SAND2018-6156C

Sandia National Laboratories

PV Lifetime Project: Measuring PV Module Performance Degradation: 2018 Indoor Flash Testing Results

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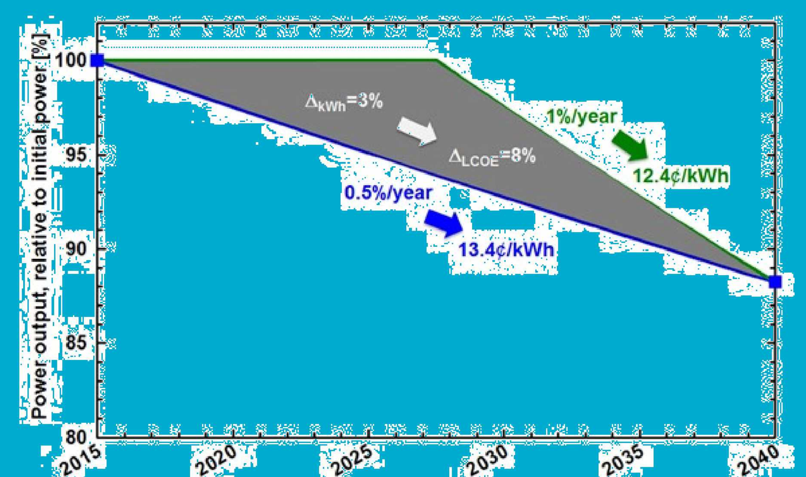
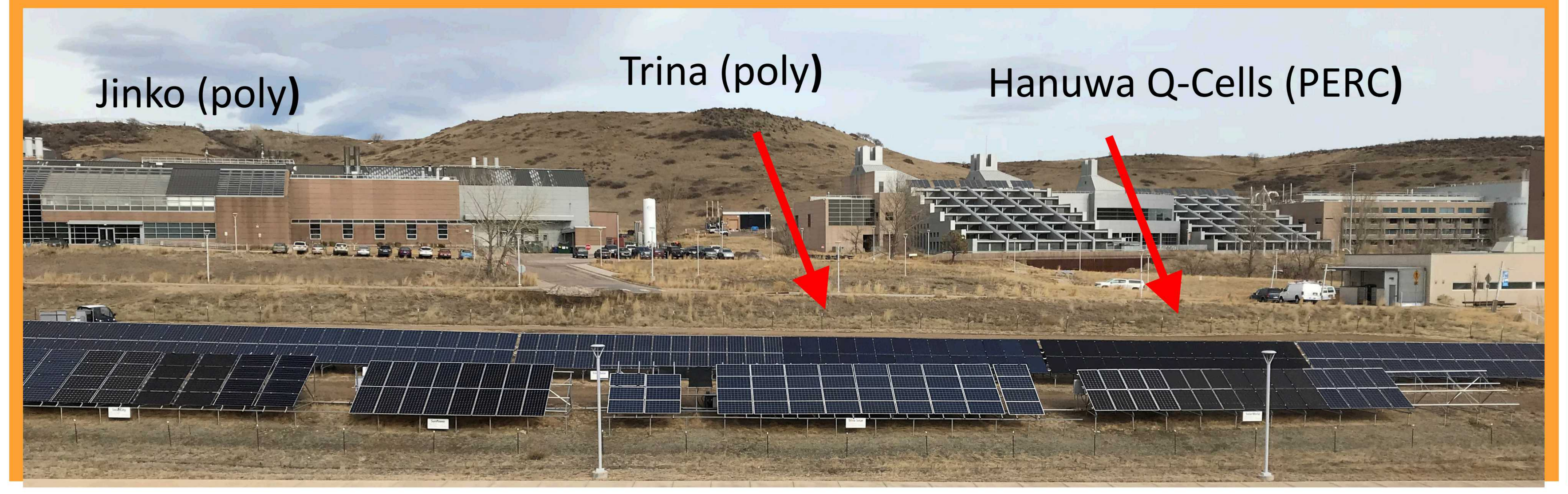
Introduction



Abstract — Photovoltaic (PV) module and system performance degradation is being measured by periodic flash testing of fielded PV modules at three sites. As of early 2018, results from modules fielded in New Mexico and Colorado are now available. These data indicate that module degradation varies significantly between module types and can also vary between modules of the same model. In addition, degradation rates for some module types appear to vary over time. Great care is made to control for stability and repeatability in the measurements over time, but there is still a +/-0.5% uncertainty in flash test stability. Therefore, it will take several more years for degradation rate results to be known with higher confidence.

