Thermal and mechanical loads of PV modules under real world conditions

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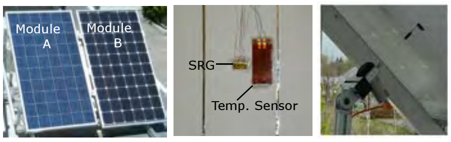
Ch. Hirschl[1], M. Granitzer[1], R. Leidl[2] , L. Neumaier[1], W. Mühleisen[1], A. Plösch[3], M. Spielberger[4], R. Velik[1]
[1] CTR Carinthian Tech Research, Europastr. 4/1, 9524 Villach, Austria
Contact: Email: christina.hirschl@ctr.at, T: +43 4242 56300-260
[2] AIT Austrian Institute of Technology GmbH, A-1220 Vienna, Austria
[3] energetica Energietechnik GmbH, A-9073 Klagenfurt-Viktring, Austria
[4] KIOTO Photovoltaics GmbH, A-9300 St.Veit/Glan, Austria

Abstract

One of the most important topics in the photovoltaic industry is quality assurance and in this context the question what factors cause cell damages and as a consequence reduce long-term energy performance. In this study, the strains on 60 cells PV modules due to wind and temperature are investigated and possibly resulting damages are observed via electroluminescence and thermography measurements. Furthermore, international standard load and hail test are performed.

Experimental setup

Two 60 cells PV modules were equipped with always three temperature sensors and three strain resistance gauges (SRG), mounted on three different silicon cells before lamination. Each of the SRG sensors measures the elongation of a silicon cell inside the PV module in three coplanar directions. From these 3-directional strains, the first principal strain can be determined. The thermal expansion of the silicon is compensated with an additional SRG sensor. In addition, the deflections of the modules are measured with cable pull sensors.

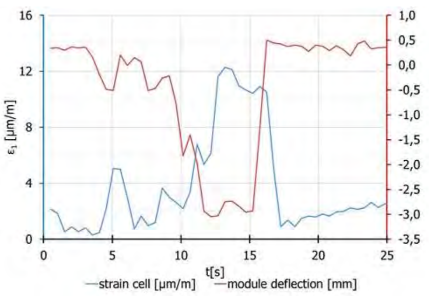


Left: 60 cell PV modules
Middle: The sensor setup
Right: Cable pull sensor

Mechanical loading

The PV modules equipped with the different sensors were installed on a PV test facility in Villach (Austria). As at the location of this facility, the wind strength is low, only a slight deflection of the modules could be observed.

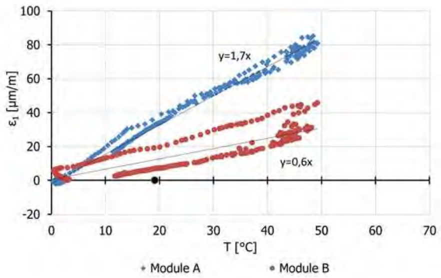
The example below shows that a deflection of three millimetres led to first principal strains in the modules of ε_1=12 µm/m. Compared to the strains during the lamination process (ε_1=230µm/m [Hirschl, PVSEC2012]), these measured strains are negligible.



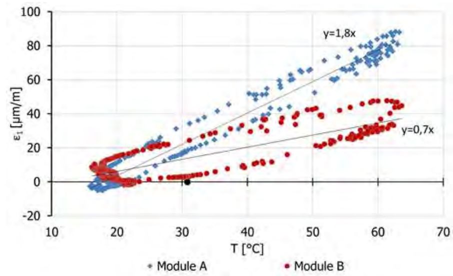
Strain and module deflection due to mechanical loading.

Temperature loading

In comparison to the mechanical loading, the temperature influences the strains in the cells to a much larger extent.



Strains in the PV modules A and B in dependence of the temperature at the 15/5/2012. The black dot indicates again the maximum daily temperature.



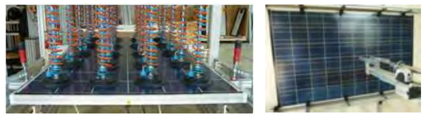
Strains in the PV modules A and B in dependence of the temperature at the 5/7/2012. The black dot indicates again the maximum daily temperature.

The dependence of temperature on strain is linear. However, the slope of the curve depends strongly on the particular build-up of the module and on the position of the sensor.

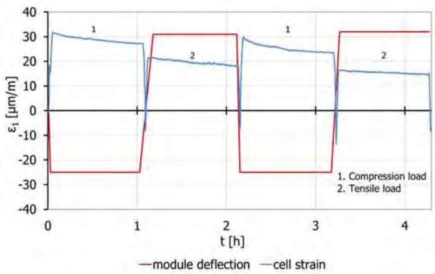
The slope for module A and B differs due to the glass thickness (module A d=4 mm and module B d=3,2 mm). The thinner glass reduces the strain in the cells. For each module, the slope is mainly independent of the maximum daily temperature.

The module specimens were in operation over 5 month (summer) and no cracks and micro cracks due to mechanical and temperature loadings were observed. Even an existing crack did not amplify.

International standard mechanical load and hail test

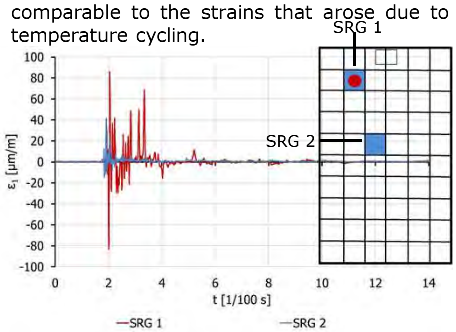


A standard mechanical load tests with 2.400 Pa was performed while the strains and the deflections of the modules were observed during application of tensile and compression pressure.



Cell strain and module deflection of a PV module due to mechanical loading with 2.400 Pa.

Although the maximal deflection of the module reached in average 25mm, the observed strains showed maximal values of only ε_1=32 µm/m, which is low in comparison to strains due to temperature loading in operation (ε_1=80 µm/m) and the lamination process (ε_1=230 µm/m [Hirschl, PVSEC2012]).
The standard hail test was performed with five hailstones impacting on different positions. The highest strains arose when the hailstone directly hits the position where the sensor is placed. The observed strains are comparable to the strains that arose due to temperature cycling.



Strain on a PV module due to hail right besides the SRG 1. The red dot indicates the hail impact.

Conclusions

- Strains during outdoor operation are much smaller than the strains on the cells during lamination [Hirschl, PVSEC2012].
- The maximal strains at 2.400 Pa mechanical load are much smaller than strains during thermal cycling (80°C).
- The maximal strain during hail test is similar (80 µm/m) to the strain due to thermal cycling even if the hail directly impacts on the position where the sensor is placed.
- Thermal and mechanical loading due to temperature change and hail have at least equal consequences on the strains in the cells.

Acknowledgements

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