Performance of Power Optimizer versus String Inverter Systems

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Research

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Indoor laboratory measurements

- DC/DC-efficiency indoor measurements [± 0.2% to ± 0.8% (k=1)] of various power optimizers by different manufacturers.

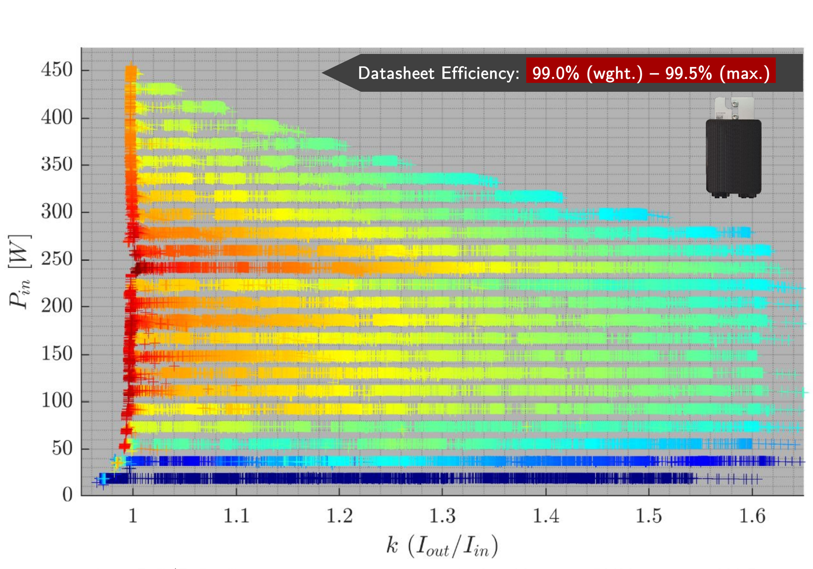

Figure 1 – DC/DC-efficiency measurement of the Huawei SUN2000-450W-P at input voltage of U_{IN} = 35V as a function of the current ratio, k_I = [0.6 : 1. 65] and input power, P_{IN} = [0.05 : 1] · P_{Rated}

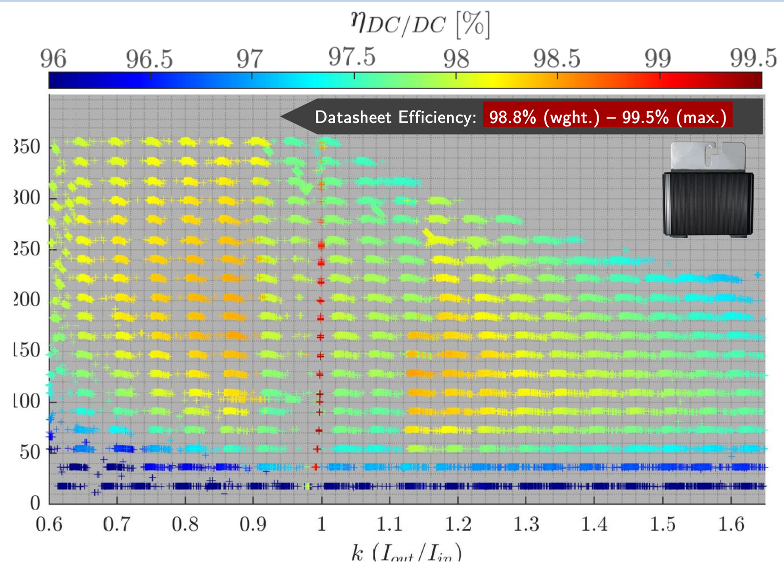

Figure 2 – DC/DC-efficiency measurement of the SolarEdge P370 at input voltage of U_{IN} = 35V as a function of the current ratio, k_I = [0.6 : 1.65] and input power, P_{IN} = [0.05 : 1] · P_{Rated}

