Energy Rating and Module Performance Modeling Workshop
30-31 March 2017, Lugano, Switzerland

Energy yield measurements of MLPE components and comparison with simulation results

D. Stellbogen, P. Lechner

Zentrum für Sonnenenergie- und Wasserstoff-Forschung
Baden-Württemberg (ZSW)
Stuttgart, Germany

Content

- Module level power electronics: performance rating issues
- MPLE systems in test
- Laboratory characterisation
- Field assessments in unshaded and shaded conditions
- Simulation trials
- Conclusions

Module Level Power Electronics (MLPE)

- Power conversion devices for individual modules
  - DC/AC inverters
  - DC/DC optimizers with/without system specific inverter
- "Smart Modules" with individual power conversion devices
  - attached to the back surface or frame
  - integrated into or substituting the connection box
  - integrated into the frame
  - laminated into the module compound?
  - inverters, module optimizers, cell string optimizers

Performance rating of Smart Modules

- Combination of
  - PV module characteristics: efficiency at STC, light level dependence, temperature coefficients
  - power electronics qualities: power extraction & power conversion efficiencies, dynamic tracking
- No general Power Rating procedure
  - Separate rating if cell string terminals are accessible
  - Flash sun simulator measurements if electronics is slow
  - Steady-state simulator measurements feasible, ignore dynamic performance
- Energy Performance Rating from steady state simulator or outdoor measurements

Yield assessment and prediction of Smart Modules / MLPE in PV Systems

- proper potential of energy gain in configurations with inhomogeneous operating conditions, e.g.
  - varying orientation
  - near neighbour shading
  - inter-row shading
  - soiling
  - bifacial modules
- Performance of the whole system / ensemble of devices
- Yield estimations to be based on field experience and modelling

⇒ requires
  - field experiments,
  - simulations and verification

Solab
ZSW Photovoltaik-Testlabor

MLPE types in the study

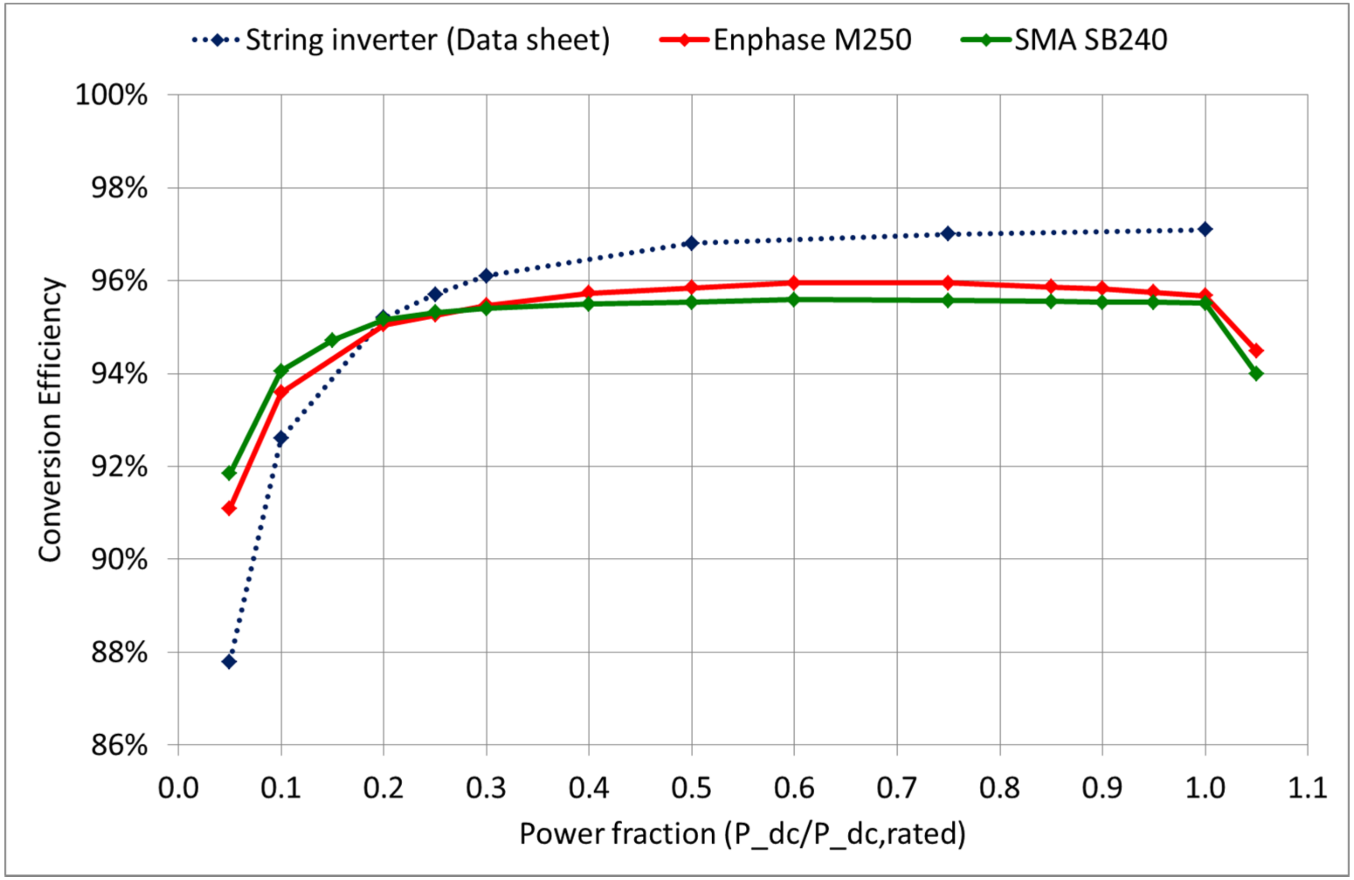


model	**Enphase M250**	**SMA SB240**	**SolarEdge P300**
type	inverter	inverter	power optimizer
power rating	250W AC	230W AC	300W DC
input range	23V – 39V	27V – 39V	9V – 48V
η EUR	95.7%	95.3%	n/a

