

# *Operational research for urban solar development*

*“PV failure detection based on operational time series”*

11/12/2023

Alexandre Mathieu



# Curriculum Plan

Today →

| Day                                  | Time                    | Duration    | Content                        |
|--------------------------------------|-------------------------|-------------|--------------------------------|
| <b>Monday</b><br><b>27/11/2023</b>   | 9h45-11h15<br>12h30-14h | 1h30 + 1h30 | 50% Lecture / 50 %<br>Hands-on |
| <b>Tuesday</b><br><b>05/12/2023</b>  | 8h-9h30<br>9h45-11h15   | 1h30 + 1h30 | 50% Lecture / 50 %<br>Hands-on |
| <b>Thursday</b><br><b>07/12/2023</b> | 8h-11h<br>12h45-15h45   | 6h          | 25% Lecture / 75 %<br>Project  |
| <b>Monday</b><br><b>11/12/2023</b>   | 8h-11h<br>12h30-15h30   | 6h          | 10% Lecture / 90 %<br>Project  |
| <b>Friday</b><br><b>22/12/2023</b>   | 8h-9h30                 | 1h30        | 100 % Project                  |

# Modeling steps

## Notebook DC Power estimation 07/12/2023

The notebook is now corrected and can be read online:

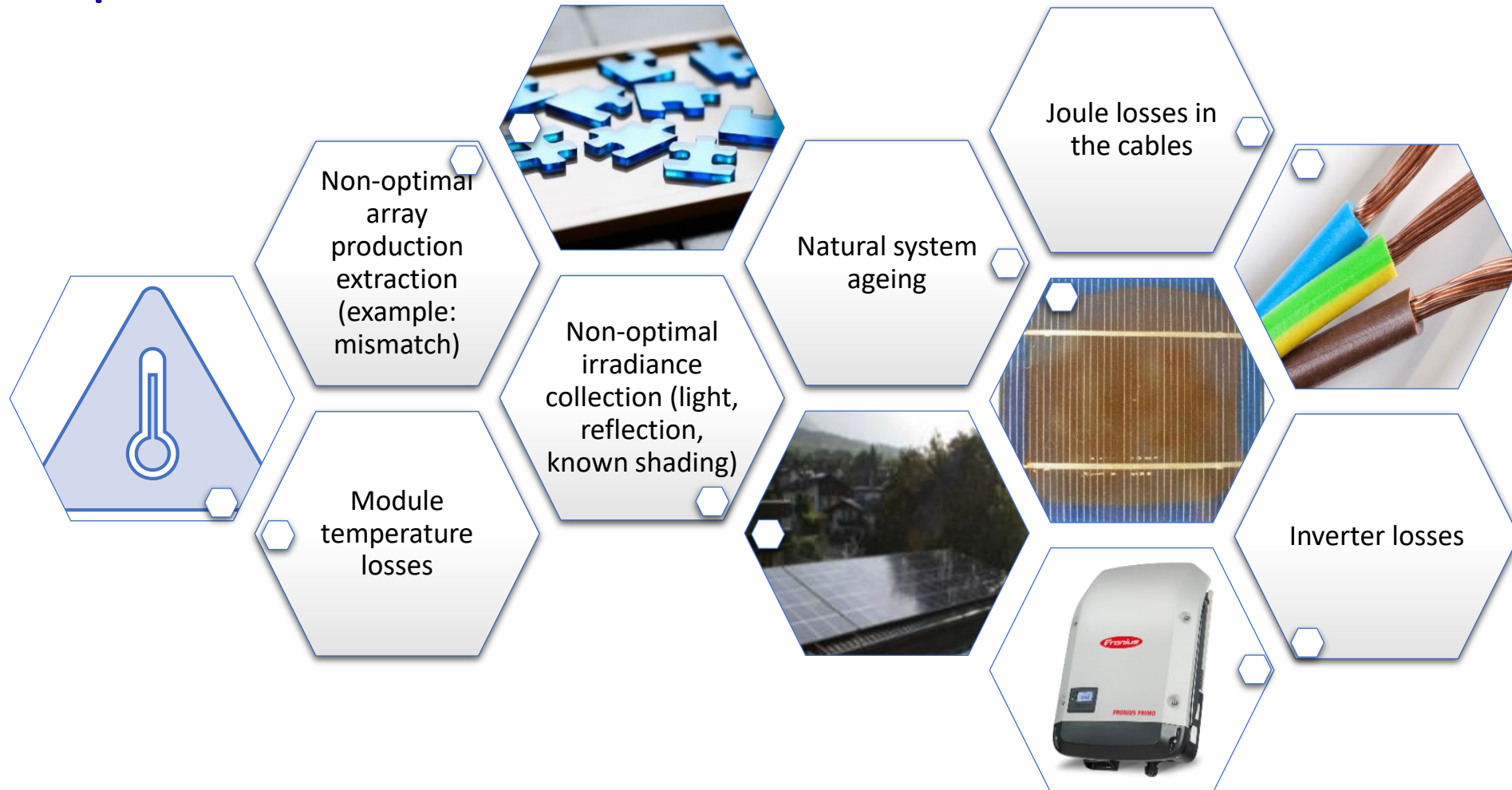
[https://github.com/AlexandreHugoMathieu/pvfault\\_detection\\_solar\\_academy/blob/master/notebooks/dc\\_power\\_estimation.ipynb](https://github.com/AlexandreHugoMathieu/pvfault_detection_solar_academy/blob/master/notebooks/dc_power_estimation.ipynb)

