

Highly Customizable PV Monitoring Systems

Irradiance Measurement Solution

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Introduction

- What is PV system monitoring?
 - › Monitoring the performance of PV system and detecting possible faults
- What is needed for PV system monitoring?
 - › Intelligent power inverter and weather station
 - › Data logger with computer software to assess the performance of PV system
- What are the benefits?
 - › Evaluation of performance of PV solar power plant
 - › Shorter time of power outage (MTTR) due to early fault notification alarms
 - › Higher economical sustainability

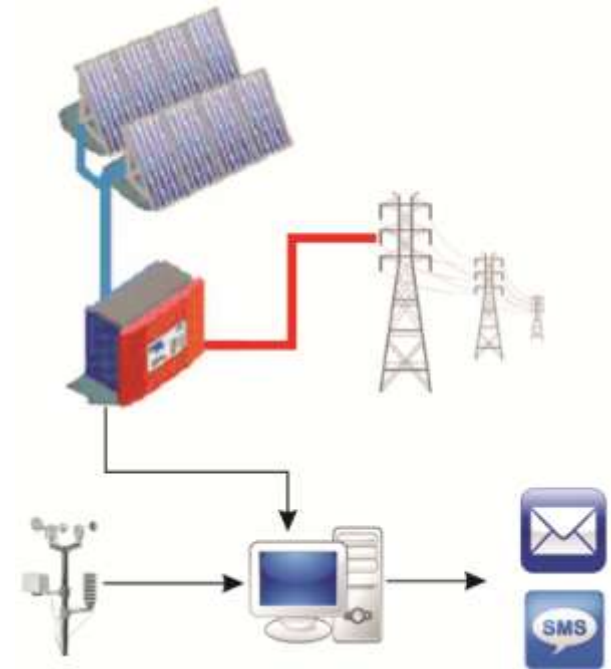
PV market

- 85 GW of total installed PV solar plants in Europe in 2013
 - › Silicon PV modules have 86 % of market share [www.epia.org]
- 256 MW of total installed PV solar plants in Slovenia today
 - › The mean power of PV solar plants in Slovenia is 75 kW [www.pv.fe.uni-lj.si]
- 17 kW PV solar power plant
 - › Faculty of Electrical Engineering
 - › Multi-crystalline silicon PV modules
 - › Location Ljubljana, Slovenia
 - › Inclination 30°, orientation 25° east



