Towards a Robust Performance Loss Rate Estimate: Minimising the Uncertainty in the Analysis of Photovoltaic System Degradation

Hugo Quest [*1, 2], Christophe Ballif [1, 3], Alessandro Virtuani [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)

EU PVSEC 2023 (Lisbon) | 4CV.1.14

* hugo.quest@epfl.ch

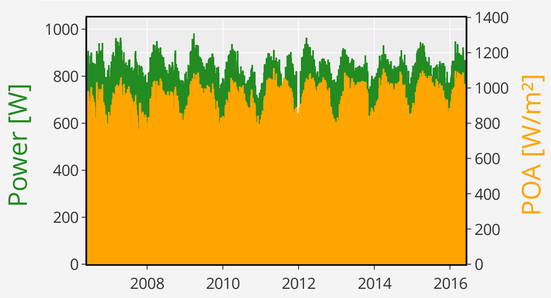
1 Context and goals

- Estimation of the performance loss rate (PLR) is complex as there is no standard method or definition, and uncertainties are often overlooked [1 – 5].
- This work proposes a simple, efficient solution to maximise data usage and minimise the PLR statistical uncertainty.

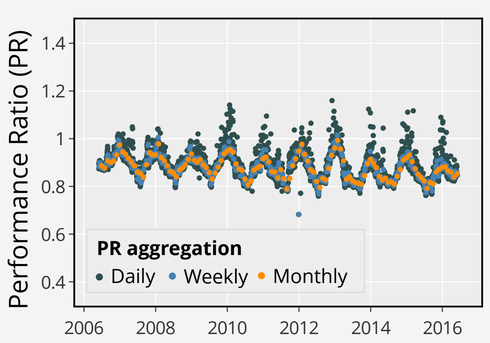
- Novel PLR estimation method with minimised uncertainty
- Relies on multi-annual year-on-year comparisons: multi-YoY
- Effectively reduces the PLR confidence interval (up to 92%)

2 Methodology

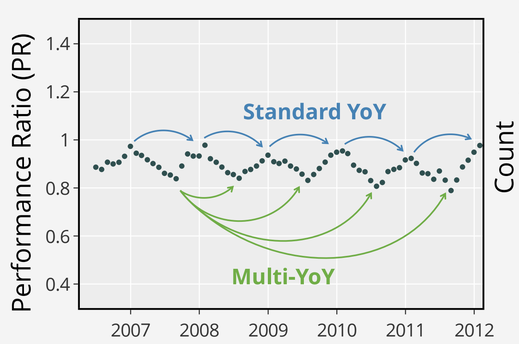
1 Raw data: Power and plane-of-array (POA) irradiance



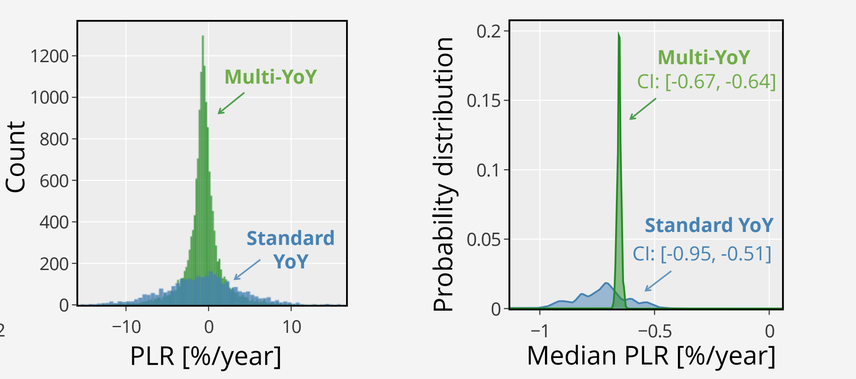
2 Compute the Performance Ratio (PR)



