Systematic Approaches to Ensure Correct Representation of Measured Multi-Irradiance Module Performance in PV System Energy Production Forecasting Software Programs

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Outline

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  - Multi-irradiance behavior of PV modules
  - Self-reference method
- Multi-irradiance behavior in **PV*SOL®** and **PVsyst**
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- Systematic approaches for fitting PV module models
  - PV*SOL®
  - PVsyst
- Impact on energy forecasts
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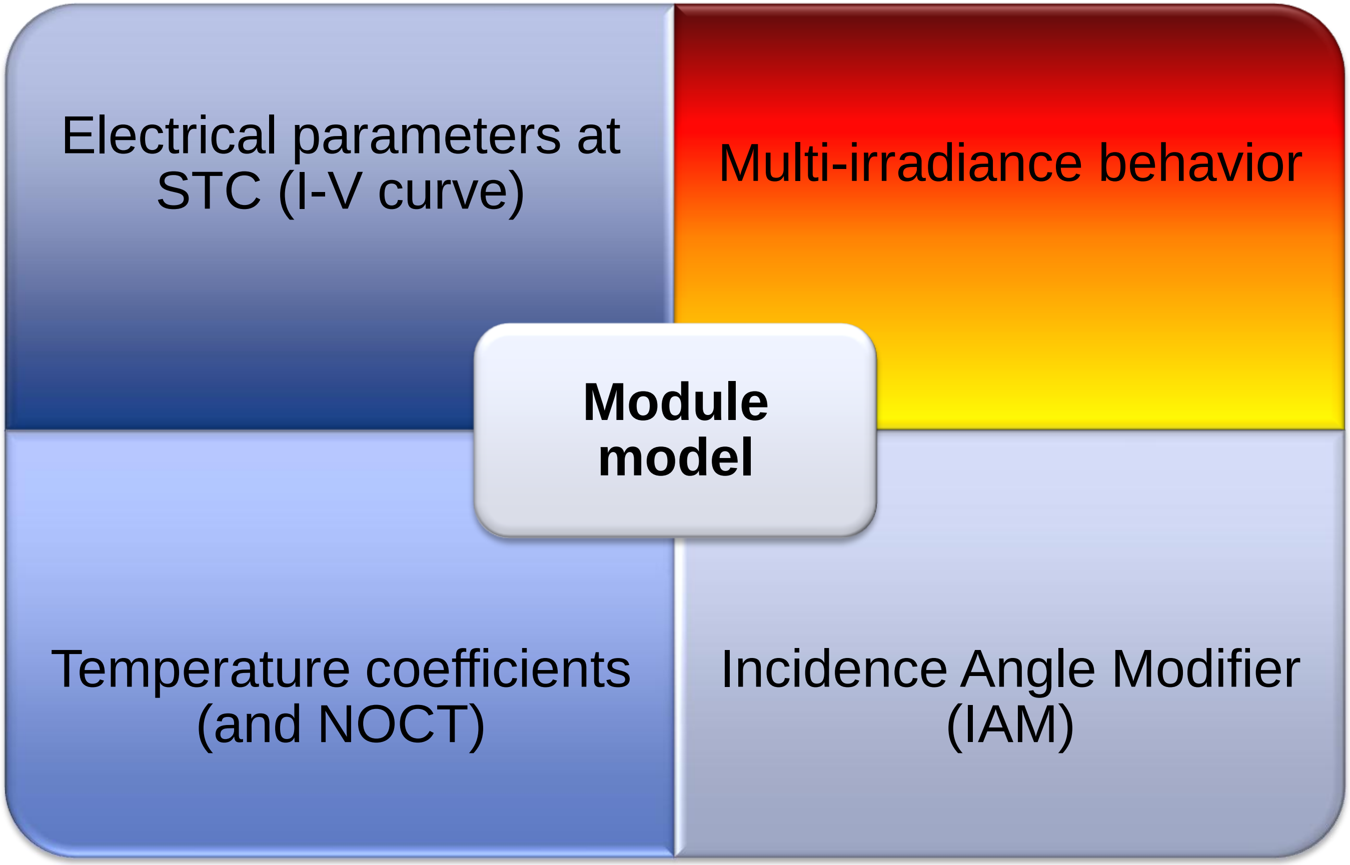
Basics: Main components of PV module models