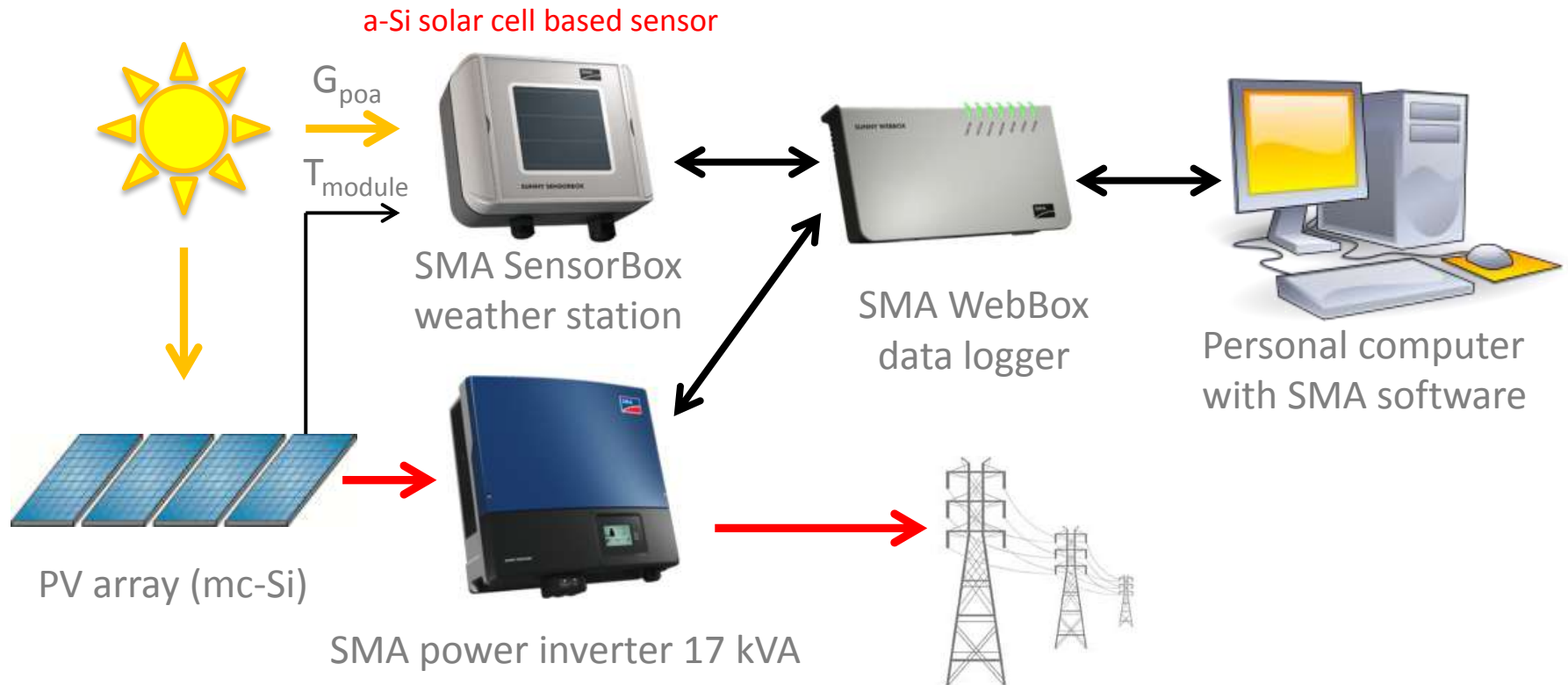
Monitoring PV system performance

- Power inverter
 - › Measurement of voltage, current, power,...
- Weather station
 - › Irradiance in a plane of array (G_{poa}),
 - › PV module operating temperature (T_{module})
 - › Wind speed, humidity, air pressure,...
- Personal computer or data logger
 - › Comparison of calculated versus measured power
 - › Alert in case of higher discrepancy



SMA PV monitoring solution

- 17 kW mc-Si PV solar power plant at the Faculty of El. Eng.



Improving the current PV monitoring setup

- Demands for new weather station solution
 - › Option for external high accuracy solar irradiance sensors
 - › Temperature measurement inputs for irradiance sensors
 - › Easy integration into existing system
 - › Support for SMA communication protocols
 - › Additional temperature inputs for monitoring PV modules' temperature
- Irradiance sensors
 - › Equivalent Technology Solar Cell (ETSC) irradiance sensor
 - › Thermopile pyranometer
 - › Temperature compensation of irradiance sensors

LPVO Sensor Interface

■ Features

- › Four channels for irradiance sensors
- › Automatic dual gain capability
- › PT1000 or NTC 10 k Ω temp. sensors
- › Easy integration in SMA PV systems
- › Eight channel digital temp. input



■ Integration into 17 kW PV system

- › mc-Si solar cell based irradiance sensor with internal temperature correction
- › CMP6 thermopile pyranometer



Irradiance sensors comparison

- 3 types of irradiance sensors

- › A-Si and mc-Si solar cell based sensor and thermopile pyranometer
- › 3 days of monitoring data comparison (cloudy, partially cloudy and sunny day)

- PV module performance model with 3 coefficients [Ding et al.]

$$P_{\text{mpp}}(G_{\text{poa}}, T_{\text{module}}) = \left[k_{nl1} \cdot G_{\text{poa}} + k_{nl2} \cdot G_{\text{poa}}^2 + k_{nll} \cdot G_{\text{poa}} \cdot \ln \frac{G_{\text{poa}}}{G_{\text{STC}}} \right] \cdot [1 + \gamma \cdot (T_{\text{STC}} - T_{\text{module}})]$$

- Least squared error fitting method

- › Comparing the RMSE of PV performance model for all three solar irradiance sensors