Reference: String inverter SMA SB3000TL-21 with global MPP tracking option

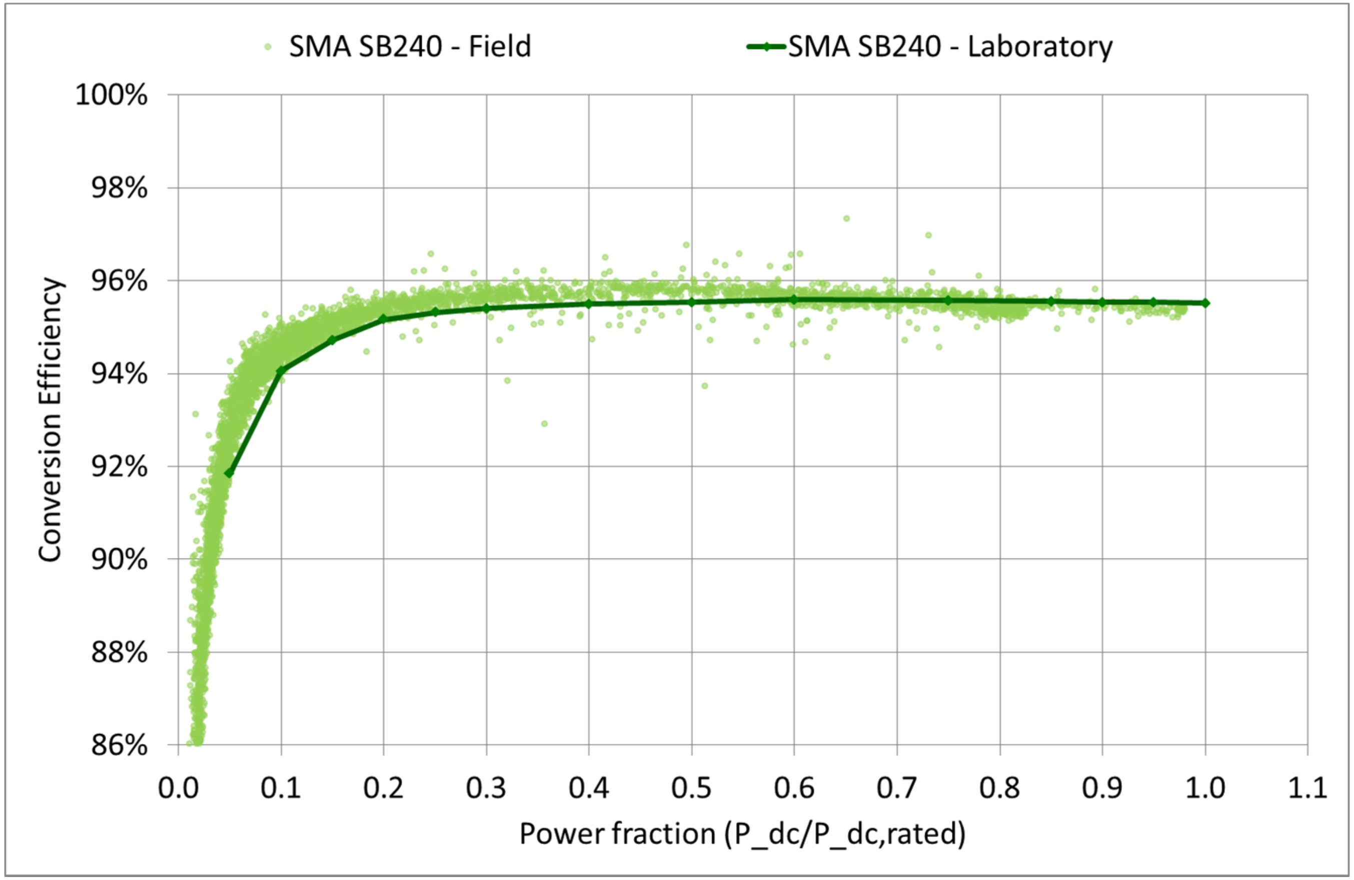
Solab ZSW Photovoltaik-Testlabor

Static DC/AC conversion efficiencies of module inverters vs. reference string inverter



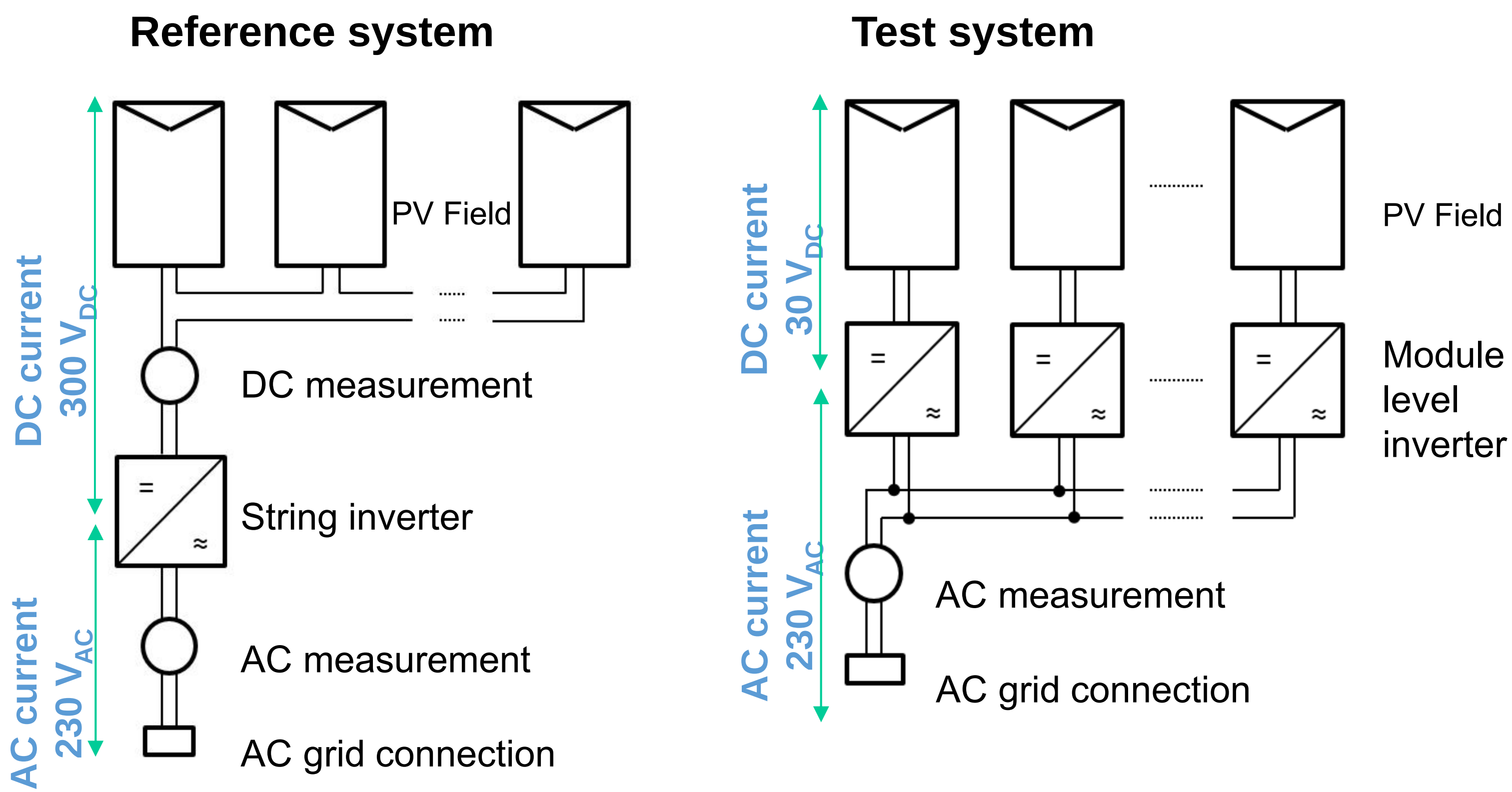
- module inverters outperform string inverter at low power
- Enphase M250 slightly better at medium to high power levels

