The Temperature as the Real Hot Spot Risk Factor at PV-Modules

Autors:

Wendlandt, Stefan; Giese, Anne; Drobisch, Alex; Tornow, Dirk; Hanusch, Matthias; Berghold, Juliane; Krauter, Stefan; Grunow, Paul

Abstract/Summary:

The hot spot stability is part of the product qualification test sequence of PV modules. Therein the major challenge is the selection of the cell with the highest hot spot risk. Currently, the electrical properties of the cells are used as selection criteria, e.g., the highest threshold currents at the point where the bypass diode turns “on” and/or cells with maximum and minimum values for the parallel resistance. The weak point of this procedure is, that the cells with a hot spot risk are not ranked by temperature, which may cause a hot spot event. The paper presents the results of a comparison between the electrical and thermal properties of shadowed solar cells in PV modules. Finally, an improved hot spot test sequence is presented that shows a better prediction probability for this specific module failure.

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

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Temperature as the Real Hot Spot Risk Factor at PV-Modules

Stefan Wendlandt[1,2], Anne Giese[1], Alex Drobisch[1], Dirk Tornow[1], Matthias Hanusch[1], Juliane Berghold[1], Stefan Krauter[1,2] and Paul Grunow[1]
[1] Photovoltaik Institut Berlin AG (PI Berlin), Wrangelstr. 100, D-10997 Berlin, Germany
PV Module Technology: Testing | Consulting | Development | Research, e-mail: wendlandt@pi-berlin.com
[2] University of Paderborn, Department of Electrical Engineering, Institute for Sustainable Energy Concepts, Pohlweg 55, D-33098 Paderborn, Germany

→ Approach

One of the most crucial issues for pv modules is the thermal stability during shading situations. The hot spot stability is part of the product qualification test sequence of pv modules. Therein the major challenge is the selection of the cell with the highest hot spot risk. Currently, the electrical properties of the cells are used as selection criteria, e.g., the highest threshold currents at the point where the bypass diode turns “on” and/or cells with maximum and minimum values for the parallel resistance. The weak point of this procedure is, that the cells with a hot spot risk are not ranked by temperature, which may cause a hot spot event. The paper presents the results of a comparison between the electrical and thermal properties of shadowed solar cells in pv modules. Finally, an improved hot spot test sequence is presented that shows a better prediction probability for this specific module failure.

Selection of the risked cell

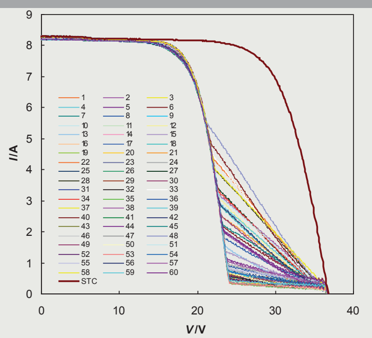

Fig. 1: The figure shows the *IV* characteristics of a shadowed and unshadowed (brown line) standard c-Si module. All cells in reverse bias are strongly influenced by the parallel resistance.

Leakage current vs. temperature

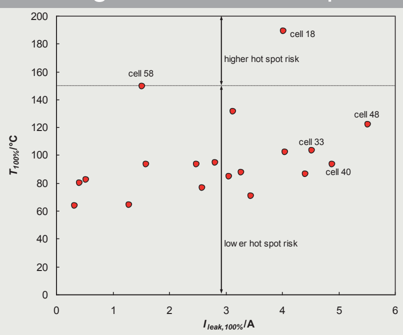

Fig. 2: No clear correlation between the leakage currents and the hot spot temperature is obviously. In this case the panel passed the hot spot test according to the IEC 61215: Ed.2 because the cells with higher hot spot risk have not been tested / selected.

New test sequence

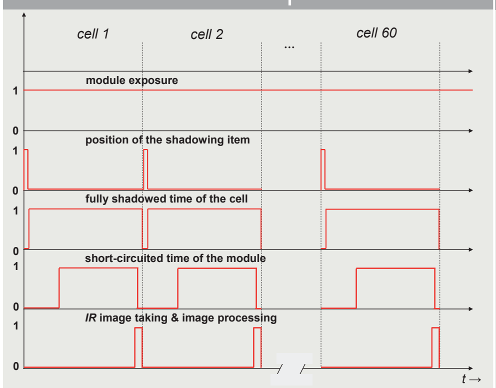

Fig. 3: The figure displays the rapid thermal test sequence for selection the cell with the highest hot spot risk. In the sequence cell after cell is fully shadowed and the remaining cells were radiated. The shadowing time of the cells lies at 50 sec. In this time the module is for 30 sec short-circuited and at the end of this time an IR image has been taken.