# Agenda



**PV « expected » losses**

## PV « expected » losses



# Agenda



## PV Failure

# PV failure definition

Inspired from the IEA definition\*, a failure occurs when\*\*:

$$P_m(t) + \Delta P_m(t) < P_{expected}(t) - \Delta P_{expected}(t)$$

$P_m(t)$  the system power measured according to IEC 60904

$\Delta P_m(t)$  the total uncertainty of the measurement

$P_{expected}(t)$  the expected system power

$\Delta P_{expected}(t)$  the expected system power tolerance

In other words, a failure is an underperformance which is not planned at the design phase.

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\*\*A. Mathieu, G. Fraisse, M. Thebault, S. Thebault, S. Boddaert, and L. Gaillard, ‘Failure Risk Analysis of Photovoltaic Systems Based on Literature Review’, presented at the Eurosun 2022, Kassel, Germany, Sep. 2022.

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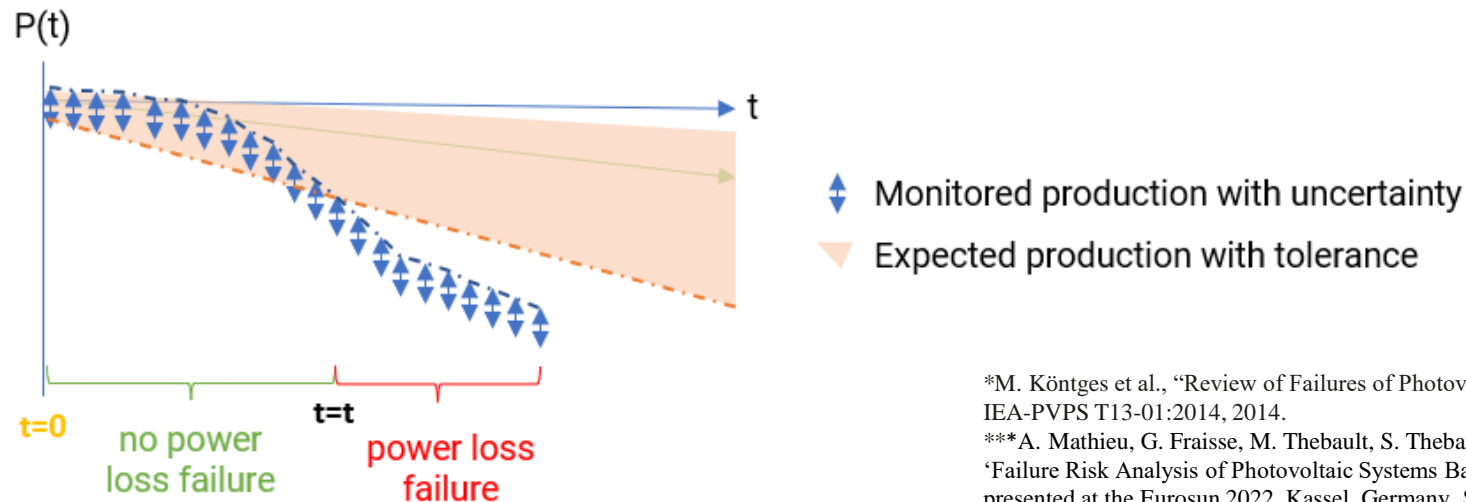
