



MODULE LIFE-CYCLE TESTING PLAN

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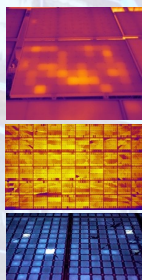
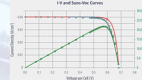


1. Goals

- Minimize defects in modules and module degradation rates
- Reduce “finger pointing” when problems arise
- Reduce investor and insurer risk
- Provide better feedback to investors and insurers to incentivize the more durable technologies

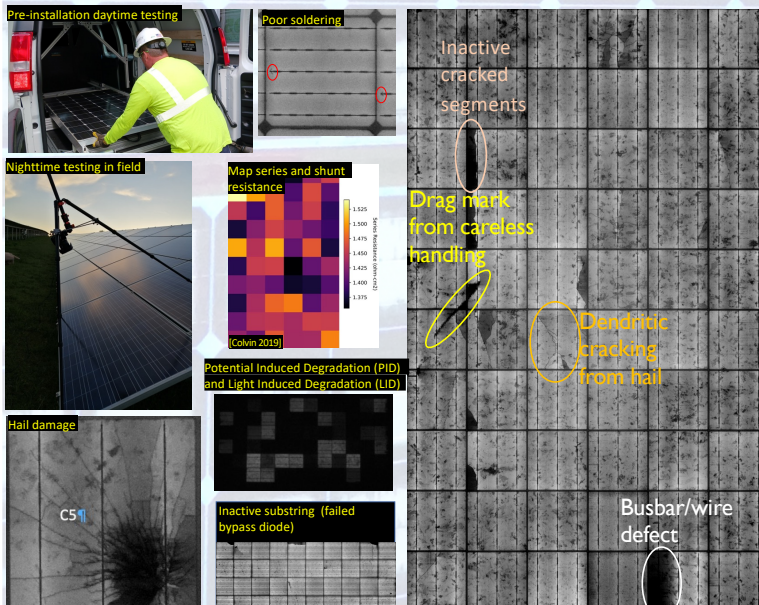
2. What is Life-Cycle Testing?

- Define how and when modules will be tested and the consequences and responses should defects be found BEFORE SIGNING THE CONTRACT
- IV Testing: Current-voltage scans to measure module power
 - Well controlled in the factory with a solar simulator
 - Less accurately outdoor using the sun at varying irradiances and temperatures
- Thermal IR: Infrared imaging typically from a drone or aircraft, where variations in the temperature of cells, substrings in a module, and entire modules can point out various problems (e.g. – failed bypass diodes, hotspot cells from cracks or partial shading)
- EL Testing: Electroluminescence scans to image a variety of defects (e.g. – cracks, Potential Induced Degradation)
- UVF Testing: Ultraviolet Fluorescence scans to image a variety of defects. A relatively new technique (see section #4)

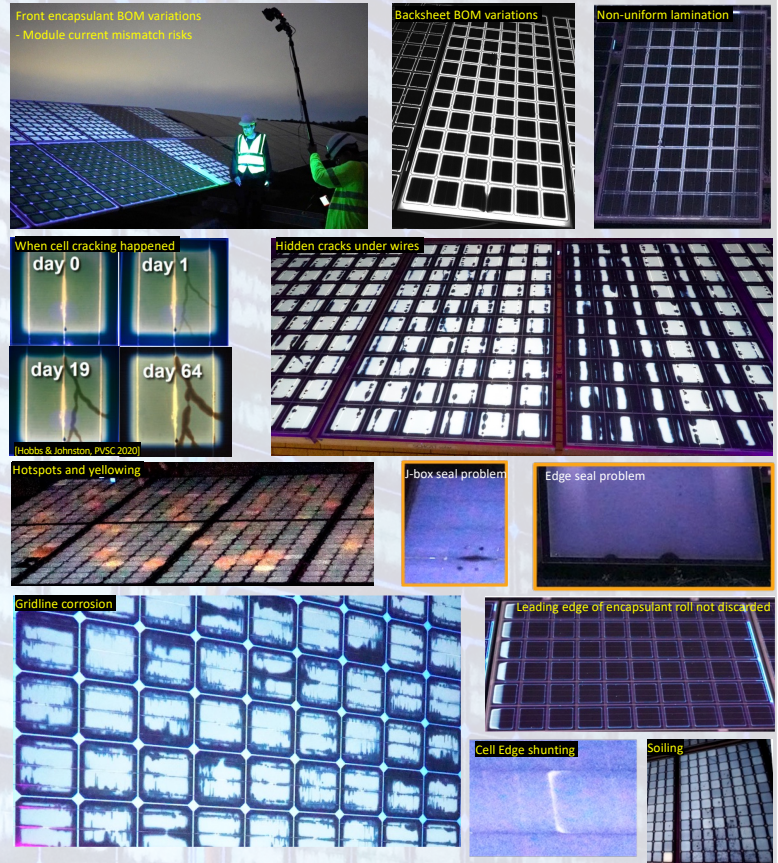


Testing Occasion	Thermal IR	UVF	EL	IV	Comments
At the factory		X	X	X	Demand data from manufacturer. Verify testing process, acceptance criteria, and quality before signing.
Off truck -sampling			X		Sample each truckload. Test more from damaged pallets
After installation - sampling			X	X	Catch bad operator handling early in project (e.g. – drag mark cracks from backsheet scratches)
Periodic O&M	X	X	X	X	Thermal IR & UVF inform where to do EL & IV
Prior to Warranty End	X	X	X	X	“
Change of ownership event	X	X	X	X	“
After catastrophic event	X	X	X	X	Do UVF within 2 months to tell if new damage
End of life/ Recycling	X	X	X	X	

3. What Can Electroluminescence Tell Us?



4. What Can UV Fluorescence Tell Us?



5. Example: What Should I Do After a Hailstorm?

- UVF test within first month if possible
 - Width and darkness of dark lines can show which cracks are old vs new; otherwise
- Thermal IR and RGB scan entire plant looking for broken glass, hotspot cells, and other problems
- UVF scan strings with problems from Thermal IR
- EL scan modules with problems from UVF and sample all modules
 - Examine crack patterns to determine whether caused by hail
- Recycle modules with broken glass, dead substrings, and low EL grades

6. What new developments should we expect?

- Drone UVF: throughput > 5000 modules/hour
- Machine learning for automatic defect detection
 - Classify into different defect categories including the origin of the damage (e.g. – hail, installer damage, manufacturing)
 - Classify into different quality and risk categories based on data from environmental chamber testing data for that module technology
- Insurance rates that are technology dependent based on durability data
 - This will drive adoption of the more robust products

