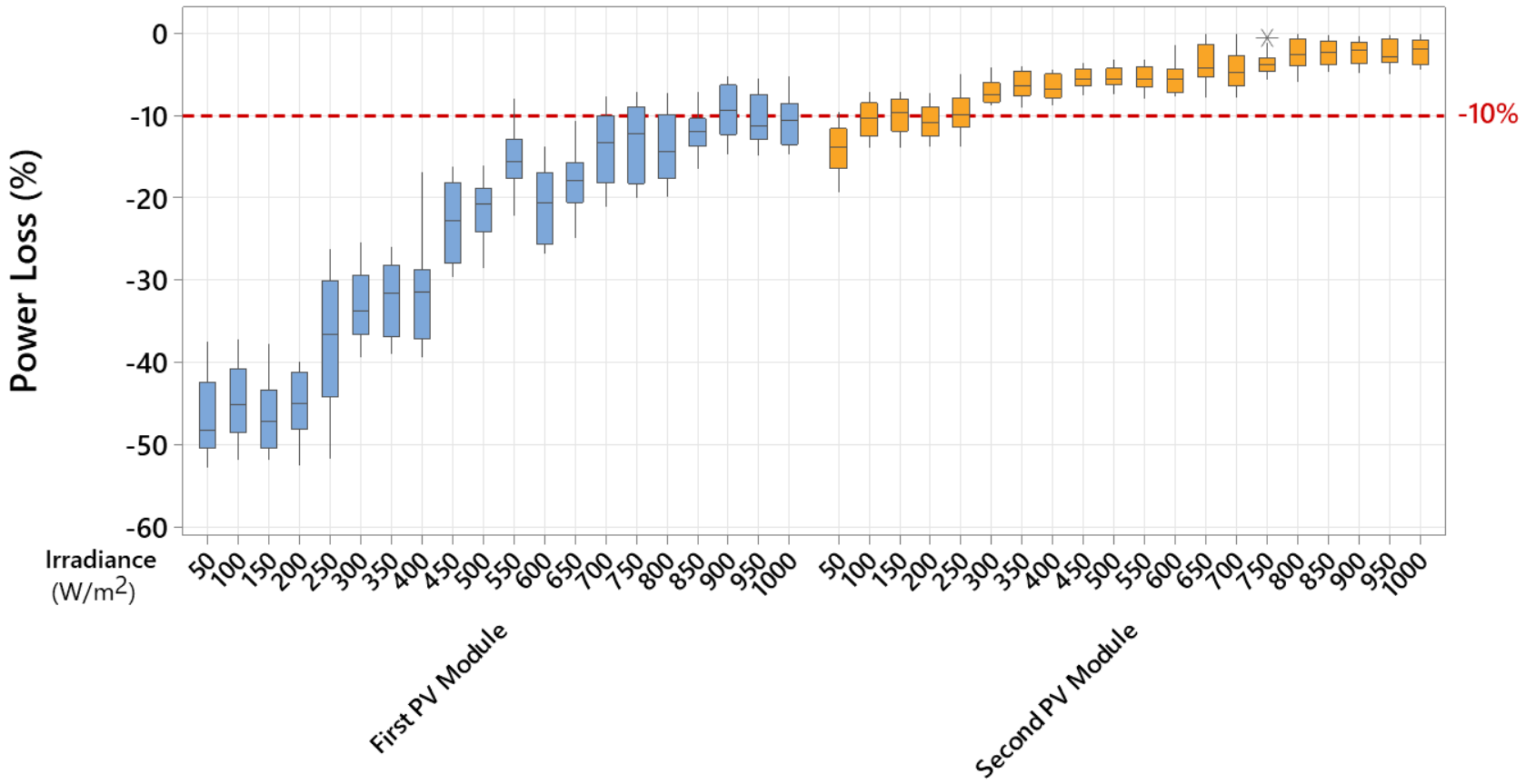

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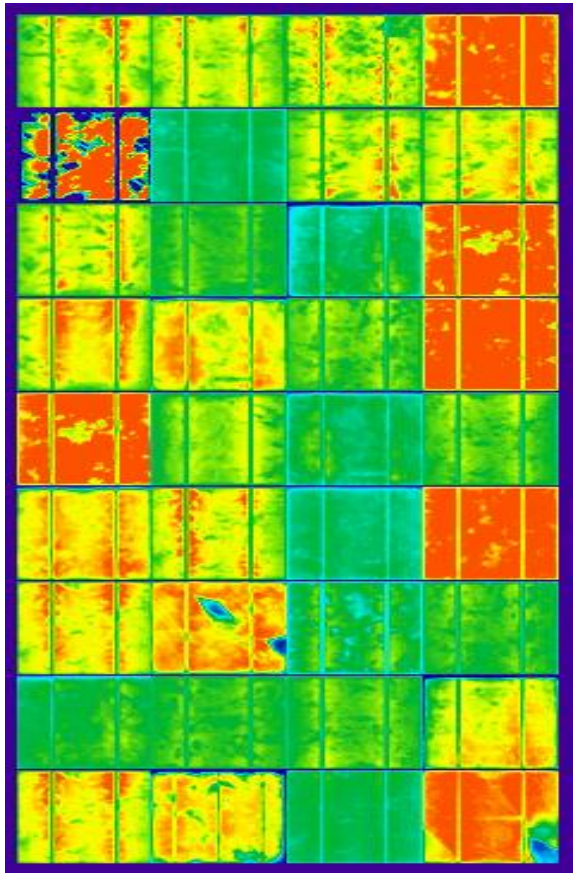