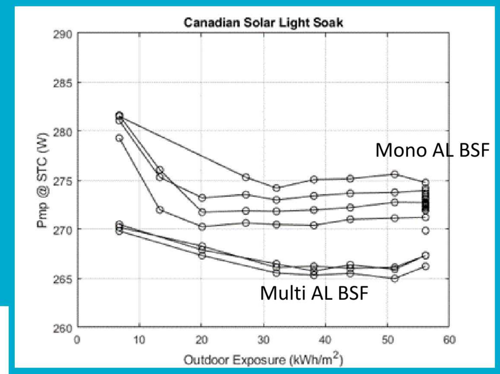
Due to the typically slow pace of PV module degradation in operation, often less than 1% per year [1], as well as variations in the operating and test conditions, any resulting differences in degradation rate are difficult both to measure and compare.

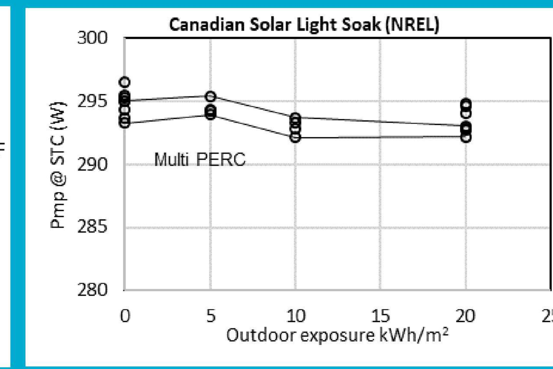


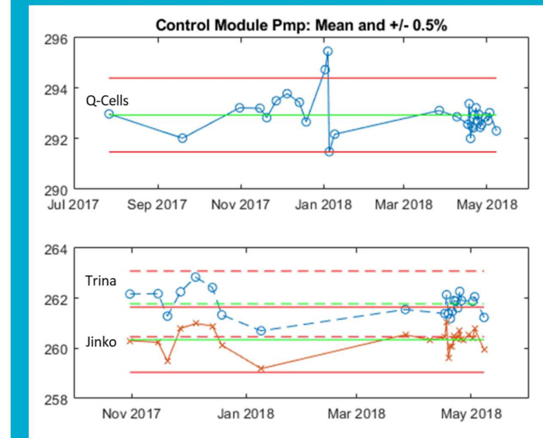
Flasher Stability and Initial Degradation

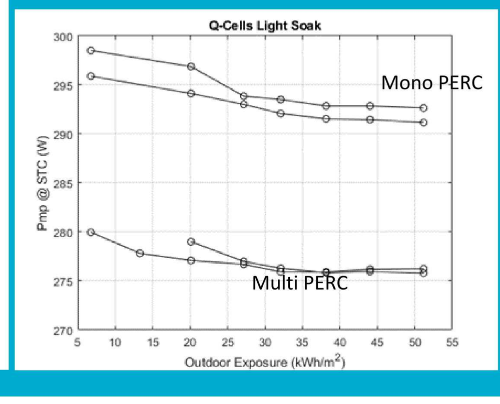
LID can cause initial degradation in multi-crystalline and mono-crystalline silicon modules within the first 10 kWh/m^2 of light exposure through formation of boron-oxygen defects [2]. A selected number of modules from Canadian Solar and Q-Cells were monitored in NM and Colorado for degradation in the first few days of light exposure. The standard aluminum back-surface field (Al-BSF) Canadian Solar modules deployed in NM show a larger initial loss of about -3.3% for the monocrystalline technology, compared with -1.5% for multi-crystalline. This difference is to be expected, with LID known to more strongly affect mono Al-BSF vs multi-crystalline cells [3]. LID was also monitored in four additional multi-crystalline Al-BSF module types in Colorado, showing initial loss of -0.4% for Trina TSM255 and TSM260 module types, and -0.5% — -1.5% loss in Jinko JKM260 and JKM265 types, respectively (not shown).

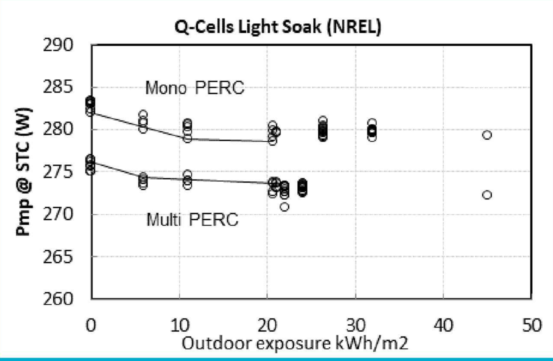
The stability of the flash simulators at each lab was monitored by regularly measuring control modules that are stored indoors. We found that we could maintain approximately +/- 0.5% stability in power.









