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PV Module Degradation Root Cause Analysis: Case Study

Date: 5 November 2020
Distribution: All Energy Australia
Author: George Touloupas, Director
Department: Technology and Quality
Version: 1.1

CEA Snapshot

Clean Energy Associates is a technical advisory and quality assurance company that provides unrivaled insight into the solar PV and storage manufacturing industries to ensure the success of solar PV and storage projects worldwide.

1,000+

Years of industry experience

135+

Professionals

85+

Engineers

12+

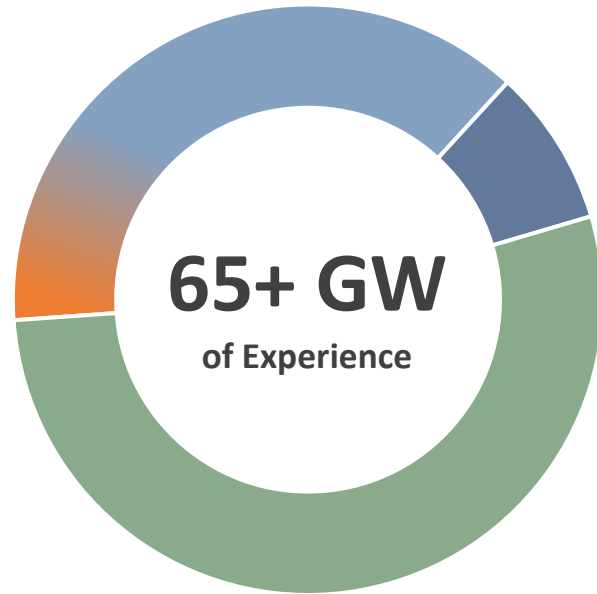
Year track record

12

Countries with physical presence

Supply Chain Management

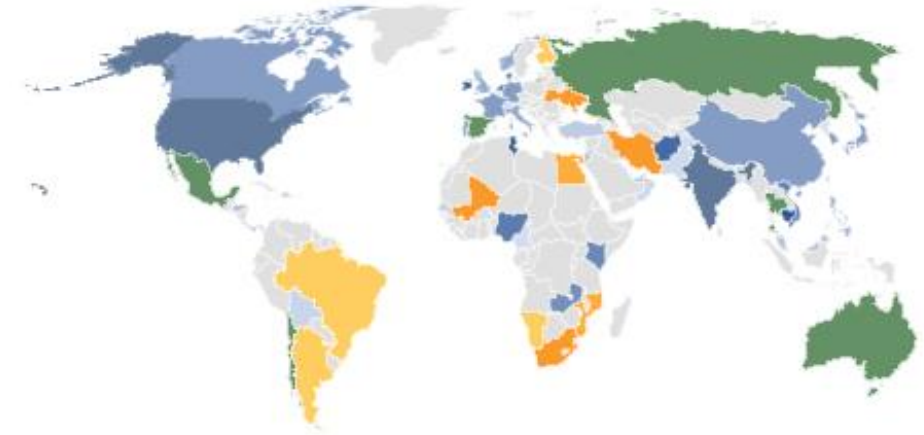
Market Intelligence



Engineering Services

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Client engagements in **55+** countries



Engagements at **350+** solar and storage factories worldwide

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What is PV Module Degradation? (1)

Degradation is typically defined as the difference between the initial Pmax and the Pmax measured at a point in time after the module has been installed and operated.

There are 2 ways to define it:

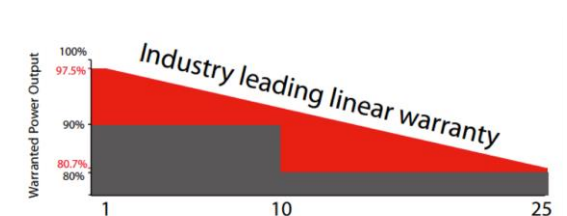
1. Nominal Power @ STC – Pmax @ STC (measured at a point in time)
2. Pmax @ STC (factory) – Pmax @ STC (measured at a point in time)

Manufacturers **only** accept definition #1 as base for warranty claims.

As PV modules are typically produced in 5 W bins with positive tolerance, the actual “flashed” Pmax of a production module **should** be higher than the Nominal Power, by an average of ~2-3 W (may be higher in some cases, e.g. when extra tolerance has been agreed, or when low power cells are not available).

Typical warranties start with a steep first year maximum degradation (~2.0% - 2.5%), with immediate effect, mostly due to LID after exposure of the PV module to light and explained by the forming of Boron-Oxygen defects in Boron doped cells.

From the 2nd year on, a constant yearly degradation (~0.7% - 0.4%) comes into play.



What is PV Module Degradation? (2)

The measured Pmax value of a PV module is subject to a measurement uncertainty.