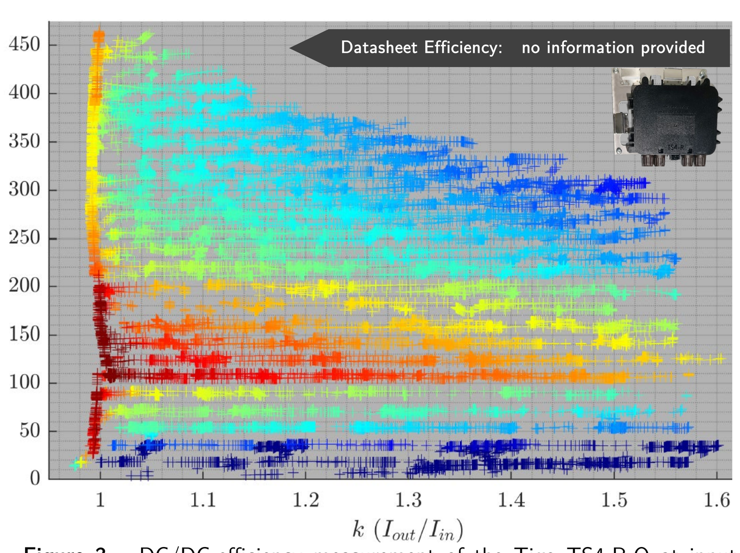

Figure 3 – DC/DC-efficiency measurement of the Tigo TS4-R-O at input voltage of U_{IN} = 35V as a function of the current ratio, k_I = [0.95 : 1.65] and input power, P_{IN} = [0.05 : 1] · P_{Rated}

Abstract

The ZHAW IEFE is involved in the performance research of power optimizer systems, which is funded by the Swiss Federal Office of Energy.[1, 2] The ZHAW PV shading simulation tool was compared to commercial tools, which show forecasts of additional yield by power optimizer systems with percentages in the double digits (PVSyst: 7.2% | PVSol: 14.6 %) relative to the conventional string inverter PV system for the heavy shading case. The reason for this is the use of the manufacturers' data-sheet values, whereas the effectively indoor measured power optimizer efficiency is generally 1.0 to 2.5% lower in points relevant for real-life operation. Finally, according to the results a list of performance-based recommendations for the application of the different PV systems was formulated.

Evaluation of commercial tools

- Accuracy of ZHAW simulation to PVSyst without shading or MLPE:
  - PVSyst: PR_{DC} = 89.2% (semi-integrated)
  - ZHAW: PR_{DC} = 85.2% (close roof mount) | 91.1% (open-rack)
- PVSol is not capable of calculating shading on cell-substrings.

Table 1 – Simulation results of the ZHAW PV shading tool and two commercial tools for two cases and three PV system types.

Case	Shading index $SI_{DC,Max}$	SINV SAE [%]	allMLPE SAE [%]	allMLPE yield gain [%] «ZHAW»	allMLPE yield gain [%] PVSyst	allMLPE yield gain [%] PVSol	indMLPE SAE [%]	indMLPE yield gain [%] «ZHAW»	indMLPE yield gain [%] PVSyst	indMLPE yield gain [%] PVSol
Weak shading	2.8%	96.0	96.6	+0.6	+3.3	+4.3	96.9	+1.0	(+1.6)*	+2.1
Heavy shading	9.0%	94.4	96.5	+2.2	+7.2	+14.6	96.1	+1.8	(+4.1)*	+12.1

+12.4%

Buck-boost-type power optimizer DC/DC-efficiency during a day

- The performance of allMLPE system is 2% lower when the total PV string voltage is 40% higher than the fixed-string voltage (here: +5 PV modules).