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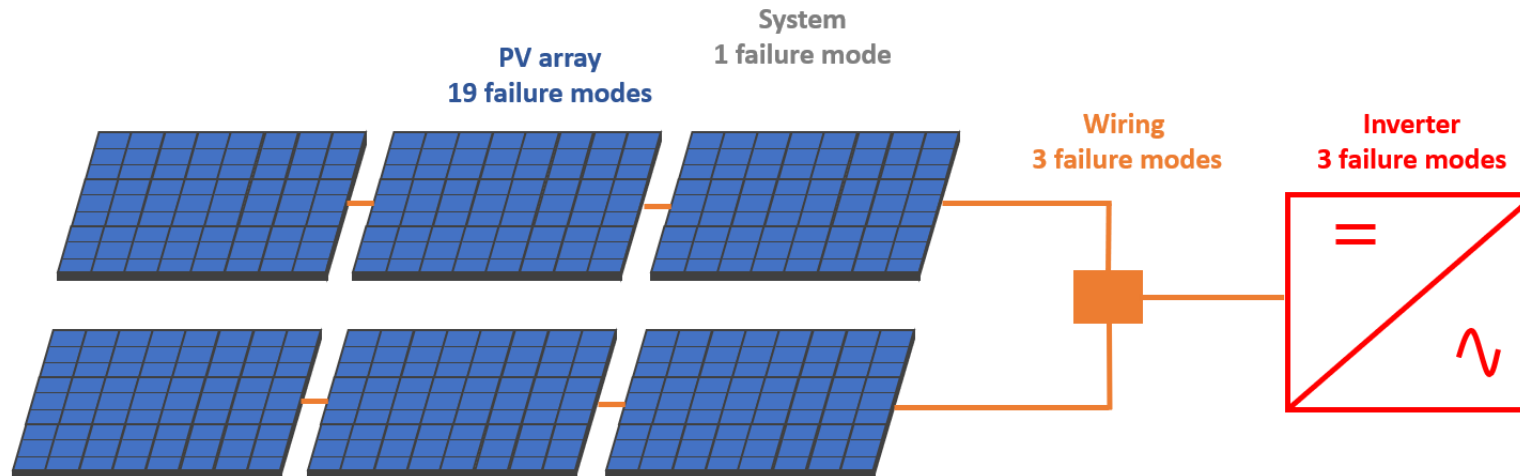
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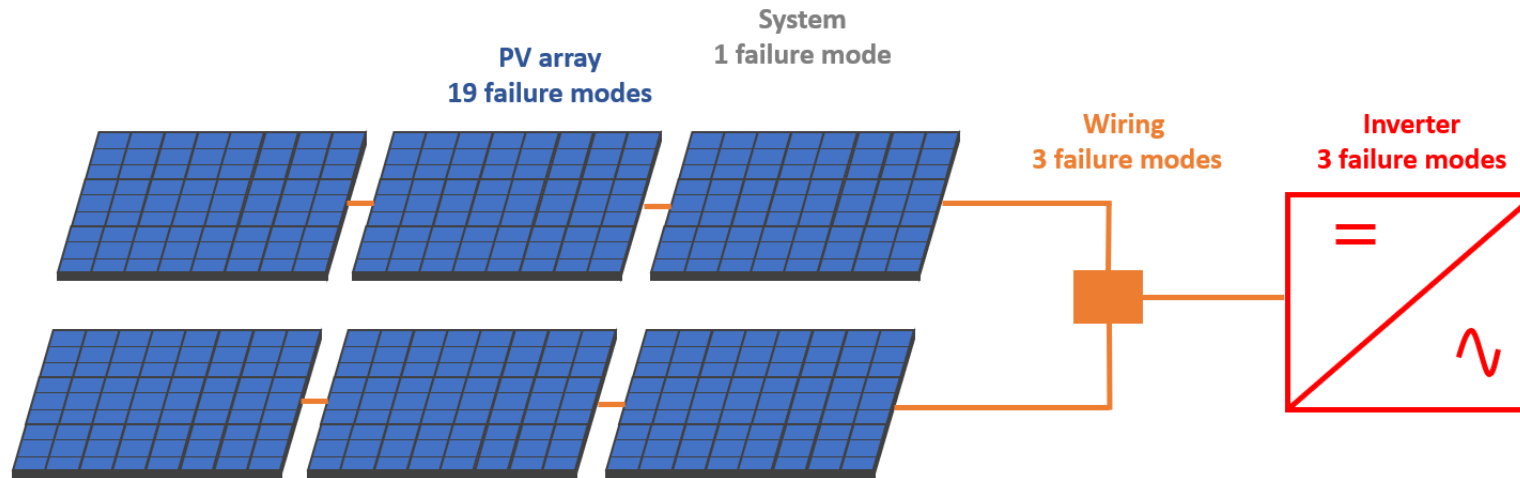
# Failures

One list of failures...  
Total: **26**



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| System  | Module/Array   |
|---|--|
| Insulation failure and ground connection defect | Backsheet degradation  |
|   | Burn marks   |
|   | Bypass diode defect  |
|   | Cell cracks  |
|   | Cell interconnection defect  |
|   | Corrosion  |
|   | Delamination   |
|   | Encapsulant degradation  |
|   | Frame/Mounting structure defect  |
|   | Glass breakage   |
|   | Hot spot   |
|   | Junction box defect  |
|   | Light Induced Degradation (LID) and Light and elevated Temperature Induced Degradation (LETID) |
|   | Module under-ventilation   |
|   | Not conform power rating   |
|   | Potential Induced Degradation (PID)  |
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The 12 most critical according to \*