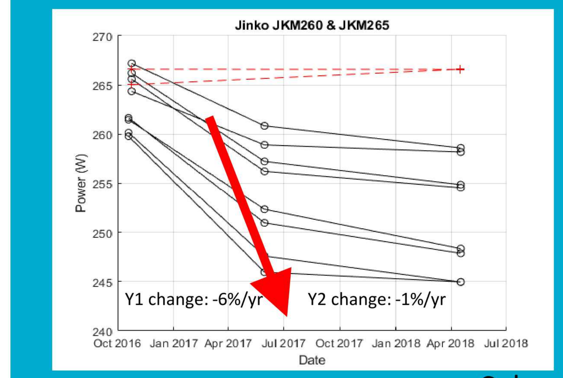


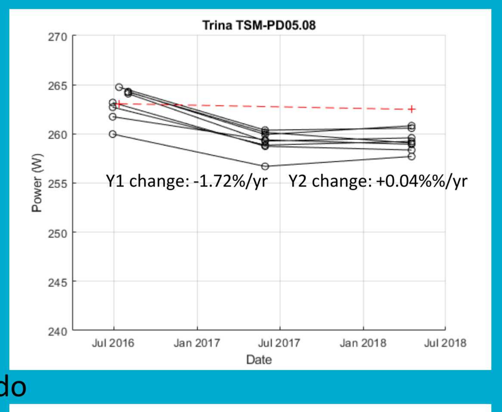
Modules Under Test

Site	Manufacturer	Model	Technology	# of modules	Installation Date
NM	Trina Solar	TSM-PD05.08 260W	poly-Si	56	Jun-16
NM	Jinko Solar	JKM260P-60 260 W	poly-Si	56	Jun-16
NM	SolarWorld	SW 245W Mono	mono-Si	21	2013
NM	Canadian Solar	CS6K-270P 270W	poly-Si	48	Oct-17
NM	Canadian Solar	CS6K-275M 275W	mono-Si	48	Oct-17
NM	Hanuwa Q-Cells	Q.Plus BFR-G4.1 280W	poly-Si PERC	48	Oct-17
NM	Hanuwa Q-Cells	Q.Peak BLK G4.1 290W	mono-Si PERC	48	Oct-17
NM	Panasonic	N325SA16 325W	HIT Mono	48	May-18
NM	LG	LG320N1K-A5 320W	N-type Si	48	May-18
CO	Trina Solar	TSM-PD05.08 255W	poly-Si	28	Sep-16
CO	Trina Solar	TSM-PD05.08 260W	poly-Si	28	Sep-16
CO	Jinko Solar	JKM260P-60 260W & 265W	poly-Si	56	Sep-16
CO	Hanuwa Q-Cells	Q.Plus BFR-G4.1 280W	poly-Si PERC	28	Oct-17
CO	Hanuwa Q-Cells	Q.Peak BLK G4.1 290W	mono-Si PERC	28	Oct-17
CO	Canadian Solar	CS6K-300MS 300W	mono-Si PERC	28	Jun-18
CO	Panasonic	N325SA16 325W	HIT Mono	30	Jun-18
CO	LG	LG320N1K-A5 320W	N-type Si	28	Jun-18
			Total	675 modules	