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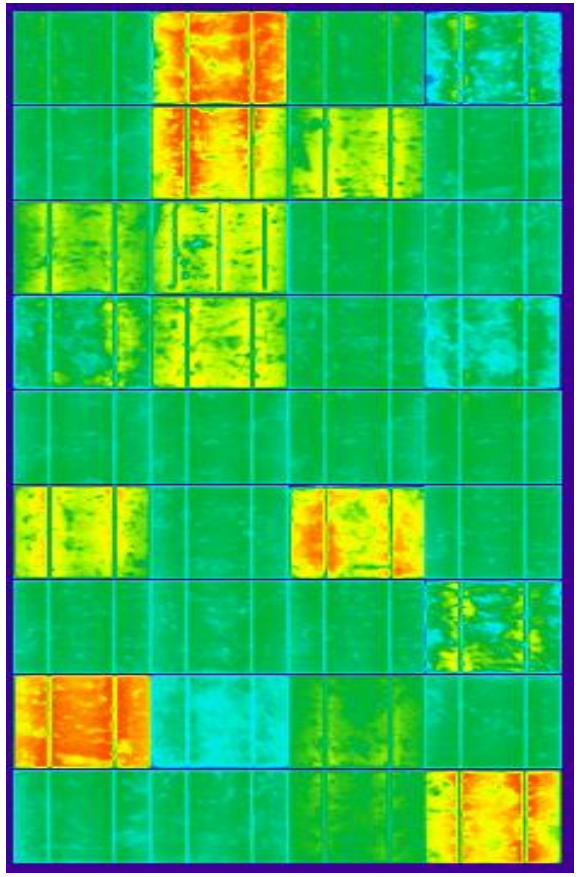
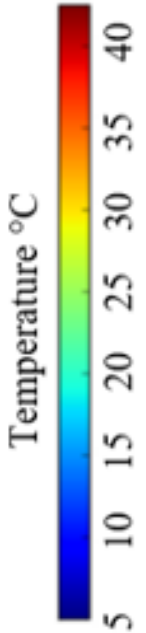


Contain SiO_2 thin film layer (Second Module)



PID DEFECTS ACCELERATION AND CORRELATION

IMPACT OF SOLAR CELL CRACKS CAUSED DURING POTENTIAL INDUCED DEGRADATION (PID) TESTS

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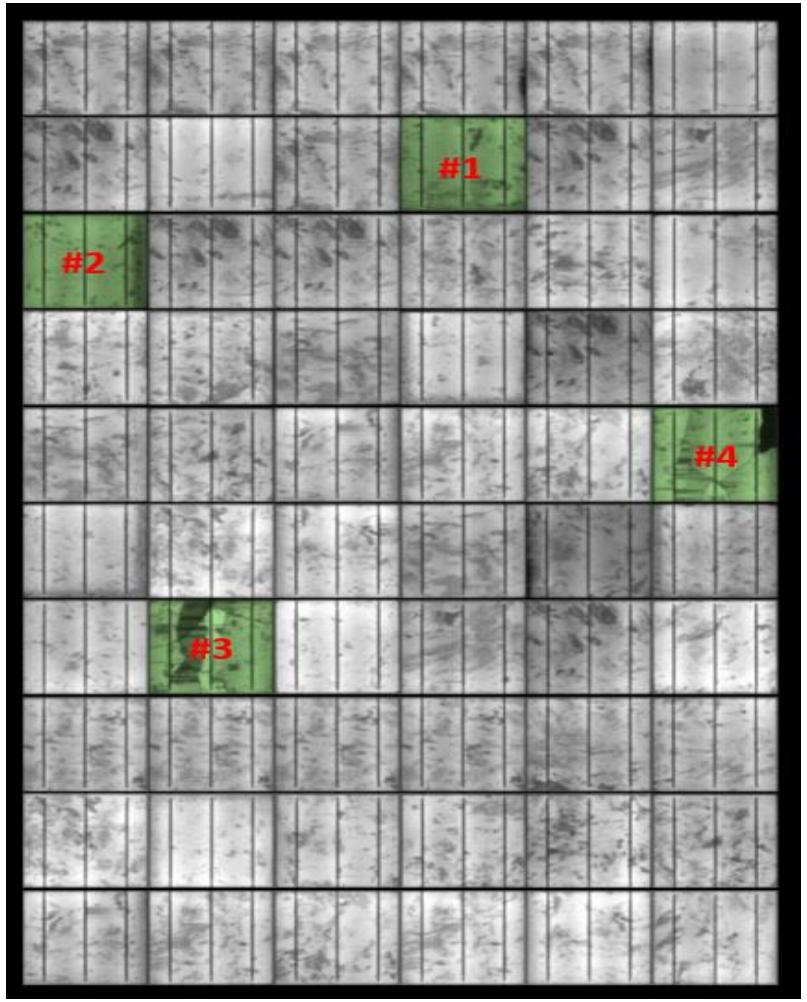