# Agenda



## Common PV Failures

# Shading

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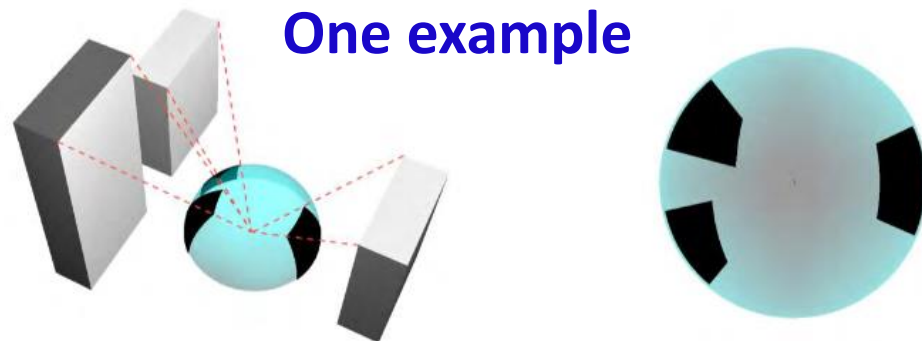
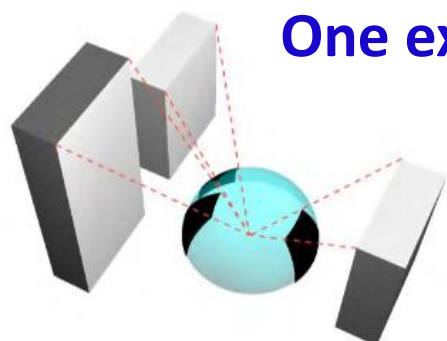


Image: "Measuring sky view factor of urban canyons using hacked Gopro hemispheric video processing",  
December 2015, Conference, Melbourne, Australia, White et Kimm

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**One example**

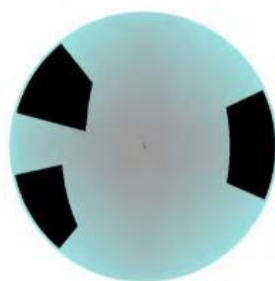
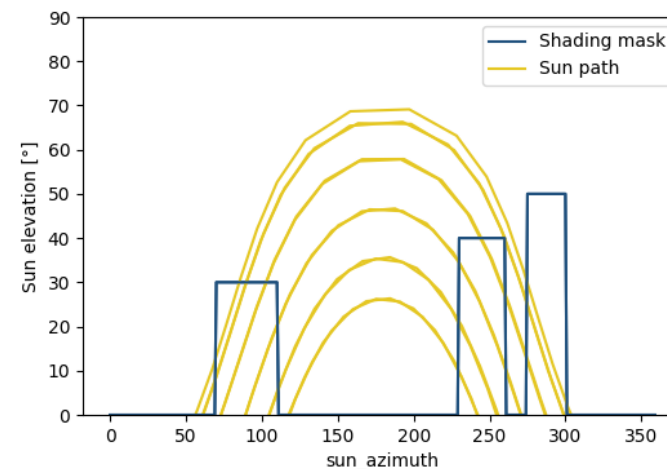


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\*Process illustration, assumptions made on the building masks.