3 Compute Year-on-Year (YoY) performance loss rates (PLR) with standard or multi-YoY method



4 Monte Carlo confidence interval for median PLRs



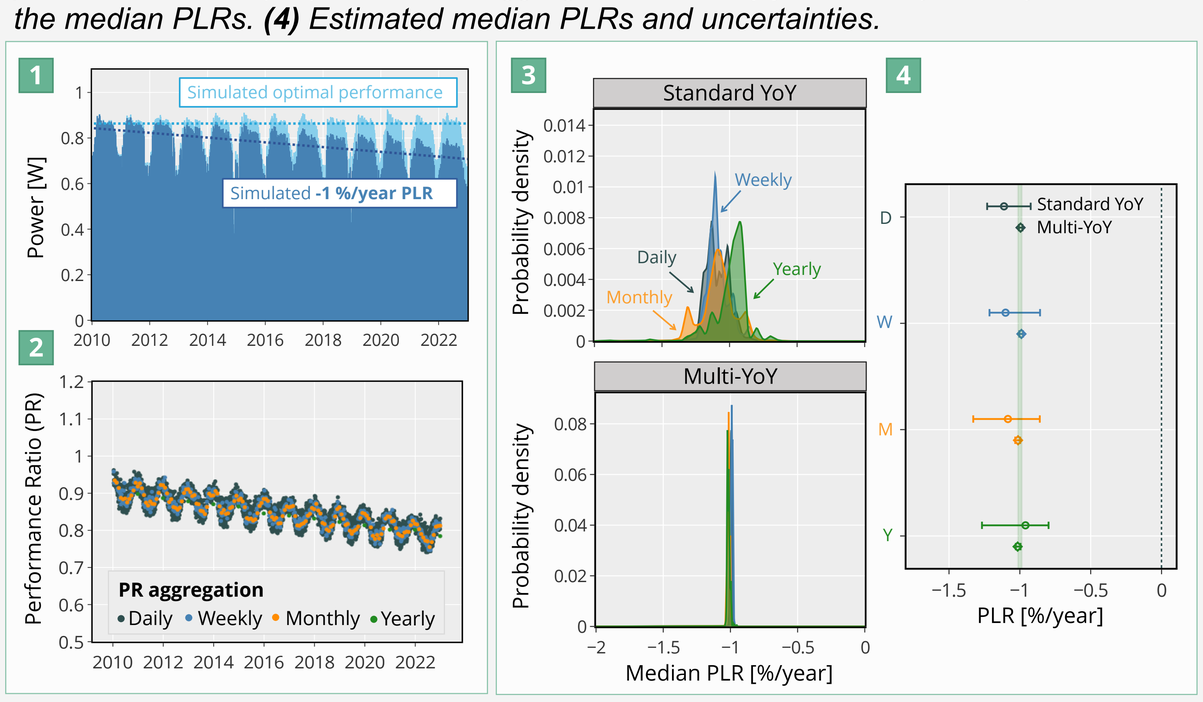
3 Results

3.1 | Validation

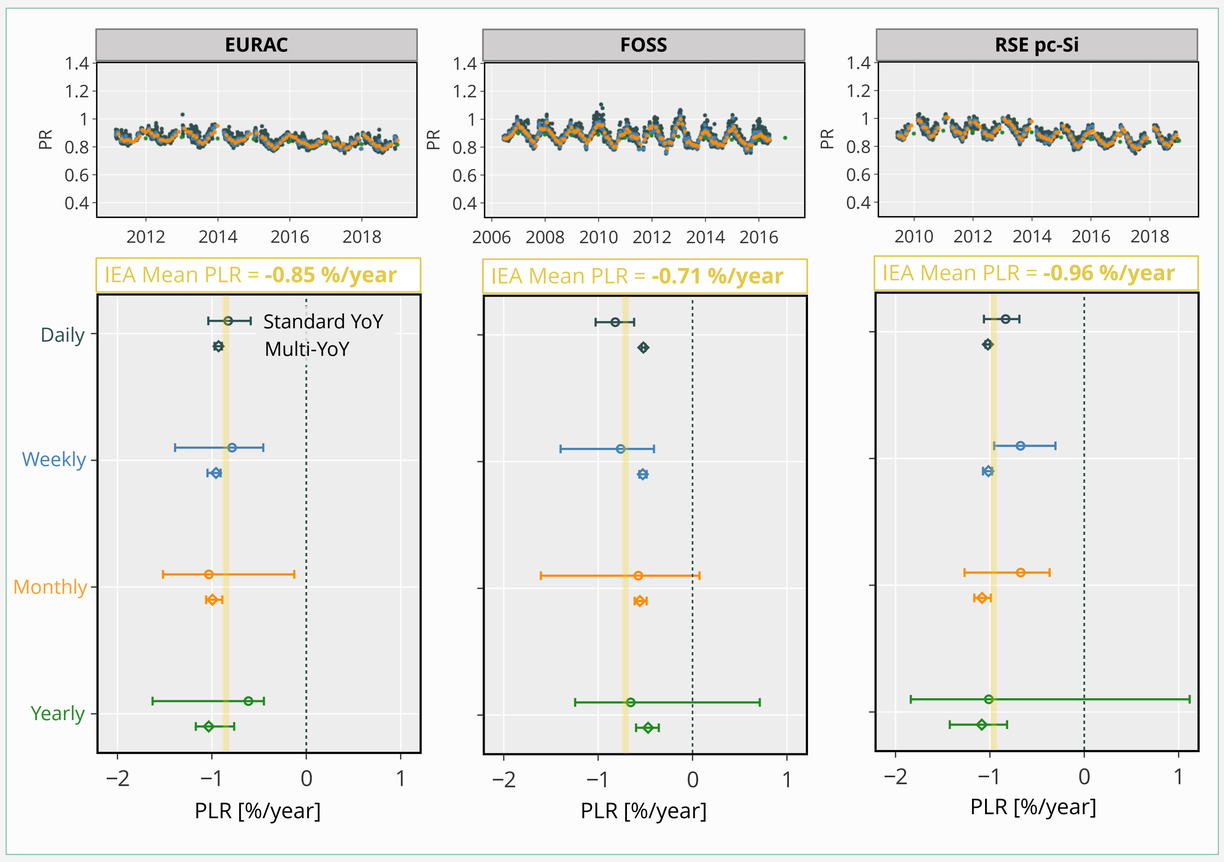
- Simulation of 12 years of PV production with satellite weather data, and artificial PLR of -1 %/year (i.e., known true value of PLR).
- Comparison of two PLR pipelines: standard YoY and multi-YoY.
- Results show average relative errors (RE) of **8%** vs. **1%** for standard vs. multi-YoY compared to the true -1%/year, and a **92% reduced uncertainty** for the multi-YoY method.