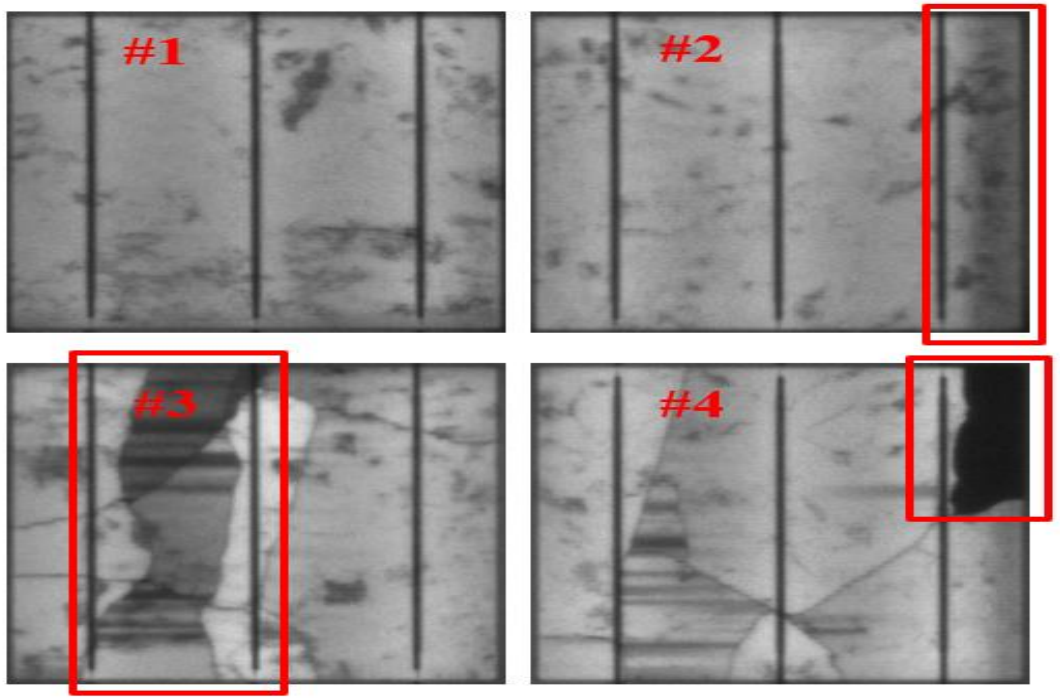

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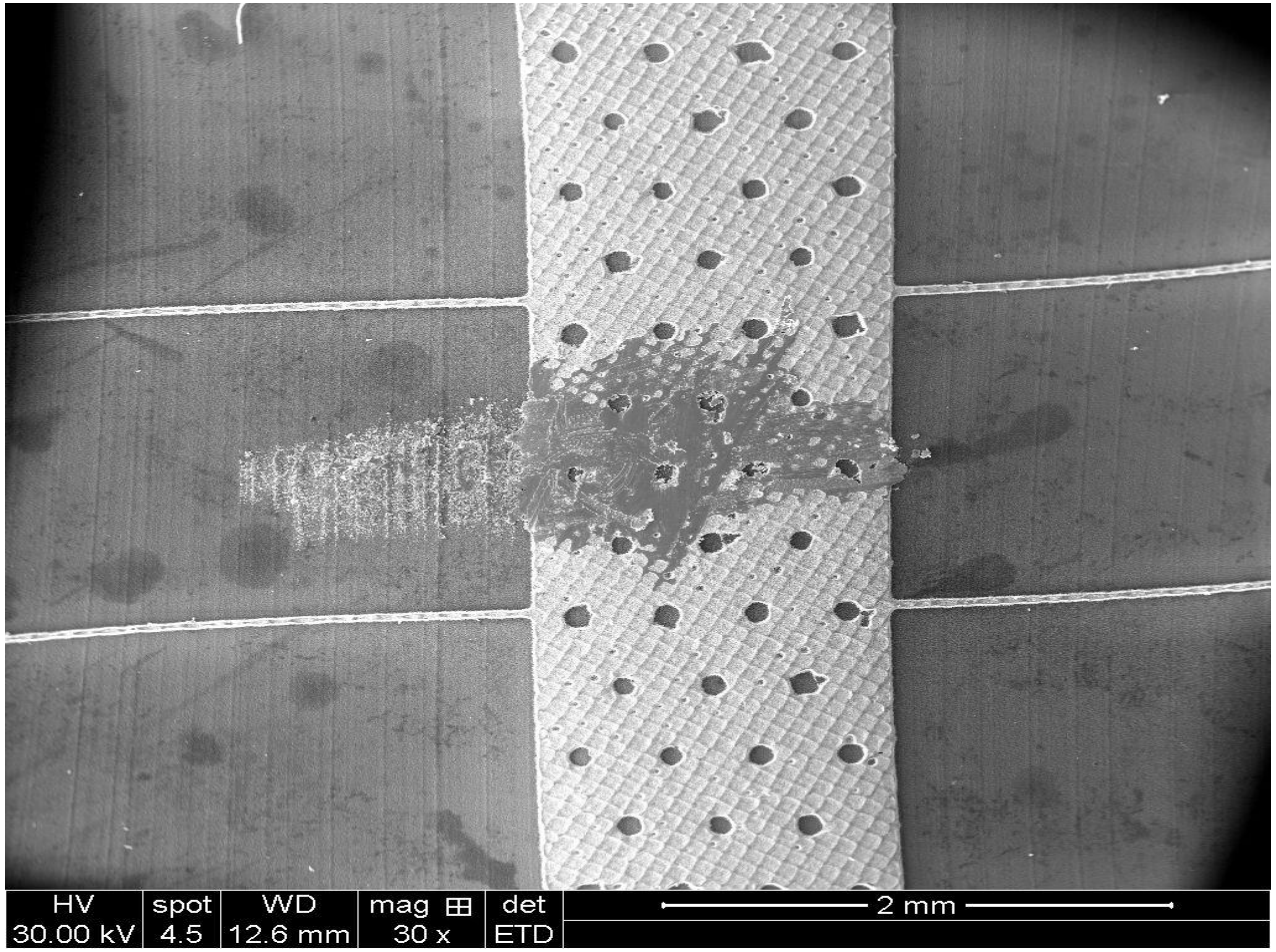