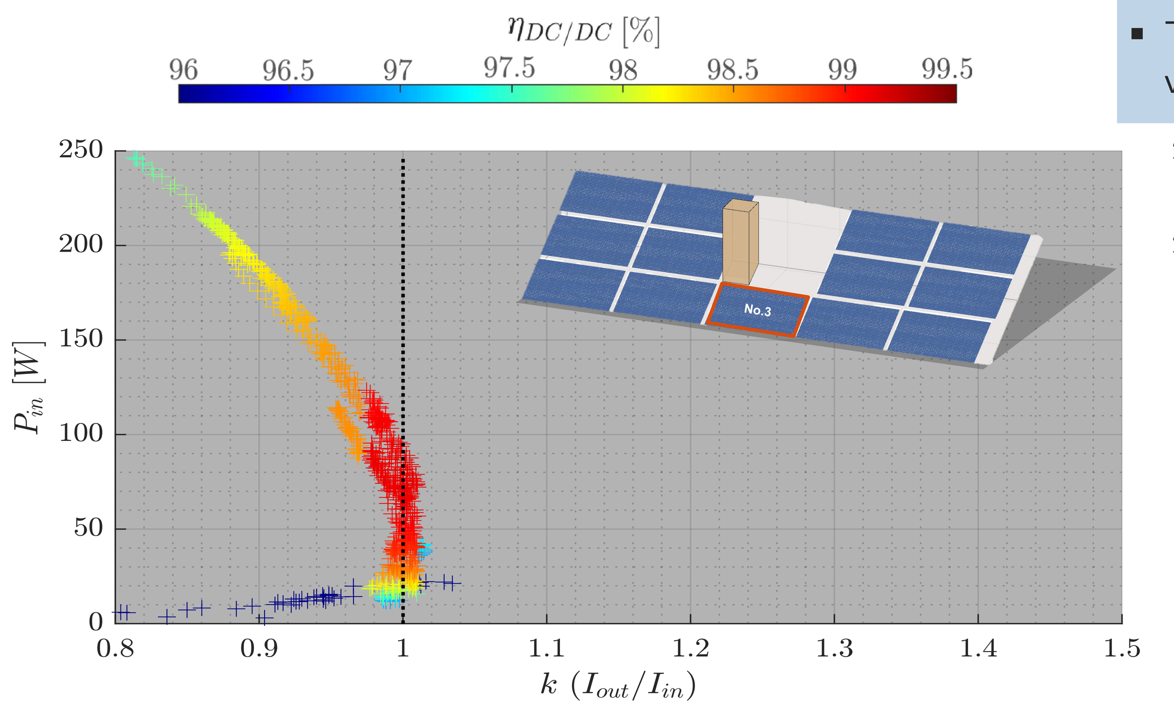

Figure 4 – Simulated DC/DC power optimizer efficiency during a day for the 13-Module PV System (1-Phase) with chimney.

