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Pathways of Uncertainties in Service Lifetime Prediction (SLP) Models for PV modules: How to Improve the Accuracy?

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INTRODUCTION

Degradation models are used to predict the lifetime of PV modules. As for any predictive models, they are associated with different forms of uncertainties. Different sources of uncertainties in SLP models have been investigated

- Most of these models are developed on the basis of quantifying the effects of applied climatic loads. The uncertainties due to input climatic loads have been investigated.
- Other sources of uncertainties such as the assumptions used in model formulations are also discussed.

DEGRADATION RATE MODELS

Two models, one by Kaaya et al.[1] (Eq.1) and the other by (Subramaniyan et al. [2] (Eq. 2) are used. These models are proposed for outdoor door degradation rates evaluation based on combined climatic stresses: such as static module temperature, T, cyclic module temperature ,ΔT, UV radiation, and relative humidity ,RH. The degradation rates are evaluated as:

$$k_1 = A_N.(1 + k_h[RH,T])\big(1 + k_p[UV,T,RH]\big)(1 + k_{Tm}[\Delta T, T_{max}]) - 1 \quad \text{(Eq.1)}$$

$$k_2 = \beta_0.exp(-\beta_1/k_B.T_{max}).\Delta T^{\beta_2}..UV^{\beta_3}.RH^{\beta_4} \quad \text{(Eq.2)}$$

MONITORING OF CLIMATIC DATA

- PV modules and components are being exposed in different test-sites in very different climates
- Simultaneous monitoring of the climatic conditions and sample properties, makes it possible to find correlations between the external climate, sample stresses and long-term performance

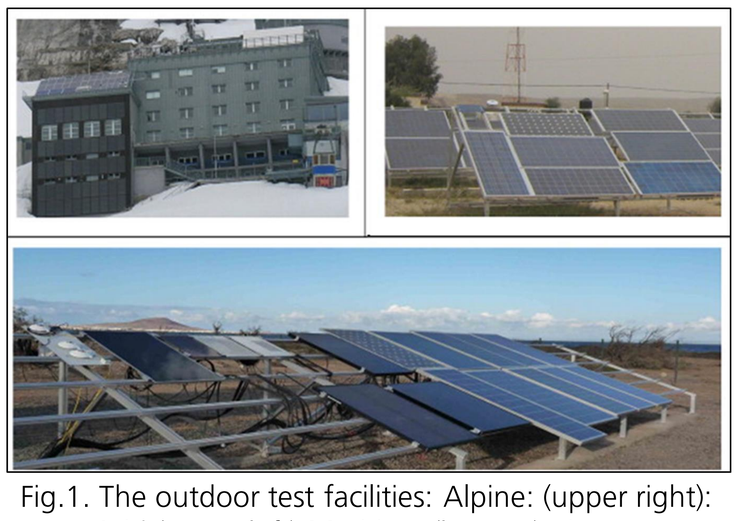

Fig.1. The outdoor test facilities: Alpine: (upper right): Arid (upper left) Maritime (lowest) picture

UNCERTAINITIES DUE TO CLIMATIC DATA INPUTS

Uncertainties due to module temperature estimation

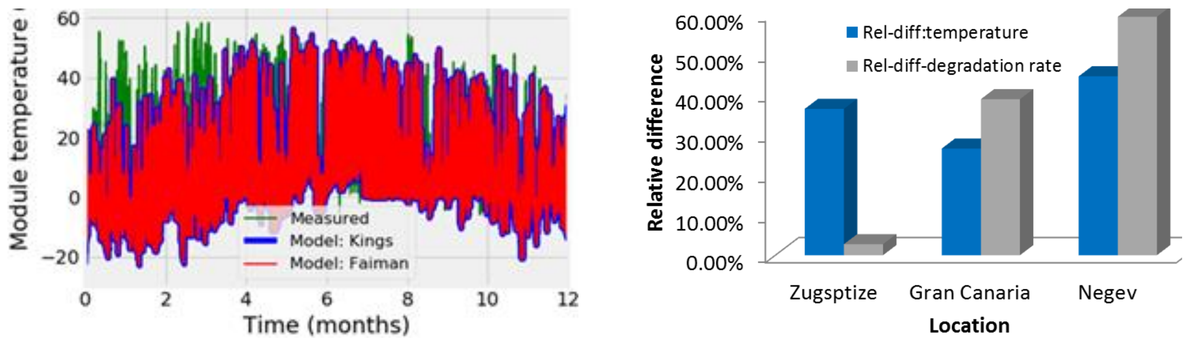

Fig.2. Measured (green) and modeled module temperature [°C] (right) and corresponding relative differences in percentage (left) .

The relative differences between the measured and calculated temperatures were evaluated for all the three climatic zones and correlated with the relative differences in degradation rates as well as service lifetime predictions.