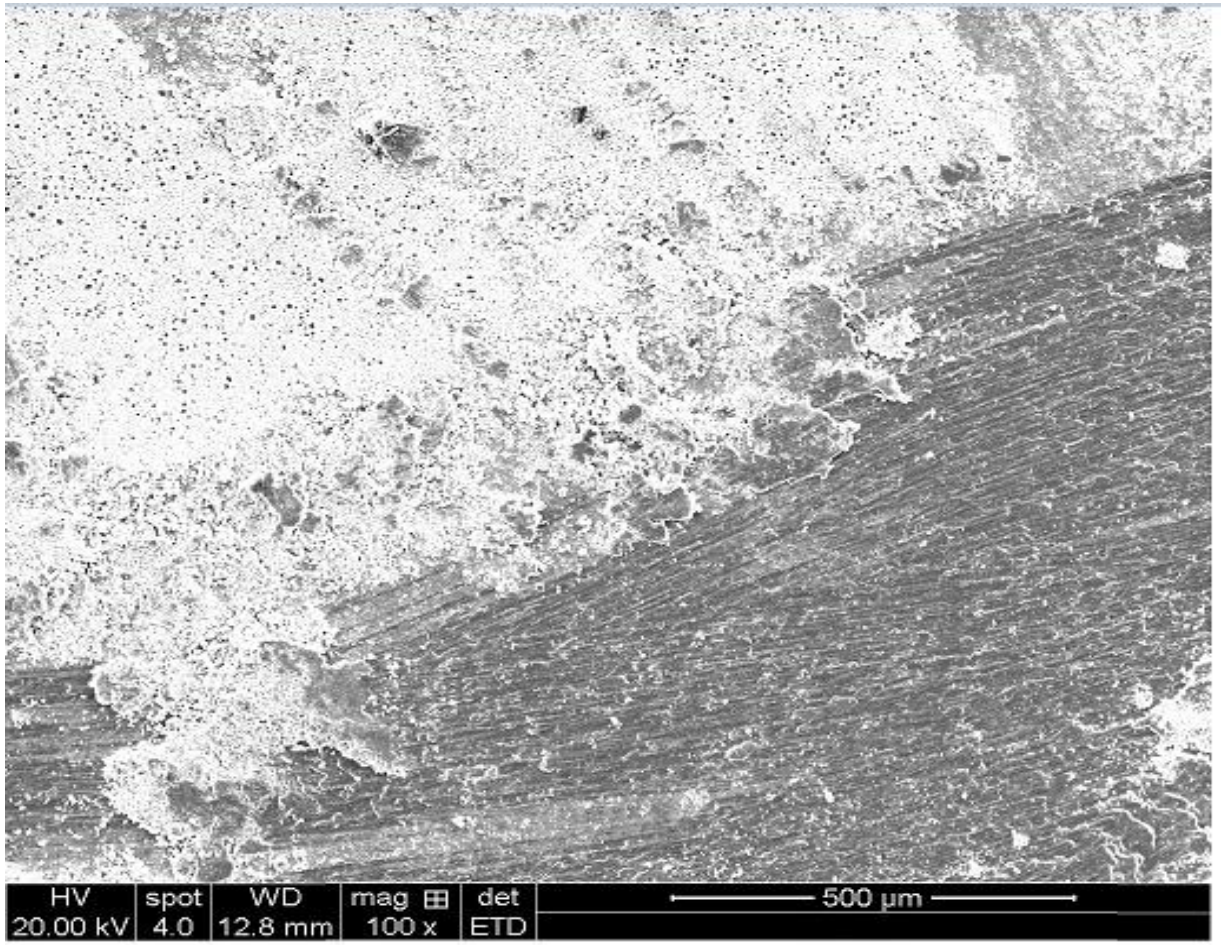

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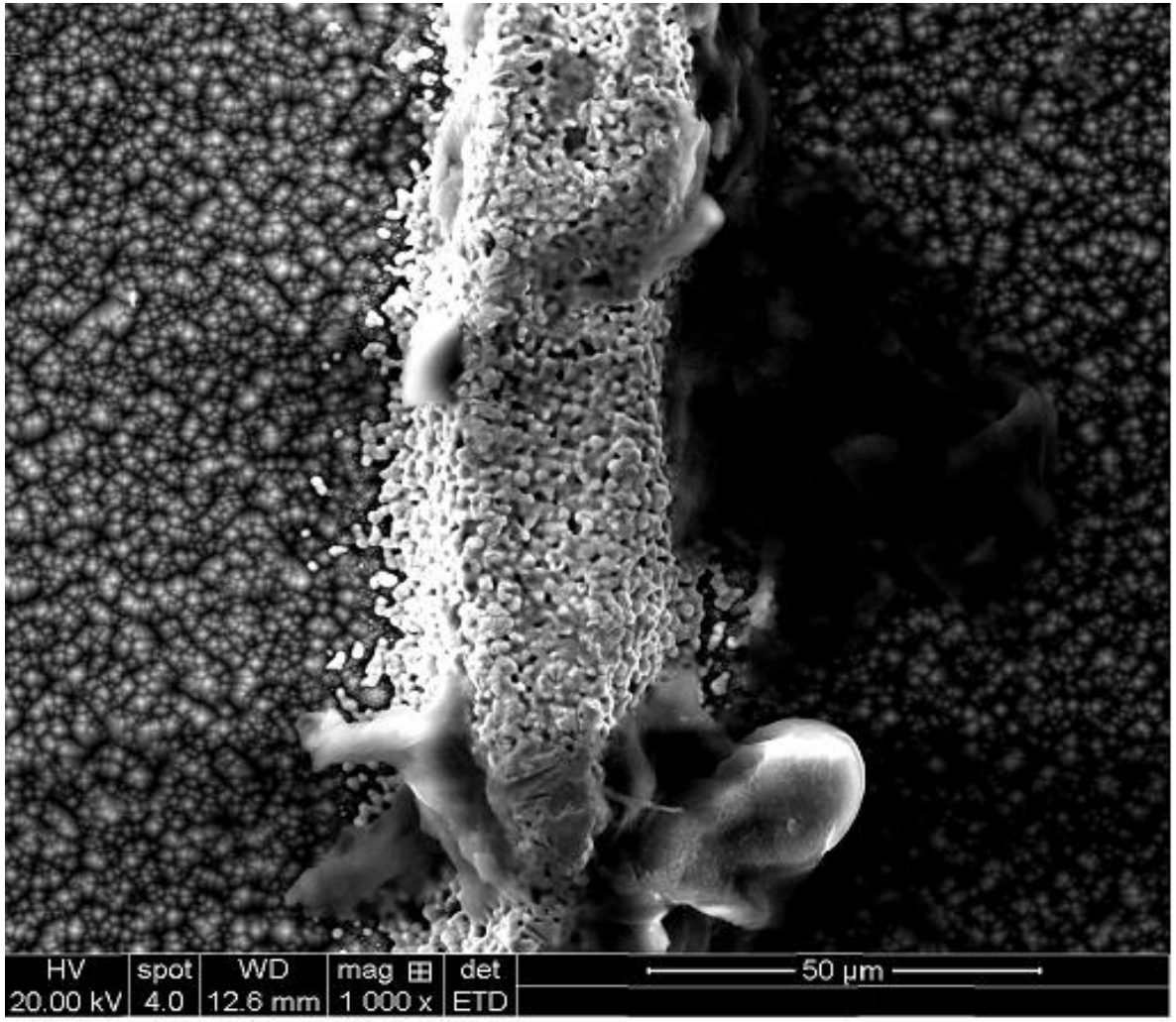

"By inspection of the busbar's metallic (solder) joint to the solar cell surface, it is evident that the solder has migrated and deformed around the solder joint."

