Temperature Coefficients Measured pre-post Thermal Stress Testing and Comparison of Four Measurement Procedures

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Introduction The IEC 61215 standard requires that module performance be measured post stress testing to observe any degradation in power output. However, the standard does not require that temperature coefficients be measured post stress testing. Here we present the temperature coefficients of four different mono-crystalline silicon module types measured before and after IEC 61215 stress testing. Modules are selected to undergo either Damp Heat (DH), Thermal Cycling (TC200), or Humid Freeze (HF10) testing.

Additionally, the temperature coefficients of a non-stressed mono-Si module are measured using four separate procedures. Three procedures are done in a solar simulator wherein three different heating and cooling profiles are used. The fourth set of temperature coefficients are measured outdoors per a procedure developed by Sandia National Laboratories. Temperature profiles are varied in the solar simulator to observe if results differ when the cell and back sheet temperatures are uniform. We compare these four procedures to see if any significant differences in temperature coefficient values arise due to the measurement method used.

Procedures Temperature coefficients of ten mono-Si modules (four types from three manufacturers) were measured for the pre-post thermal stress analysis. Four of these modules (one from each type) were chosen as controls and two to three modules from each type underwent a specific IEC 61215 stress test. The temperature coefficients were measured per IEC 61215 § 10.4 with a class AAA+ h.a.l.m. solar simulator. An Espec climate chamber was used for the thermal stress tests.

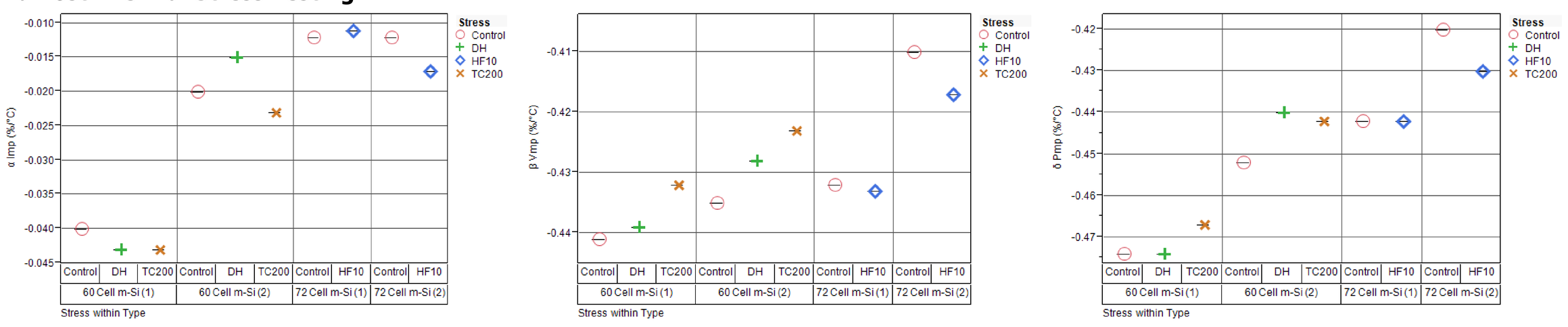

Espec Climate Chamber (left) and h.a.l.m Class AAA+ Solar Simulator (right)

For the second part of this study, we measured the temperature coefficients on a non-stressed mono-Si module using four different procedures:

1. **Indoor Flasher Linear Heat up** - Heat the test bed from 25-65 °C, with I-V measurements every 2 °C.
2. **Indoor Flasher Temperature Stabilization** – Same as Procedure 1, but allow the back sheet temperature to remain constant for 5 minutes before measurement.
3. **Indoor Flasher Cool Down** – Cool the test bed from 65-35 °C, with I-V measurements every 1 °C.
4. **Outdoor per Sandia Labs** – Module is heated naturally by the sun from a shaded state to a minimum temperature increase of 25 °C.

Results

Pre and Post Thermal Stress Testing



Variability plots showing temperature coefficients for Imp (left), Vmp (center), and Pmp (right) in absolute units. The stress received is indicated within the module type.

Four Temperature Coefficient Measurement Procedures

Tester and Procedure	Imp (%/C)	Isc (%/C)	Vmp (%/C)	Voc (%/C)	Pmp (%/C)
Indoor Flasher - Linear Heat up	-0.03	0.03	-0.41	-0.31	-0.43
Indoor Flasher - Temperature Stabilization	-0.03	0.03	-0.42	-0.31	-0.44
Indoor Flasher - Cool Down	-0.04	0.02	-0.41	-0.31	-0.45
Outdoor Curve Trace - Sandia Labs	-0.05	0.04	-0.50	-0.38	-0.56

Summary table showing the temperature coefficients of a 250W mono-Si module measured with four different procedures.

- No significant differences are seen between the control and stressed modules.
- The largest shifts are seen in the Pmp temperature coefficients (< 0.01%/ °C), which are primarily driven by changes in Vmp.
- No differences are seen pre and post stress, likely because a module's temperature sensitivity arises from the intrinsic properties of the semiconductor's band gap, which likely remain intact after the stress test.
- All three methods done within the class AAA+ solar simulator show good agreement.

Conclusions

- Module temperature coefficients did not change after DH, TC200 and HF10 tests.
- The Outdoor Sandia Labs procedure was the only measurement method significantly different than the others. This delta is being studied in order to improve the outdoor method and results will be presented at PVSC 40.
- There was good agreement between the Indoor Linear Heat up and Temperature Stabilization methods, which reduces some concerns over the delta between cell and back sheet temperature during testing.

References

- D. King, B King "Measurement of PV Module Temperature Coefficients" Sandia National Laboratories, Albuquerque, NM, 2013.
- IEC 61215, Edition 2.0, 2005
- IEC 60904, Photovoltaic Devices, Parts 1-10
- K. Emery, et al., "Temperature Dependence of Photovoltaic Cells, Modules, and Systems" in *25th IEEE PVSC,* 1996