Rapid thermal hot spot analysis

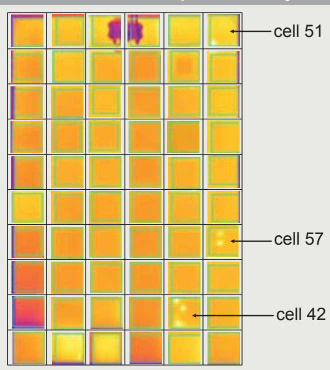

Fig. 4: The figure displays the measured IR images of each cell following the test sequence in figure 3. From the images it becomes clear that the module has three cells which are hot spot susceptible. All these three cells have a different number of strong hot spots. Thereby the cell # 51 has got one hot spot with T_{max} = 83.5°C which is the highest temperature of the three marked cells.

Validation of short to long time test

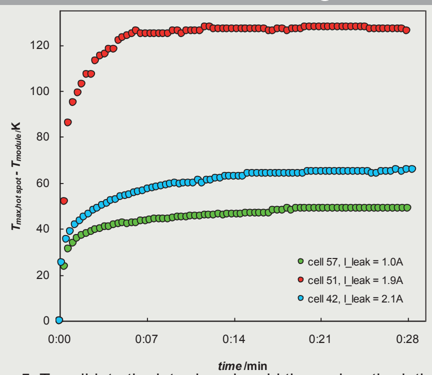

Fig. 5: To validate the introduced rapid thermal method, the three hot spot risked cells were fully shadowed and the remaining cells were radiated until a stable module temperature was reached and short circuited operating. The figure shows the time temperature profile of the cells. The temperature is the difference of the maximum hot spot temperature minus the module temperature displayed.

Temperature data analyse

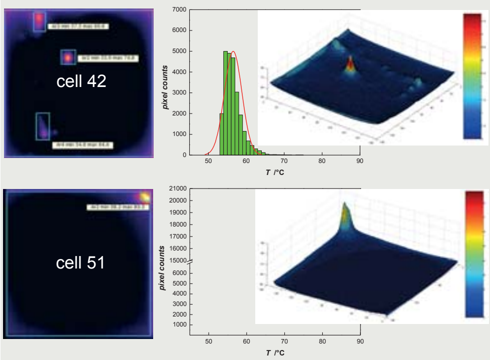

Fig. 6: By analyse the temperature data matrix it can be said that cells with a higher number of hot spots have a lower maximum temperature, a wider temperature distribution and a shift of the mean temperature to higher values. Furthermore cells with a higher number of hot spots show smaller local temperature gradients.

Breakdown ranges

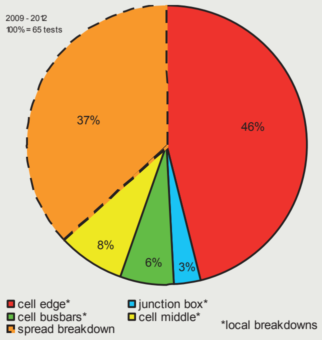

Fig. 7: The diagram made clear that the breakdowns can be divided into two types: *Type 1*: spread breakdowns and *Type 2*: local breakdowns at the cell. The local breakdowns can be subdivided into the cell edge the cell bus-bars, the junction box and the cell middle. From all hot spot tests done at PI Berlin 23% failed (mostly local breakdowns). The main fail reason was the lost of electrical isolation through melted foils.

→ Conclusions

- **This paper presents a new procedure for selecting hot spot risked solar cells in pv modules. The procedure is based on the using of an IR camera to detect the temperature of the investigated solar cell. The used criterion is the maximum temperature after 30 sec from fully shadowed solar cells.**
- **The comparison of the measured temperature after 30 sec and the stable ones shows a well correlation.**
- **The analysis of the measured temperatures has shown that a direct correlation between the maximal temperature, the temperature distributions, the leakage current and the number of hot spot exist. The correlation is given for example by a less number of hot spots and a high leakage current this results in a high maximal temperature and smaller average cell temperature at the temperature distribution.**
- **The hot spots were divided into two types: the ones with spread and the ones with local breakdowns. The subdivided of the local breakdown has been shown that mostly the local breakdowns are at the cell edge. A reason for that can be bad pn junction insulation during the cell production.**

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