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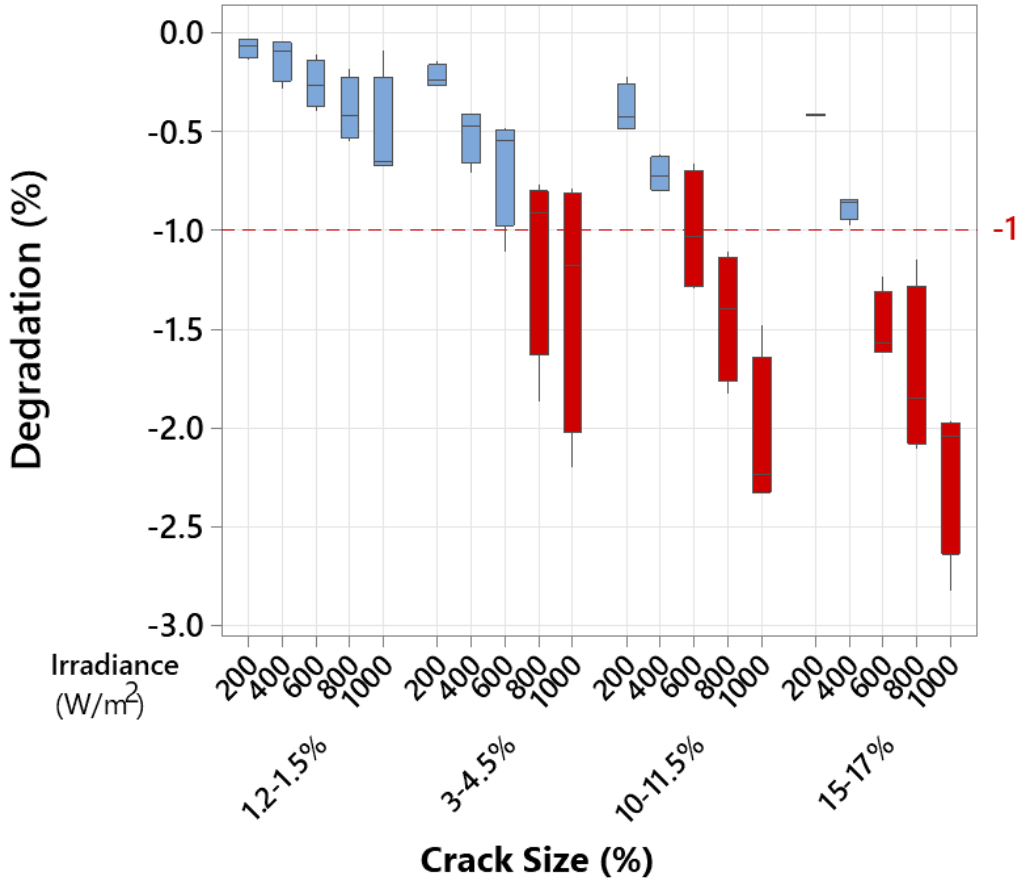