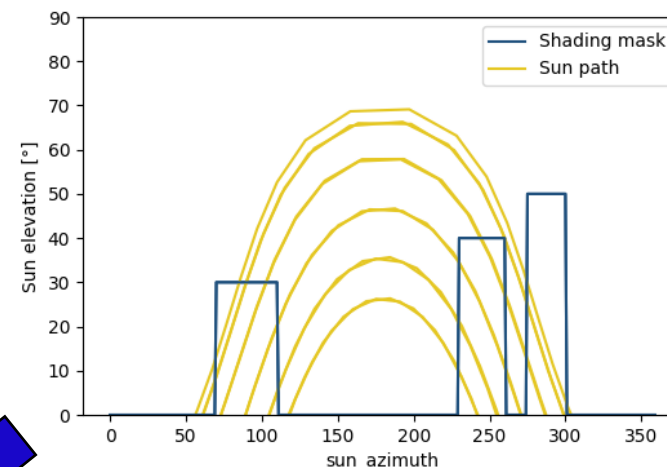
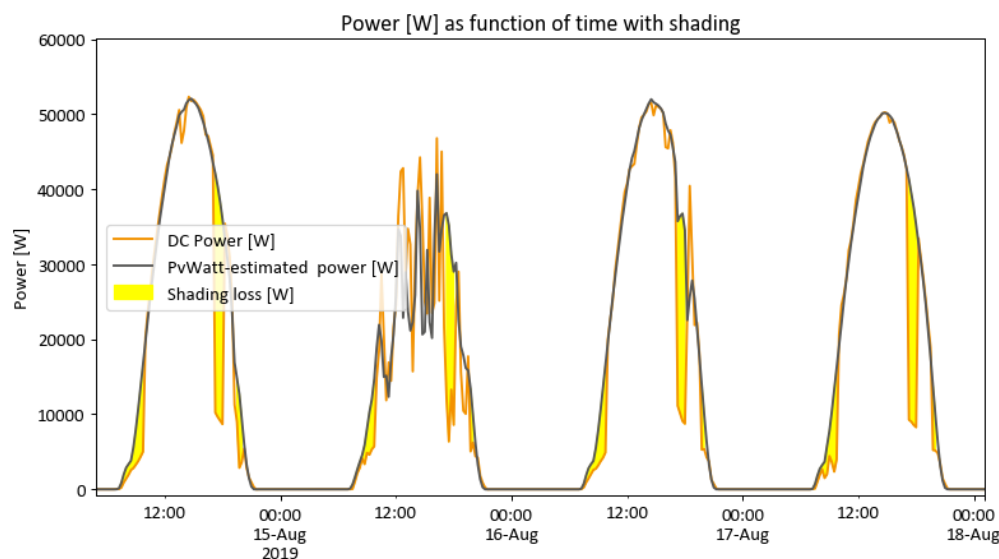
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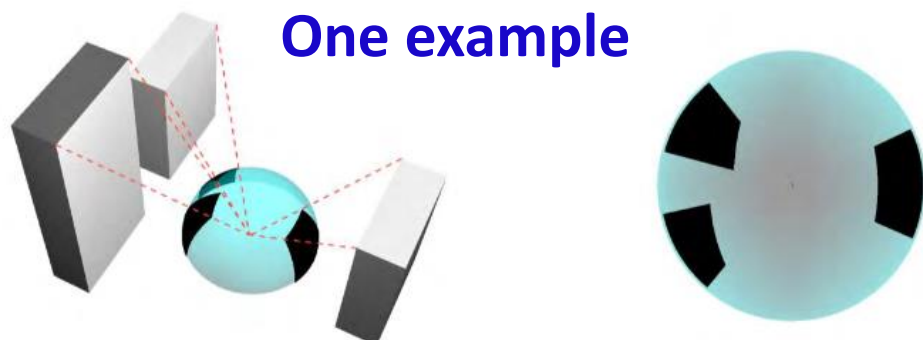
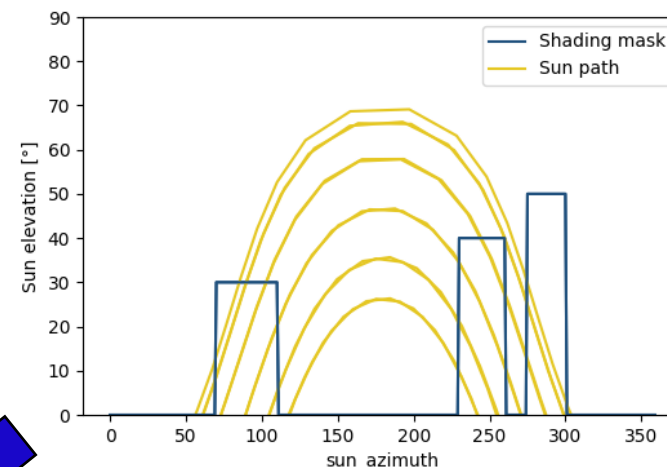
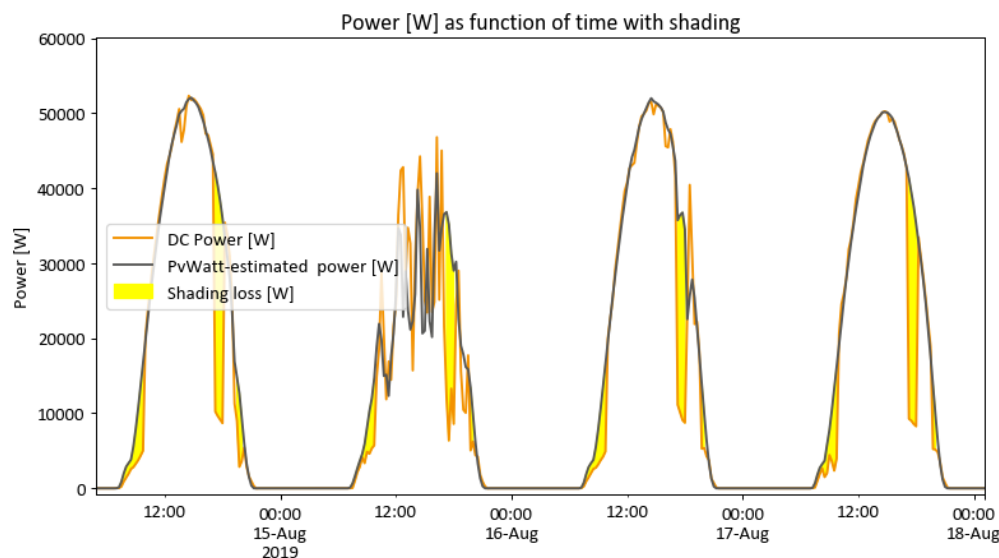