Provision via data sheet | Additional characterization

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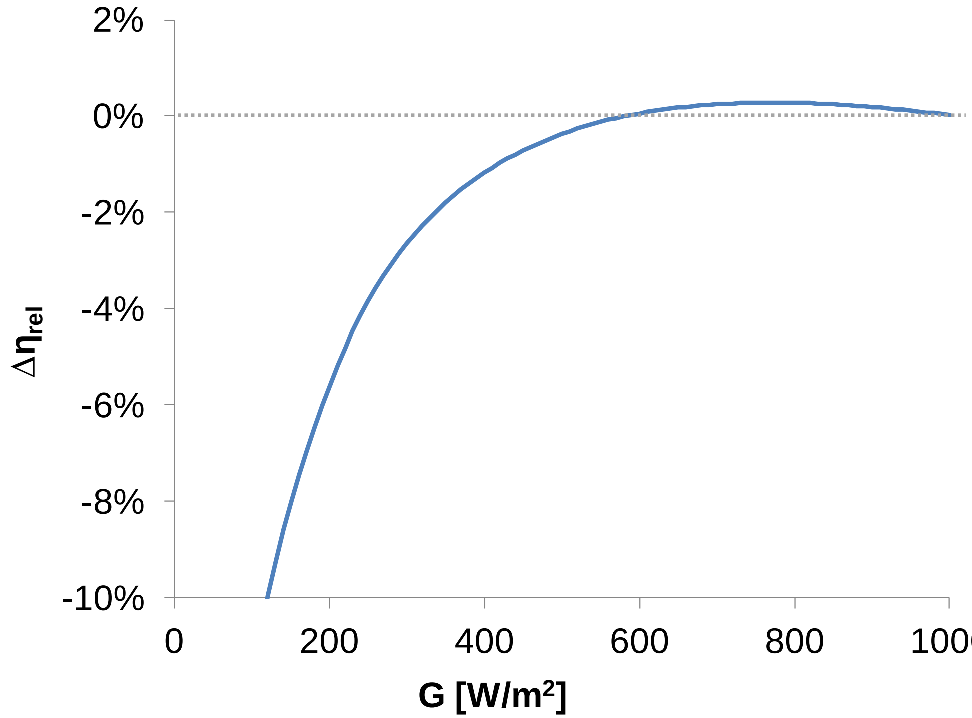
Basics: Multi-irradiance behavior of PV modules

- Characterized via "relative efficiency deviation" $\Delta\eta_{rel}$ [%] as function of irradiance G [W/m²]:

$$\Delta\eta_{rel}(G) = \left(\frac{P_{max}(G)}{P_{max,ref}} \times \frac{G_{ref}}{G} \right) - 1$$

Subscript "ref" means reference conditions; usually STC (where G_{ref}=1,000W/m²).

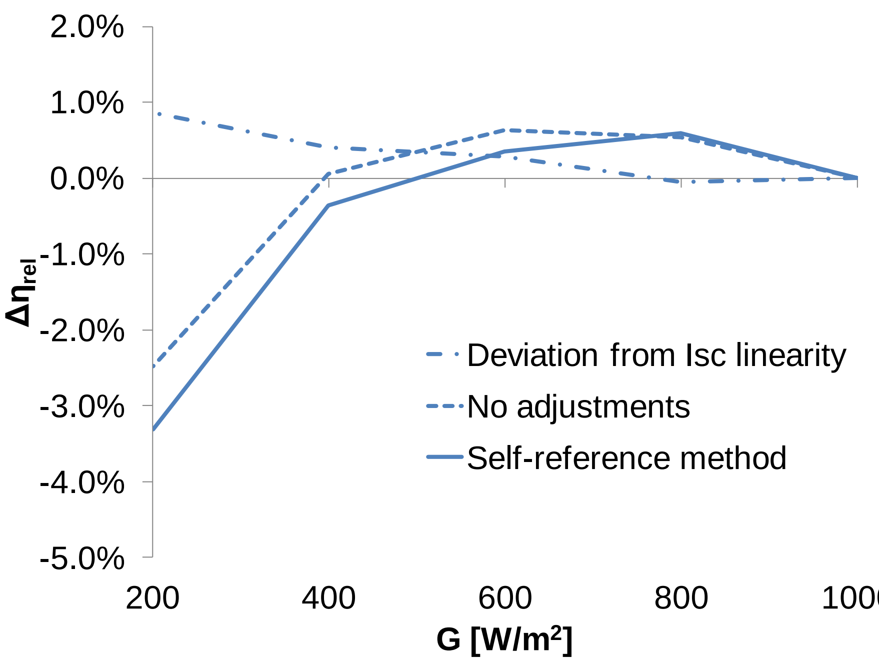
- Typical behavior:



Basics: Self-reference method

- For linear devices, if data are obtained from indoor flash testers, check that deviations from I_{sc} linearity are <1% (see IEC 61853-1 Section 8)
- Possible causes of I_{sc} non-linearity include but are not limited to:
  - Spectral mismatch between the irradiance sensor and sample under test if the spectrum changes over the irradiance range
  - Spatial non-uniformity caused by filter placement during calibration or test
- Obtain effective irradiance G used to calculate $\Delta\eta_{rel}$ following the self-reference method (IEC 61853-1 Section 8):

  $G = G_{ref} * (I_{sc} / I_{sc,ref})$.



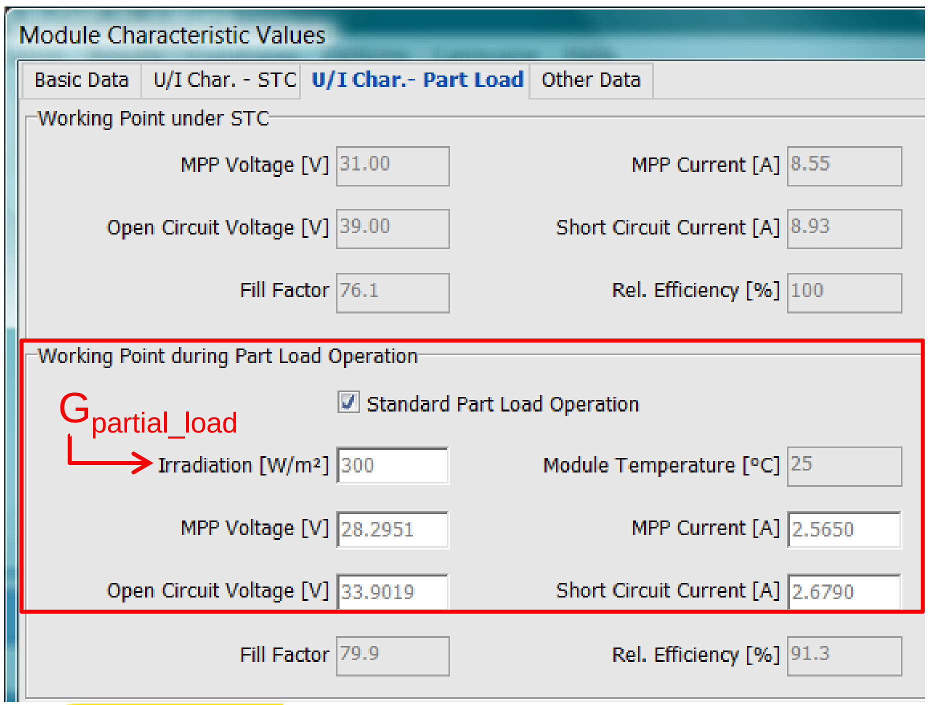
Multi-irradiance behavior in PV*SOL® and PVsyst

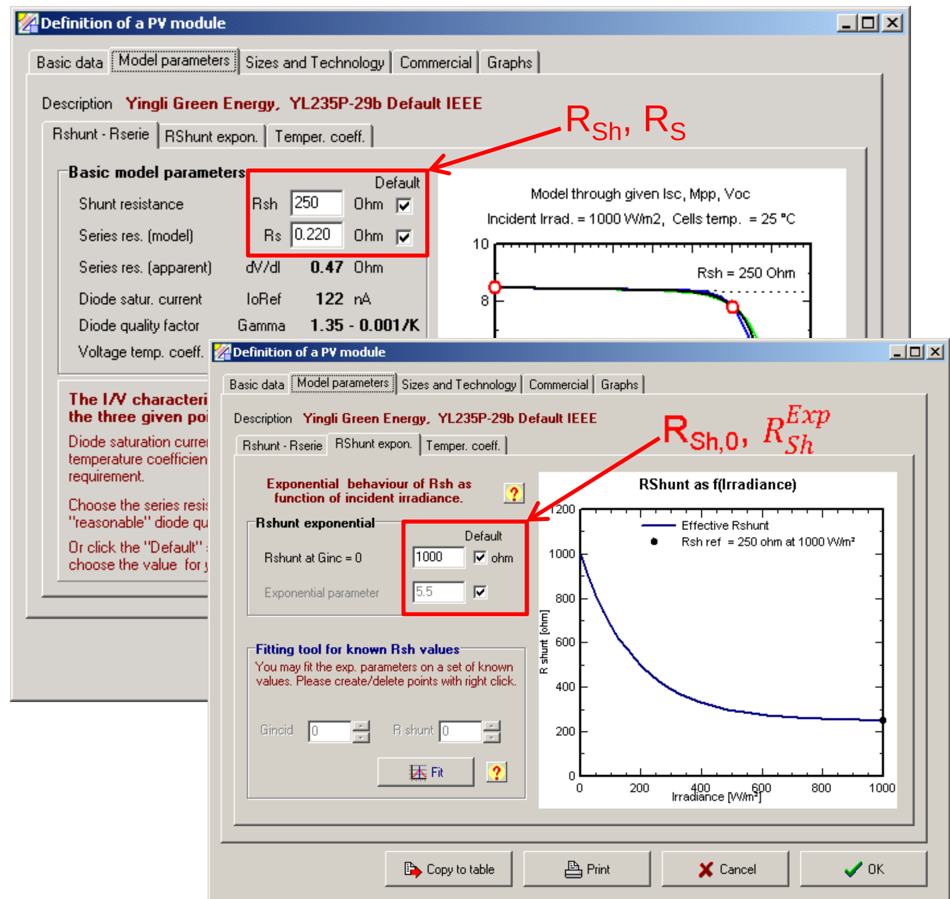
PV*SOL® (v4.0)

