Intrinsic performance loss rate: decoupling shading losses from photovoltaic system data for reliable degradation estimations

Hugo Quest [*1, 2], Alessandro Virtuani [3], Pascal Müller [2], Alejandro Pena-Bello [1], Nicolas Wyrsch [1], Christophe Ballif [1, 3]

1 – EPFL, Institute of Electrical and Micro Engineering (IEM), Photovoltaics and Thin-Film Electronics Laboratory (PV-LAB), 2002 Neuchâtel (Switzerland)
2 – 3S Swiss Solar Solutions AG, 3645 Thun (Switzerland)
3 – CSEM, Sustainable Energy Centre, 2002 Neuchâtel (Switzerland)

SWISSOLAR PV Tagung 2023

* hugo.quest@epfl.ch

1 Context and goals

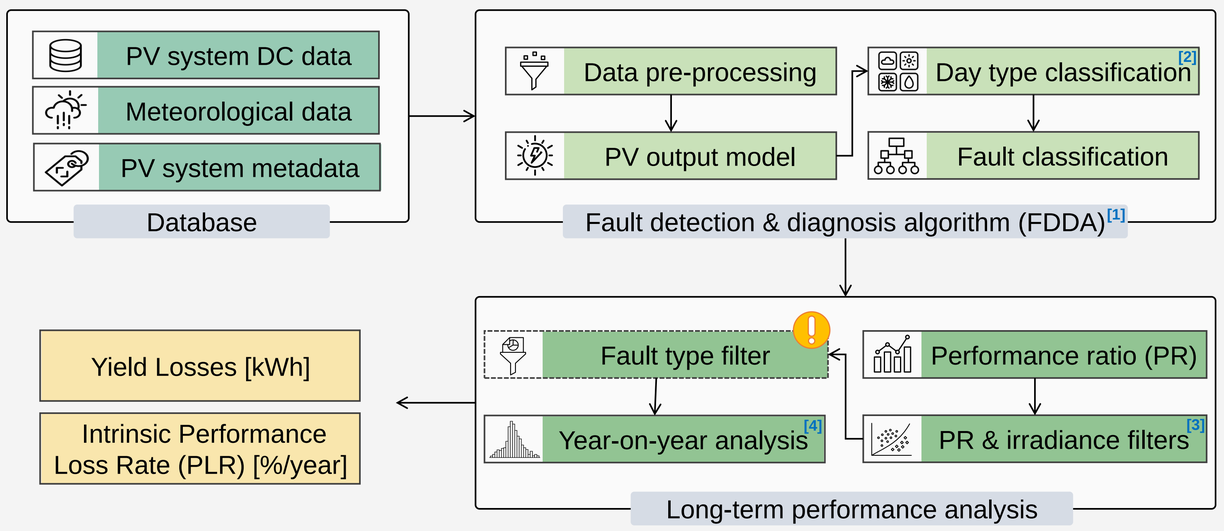
- Research on PV fault detection is separated from reliability assessments in literature, but they should be dealt with in parallel [1].
- Reversible faults such as partial shading can significantly bias a PV system's performance loss rate (PLR).
- This work aims to decouple reversible losses from PV output data, leading to the definition of the **intrinsic PLR**.

Shading fault detection & diagnosis

Data filtering & processing

Long-term performance analysis

2 Methodology



3 Results

3.1 | Loss patterns & PLR bias

- Fleet analysis of string-level building-integrated PV (BIPV) systems:
  - **Step 1** – Fault detection & diagnosis algorithm (FDDA) to identify yield losses and shading patterns.
  - **Step 2** – Compute **intrinsic PLR** with fault type filtering (eliminating shading faults) or **standard PLR**.
- Four patterns of shading losses and PLRs are identified (**Fig. 1**):

