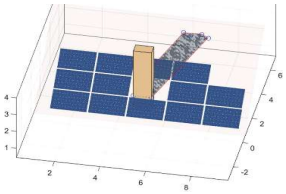

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Wirkungsgrad von Optimizer versus Stringinverter

PV Update 2021, 25th November 2021, Solothurn, Swissolar

Franz Baumgartner, ZHAW IEFE (Photovoltaic Systems), Switzerland

as a part of IEA PVPS Task 13, ST1.3

PV output estimation with partial shading

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- Shading by obstacles in Switzerland
- Estimation by simulation with 3D PV-modell

Figure 1 – SFH 13kWp by PV installer, «Alsona AG» - Webpage: https://www.alsona.ch/

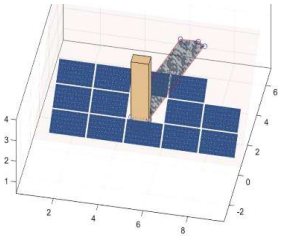

Figure 2 – ZHAW SOE ShadingTool

Figure 3 – Various rooftops in Zurich City, by Juliet Haller (AfS), Office for Urban Development – City of Zurich, «Leitfaden Dachlandschaften»

Figure 4 – Rooftops in Yverdon-les-bains, © Swiss-Fly Boris Bron, Source: www.swiss-fly.ch & www.j3l.ch

Public MLPE performance information and example

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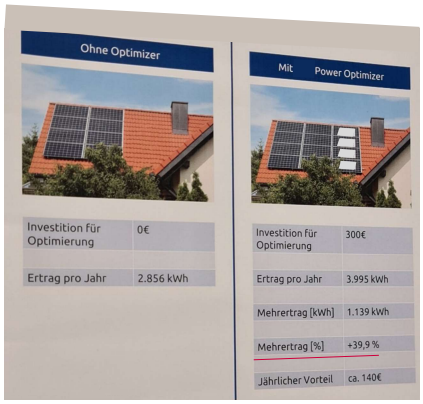
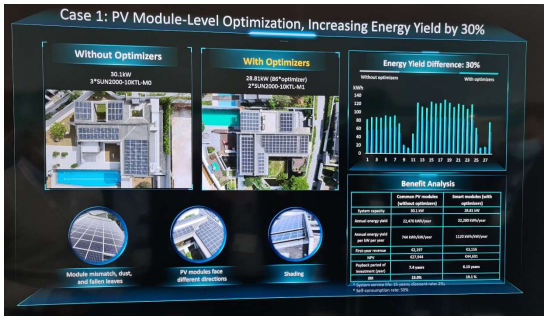
- Information provided at Intersolar 2021, Munich
- No standard for showing performance





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MLPE Principle – System Layout

Each PV Module has the capability to find the MPP

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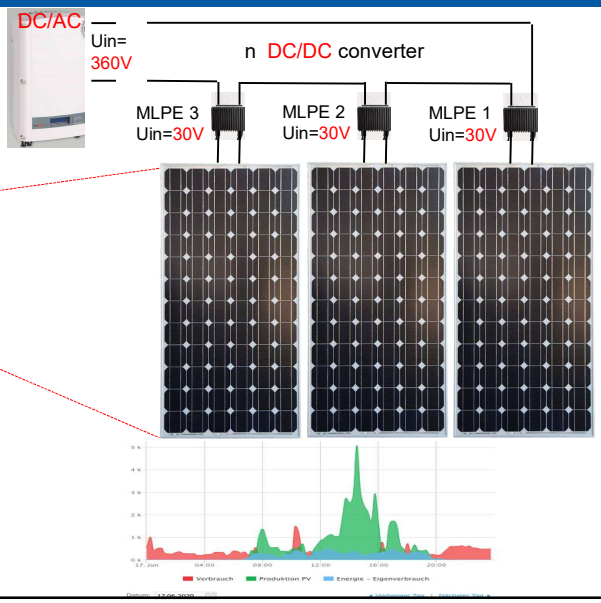