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## Detection Hints:

- Temporal cycle
- Correlated with the sun position  
(Low sun horizons have higher chances of getting shaded.)
- Decrease in the same order of magnitude as the POA-direct component ratio out of POA-global
- Sudden drops/increase

# Inverter clipping

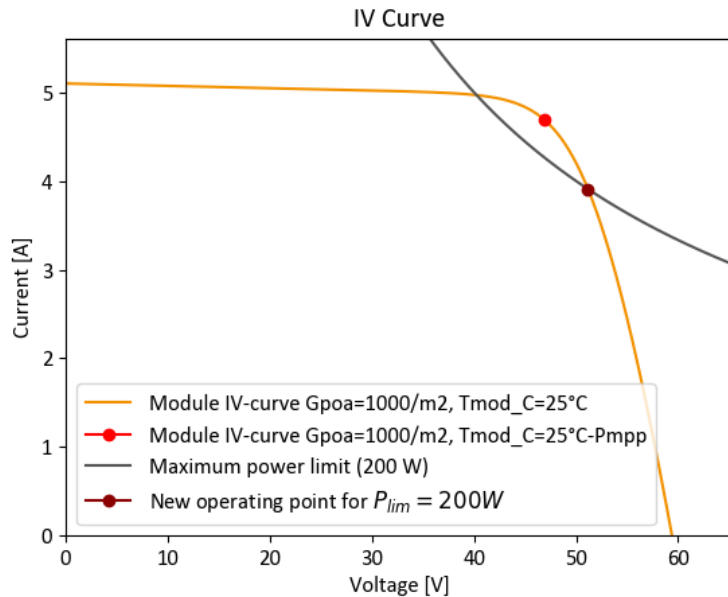
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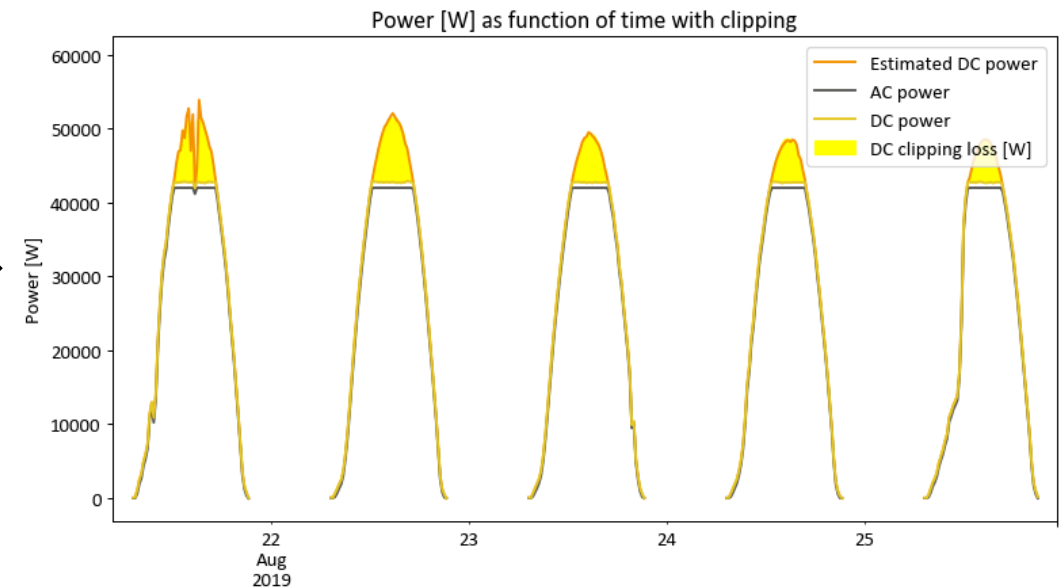
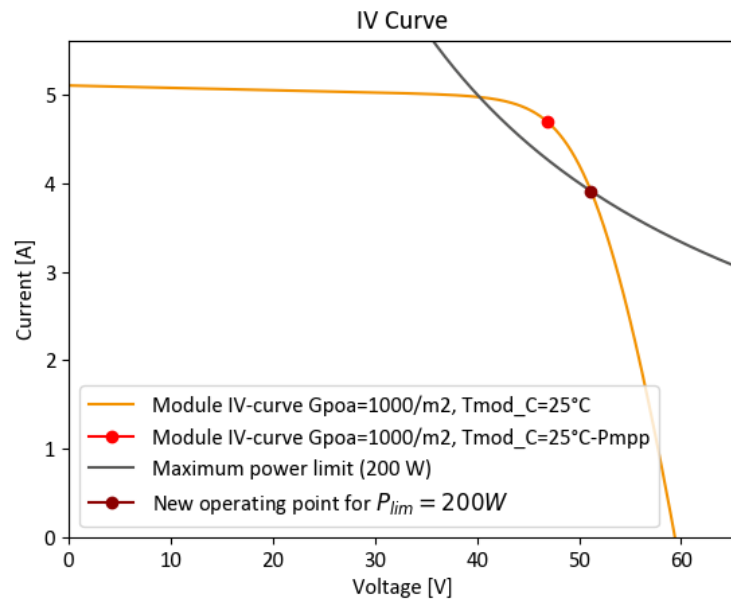
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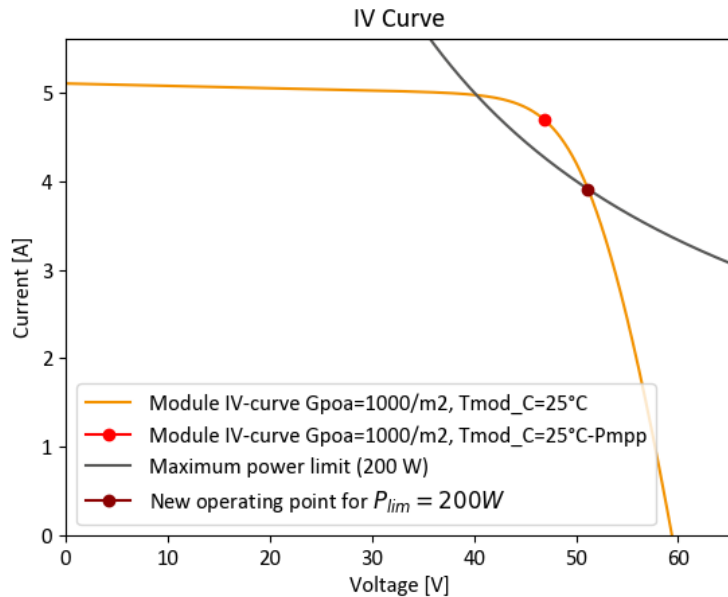