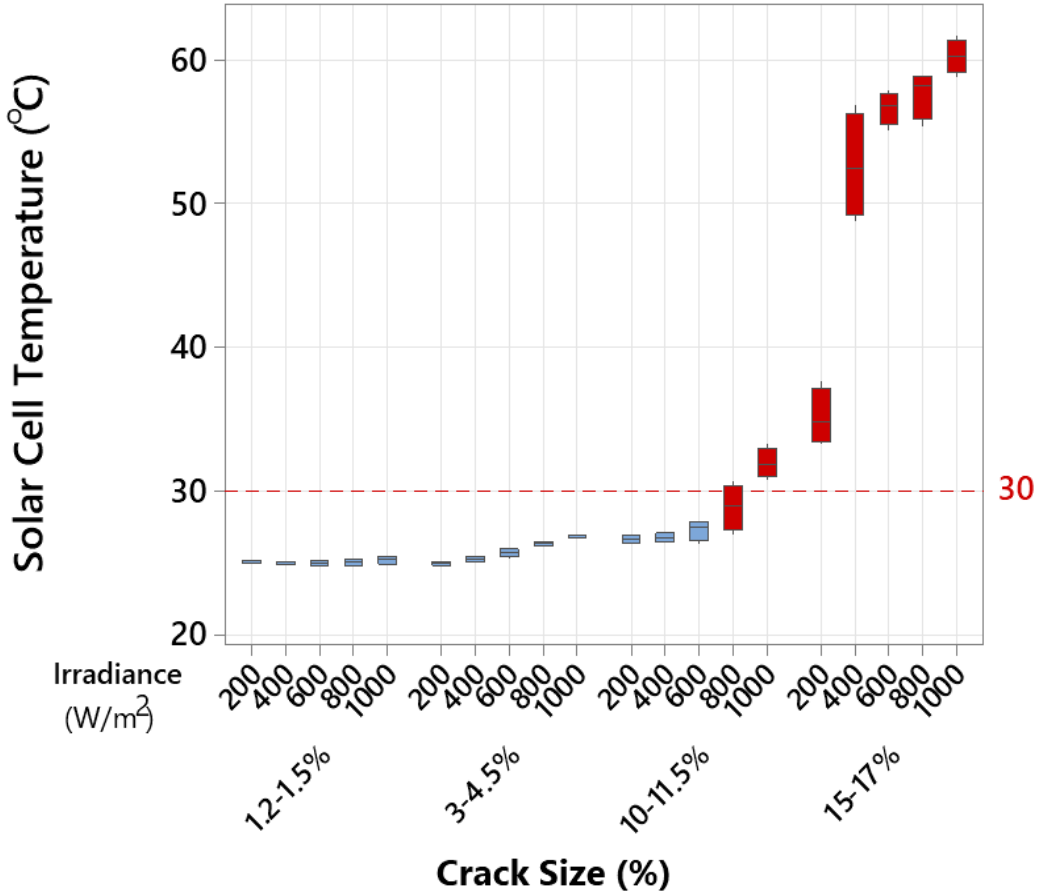

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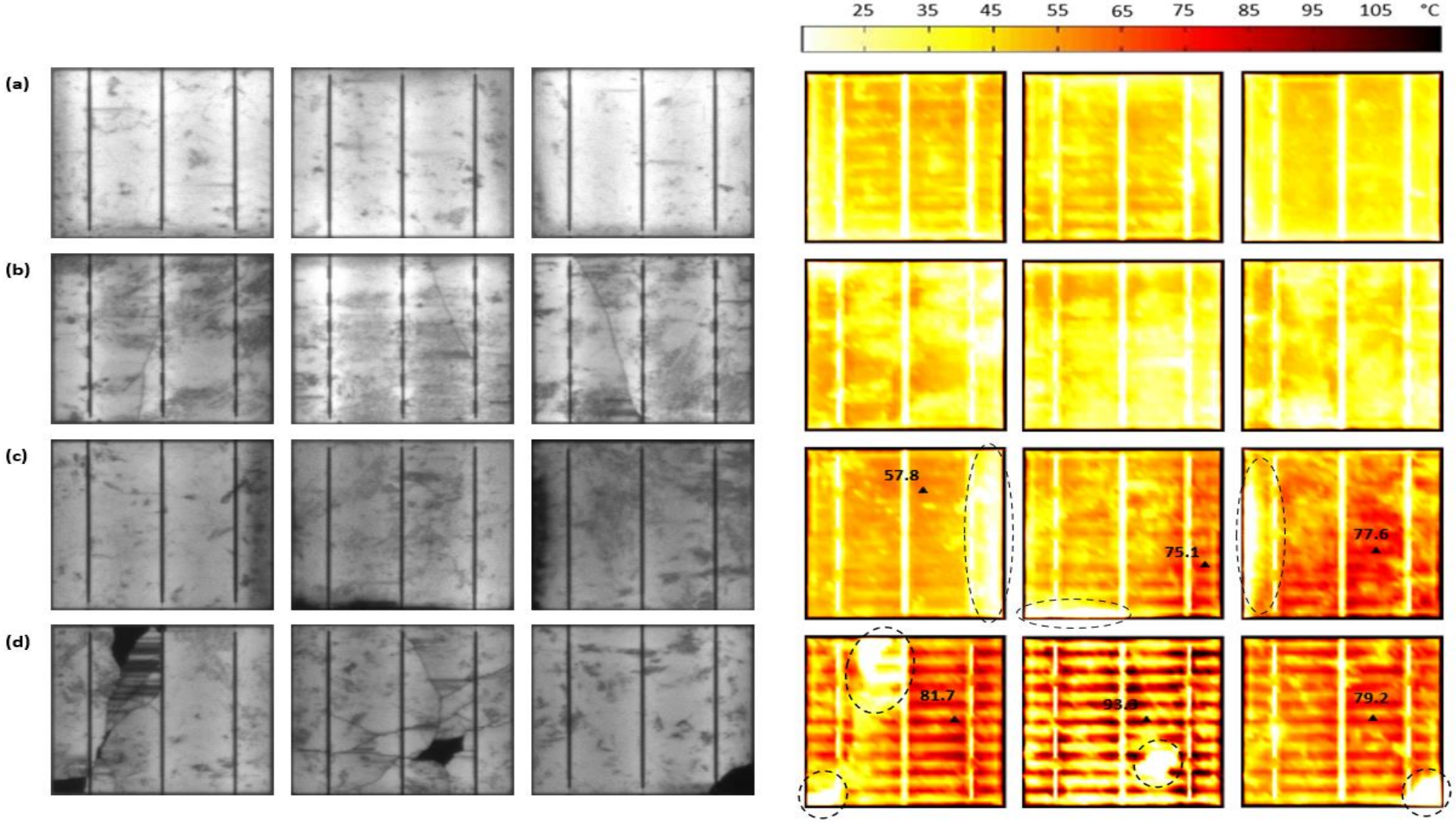
(**a**) mode 1, (**b**) mode 2, (**c**) mode 3, and (**d**) mode 4.



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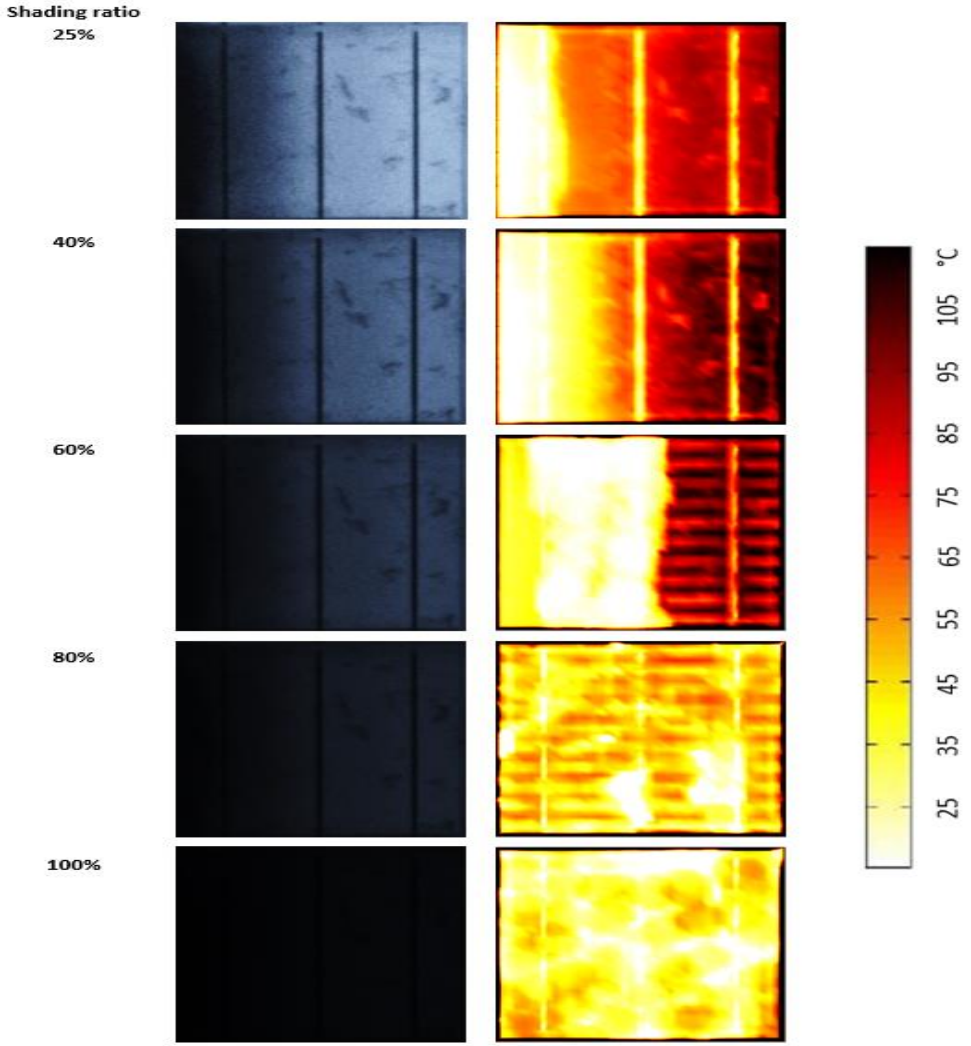