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Performance of two different setups

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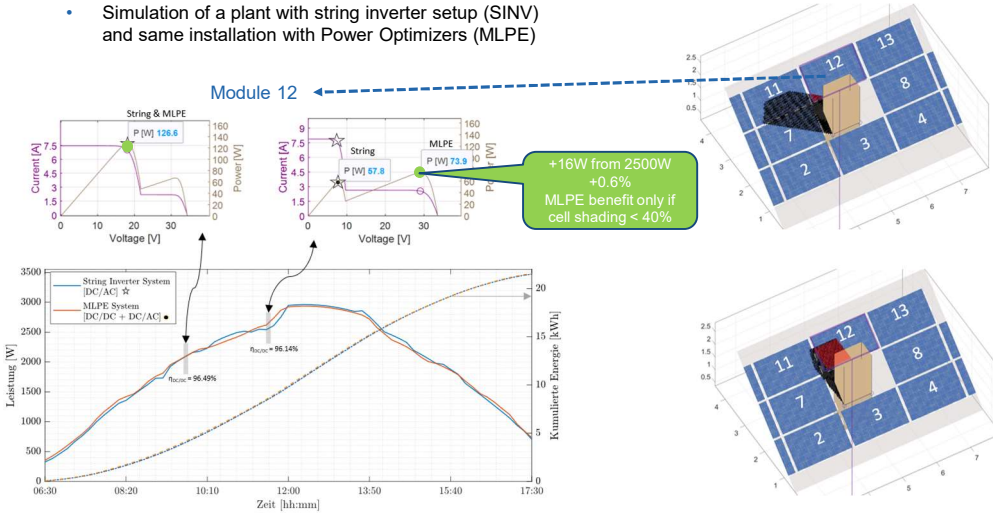
- Simulation of a plant with string inverter setup (SINV) and same installation with Power Optimizers (MLPE)



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Shading simulation overview

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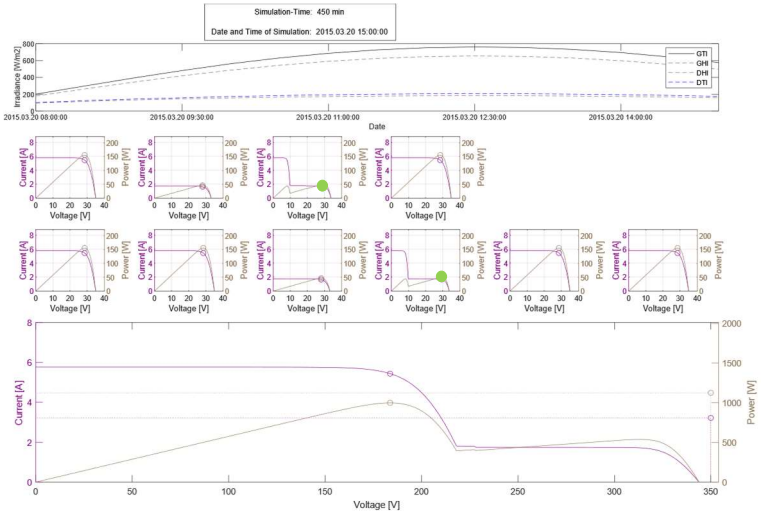

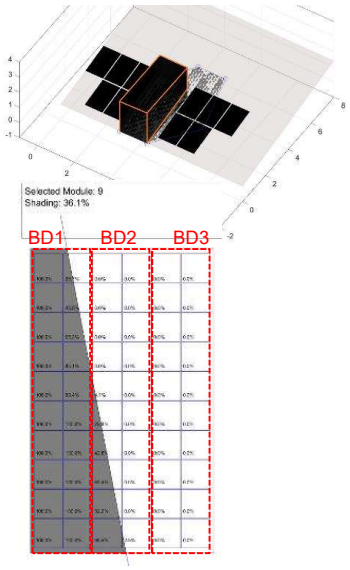

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Measurement in ZHAW indoor laboratory