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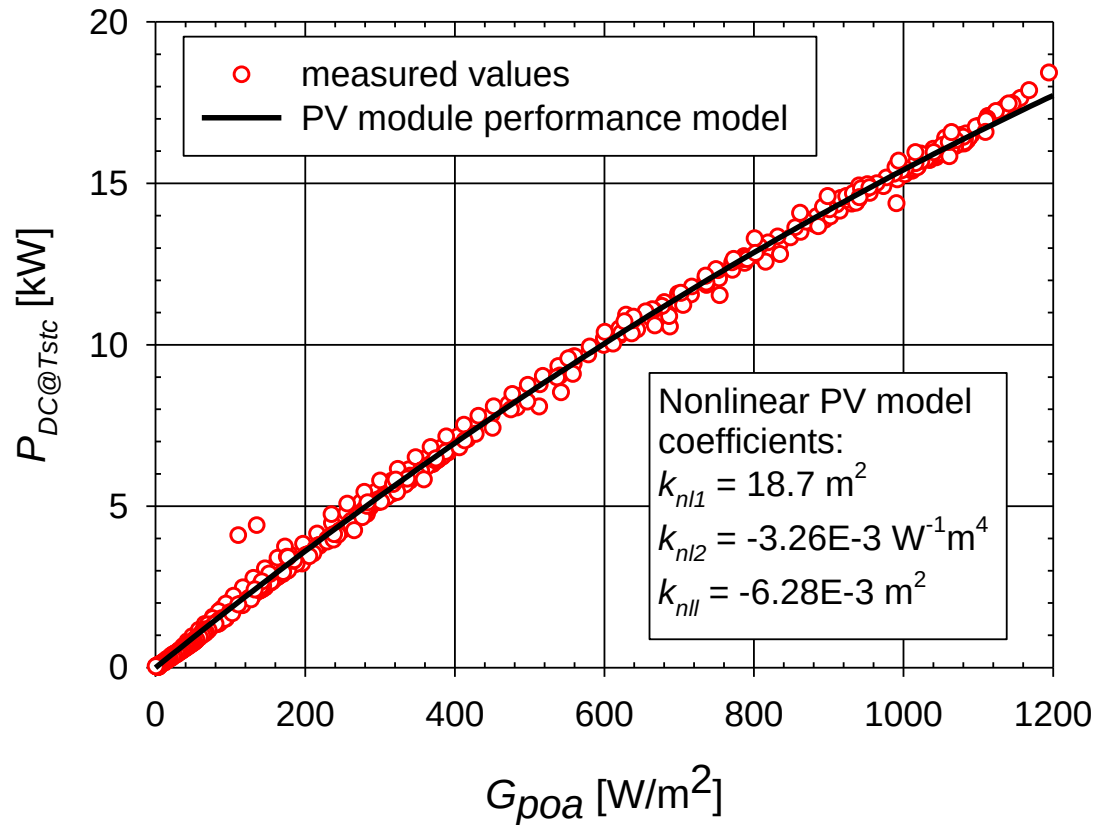
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Results

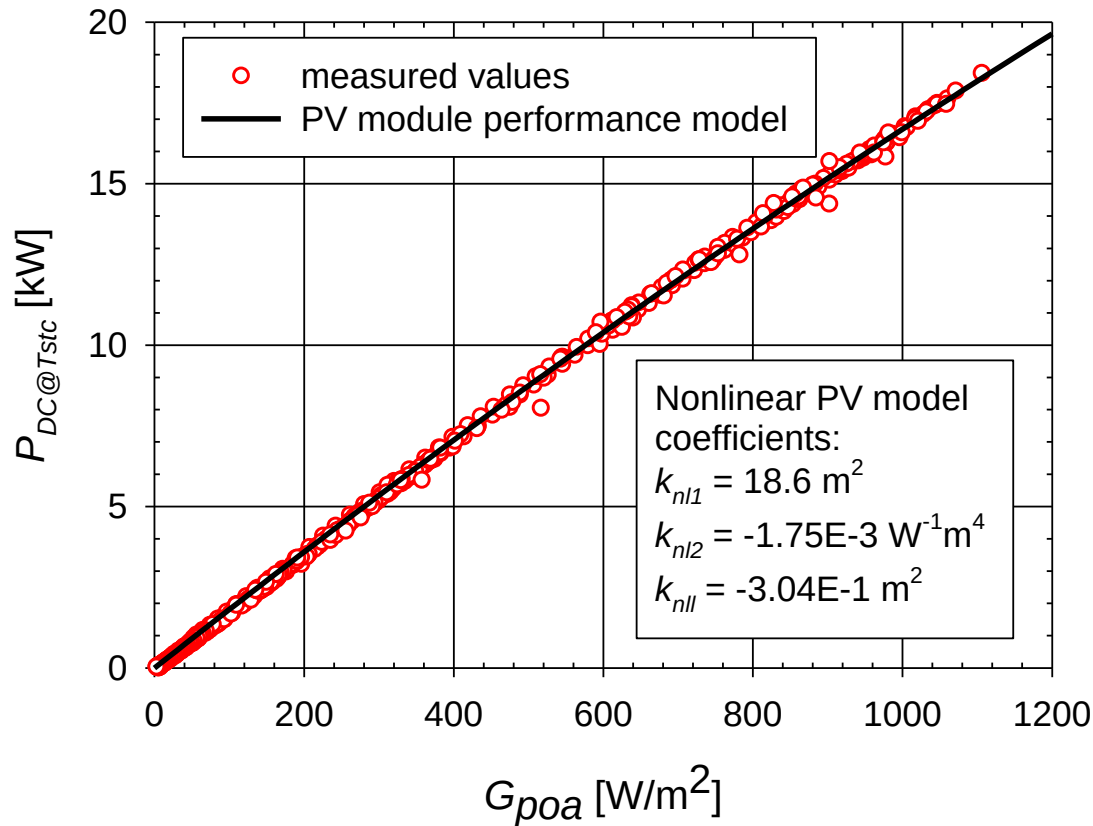
- a-Si solar cell based irradiance sensor (SensorBox)