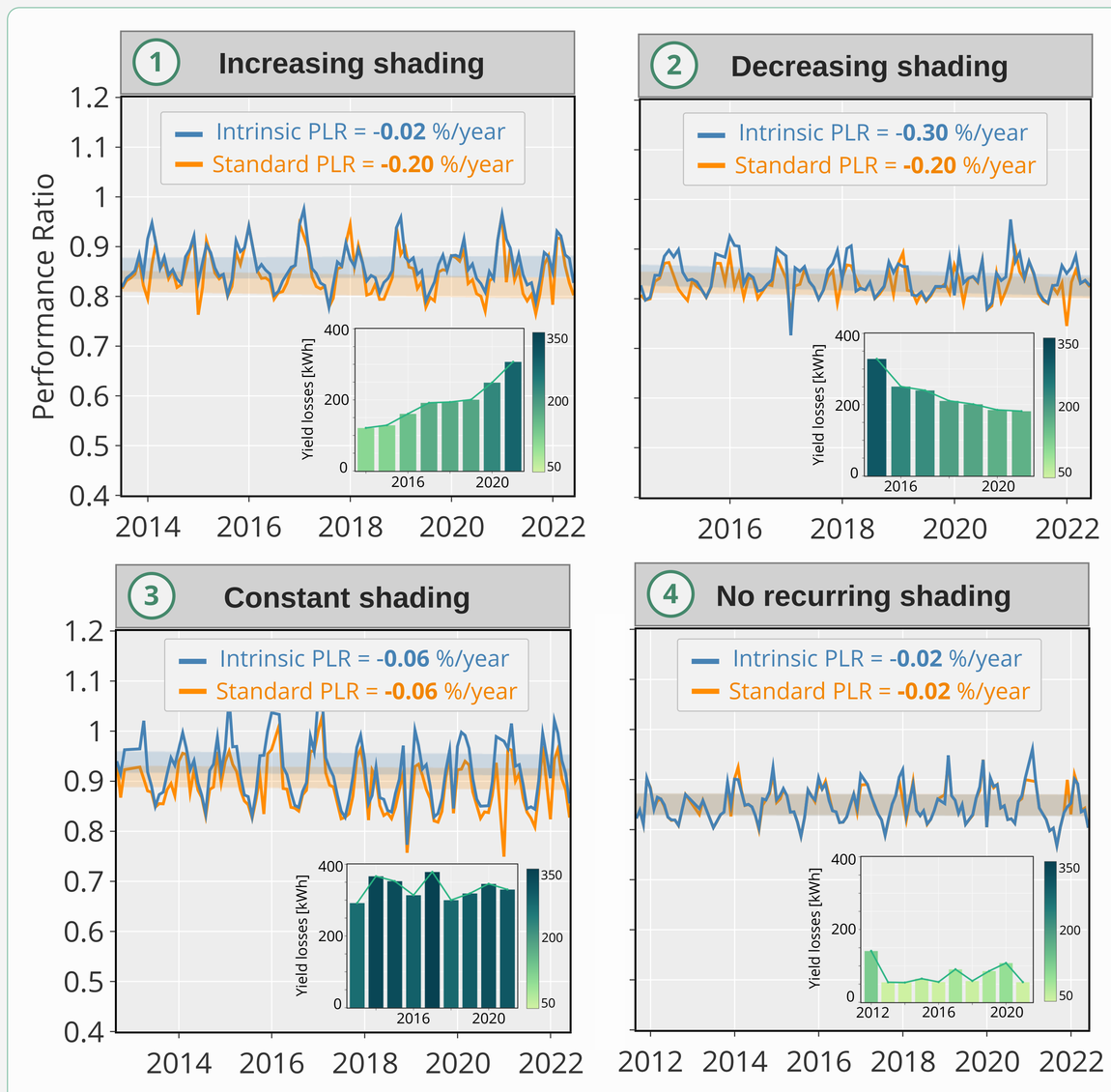
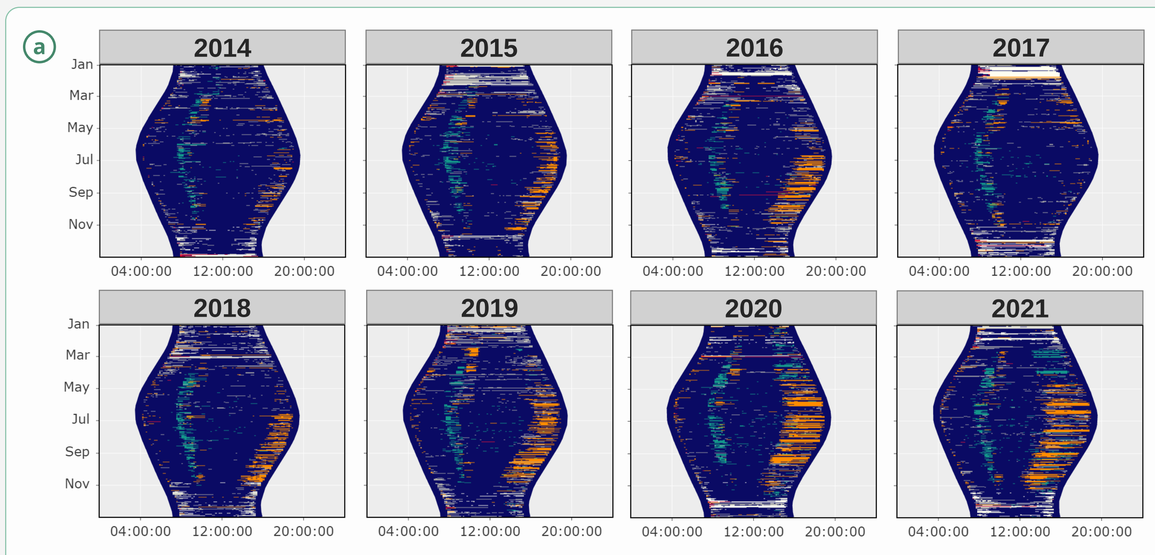
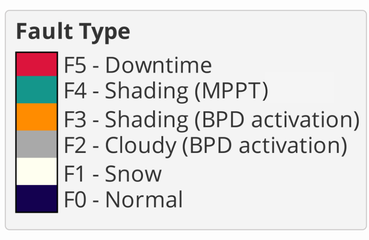
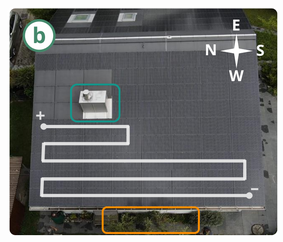