Laboratory and field measurements of DC/AC conversion efficiency for SMA SB420



- good agreement
- field measured efficiency is even slightly higher at low power

Field assessment of MLPE systems in unshaded and shaded conditions



- side-by-side evaluation of MLPE and reference string inverter
- 2 strings of 10 c-Si modules (60 cells, 245Wp)
- swapping of system connection to eliminate potential biases

Field evaluation set-up
at ZSW test site Widderstall

- ‘pole‘ shading and ’gable wall’ shading configuration

Solab
ZSW Photovoltaik-Testlabor
ZSW

Yield comparison: MLPE / String Inverter

Results of the field experiments

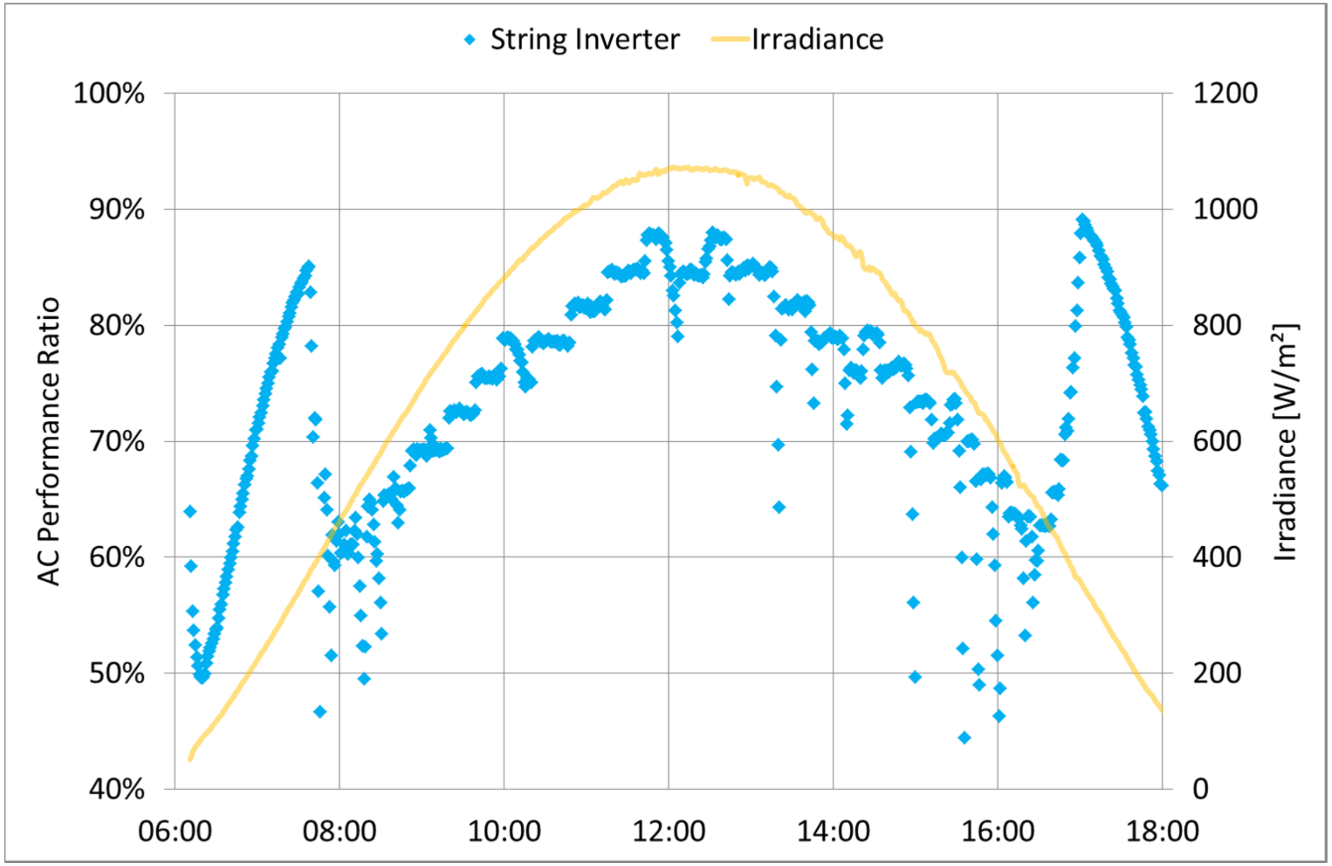
Test configuration	Number of testing days	Surplus		
		Enphase M250	SMA SB240	SolarEdge P300
unshaded	14	0.9%	0.6%	-
‘pole’ shading	12 – 27	3.5%	6.0%	4.7%
‘gable wall’ shading	9 - 14	16.2%	13.4%	-

→ dependence on respective testing period and weather (irradiance)