[1] Modeling Outdoor Service Lifetime Prediction of PV Modules: Effects of Combined Climatic Stressors on PV Module Power Degradation. IEEE Journal of Photovoltaics, 9(4), 1105–1112.
[2] Quantification of Environmental Effects on PV Module Degradation: A Physics-Based Data-Driven Modeling Method. IEEE Journal of Photovoltaics, 1–8

- Uncertainties in rates or lifetime prediction due to the uncertainties in module temperatures evaluation, are location dependent
- In hot locations, the uncertainties are drastic in comparison with cold climate
- This can be explained by the Arrhenius temperature dependence in the degradation rate models (see Fig.3).

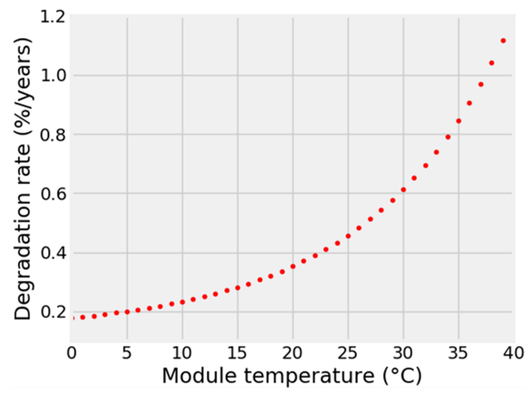

Fig.3. Module temperatures against the degradation rate.

OTHER SOURCES OF UNCERTAINITIES

1. Assumptions made during models formulation

Depending on the underlying assumptions during models derivations; models proposed for similar purpose don't usually give the same output even when calibrated using the same datasets: below we compare two models A (Eq.1) and B (Eq.2)

Location	Model A k_T [%/year]	Model A t_f [years]	Model B k_T [%/year]	Model B t_f [years]
Negev	0.74	21.4	0.80	20.0
Gran Canaria	0.50	31.6	0.50	31.6
Zugspitze	0.30	52.8	0.14	113.5

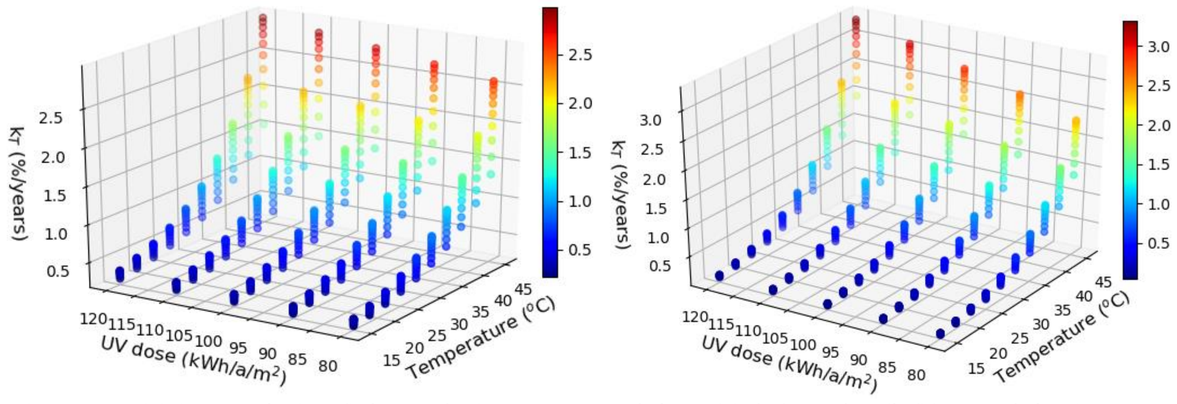

Fig.4 Sensitivity analysis of degradation rate models A (right) and B (left). Model B is more sensitive to input loads compared to model A.

2. Constant degradation rate for long term lifetime predictions

Usually a constant degradation rate is used together with a linear degradation to predict the lifetime. This is not usually the case since the degradation rate is expected to be increasing overtime and non-linearity of degradation is commonly observed as shown in fig.5.

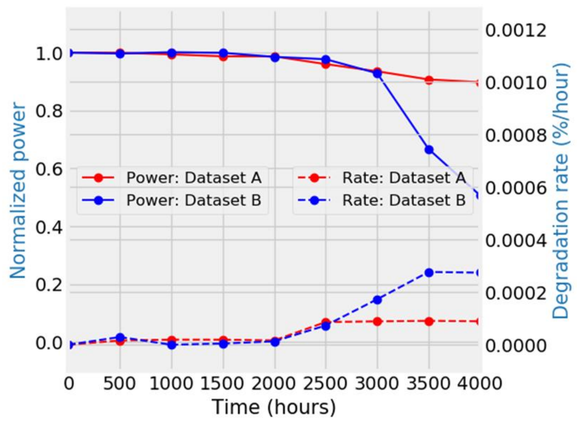

Fig.5. Extracted rates at each point of power measurement during damp heat test.

CONCLUSION

How to improve the accuracy?

- Thorough climatic data treatment to reduce uncertainties and a good choice of models for micro-climatic conditions are a prerequisite
- Simplification of the models should not exclude the physical dependences
- Time dependent degradation rates models will be proposed together with non-linear degradation functions for long term lifetime predictions

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