Prediction Model for Potential Induced Degradation Effects on Crystalline Silicon Cells

Autors:

Koch, Simon; Berghold, Juliane; Abdullah, Basel; Hinz, Cyril; Grunow, Paul

Abstract/Summary:

This paper will present a further developed PID phenomenological prediction model [1]. The potential-induced degradation (PID) progress can be manly described by three parameters (A_1, t_0 and p). The performance of a solar module is the fundamental characteristic. The power in turn is related to the shunt resistance, which reveals in advance the PID. The purpose of this work is the development of a simulation model for the PID prediction using climate data. For the mathematical description of the degradation process a logistic function is presented. This feature is already applied in other fields of research and is here adjusted for simulating the potential-induced degradation. The development of the shunt resistance can be described mathematically with this function. Additionally a mathematical description of the regeneration will be given as well. With the help of the latest outdoor data, which were measured by a special designed shunt detector, new findings are presented. This leads to innovative assumptions to develop a simplified model for PID prediction.

For more Information on the topic please contact the R&D Team of PI Berlin.

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PREDICTION MODEL FOR POTENTIAL INDUCED DEGRADATION EFFECTS ON CRYSTALLINE SILICON CELLS

Simon Koch, Juliane Berghold, Basel Abdullah, Cyril Hinz and Paul Grunow
PI Photovoltaik-Institut Berlin AG, Wrangelstr. 100, D-10997 Berlin, Germany
Phone: +49 (30) 814 52 64 204, Fax: +49 (30) 814 52 64 101, e-mail: koch@pi-berlin.com

→ Approach:

The purpose of this work is the development of a simulation model for the PID prediction using climate data. For the mathematical description of the degradation process a logistic function is presented. This feature is already applied in other fields of research and is here adjusted for simulating the potential-induced degradation. The development of the shunt resistance can be described mathematically with this function. Additionally a mathematical description of the regeneration will be given as well. Together with the latest outdoor data, measured by a special designed shunt detector, some new findings will be presented, which will lead to innovative assumption which a simplified model for PID prediction can be developed.

Test Set-up

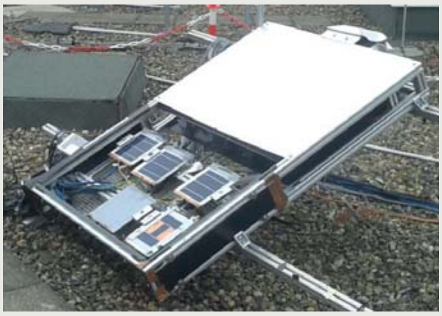

Fig. 1: Universal light-tight research installation (ULFI) for determining PID gradients.

Sunny Day Berlin

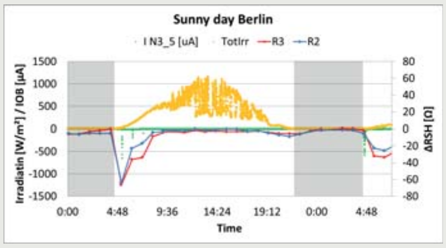

Fig. 2: ΔR_{SH} curve (blue, red) of two samples on a sunny summer day in Berlin. Irradiation (yellow) and surface conductivity (green) largely determine the degradation curve on the day (white area).

Unsettled Day Berlin

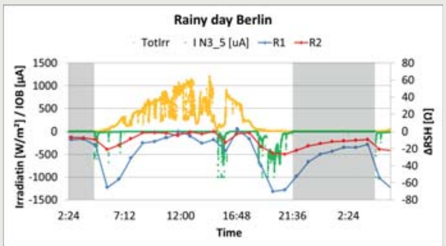

Fig. 3: ΔR_{SH} curve (blue, red) of two samples on a sunny summer day in Berlin. Irradiation (yellow) and surface conductivity (green) largely determine the degradation curve on the day (white area).

Sunny Day Nicosia

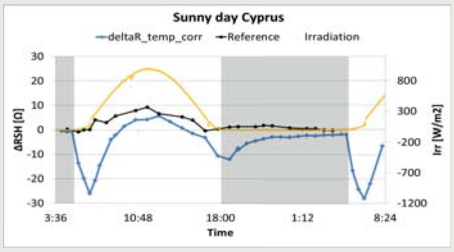

Fig. 4: ΔR_{SH} curve for a stressed sample (blue) and the reference (black) on a sunny summer day in Nicosia. The irradiation (yellow), day (white area) and night time (grey area) are also marked in the figure.

Potential Distribution

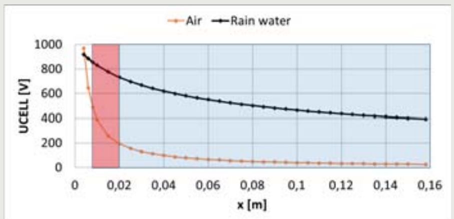

Fig. 5: Potential distribution over a one cell (blue area) mini module at rain (black) and at (orange) dry weather shows a constant high stress on the edge (red area)

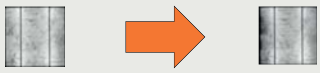

Fig. 6: Long term degradation (9 month) reveals that the main degradation occur at the edge of the module

Regeneration

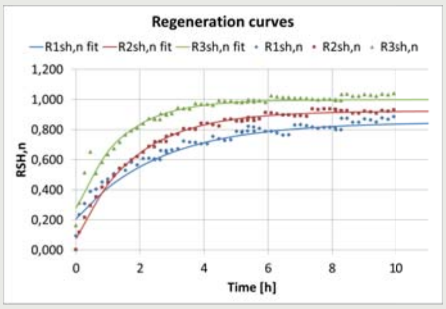

Figure 6: The three different regeneration measurements (green, red and blue dots) and their corresponding fitting curves.

Basic fitting model for regeneration:

$$R_{SH}(t) = A_2 - A_3 \times \exp(-k \times t)$$
$$A_3 = A_2 - R_{SH}(0)$$

Simulation

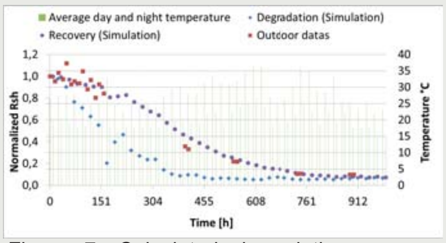

Figure 7: Calculated degradation progress separated in regeneration (purple) and degradation (blue) compared with real outdoor measurements (red) by using a simplified PID model.

Basic fitting model for degradation:

$$R_{SH}(t) = A_1 x \frac{R_{SH}(t-1) - A_1}{1 + \left(\frac{t}{t_0}\right)^p}$$

→ Summary:

By means of a specially designed test box high-resolution day courses of the shunt resistance could be shown for the first time. The analysis revealed a typical day course for sunny days and a strong influence of surface conductivity. For the first time it could also be shown that in addition to the regeneration at night an additional regeneration occurs during the day.
Simulations and long term investigations showed that the edge, in contrast to the inner of a cell, is continuously stressed by a high electric potential and therefore dominates the degradation.
With this in mind a simplified estimate of the degradation curve was developed. For a first validation based on free-field measurements in Berlin, a good agreement has been reached.