→ not easily to be generalised

Solab
ZSW Photovoltaik-Testlabor

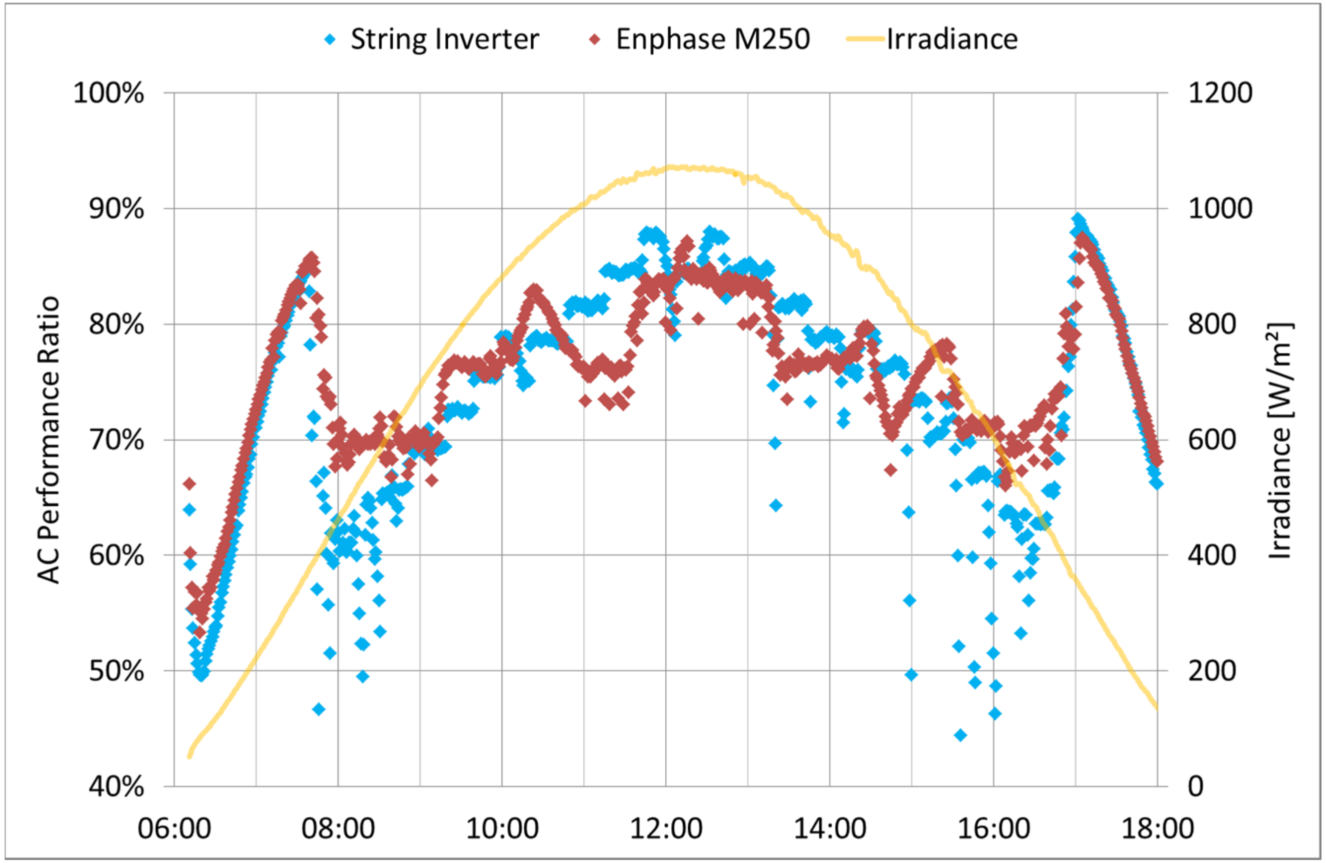
Operating behavior of string inverter
in 'pole' shading condition



- performance steps according to module substrings affected by the shadow

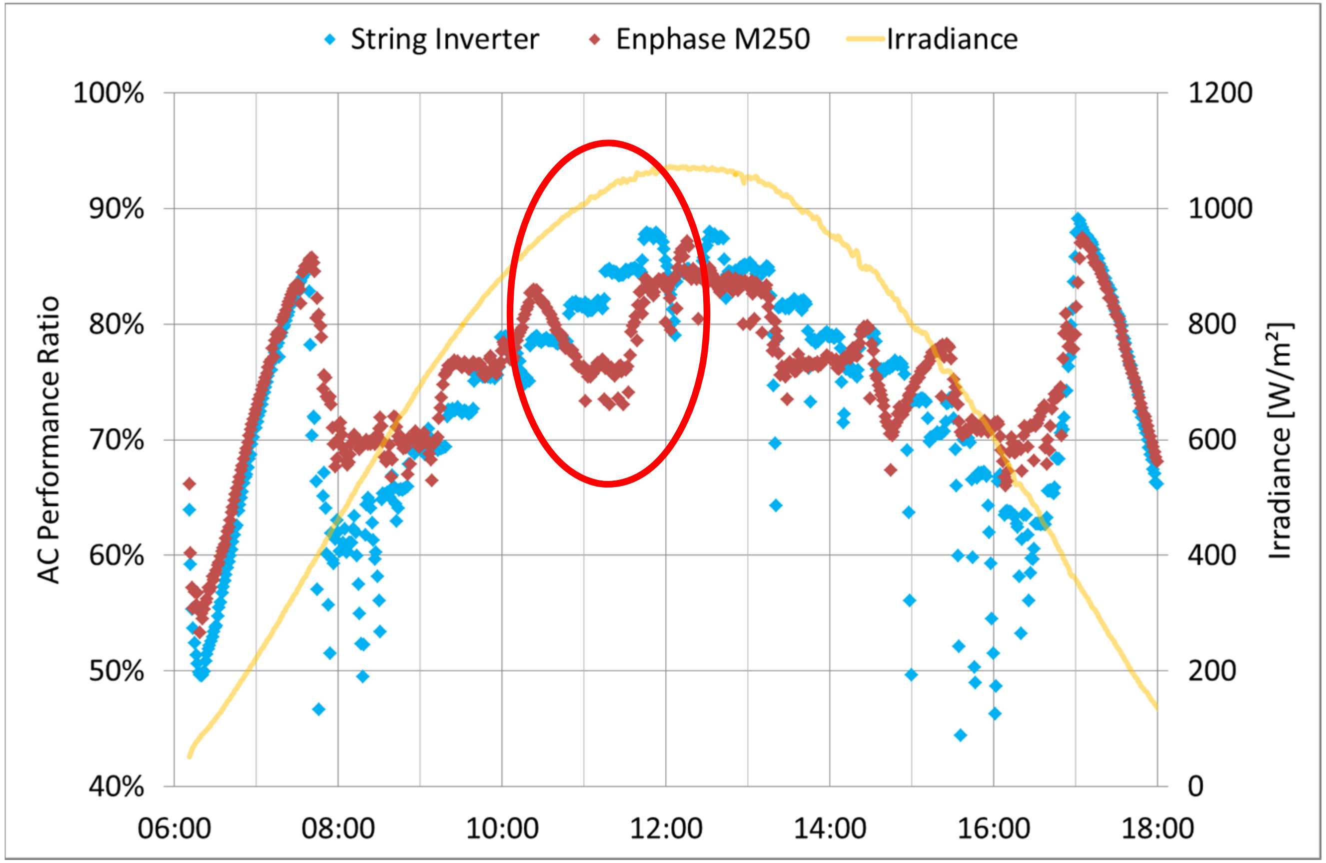
Solab
ZSW Photovoltaik-Testlabor
ZSW

Operating behavior of string and module level inverter
in ‘pole’ shading condition



- module inverters have lower yield in specific situations
- limitations are due to the MPPT voltage threshold