- Multi-irradiance behavior via one value of irradiance below reference conditions ($G_{partial\_load}$), at which I-V curve parameters must be provided

PVsyst (V5.56)

- Multi-irradiance behavior via 5 parameters of one-diode model (series and shunt resistance, photo current, saturation current and diode quality factor), where 2 additional parameters are used to describe $R_{Sh}(G)$

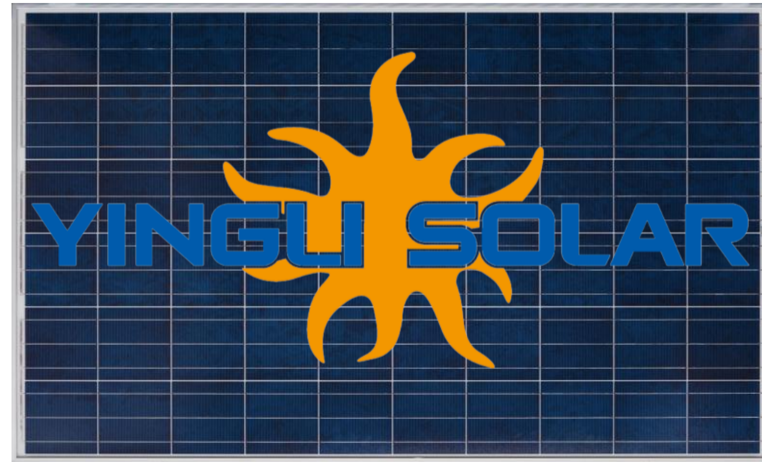




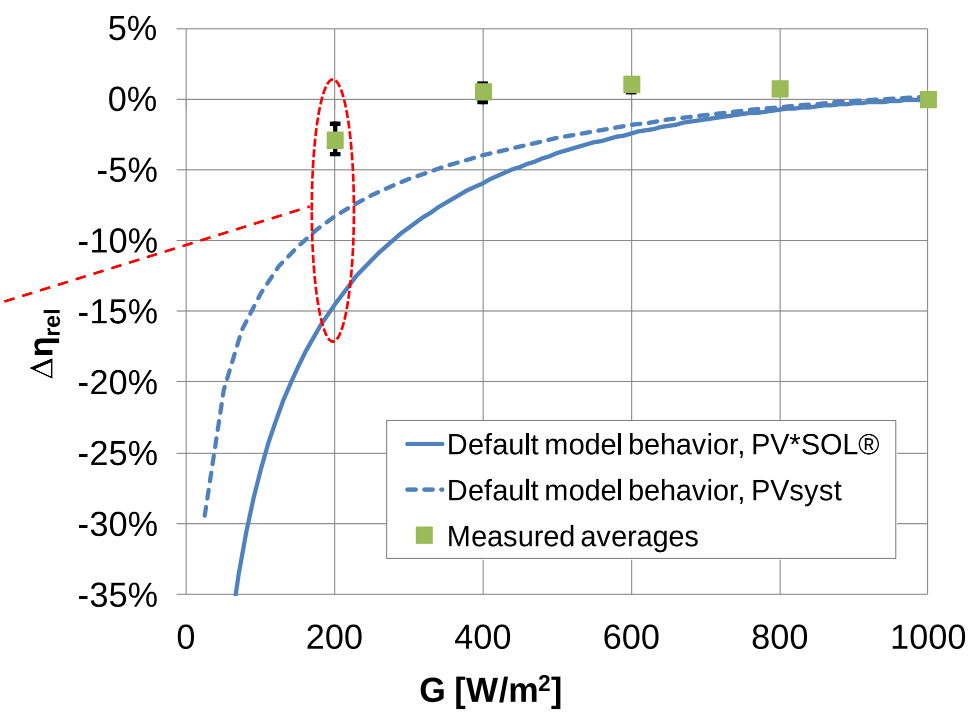
Motivation: Example data and default models