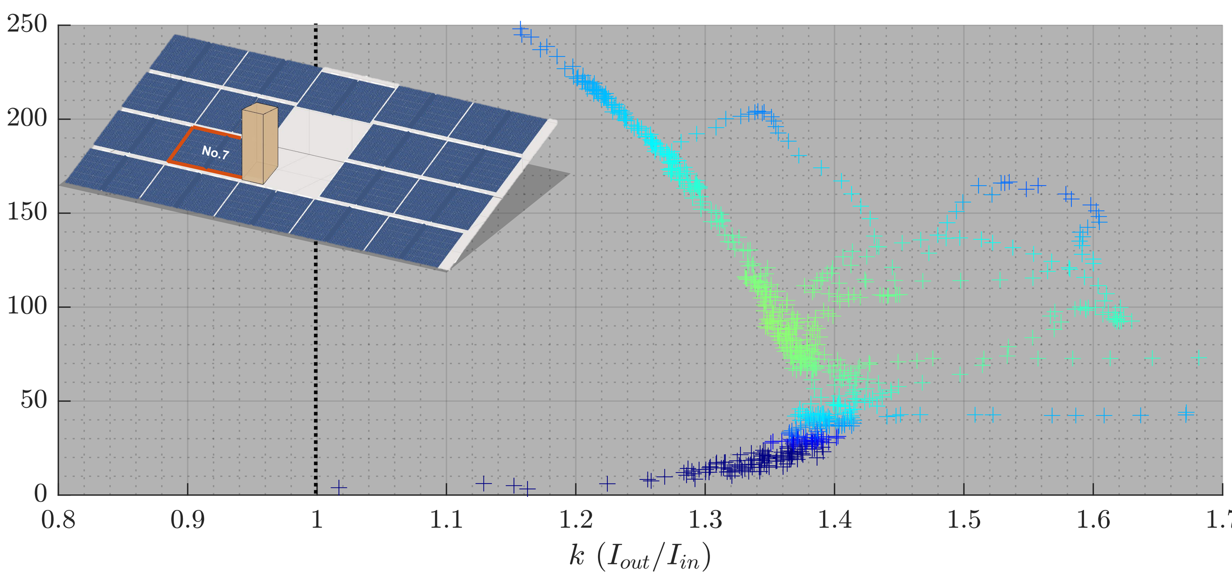

Figure 5 – Simulated DC/DC power optimizer efficiency during a day for the 18-Module PV System (1-Phase) with chimney.

Performance-based recommendations for the usage of PV systems with power optimizers

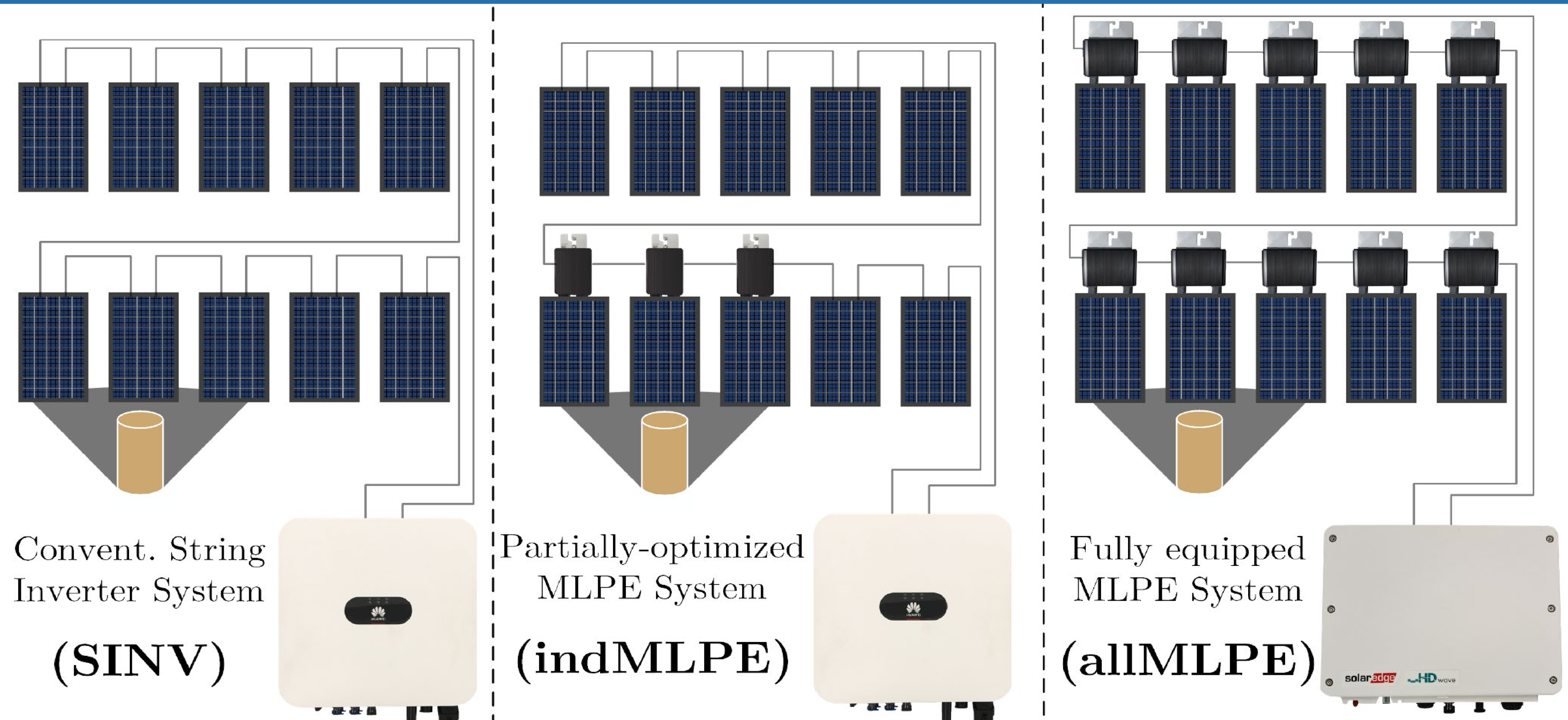

Figure 6 – PV System configurations: conventional String inverter system (SINV) | partially-optimized MLPE System (indMLPE) | fully equipped MLPE System (allMLPE)

