Comparison of Hot Spot Investigations of Photovoltaic Modules at Laboratory and Field Conditions

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Abstract/Summary:
In PV applications solar modules are not always fully illuminated but occasionally partly shaded. In this case the partly shaded cells potentially operate in reverse bias of the current voltage characteristic. For this reason the cells heat up and in the worst case the polymer foils can melt. For studying the thermal stability of a module the standardized hot spot test can be applied. The standardized conditions of the hot spot test allow some degrees of freedom like the module temperature of the non shadowed module area. In this work, the influence of the module temperature and of the radiation level on the maximum hot spot temperature will be analyzed indoor. Then, an outdoor hot spot tests will performed. Finally, this paper will show a worst case comparison between the in- and outdoor hot spot test conditions.

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

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Comparison of Hot Spot Investigations under Laboratory and Field Conditions at Photovoltaic Modules

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Approach

Because of various obstacles the solar radiation can not fully radiate photovoltaic modules. The cells of the partly reduced radiation area operate in reverse bias of the current voltage characteristic. For this reason the cells heat up and in the worst case the polymer fcol can melt. For studying the thermal stability of a module the standardized hot spot test can be applied. The standardized conditions of the hot spot test allow same degrees of freedom like the module temperature of the non shadowed module area. In a first step, the influence of the module temperature on the maximum hot spot temperature will be investigated indoor. Afterwards outdoor hot spot tests will performed. Finally this paper will show a worst case comparison between the indoor and outdoor hot spot test conditions.

Thermal indoor hot spot analysis

Outdoor worst case conditions at cloudy days:
- critical hot spot temperatures could be measured over a wide range of shadowing rates (in this case: sr = 100...42%)

Fig. 3: The study of module temperature and module irradiance on the hot spot risk shows that the highest hot spot temperature occurs at 1000 W/m² and a module temperature of 75°C. The analysis has been done indoor and for a cell shadowing rate of 100%.

Fig. 4: The hot spot temperature corrected to the ambient temperature as a function of the irradiance levels and module temperatures also corrected to the ambient temperature for a cell shadowing rate of 100%. At higher irradiance levels and higher module temperatures the highest hot spot temperature can be observed.

Electrical indoor hot spot analysis

Outdoor worst case conditions at clear sky days:
- module operating in short-circuit or operating at the mpp close to the short circuit
- partly cell shadowing (depending on the cell properties)
- high module irradiation (> 900 W/m²)
- high module temperature (> 90°C)
- irradiation of the hot spot at partly shadowed cells

The determined indoor worst case conditions are mostly comparable to the IEC standard.

Outdoor hot spot analysis (100%)

Fig. 5: Similar to figure 4 here are the hot spot temperatures for a cell shadowing rate of 75% are shown. The run of the curve itself is similar to the shadowing rate of 100%. Due to the reduced shadowing area the generated photocurrent increased the power loss of the cell. Hence, the higher hot spot temperature can be explained.

Outdoor hot spot analysis (75%)

Comparison of worst case conditions

Outdoors worst case conditions at cloudy days:
- mpp operating close to short circuit
- partly cell shadowing (depending on the cell properties)
- high module irradiation (> 900 W/m²)
- high module temperature (> 90°C)
- irradiation of the hot spot at partly shadowed cells

The determined outdoor worst case conditions are mostly comparable to the IEC standard.

Conclusions

- The indoor hot spot testing has shown that the hot spot should be investigated at partly shadowed cell situations. Furthermore it could be shown that the module temperature and the irradiation have an impact on the hot spot temperature.
- At cloudy outdoor days and shadowing rates between 50...32%, a module mismatch could be observed. Based on if the module can operate at the mpp closer to the short circuit (= higher hot spot risk).
- At clear sky outdoor days the following worst case hot spot conditions could be determined: Ee > 600...1000 W/m², Tmodule – Tamb > 20°C and an 35%, dimulating a bad mppt-logic. The module itself should be operate in short circuit or at the mpp closely to the short circuit (low-resistance).
- As long as shadowed pv modules operate in the mpp close to the short circuit, indoor and outdoor hot spot tests are comparable. By module operating at mpp closely to the open circuit voltage the hot spot temperature is stiffer to the standard indoor test.

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Fig. 1: It is more hot spot critical if the module operates at local mpp instead of operating the global mpp at module temperature > 40°C. At module temperatures ≤ 40°C and module operating at the local mpp the hot spot risk becomes higher. In this case the cell shadowing rate was 50%.

Fig. 2: The hot spot temperature increases with the irradiation level. This can be explained with the change in conductivity under irradiation and temperature. The highest hot spot risk could be determined if the hot spot is fully irradiated (>30%).