- (22) 235W Yingli Solar mc-Si PV modules
- Reputable 3rd party laboratory in USA
- Class AAA pulsed solar simulator
- I-V curve at STC
- 4 additional I-V curves (25°C and AM 1.5g)
  - 800W/m²
  - 600W/m²
  - 400W/m²
  - 200W/m²

  IEC 61853-1 Section 8.5

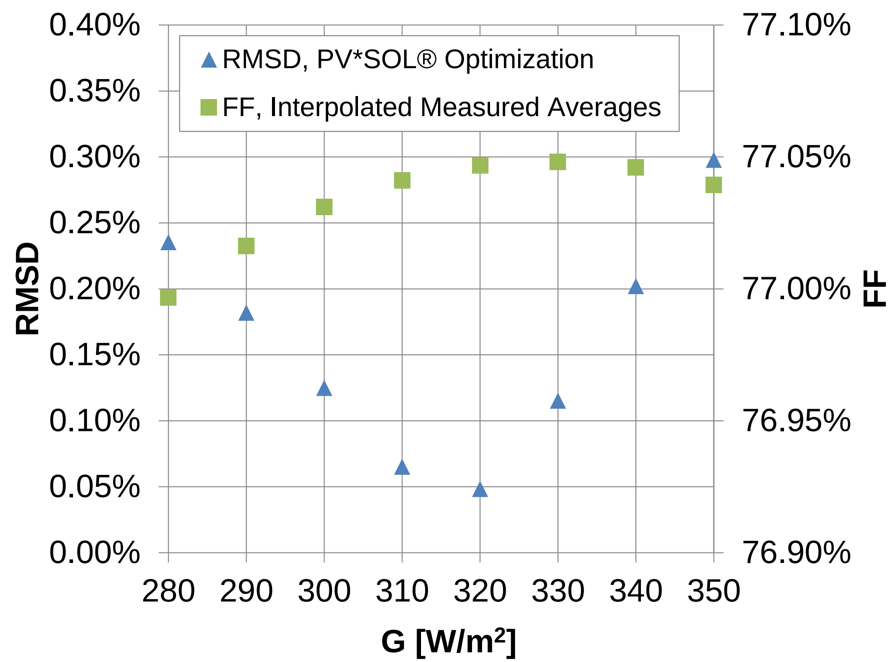


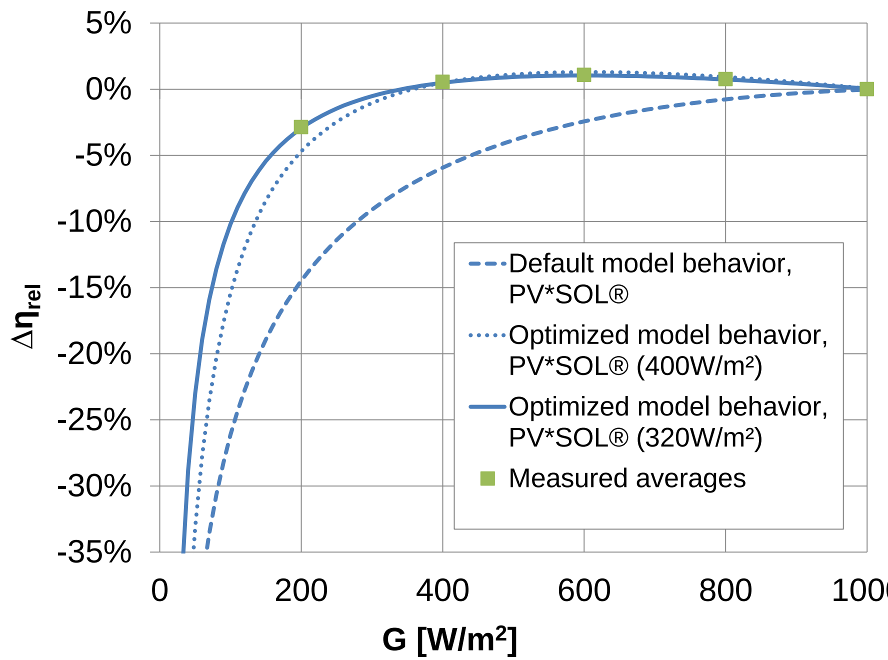
- **$\Delta\eta_{rel}$(200W/m²):**
  - **Measured averages = -2.9%**
  - **Default PVsyst (V5.56) = -8.3%**
  - **Default PV*SOL® (v4.0) = -14.5%**