- Annual energy yield change with MLPE systems in comparison to SINV systems:
  - No or weak shading: -1.0 to +1.0%
  - Medium shading: +1.0 to +2.0%
  - Heavy shading: +2.0 to +4.2%
- In scenarios with shading, adjust to shorter MPPT multi-peak scanning intervals.
- Time-to-failure is expected to be shorter for PV systems with power optimizer.[3]
- Highest annual yield estimations for PV plants with several orientations:
  - Less than 3 orientations: -> SINV Systems
  - Three or more orientations: -> allMLPE systems
  - (may change in future – Multi MPPT in SINV)[4]

Table 2 – ZHAW MLPE system recommendations

Cases	SINV	indMLPE	allMLPE
No shading	Recommended	•	• •
Weak shading	Recommended	✓	•
Medium shading	•	Recommended	✓
Heavy shading	•	✓	Recommended
Long strings + few orientations	✓✓ (multi MPPT)	•	✓
Short strings + multiple orientations	• • (may change in future)	✓	✓✓

Recommended	->	Performance-wise the best solution	•	->	Low performance
✓✓	->	Highest yield based on estimations	• •	->	Significant loss of performance
✓	->	Valid alternative	(grey)	->	Based on estimations

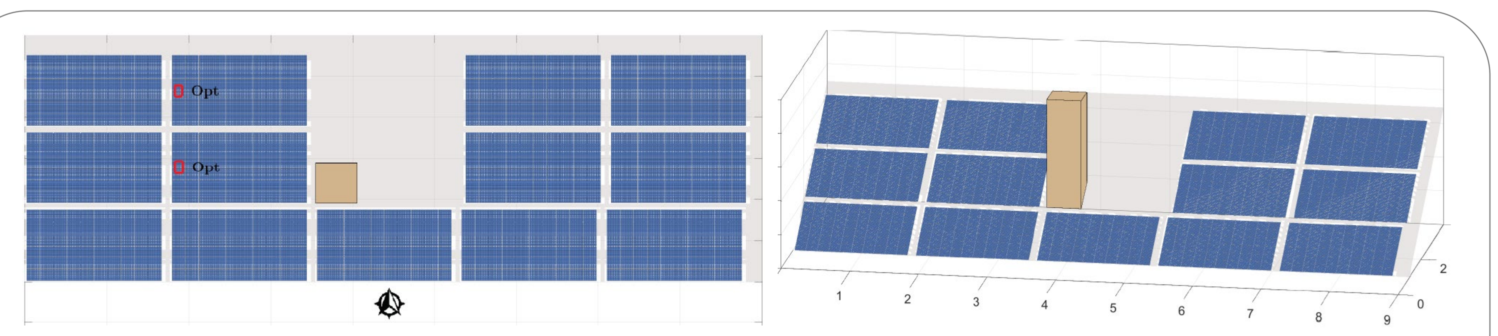

Figure 7 – 13-Module residential PV plant with shading by a chimney, used as **weak-shading** case ($SI_{DC,Max}$=2.8%) for the comparison of the ZHAW PV shading tool with the commercial tools (PVSyst and PVSol).