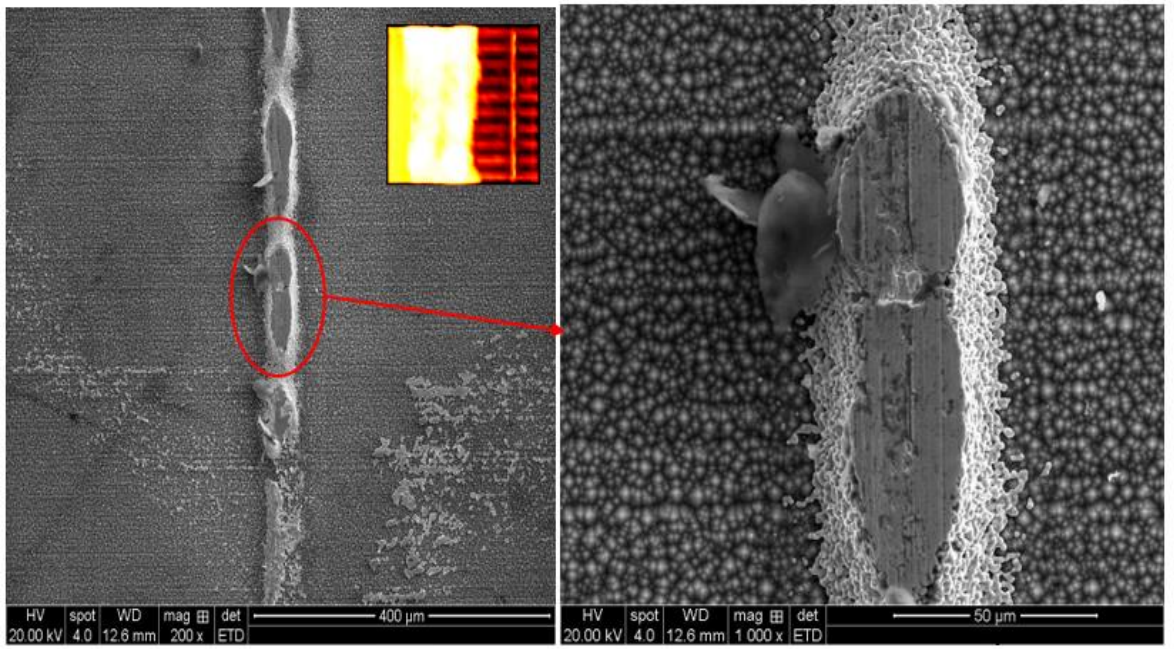

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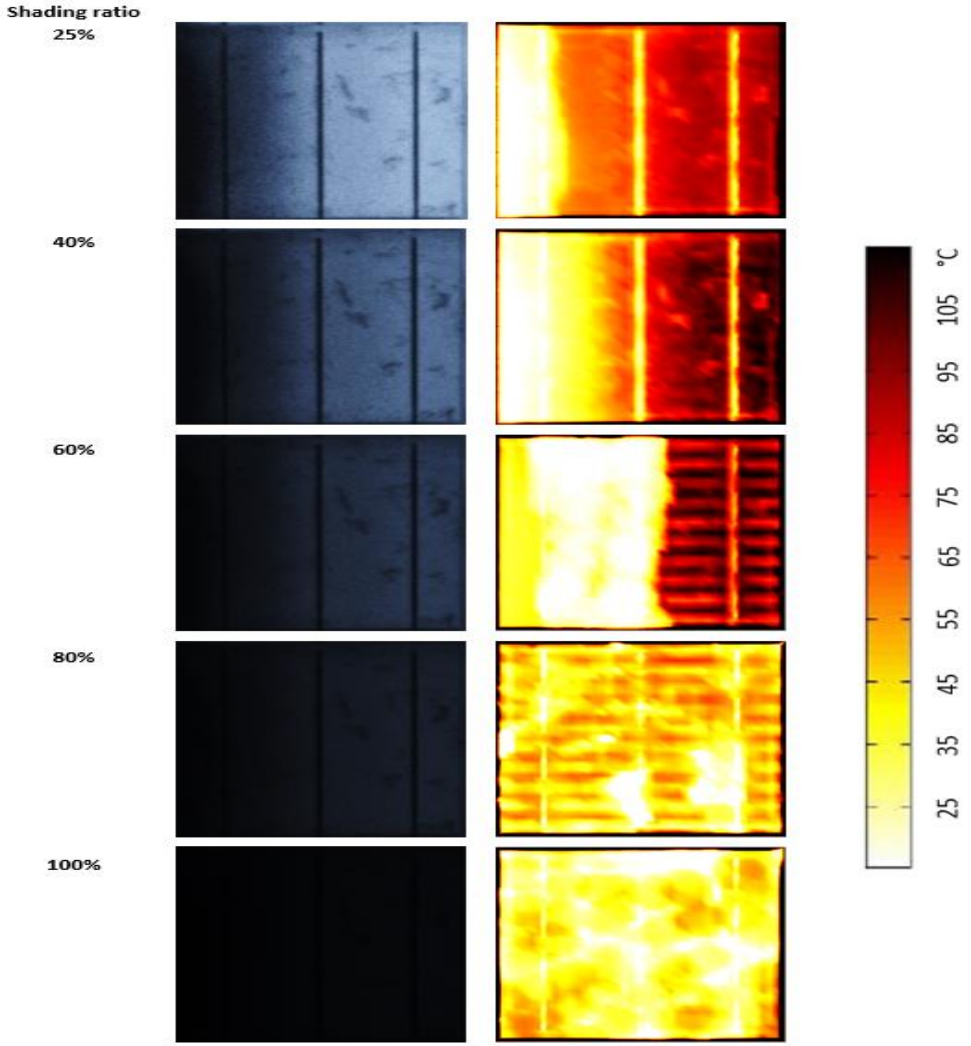