Systematic approach for PV*SOL®

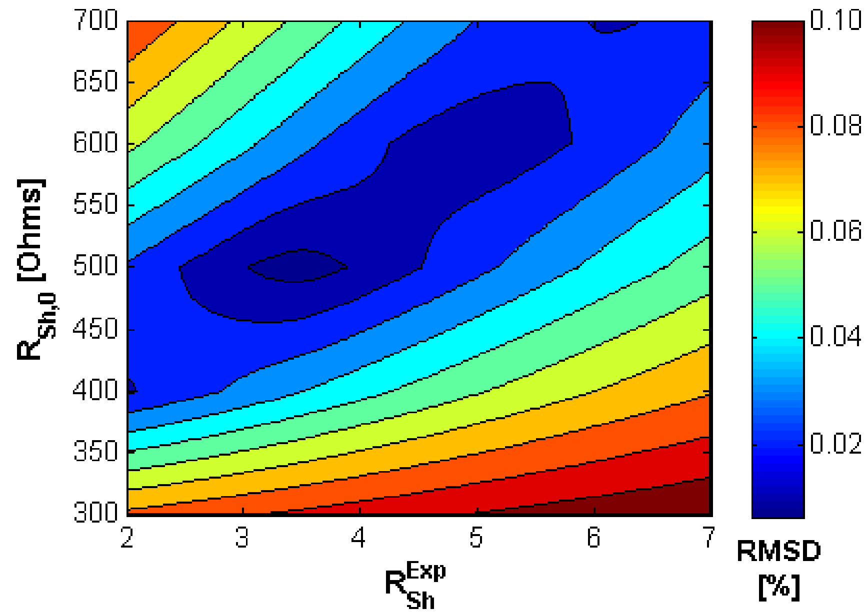
- One user-modifiable variable ($G_{partial\_load}$), thus manual optimization possible
- Limitations of coarse-grained grid of tested G
- Interpolation of measured data (IEC 61853-1 Section 9)
- RMSD: 6.19% (default) → 0.05% (optimized)