Fig. 1: Comparison of daily PR trends for the intrinsic and standard PLRs for the four identified shading loss scenarios (different BIPV systems), with corresponding yearly yield loss evolution.

3.2 | Detailed case study – shaded BIPV system







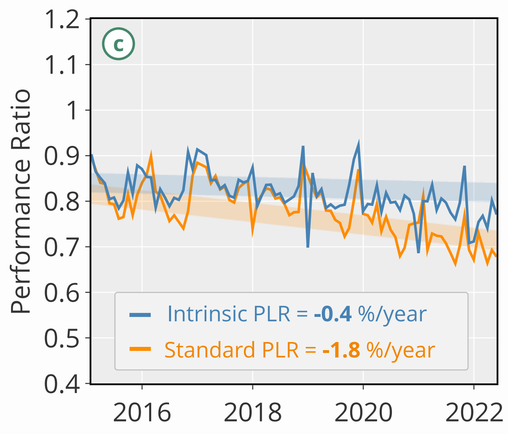


Fig. 2: (a) Yearly fault detection heat map of the studied BIPV string, showing the evolution of fault occurrences through time. **(b)** Drone photograph with highlighted string and shading elements [5].

Recurring shading losses due to rooftop chimney and nearby tree.

Increase of tree shading over time, causing increased bypass diode activation during shading events.

Anomaly in 2017 – decreased shading and improved PR, indicating the tree was trimmed.

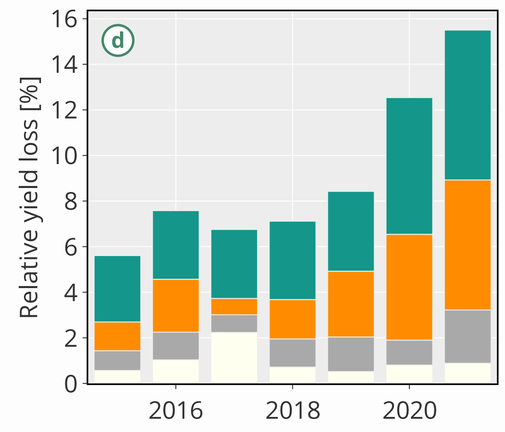


Fig. 2: (c) Daily PR trend for intrinsic and standard PLR. **(d)** Yearly relative yield losses with fault type classification.

- Filtering the reversible faults and applying the long-term analysis pipeline, the intrinsic PLR is 80% higher compared to the standard method (**Fig. 2 (c)**).
- Shading losses increase by a factor 3 between 2017 and 2021, leading to a drift in the daily PR (**Fig. 2 (d)**).
- On-site analysis of the string revealed one broken bypass diode: recurring shading can cause permanent, **irreversible faults**.

4 Conclusion

The addition of FDD analysis within PLR pipelines offers a solution to avoid the influence of reversible effects, enabling the determination of what we call the **intrinsic PLR**.

A BIPV fleet analysis revealed **four typical patterns of PLR bias** due to reversible loss effects: overestimation of PLR, underestimation of PLR, shift in PR or stable PLR.

Next steps should include on-site analysis of systems affected by recurring losses in order to **correlate them to permanent, irreversible faults**.

Acknowledgements

The authors acknowledge the financial support from the Swiss Federal Office of Energy (SFOE) through the ASSURed PV project (contract #502408-01).
The authors thank Baur AG for providing access to the PV system, and Solcast for use of their satellite-derived meteorological data.

References

[1] Fairbrother et al. (2021), doi: 10.1002/solr.202100583
[2] Quest et al. (2022), doi: 10.13140/RG.2.2.16943.82085
[3] Özkalay et al. (2021), doi: 10.4229/EUPVSEC20212021-5DO.2.1
[4] Jordan et al. (2021), doi: 10.1109/JPHOTOV.2017.2779779
[5] Quest et al. (2022), doi: 10.13140/RG.2.2.11455.79527

20th – 21st March 2023