Laboratory of Photovoltaics and Optoelectronics

ESR8 - Evaluation of PV Module Degradation Based on Analysis of Outdoor Monitoring Data

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Introduction

Project description

The project will establish a profound understanding of degradation processes of different PV module technologies based on outdoor performance monitoring. As results, comprehensive degradation models of energy yield and performance ratio throughout life-time and uncertainties parameters of outdoor performance monitoring data are expected.

PV systems at LPVO

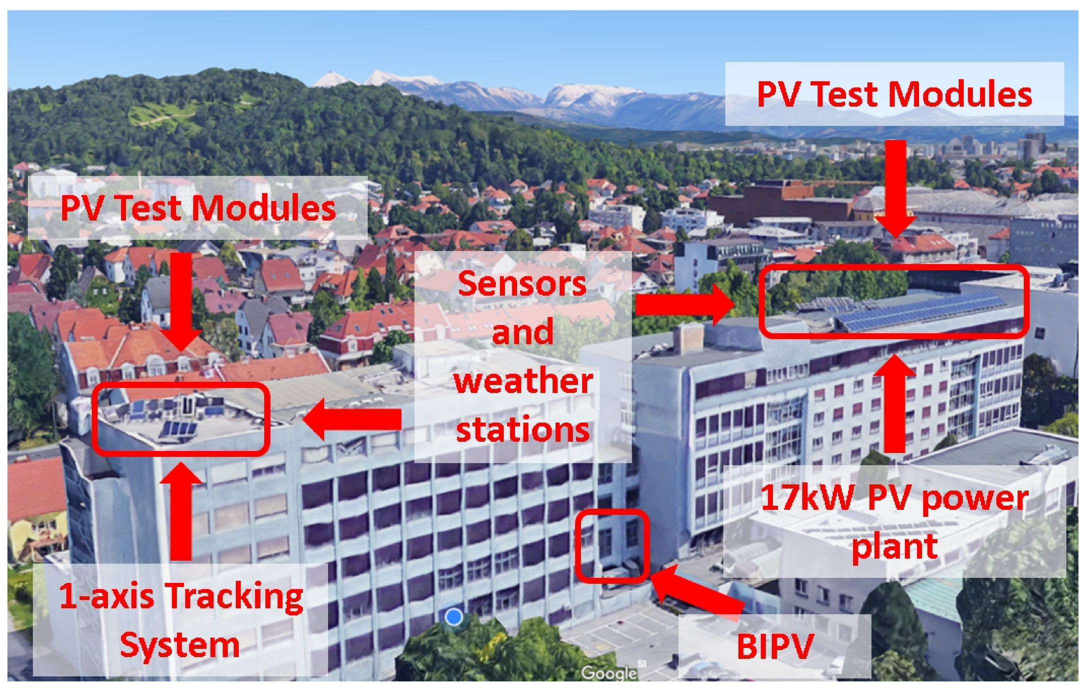

Fig.1 - PV systems and test sites at the Laboratory of Photovoltaics and Optoelectronics (LPVO) at the University of Ljubljana.

Degradation rate (D) and Performance Ratio (PR)

Importance of D and PR

- Economic viability is based on the capacity of delivering rated power over the expected service lifetime.
- Calculations of energy indicators such as LCOE and Grid Parity also include the performance degradation variable.

$$LCOE = \frac{CAPEX + \sum_{n=1}^{N} \frac{OPEX - RV}{(1+r)^n}}{\sum_{n=1}^{N} \frac{Y_o \cdot (1-D)^n}{(1+r)^n}}$$