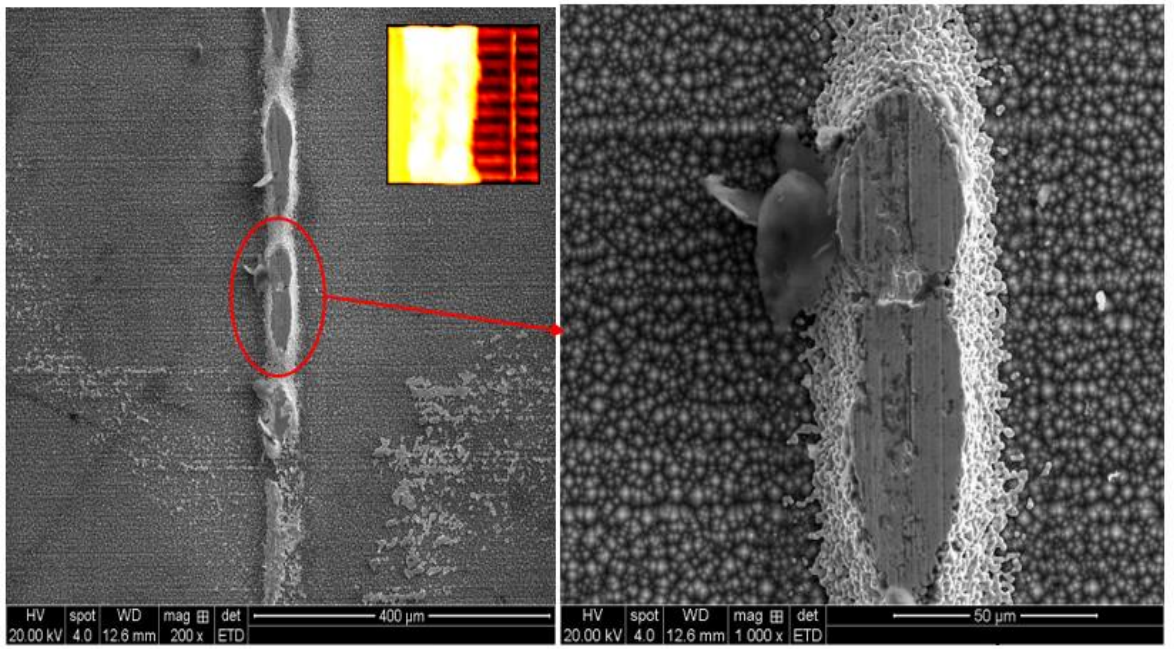

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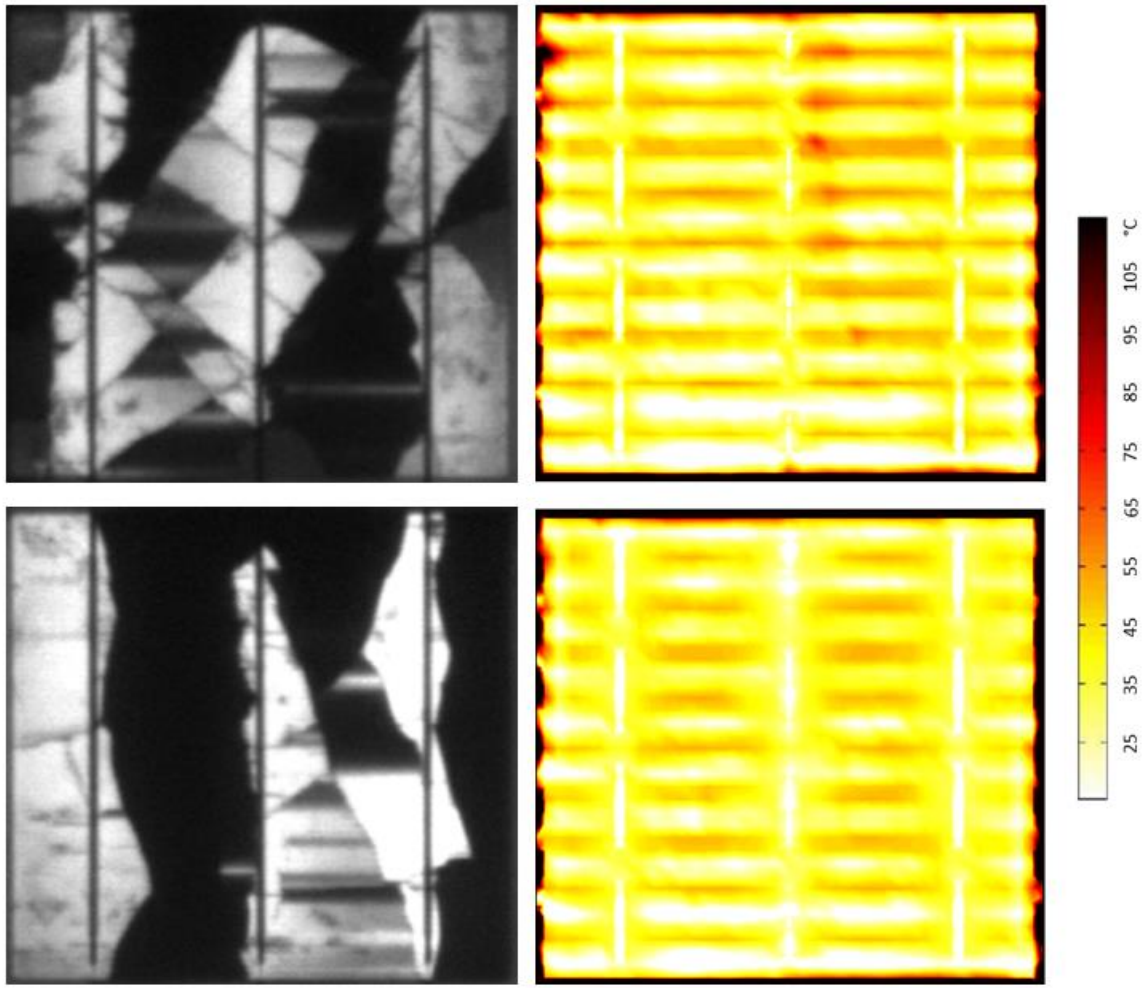

CONCLUSION!

We are still have limited knowledge of the impact of PID! we need more case studies and long-term field analysis!

What is the actual correlation between cracks, PID, hotspots, and other mismatching PV conditions!

QUESTIONS!

CONSTRUCTIVE DISCUSSION!