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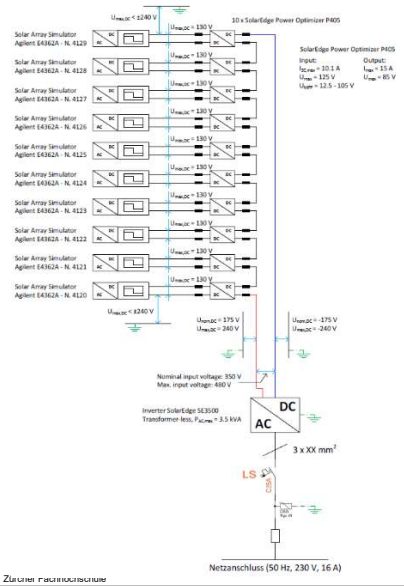

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Efficiency of MLPE in datasheets

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www.solaredge.com

P320 / P340 / P370 / P400 / P401 / P405 / P485 / P

Optimizer model (typical module compatibility)	P320 (for 60-cell modules)	P340 (for high-power 60-cell modules)	P370 (for higher-power 60 and 72-cell modules)	P400 (for 72 & 96-cell modules)	P401 (for high power 60 and 72 cell modules)
INPUT					
Rated Input DC Power[1]	320	340	370	400	
Absolute Maximum Input Voltage (Voc at lowest temperature)	48		60	80	60
MPPT Operating Range	8 -			8 - 80	8-60
Maximum Short Circuit Current (Isc)				10.1	11.75
Maximum Efficiency				99.5	
Weighted Efficiency				98.8	

max eff 99.5%

weight. eff 98.8%

solar.huawei.com

Technical Specification	SUN2000-450W-P
	Input
Rated Input DC Power [1]	450 W
Absolute maximum input voltage	80 V
MPPT operating voltage range	8 - 80 V
Maximum Short Circuit Current (Isc)	13 A
Max. efficiency	99.5 %
Weighted efficiency	99.0 %
Overvoltage category	II

TS4-A-O www.tigoenergy.com

PV Module Advanced Add-On/Retrofit

The TS4-A-O (Optimization) is the advanced add-on/retrofit optimization solution that brings smart module functionality to standard PV modules for higher reliability. Improve energy efficiency by upgrading underperforming PV systems or adding smart features to new installations.

Included Features

Module-level **optimization** for increased energy yield and greater design flexibility

No efficiency data given by the manufacturer

Table 1 Overview of Power Optimizers and Micro Inverter products: Overview of performance related information provided by the manufacturers in the datasheets (non exhaustive list).

Product Category*	Manufacturer and Model	Performance figures according to datasheet		Datasheet information acc. to EN 50524
		Conversion efficiency	MPPT efficiency	
Products available on the market today				
DC.UP.S	Solar Edge PB250-AOB [9]	Maximum 98.6 % European/CEC 97.8/97.7%	No information	No
DC.DN.S	TIGO Energy MM-ES [10]	No information	No information	No
DC.UP.S	ST Microelectronics SPV1020 [11]	"Up to 98% efficiency"	No information	N/A (only chipset, no final product)

R. Bründlinger, N. Henze, et. al.; Module Integrated Power Converters, 25th EUPVSEC Valencia, 2011

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Performance 1a: Euro-Efficiency of Optimizers

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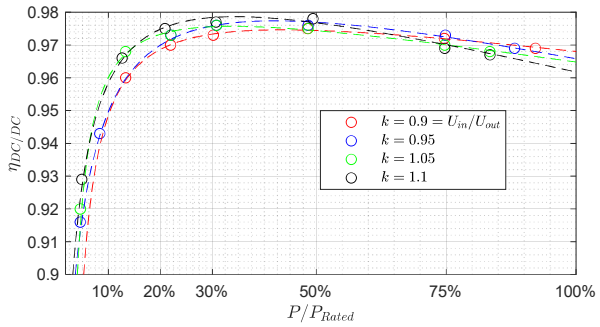
	0.9	0.95	1.05	1.1
EURO Eff.	96.9%	97.0%	97.0%	97.1%

DC/DC-Efficiency of P405



Euro efficiency according to inverter standard IEC 61683 and DIN EN50530.