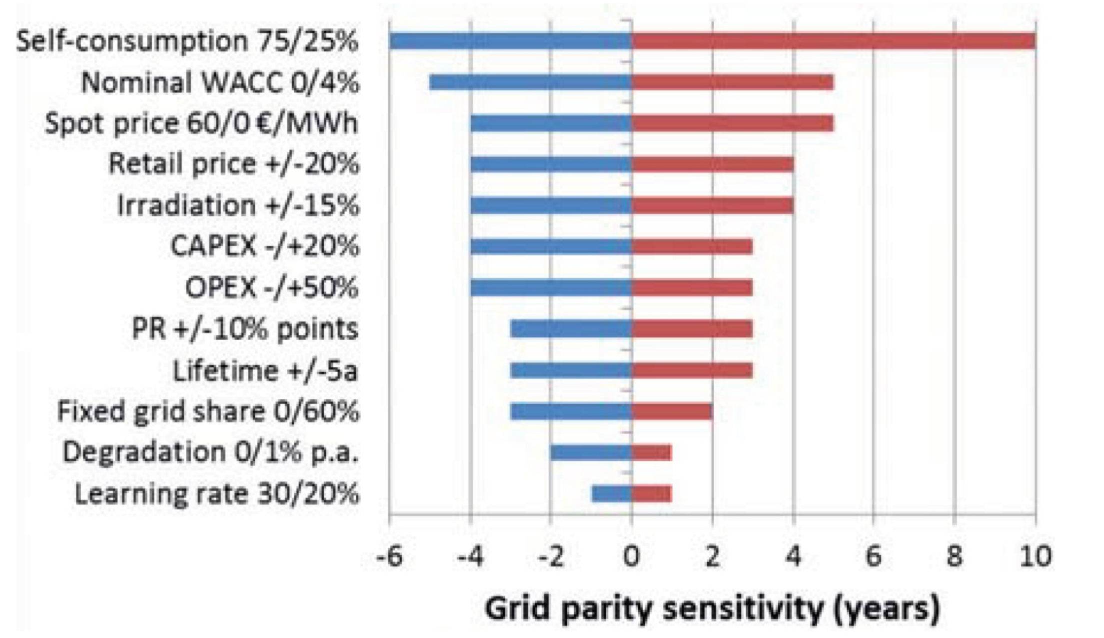

Fig.2 - Sensitivity of true grid parity for a residential 5kWp system in Finland.

Uncertainty and Methods

Uncertainty dependence

- Measuring equipment
- Data qualification and filtering criteria
- Performance metric
- Statistical method for trend estimation

Statistical Analysis

- Linear Regression
- Classical Seasonal Decomposition (CSD)
- HW exponential smoothing
- ARIMA
- LOESS

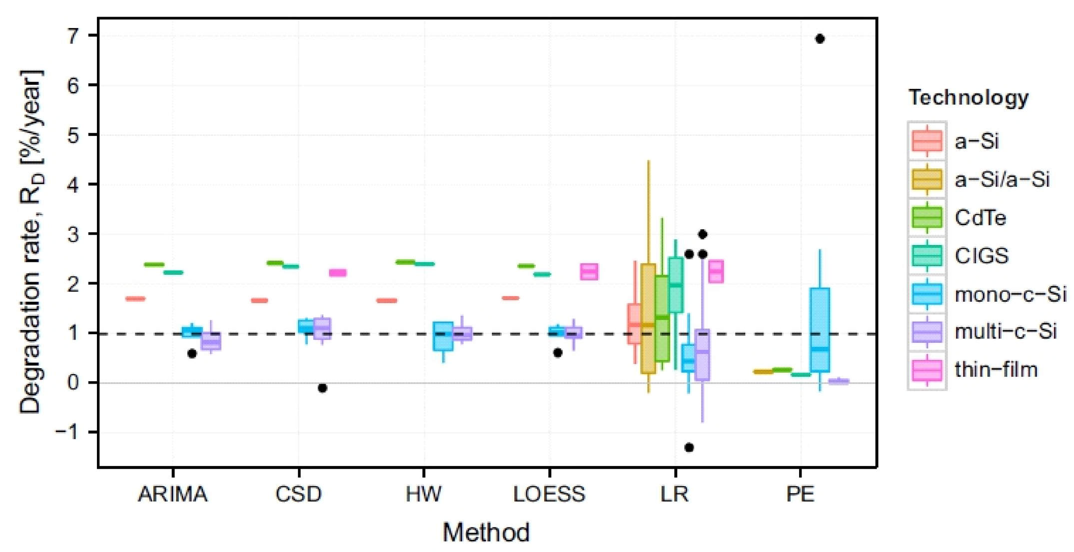

Fig.3 - Degradation rates, categorized by the PV technology and statistical analysis method.

Expected Results

Degradation models for energy yield and PR for different PV module technologies and types that are location and installation type specific and parameters for the rating of uncertainties of outdoor performance monitoring data for PV modules.