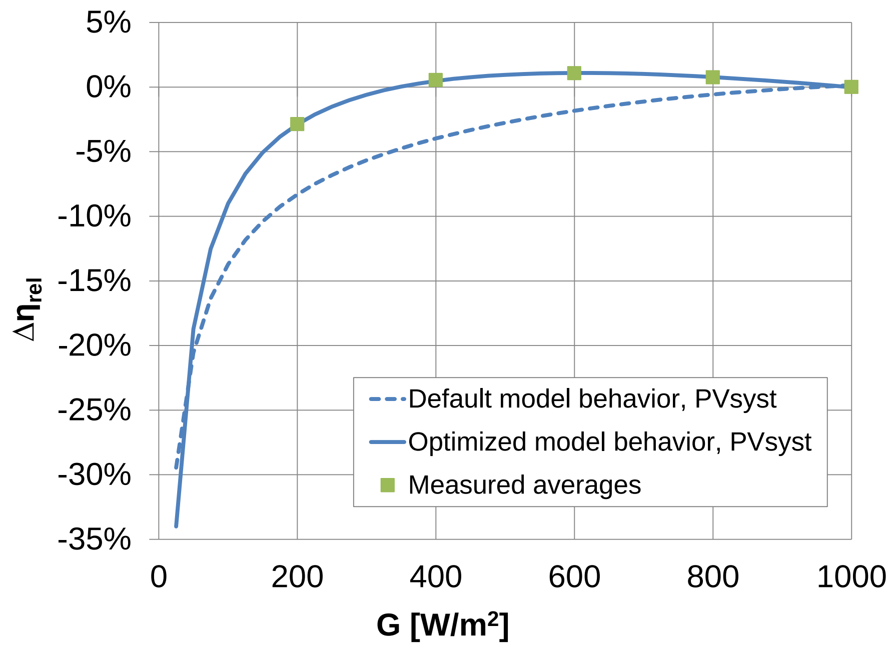




Systematic approach for PVsyst

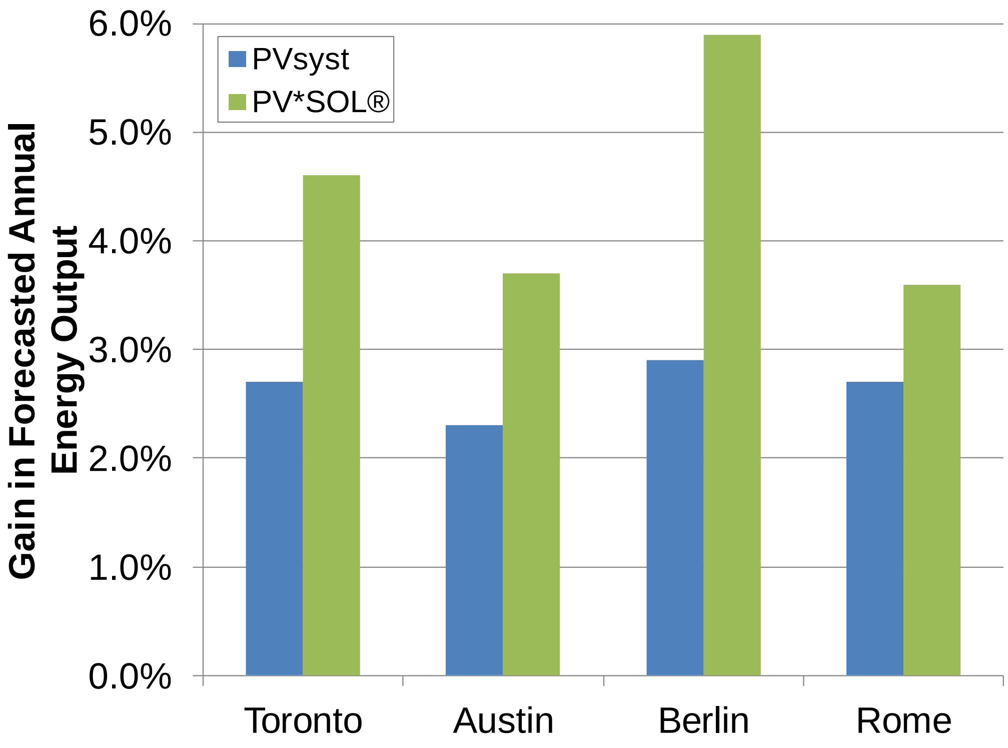
- Optimization over a 4-dimensional space of parameters describing parasitic series and shunt resistances
  - Numerical optimization procedures are required
- RMSD: 3.46% (default) → 0.07% (optimized)





Impact on energy forecasts

- Annual energy production simulated over four geographically distributed locations
- Reported as gains in forecasted outputs using optimized models over forecasted outputs using default models
  - PV*SOL®: 3-6% gains
  - PVsyst: 2-3% gains



Summary and outlook

- Risk of relying on default settings that prescribe irradiance behavior in PV*SOL® and PVsyst module models
- Importance of characterizing PV modules following, e.g., IEC 61853-1
  - Plus fine-grained measurements close to max[FF(G)]
- Systematic optimization procedures reported for fitting PV module models to measured data
- Next step: field validation of optimized models