In unshaded cases:
(without mismatch & soiling)

Module
100%
Optimizer (DC/DC)
96.5% ~ 97.5%
Inverter (DC/AC)
[98% – 99%]
95.0% ~ 96.5%

Modules
100%
String-Inverter
[97% – 98%]
97% ~ 98%

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Performance 1b: Static efficiency

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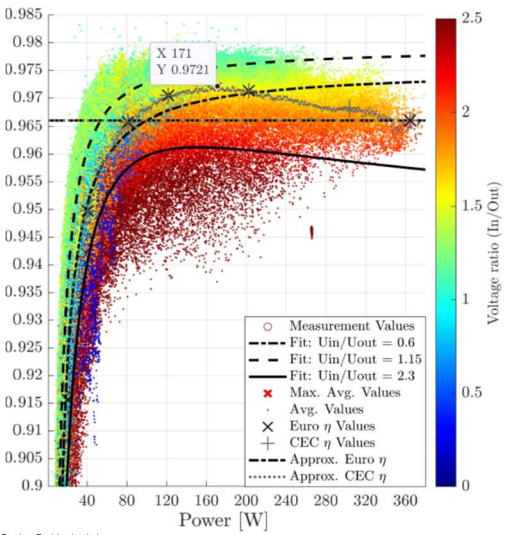

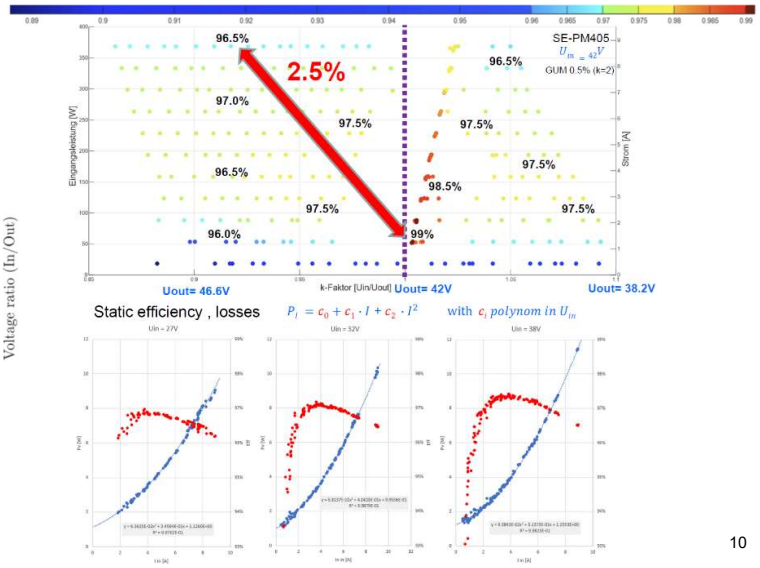

Static efficiency , losses $P_l = c_0 + c_1 \cdot I + c_2 \cdot I^2$ with c_i polynom in U_{in}

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Performance 2: Shading adaption Efficiency

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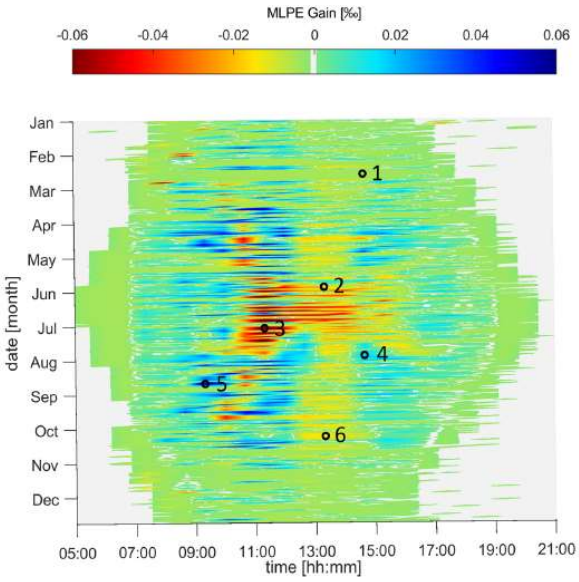
Shading adaption efficiency based on yearly performance, representative operating points and coefficients