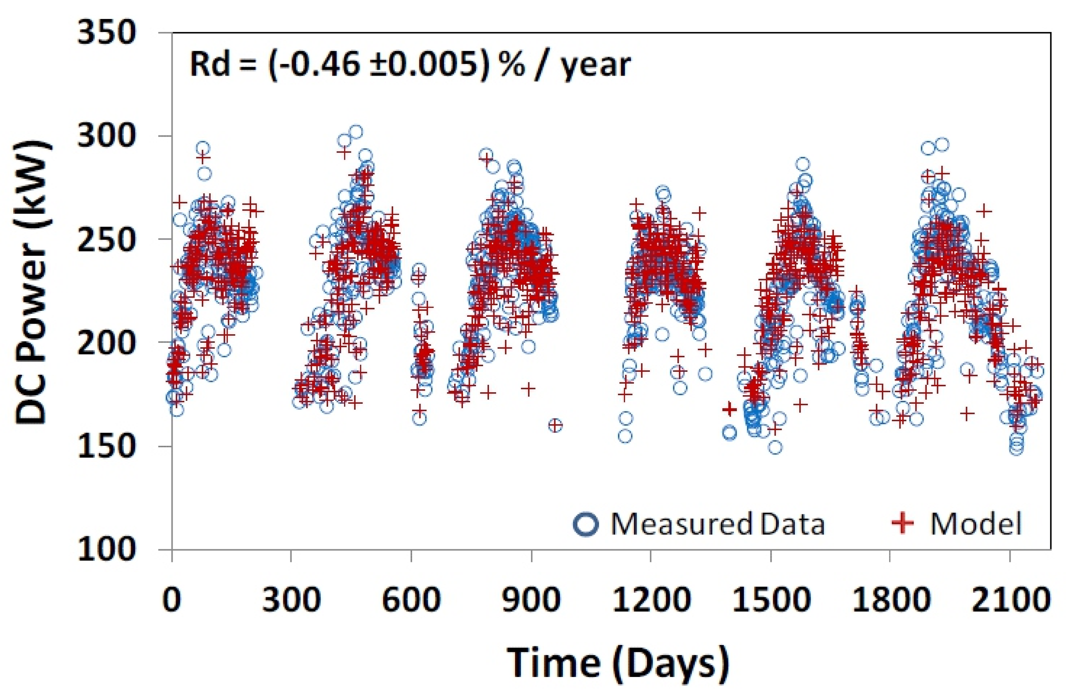

Fig.4 - Degradation rates calculated with linear regression on the DC-side and modeled data including Tamb, RH, WS and Gpoa variables.

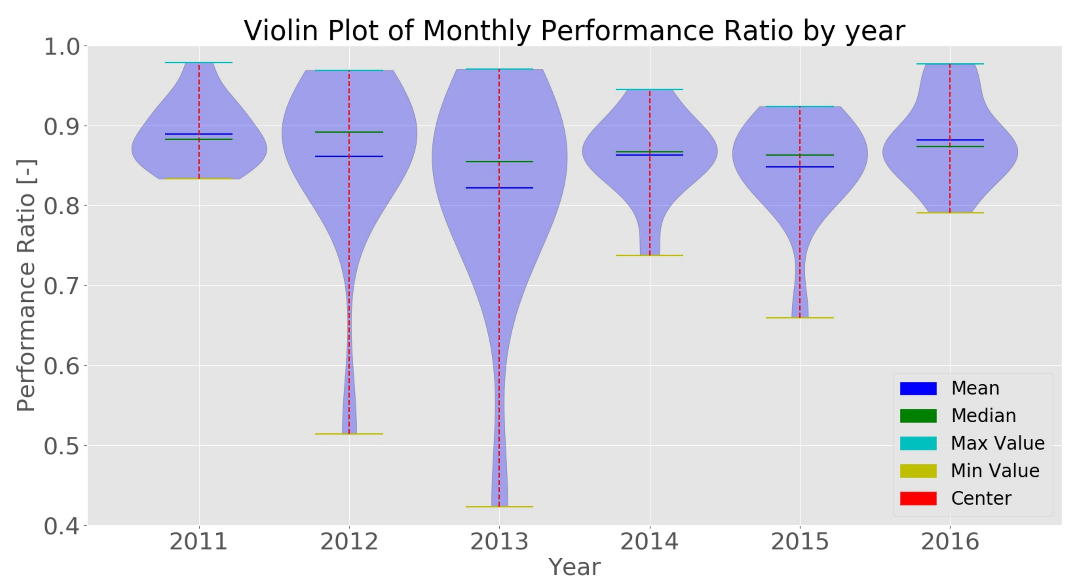

Fig.5 - Example of annual PR analysis from 2011 to 2016 of 17kW PV plant at the University of Ljubljana.

Conclusion

- Financial risk of overestimating or underestimating the true degradation.
- Degradation Rate is not only technology and site dependent, but also methodology dependent.
- Current literature proves the need for defining a standardized methodology.
- Too much uncertainty with linear or traditional models.
- Need to have clean and consistent raw data to neglect seasonal variations.
- Sophisticate statistical methods are showing better results.

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