Aggregation	Standard YoY		Multi-YoY	
	PLR [%/year]	RE [%]	PLR [%/year]	RE [%]
Daily	-1.11	11	-1.00	0
Weekly	-1.10	10	-0.99	1
Monthly	-1.08	8	-1.01	1
Yearly	-0.96	4	-1.02	2

PLR analysis pipeline: ***(1)*** *Simulated PV production with artificial PLR.* ***(2)*** *Computed performance ratio (PR) at different aggregation levels.* ***(3)*** *Probability density function of the median PLRs.* ***(4)*** *Estimated median PLRs and uncertainties.*



3.2 | Case study: IEA PVPS Task 13 datasets



- Detailed analysis of three datasets from the IEA PVPS Task 13 [1]:
  - EURAC – Bolzano (Italy)
  - FOSS – Nicosia (Cyprus)
  - RSE pc-Si – Milan (Italy)

System	PLR [%/year]		
	IEA Mean	Standard YoY	Multi-YoY
EURAC	-0.85	-0.82	-0.94
FOSS	-0.71	-0.80	-0.52
RSE pc-Si	-0.96	-0.94	-1.01

- Comparison of the mean PLR from [1] to the standard and multi-YoY methods (same filtering and aggregations).
- Results with standard YoY match well with IEA mean PLRs, but vary with the multi-YoY method, although with minimised uncertainties.

4 Conclusion

Developed a novel method for PLR estimation (**multi-YoY**) based on the multi-annual year-on-year comparison of performance ratios.

The method is successfully **validated** with synthetic performance data and tested with IEA PVPS Task 13 datasets.

Compared to the standard YoY method, multi-YoY **increases both accuracy and precision** of PLR estimations.

Future research will aim to further validate the method's **robustness** to data-related issues, such as gaps, non-linearity and outliers.

Acknowledgements

PV-lab IEM NEUCHATEL
International Energy Agency Photovoltaic Power Systems Programme
ASSURed PV
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra
Copernicus Europe's eyes on Earth
Atmosphere Monitoring Service

References

[1] Lindig et al. (2021), doi: 10.1002/pip.3397
[2] Lindig et al. (2022), doi: 10.1088/2516-1083/ac655f
[3] Jordan et al. (2016), doi: 10.1109/PVSC.2016.7749593
[4] Jordan et al. (2018), doi: 10.1109/JPHOTOV.2017.2779779
[5] Hasselbrink et al. (2013), doi: 10.1109/JPHOTOV.2017.2779779

18th – 22nd September 2023