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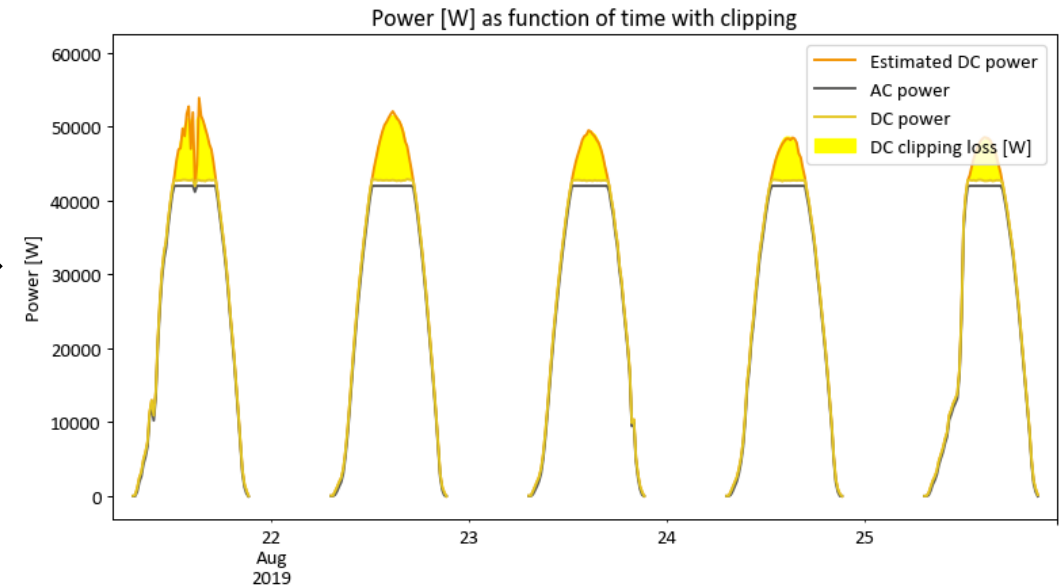
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## Detection Hints:

- Clipping threshold is generally fixed
- Occurs at high sunny conditions
- Slope = 0 W/m<sup>2</sup>/h

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### Potential causes:

- Improper manufacturing (soldering error, bus bar misalignment...)
- Faulty bypass diodes in short-circuit position
- Improper installation (connection error, damaged connectors...)