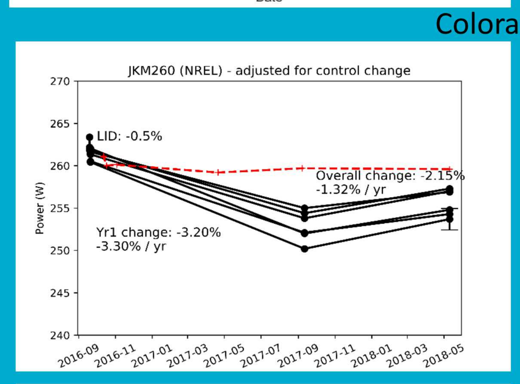
Preliminary Results

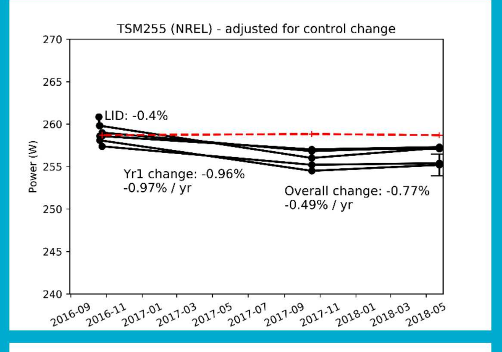
New Mexico

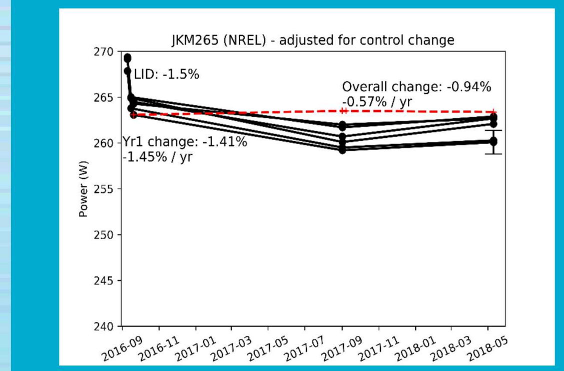


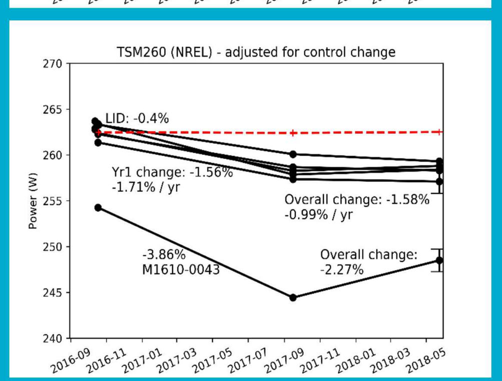


Colorado





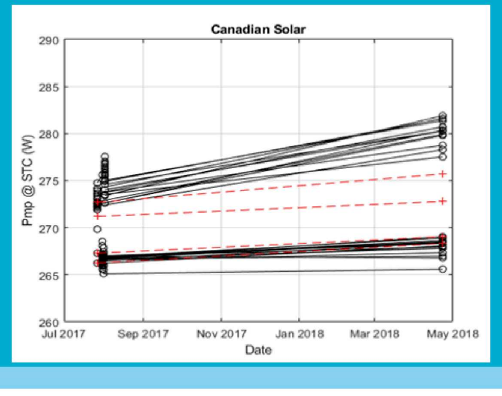




Degradation of Trina and Jinko modules (AL-BSF cells) appears to show evidence of rapid initial degradation during the first year of field exposure and some possible recovery (or at least stability) in year 2. Rates of power loss vary both between different module types but also within a population of modules of the same type.

Possible recovery during year 2 may be the result of post-LID regeneration (possibly of LeTID [5]), which may be sensitive to climate factors at each site. Further monitoring will be required to see if such recovery continues.

New Mexico



Canadian Solar fielded and control modules in NM appear to increase in power over the first year. This may be a recovery of the initial ~3% LID losses

Conclusions

- There is significant variation in the initial unexposed power rating of modules compared with their nameplate, however the uncertainty in the absolute power is considerably higher (approx. +/-2% or higher) than for the repeatability (+/-0.5%). Some modules in our test appear to be "under-rated" (measured power > nameplate) while others are near or over nameplate. This is important since degradation in the context of a warranty is relative to the nameplate power. Module that are "under-rated" can degrade further before a warranty claim can be made. The reported degradation rates here are relative to the initial flash test after light soaking stabilization.
- Initial LID of modules was measured a sample of modules. In NM, Q-Cells and Canadian Solar modules showed about 1.5% and 2% LID, respectively (+/- 0.5% uncertainty). In CO, Q-Cells and Canadian Solar showed about 1-1.5% decrease. The two different power bins of Jinko in CO showed very different LID with the 260W modules experiencing a 0.5% decrease and the 265W modules experiencing a 1.5% decrease.
- Degradation in Pmp measured during the first year of field exposure varied significantly. This is possibly because of LeTID, whose effects can be mitigated by careful treatment of cells, but otherwise can cause degradation in the first ~1000 hours of system operation [5]. While typically associated with PERC cells, LeTID has been identified in standard Al-BSF multi-crystalline cells as well [6]. Other characteristics of LeTID include a temperature dependence in both the speed of degradation, and the final degradation amount, which might help explain some differences seen between CO (cooler climate) and NM (hot climate). LeTID is also recoverable, on timescales from days to years, depending on the temperature and kinetics of the defect [5]. This can help explain some of the recovery in power seen in NM and CO for multiple module types.
- For the systems for which we have data from the second year of field exposure, degradation rates appear to have slowed down. In NM, Trina Solar modules have no measurable degradation. Jinko Solar modules degraded by a mean of 1% in year 2. In CO, Jinko Solar 260W modules appear to have increased in year 2 for both power bins, but these increases are near the measurement uncertainty.

References

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SAND2018-5603