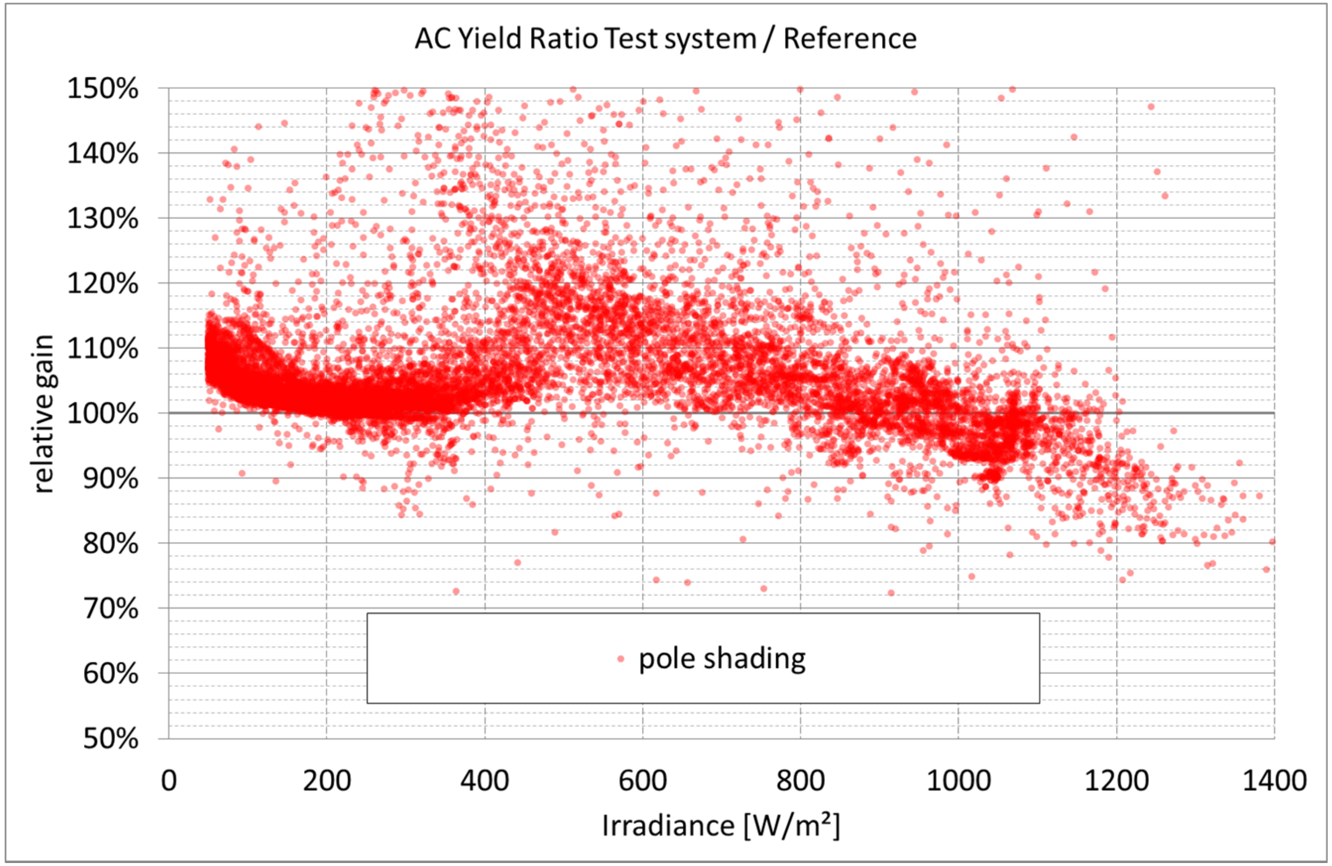
Operating behavior of string and module level inverter
in ‘pole’ shading condition



- module inverters have lower yield in specific situations
- limitations are due to the MPPT voltage threshold

Solab
ZSW Photovoltaik-Testlabor
ZSW

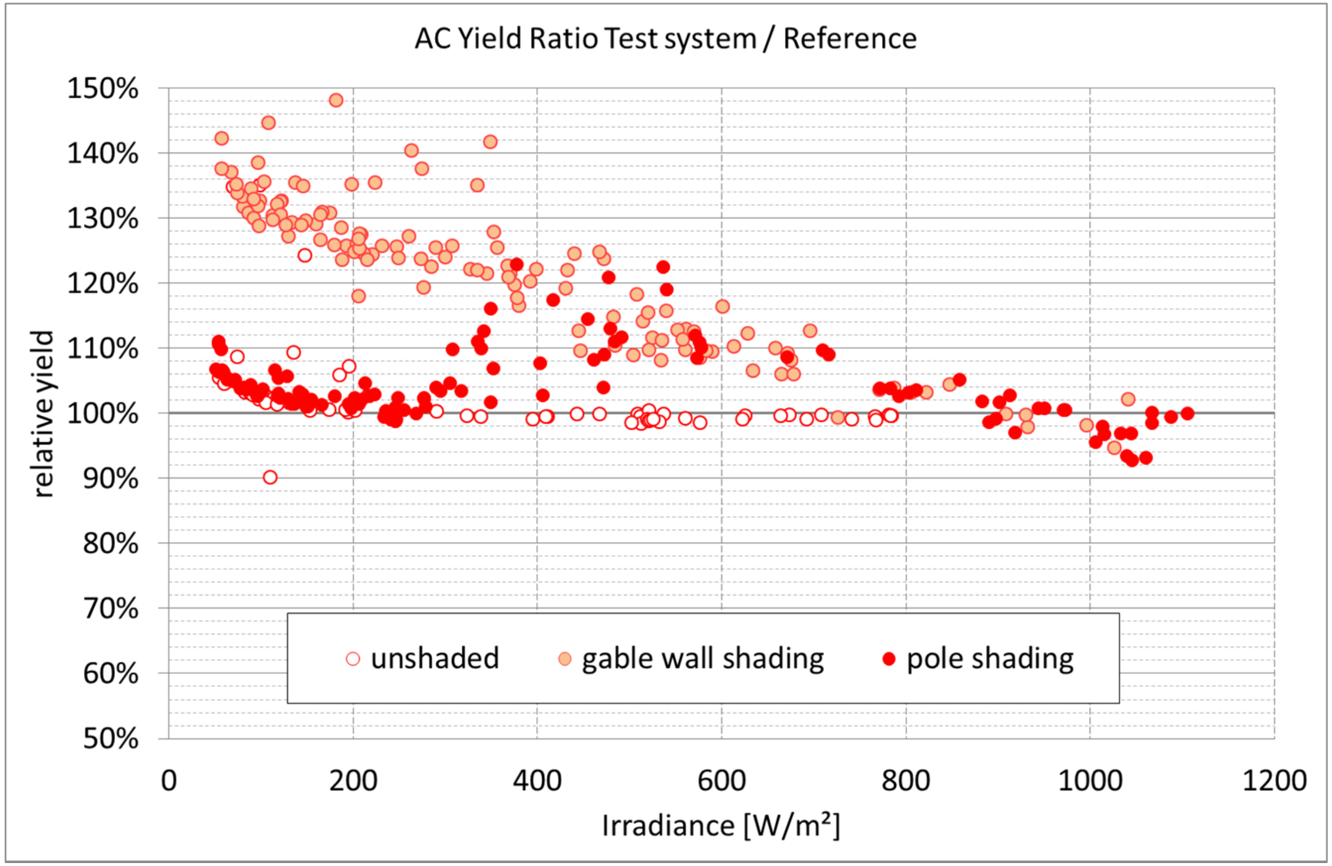
Yield Ratio: Module Inverter Enphase M250 / String-Inv.
‘pole’ shading configuration, 1-minute-values



- large variation of relative yield from many different operating conditions

Yield Ratio: Module Inverter Enphase M250 / String-Inv.