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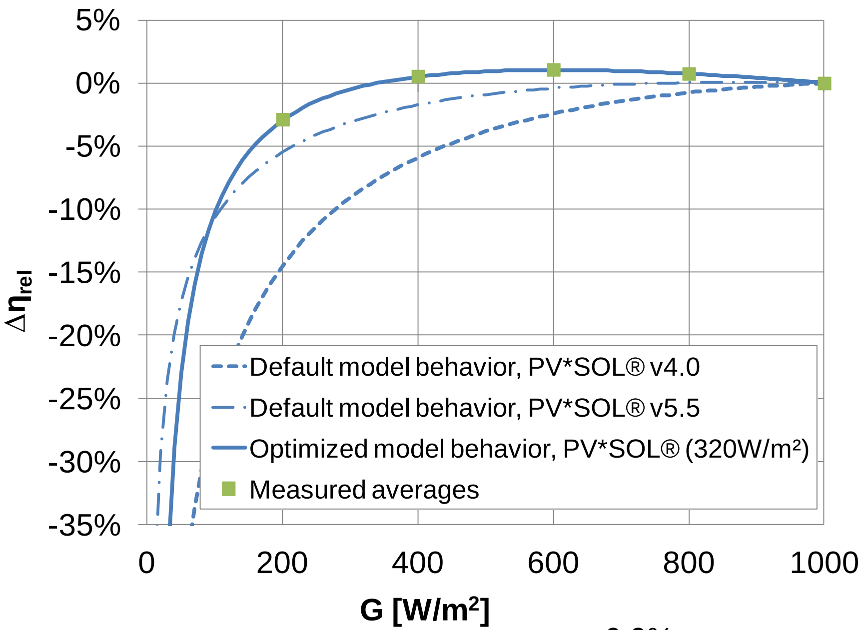
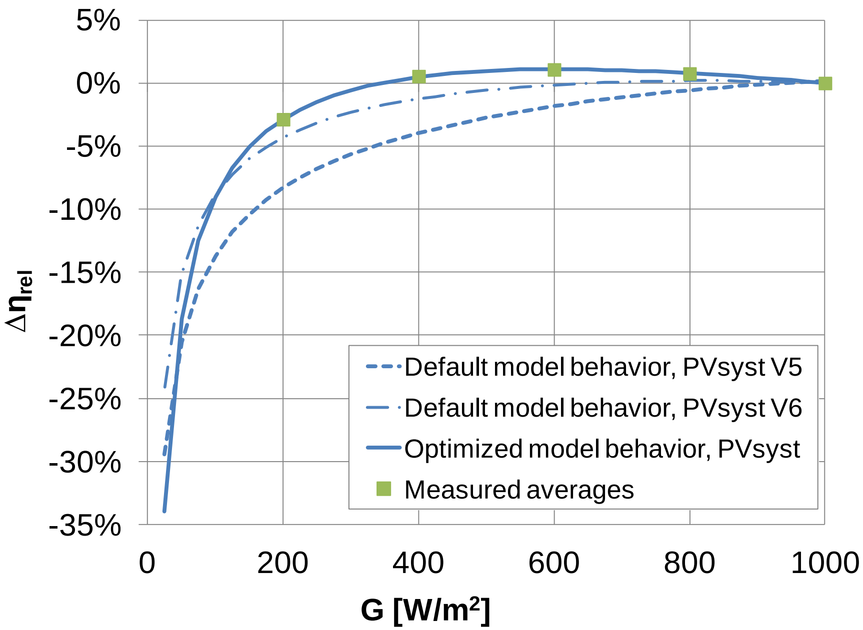
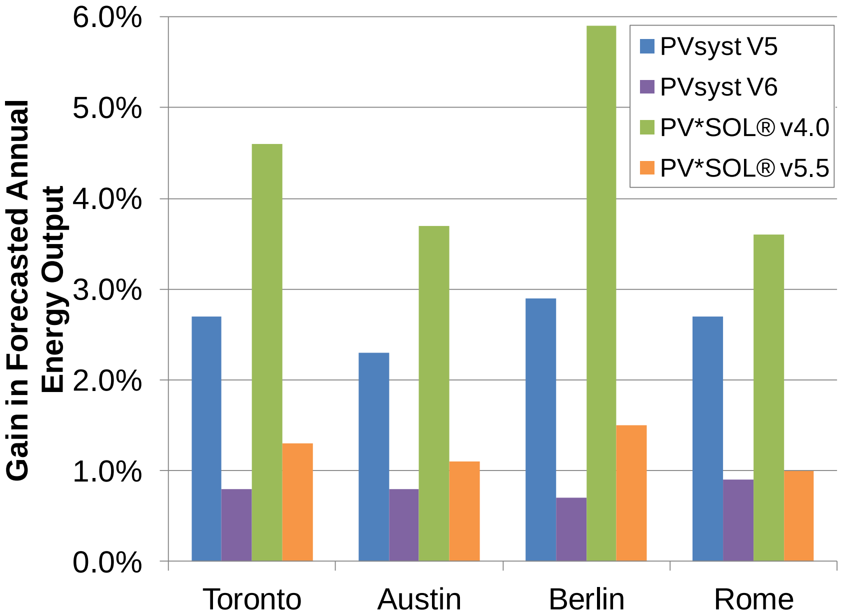
Appendix: New software versions







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