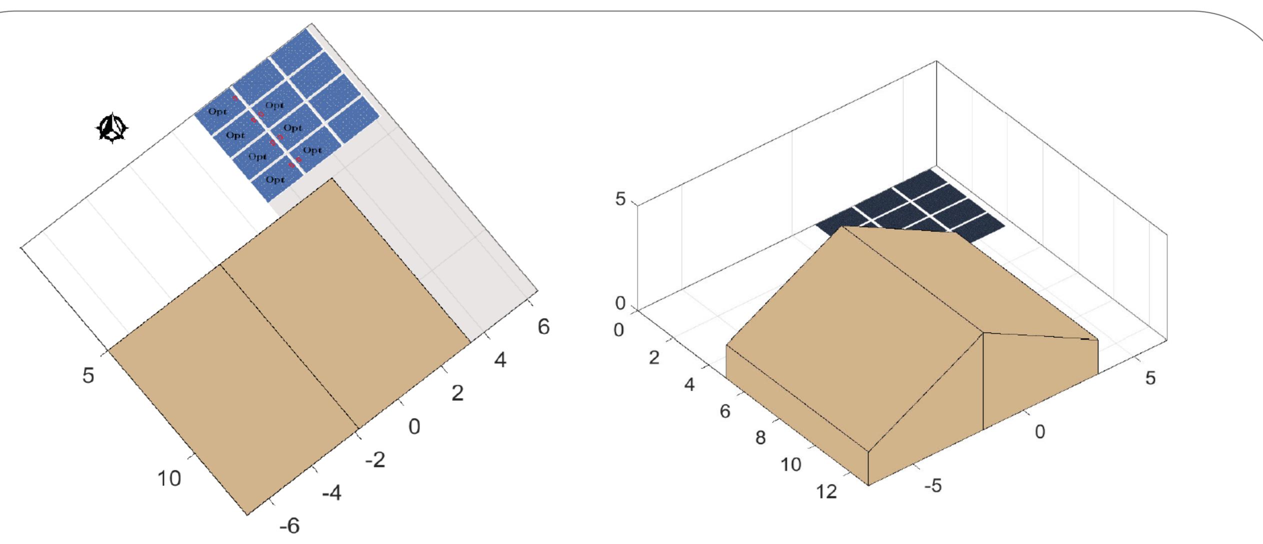

Figure 8 – 12-Module residential PV plant with shading by a neighbouring building, used as **heavy-shading** case ($SI_{DC,Max}$=9.0%) for the comparison of the ZHAW PV shading tool with the commercial tools (PVSyst and PVSol).

International collaboration

To support the development of a technical specification within the IEC TC 82/WG 6,[5] benchmark cases for the shading adaption efficiency (SAE) calculation need to be defined. As a part of the IEA PVPS Task 13 ST2.5, the ZHAW is involved in the identification of characteristic, benchmark shading situations.[6] The MLPE research of the ZHAW is funded by the Swiss Federal Office of Energy, with Project Number: SI/502247-01.[7]

References

[1] C. Allenspach, «Module Level Power Electronics Dynamic and Static Performance in Partial Shaded Photovoltaic Systems» (Master Thesis), ZHAW School of Engineering, Winterthur, Jan. 2023.

[2] C. Allenspach, F. Carigiet, A. Bänziger, A. Schneider and F. Baumgartner, « Power Conditioner Efficiencies and Annual Performance Analyses with Partially Shaded Photovoltaic Generators Using Indoor Measurements and Shading Simulations», Wiley Solar RRL 2200596, [Online] DOI: doi.org/10.1002/solr.202200596 (2022).

[3] C. Bucher et al., «Life Expectancy of PV Inverters and Optimizers in Residential PV Systems», In Proceedings of the 8th World Conference on Photovoltaic Energy Conversion (WCPEC), pages 865 – 873, Milan, Italy, 2022.

[4] Tesla Inc., «Tesla Solar Inverter Architecture White Paper», tesla-cdn.thron.com, [Online: accessed 22.02.2023].

[5] International Electrotechnical Commission (IEC), «Technical Committee 82: Solar Photovoltaic Energy Systems - Working Group 6: Balance-of-System Components».

[6] International Energy Agency, «PVPS Task 13 Subtask 2: Performance of Photovoltaic Systems», 2022 - 2025.

[7] Swiss Federal Office of Energy (BFE), «Project EFFPVShade - Project Number: SI/502247-01», 2021 - 2023.

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