‘pole’ and ‘gable wall’ shading, hourly means

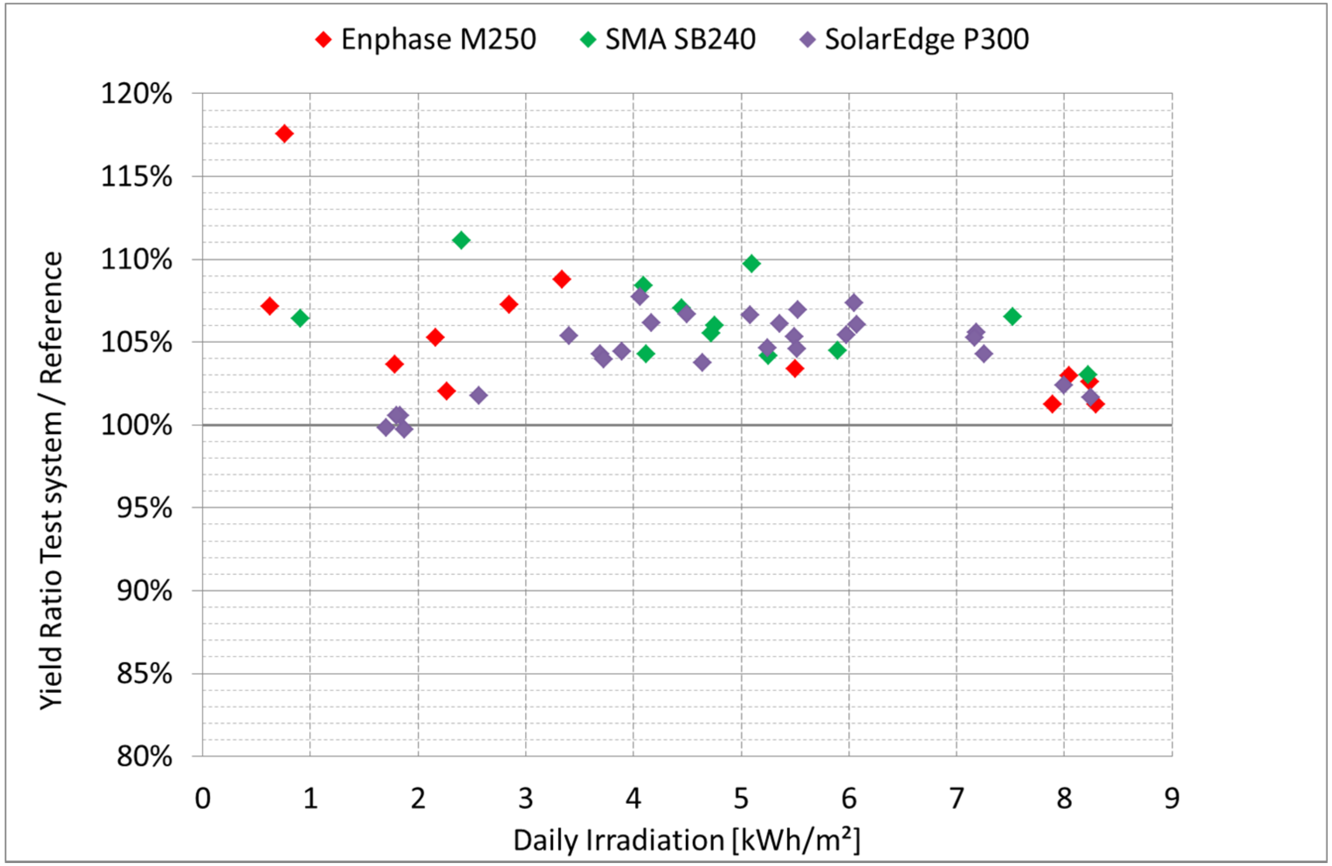


- gain depends on the mean irradiance
- higher efficiency of module inverters at low power is effective

Solab
ZSW Photovoltaik-Testlabor
ZSW

Yield Ratio: MPLE / String Inverter

‘pole’ shading configuration, mean daily values



- large variation of MPLE gain vs. string inverter
- 0 - 10% surplus on daily basis

