

COMPARISON OF LONG-TERM INDOOR AND OUTDOOR PERFORMANCE MEASUREMENT TECHNIQUES OF CRYSTALLINE SILICON PV MODULES TO VALIDATE ANNUAL DEGRADATION

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Introduction and innovation

The presented degradation of the nominal power results are established by a detailed analysis of highly accurate indoor and outdoor measurements of crystalline silicon PV modules over 10 year. All modules have been installed and monitored by 1-minute voltage/current, IV curve and irradiance (pyranometer and monocrystalline silicon ISE reference cells) measurements on a rooftop in Dietikon, Switzerland, since 2009 [1, 2]. Once a year, the modules were dismantled and measured indoor by the Swiss Mobile Flasher Bus [3, 4]. The two completely different measurement setups and analysis methods are used to identify the degradation rates for multi c-Si modules (Sunways) under outdoor conditions.

Highlights:

- Indoor and outdoor measurements
- High data resolution (1 minute)
- String and single reference modules setup
- High uptime over 10 year
- Low outdoor measurement uncertainty
- No defect c-Si modules

Measurement setup

System	
Manufacturer	Sunways
Model	SM210 UA65
Technology	multi c-Si
Module efficiency	13.8%
Installation date	Sep 2009
Module	
Total # modules	1
P _n Label [W]	230
V _{MPP} at STC [V]	29.3
I _{MPP} at STC [A]	7.86
V _{OC} at STC [V]	36.9
I _{SC} at STC [A]	8.34
TC P _{MPP} [%/K]	-0.43
TC V _{OC} [%/K]	-0.36
TC I _{SC} [%/K]	0.06
Length [m]	1.68
Width [m]	0.99
Area [m ²]	1.663
# serial cells	60
# parallel branches	1
Tilt angle [°]	30
weight [kg]	24
String	
Total # modules	15
P _n Label [W]	3450
Tilt angle [°]	30°
Mounting	fix
# serial modules	15
# parallel branches	1
V _{MPP} at STC [V]	439.5
I _{MPP} at STC [A]	7.86
V _{OC} at STC [V]	553.5
I _{SC} at STC [A]	8.34

Reference power plant in Dietikon [4]

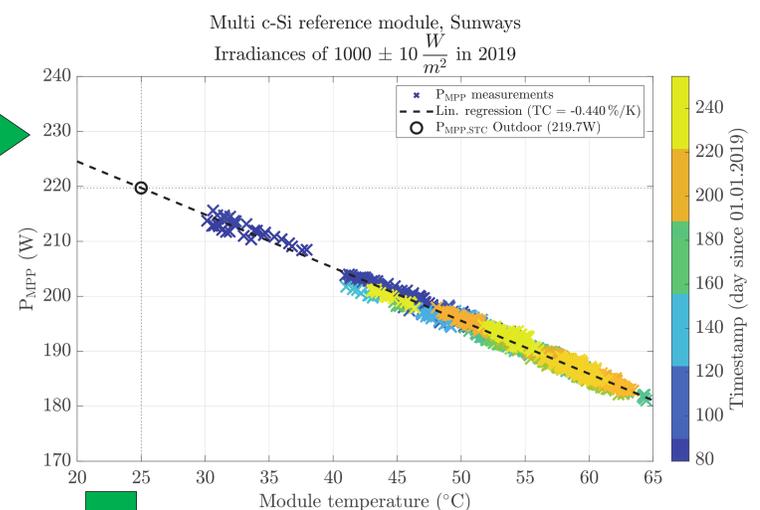


Swiss Mobile Flasher Bus [4]

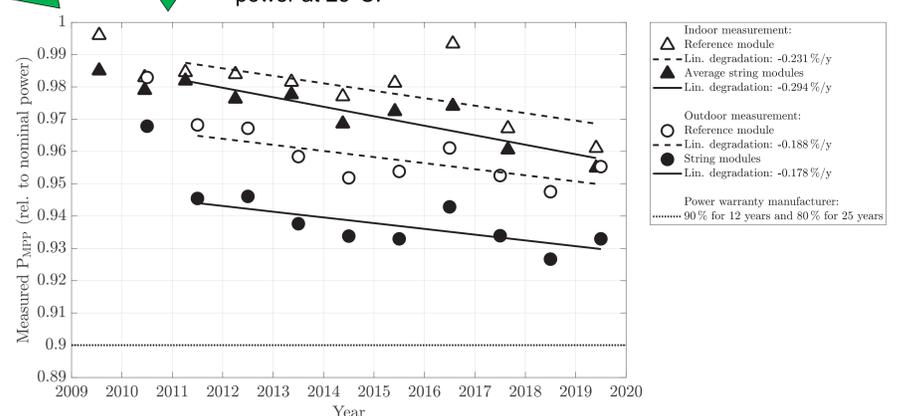


Measurements	Uncertainty (k=2)
Irradiance (Pyranometer)	1.19 %
Module temperature	0.55 %
DC voltage (String)	0.14 %
DC power (String)	0.19 %
DC voltage (Module)	0.24 %
DC power (Module)	1.24 %
Flasher measurement	3.20 %

Degradation results



For each year, the measurement data were selected where clear sky day condition prevailed and the irradiances were between 1000W ± 10W/m². Then, the linear regressions between the power and temperature measurements were performed to determine the power at 25°C.



Conclusion and Outlook

The multi c-Si modules showed an average annual degradation rate in the range between 0.178 % measured by the indoor system and 0.294 % measured by the outdoor system. This is lower than the guaranteed annual degradation given from the manufacturer data sheet [5]. Further results, the details about the measurement setup and the analysis methodology are submitted for journal publication in 2020 [5].

Acknowledgment

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