Situations where the PV module is « intentionally » bypassed thanks to the bypass diodes:

- Damaged cells (from hailing, lightning...)
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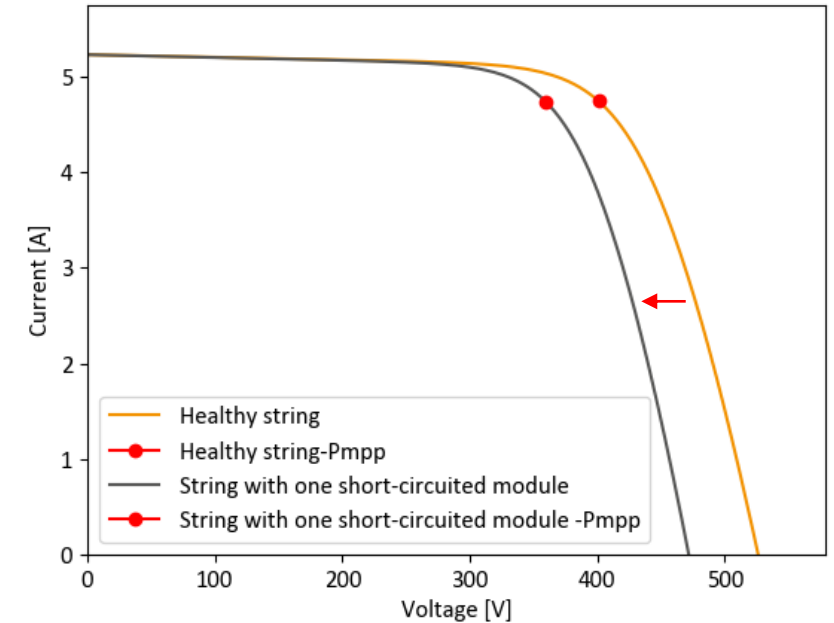
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IV Curve





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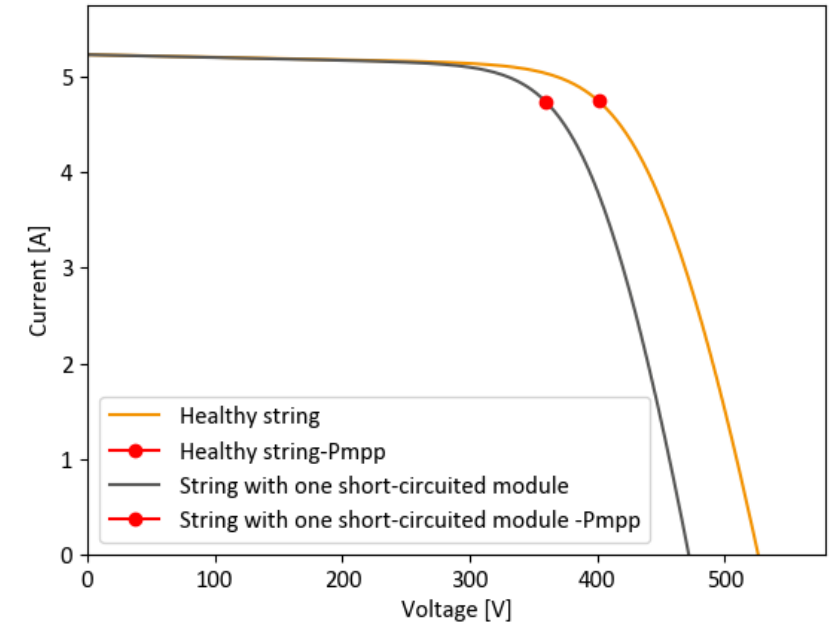
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### Detection Hints:

- Constant underperformance
- Start at a specific date
- The power reduction is proportional to the number of short-circuited modules

*That's it*



## Resources to go further

- Modeling guide PVPMC: <https://pvpmc.sandia.gov/modeling-guide/>
- Python / Pvlb tutorial: <https://pvsc-python-tutorials.github.io/PVSC48-Python-Tutorial/>
- To go further:
  - The Use of Advanced Algorithms in PV Failure Monitoring , IEA PVPS 2021: [https://iea-pvps.org/wp-content/uploads/2021/10/Final-Report-IEA-PVPS-T13-19\\_2021\\_PV-Failure-Monitoring.pdf](https://iea-pvps.org/wp-content/uploads/2021/10/Final-Report-IEA-PVPS-T13-19_2021_PV-Failure-Monitoring.pdf)
  - Improving Efficiency of PV Systems Using Statistical Performance Monitoring, IEA PVPS 2017: <https://iea-pvps.org/wp-content/uploads/2020/01/Report IEA-PVPS T13-07 2017 Improving Efficiency of PV Systems Using Statistical Performance Monitoring.pdf>