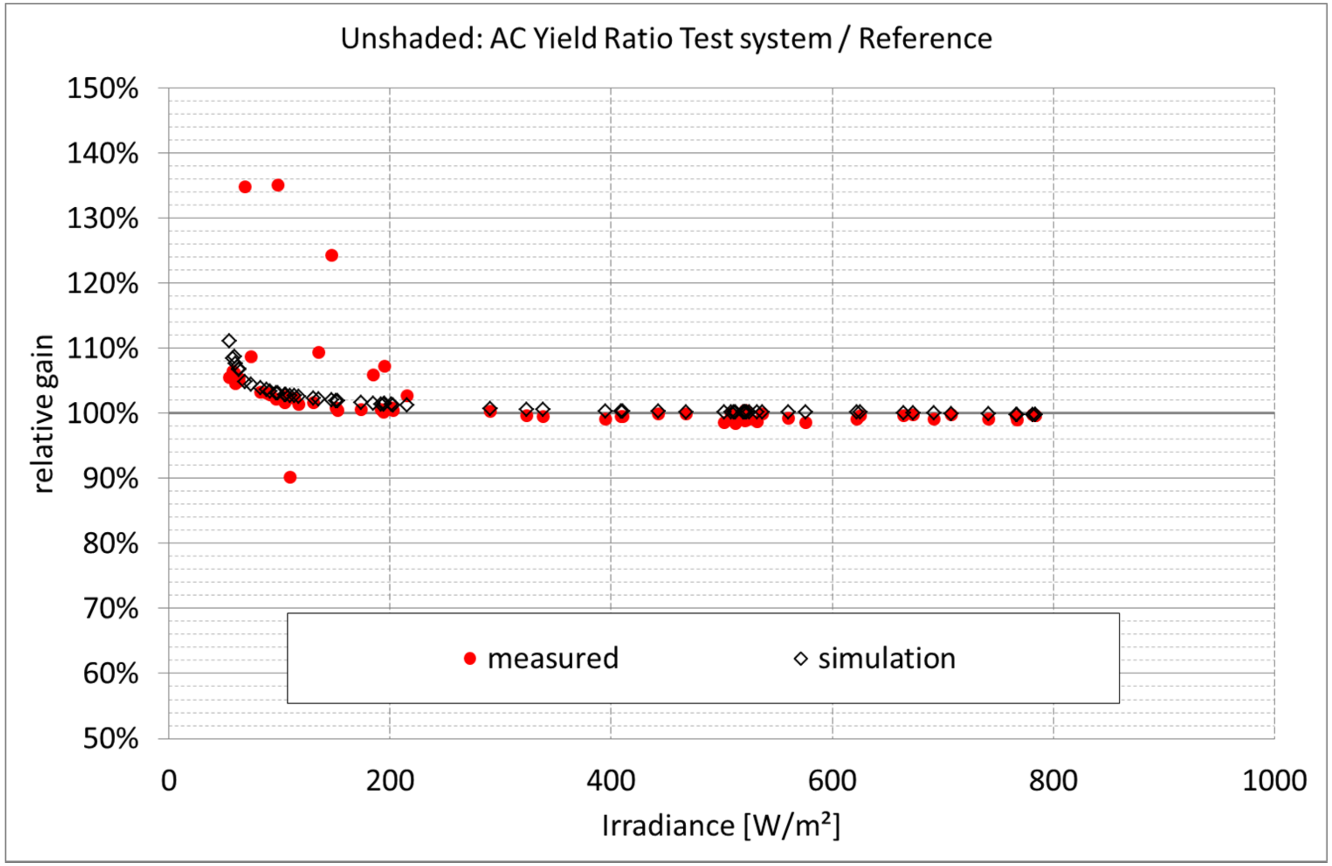
Solab
ZSW Photovoltaik-Testlabor
ZSW

Comparative simulation calculations

- Assessment of representation quality in simulation model
- PVsyst (Version 6)
  - Computation of 3D shading scenarios
  - Modelling of module inverters and module optimizers

  - Parameters have been adjusted to laboratory results
  - Irradiance and ambient temperature measured in field experiment as input data (hourly means)

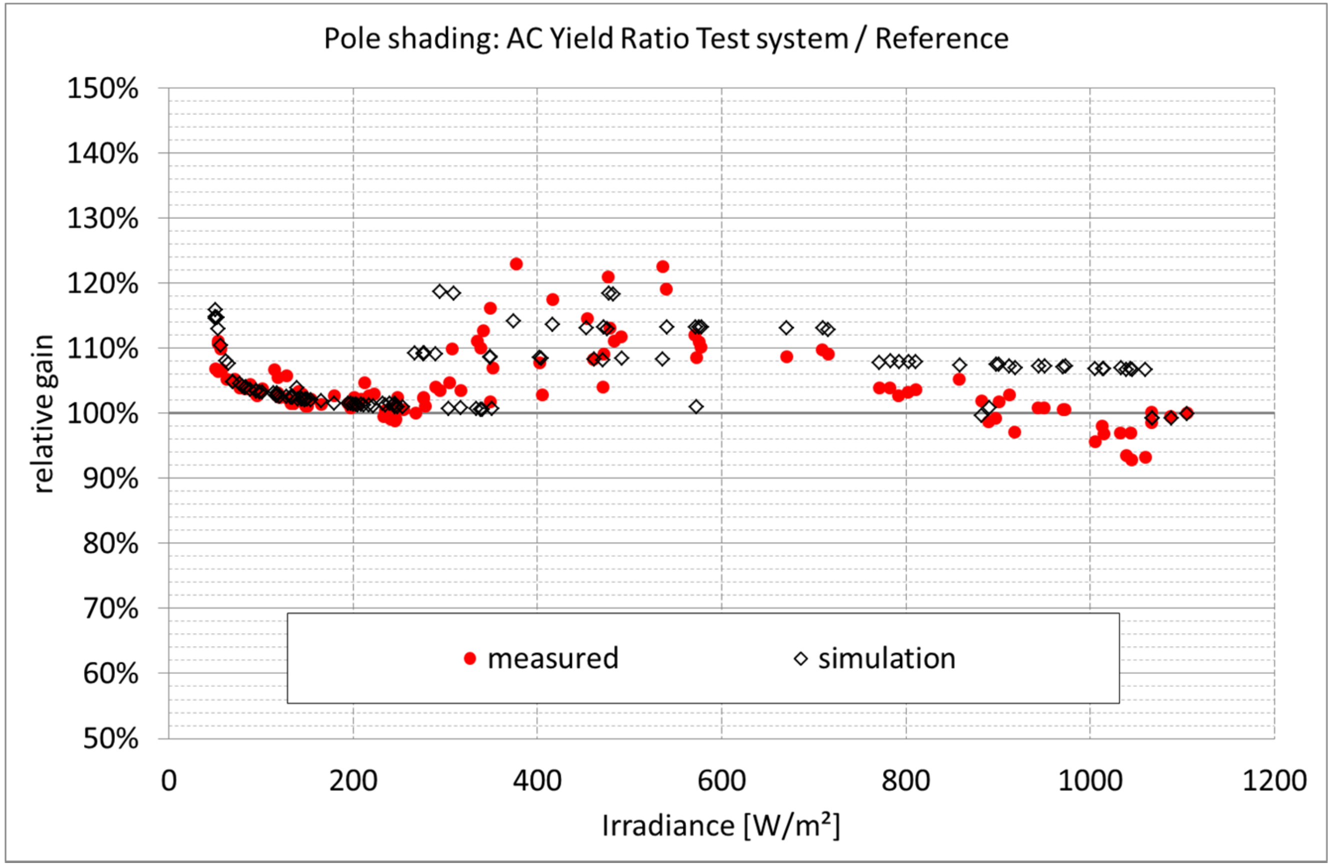
Comparison of Field experiment and Simulation
unshaded, Enphase M250 / String Inverter



- good agreement for unshaded condition
- advantage at low power is computed appropriately