$$\eta_{shad,a} = \frac{P_{ac}}{\sum_{i=0}^{k} P_{mod,i}} \quad (2)$$

$$\eta_{shad,a} = \sum_{n=1}^{N} a_{shad,a,n} \cdot \eta_{shad,a,n} \quad (3)$$

Shading Adaption Eff. Coefficients $a_{shad,a,n}$



Conclusion & Take-home messages

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Efficiency and performance:

- So far, in unshaded cases, laboratory measurements have shown no improved yield of MLPE system due to additional losses
- Indoor lab measurements showed MLPE efficiency values 2% lower at nominal power than data sheet max efficiency
- Efficiency in many (relevant) operating points is between 96%-98%, but higher efficiency of DC/AC stage (inverter without MPPT) helps to keep the additional losses low
- MPP-Tracking at module-level of the MLPE system often still improves yearly output of partial shaded systems
- 1.2% gain in annual efficiency was calculated using MLPE I component (P405) relative to String Inverter, SINV II (Fronius Symo), with an EURO EFF of 97.5%

Shading cases of PV Systems	Shading objects a	I MLPE	II SINV
Single roof tilted - chimney	1	96.6%	95.8%
Single roof tilted - dormer	2	x	x
Single roof tilted - tree	3	x	x
Flat roof - ventilation pipe	4	x	x

Yield and economics

- Price of MLPE system is often higher, and if single digit improvements of yearly energy yield can offer higher earnings over life-time, must be evaluated on a case-by-case basis.
- In reality, safety concerns such as high dc-voltage at module-level for installation personell or firefighters can be tackled with rapid-shutdown of MLPE devices (e.g. 1V at output)
- Monitoring at module level is a practical for O&M, however, more components («moving parts») in a system will increase chance of failure

Research and standards:

- Transparent information (e.g. efficiencies) is needed, so that the installer can expect similar performance in the field
- Standard must be developed to measure MLPE and SINV for the shading adaption efficiency (IEC TC82 is interested), collaboration within Task 13 will be started
- With these future informations, installers should know what approximate performance to expect and can focus on other requirements and planning aspects

Sources & more information

Work initiated and supervised by Franz Baumgartner and realised with the support of Fabian Carigiet, Roman Vogt, Samuel Richter, Victor Gonzalez de Echavarri Castro and Christoph Meier.

Main sources:

- C. Allenspach, D. Riley; Performance Assessment of MLPE Equipped PV modules and Performance rating of shaded PV systems; Intersolar 2021, 06.10.2021, Munich; Online: https://iea-pvps.org/wp-content/uploads/2021/10/03_ALLENSPACHRILEY_MLPE-AC-Modules.pdf.
- F. Baumgartner, C. Allenspach, et al.; Performance Analysis of shaded PV Module Power Electronic Systems (2021), IEA Task 13 (ST 1.3), Online: Video-MLPE-Presentation-21 (English), EUPVSEC 2021.
- F. Baumgartner, Optimizer: Nur ein Hype oder die Zukunft (German), Electrosuisse Bulletin, May 2021.
- C. Allenspach, F. Baumgartner, et al.; Module-Level Power Electronics under Indoor Performance Tests (2020), IEA Task 13 (ST 1.3), Online: , EUPVSEC 2020.

Additional information:

- Links to papers, presentations and videos of our work: www.zhaw.ch/=bauf
- Video-Channel for presentations by Franz Baumgartner: www.youtube.com/channel/bauf

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Thank you for your attention

and the ZHAW SoE Team
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