RMSE = 2.3 %

Results

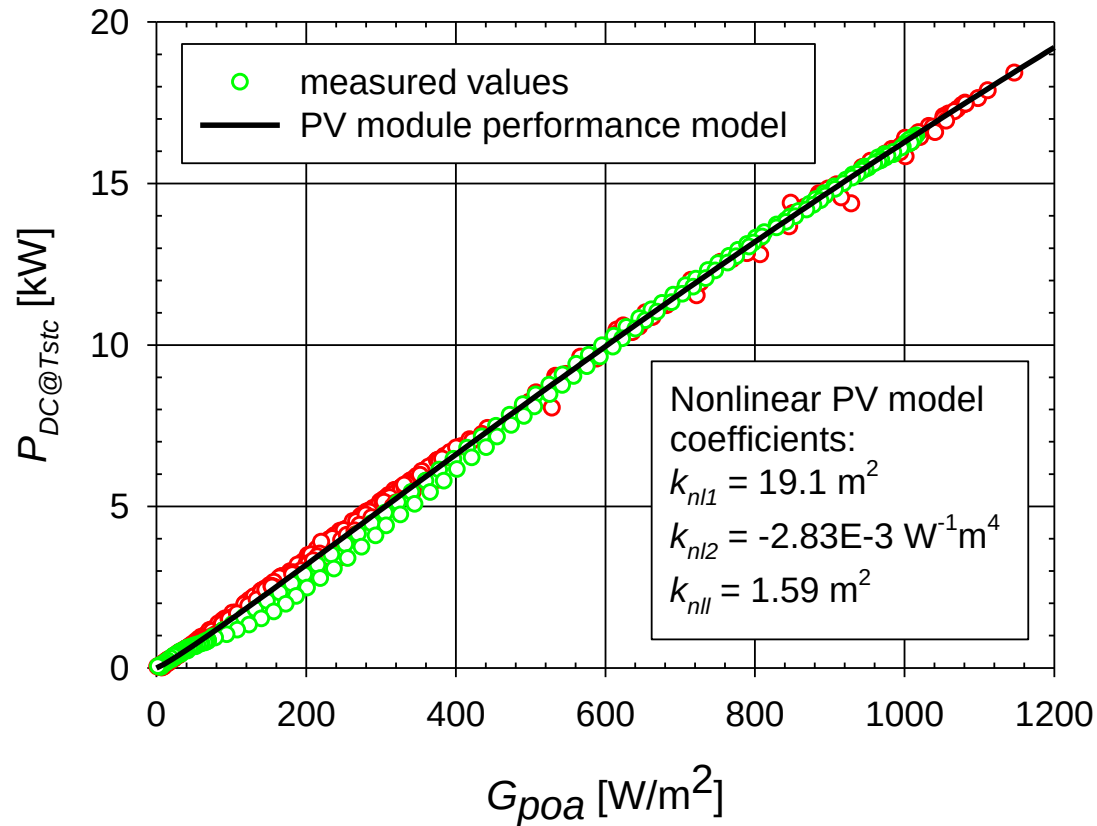
- mc-Si solar cell based irradiance sensor



RMSE = 1.6 %

Results

■ Thermopile pyranometer



RMSE = 3.0 %

Conclusions

- ETSC irradiance sensor is recommended option for PV monitoring
 - › mc-Si solar cell based sensor: RMSE 1.6 %
 - › a-Si solar cell based sensor: RMSE 2.3 %
 - › CMP6 thermopile pyranometer: RMSE 3.0 %
- Spectral and angular losses evaluation
 - › Combination of ETSC irradiance sensor and thermopile pyranometer
- Additional research
 - › Long term comparison of different types of solar irradiance sensors
 - › Evaluation of different PV performance models to achieve lower RMSE

Thank you for your attention