Solab
ZSW Photovoltaik-Testlabor
ZSW

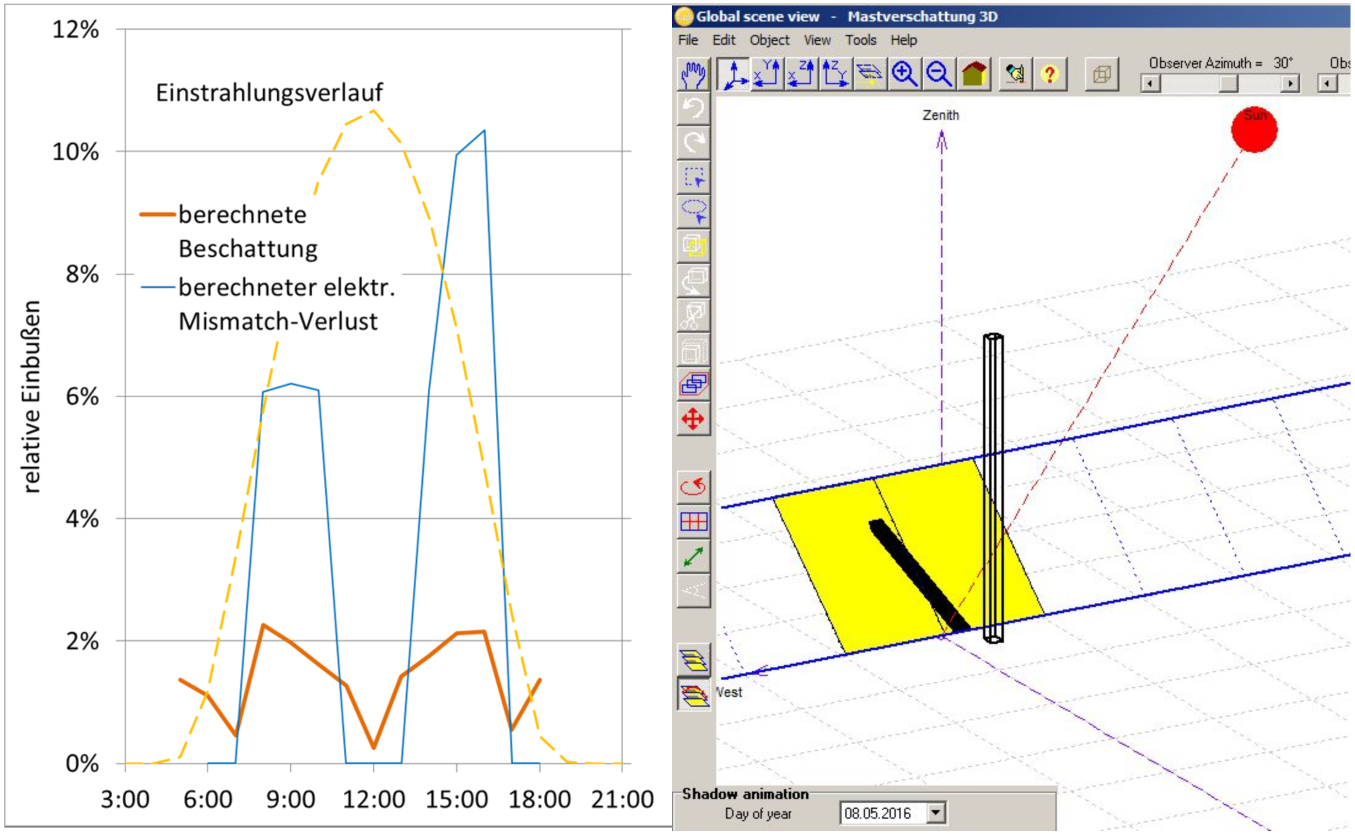
Comparison of Field experiment and Simulation
'pole' shading, Enphase M250 / String Inverter



- large scatter at medium irradiance levels
- strong overestimation at high irradiances

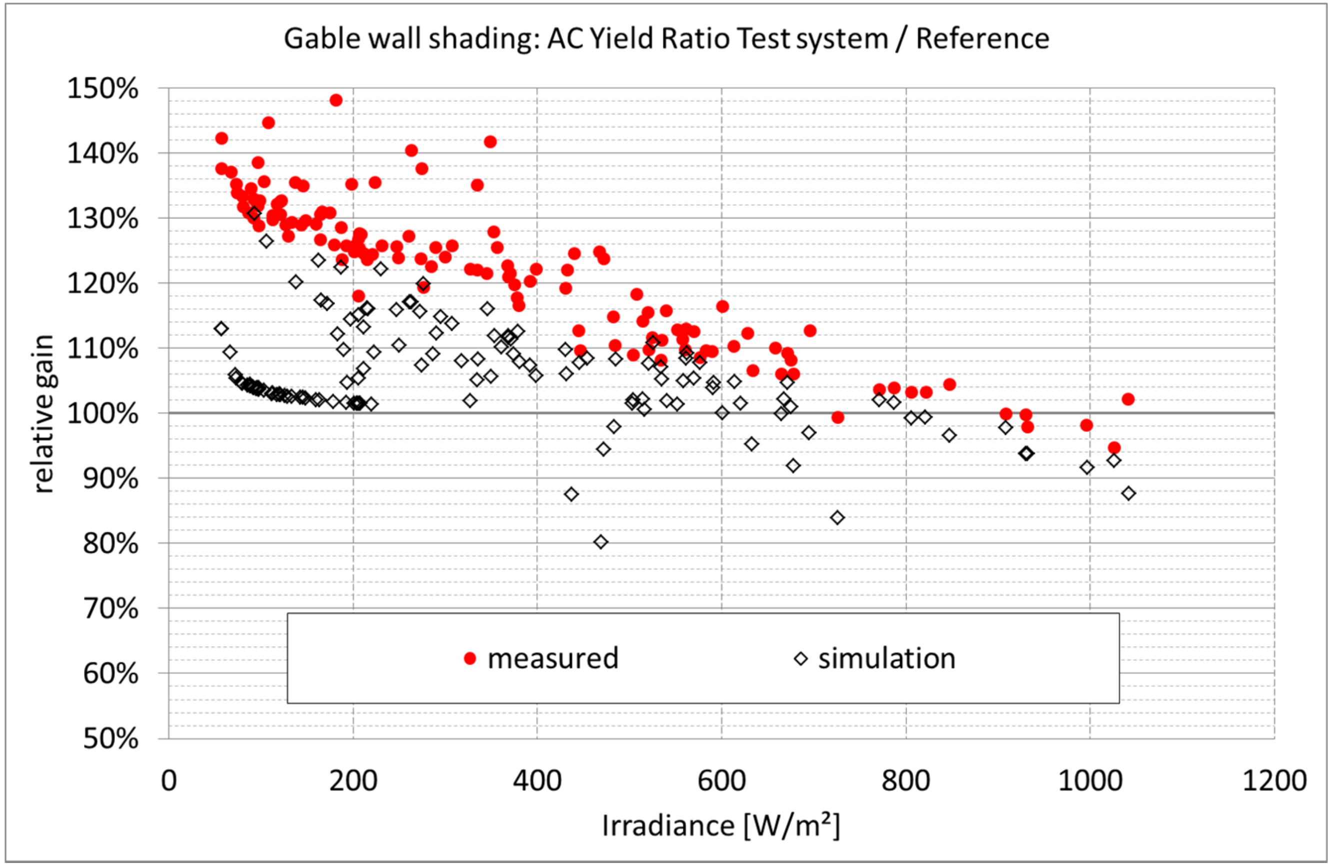
Issue in PVsyst modelling

case 'pole' shading



- computed shading effect drops strongly around noon although shadow is continuously present

Comparison of Field experiment and Simulation
‘gable wall’ shading, Enphase M250 / String Inverter



- simulation underestimates surplus considerably

Summary

- Module level inverters are comparable to reference string inverters in terms of power conversion efficiency
- Almost equal yields in unshaded configuration
- ‘Pole’ and ‘gable wall’ shading scenarios:
  - Surplus of MLPE mainly at medium irradiance levels with oblique sun angle / long shadows
  - small gains at high irradiances / directly cast shadows
- Considerable deviations of PVsyst simulation calculations from field results
- Improvements required for proper utilization for PV system yield estimates

Solab ZSW Photovoltaik-Testlabor ZSW

// Energy with a future

// Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW)

Thank you for your attention!

Stuttgart:
Photovoltaics Division (with Solab), Energy Policy and Energy Carriers, Central Division Finance, Human Resources and Legal

Solar Test Facility
Widderstall

Ulm:
Electrochemical Energy Technologies Division with eLaB

Solab
ZSW Photovoltaik-Testlabor
ZSW