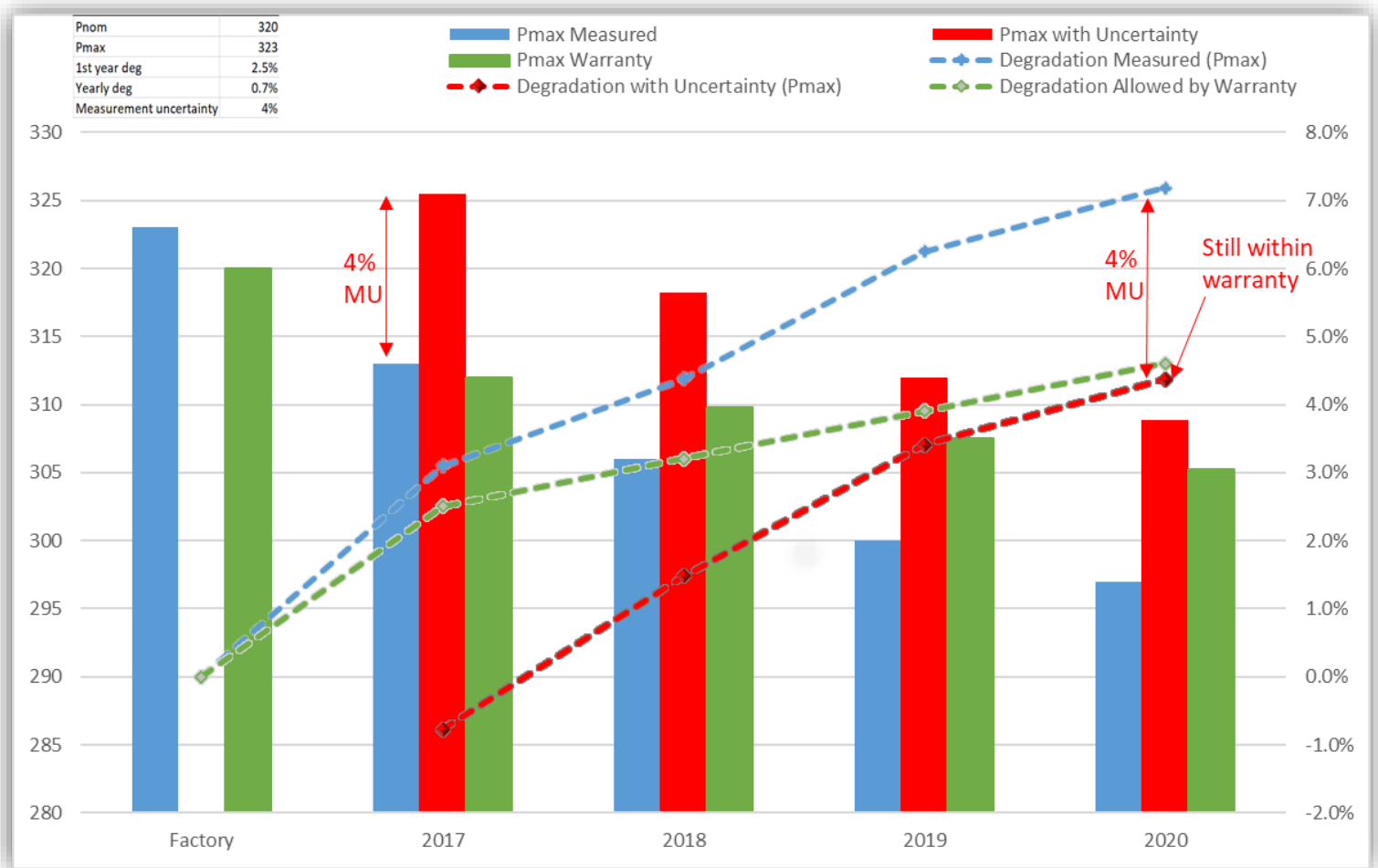
Measurement (IV tracing) in the field has higher uncertainty than measurement in a controlled lab environment.

Manufacturers request that this measurement uncertainty is added to the measured Pmax values.

This practically means that the measurement uncertainty value is “lost” from any potential warranty claim.

Modules with degradation higher than the maximum warranted value, can still be deemed as within warranty by applying the warranty clauses on “testing equipment tolerance”.

The actual power shall be determined for verification under STC conditions only. The measurement method is either carried out by [redacted] measurement facilities or [redacted] recognized 3rd-Party test institutes. Testing equipment tolerance will be applied to all actual power output measurements. In the event of a negative deviation of actual performance from the warranted output, [redacted] shall at its



Source: CEA, example of power measurement to identify degradation

Types of Module Degradation

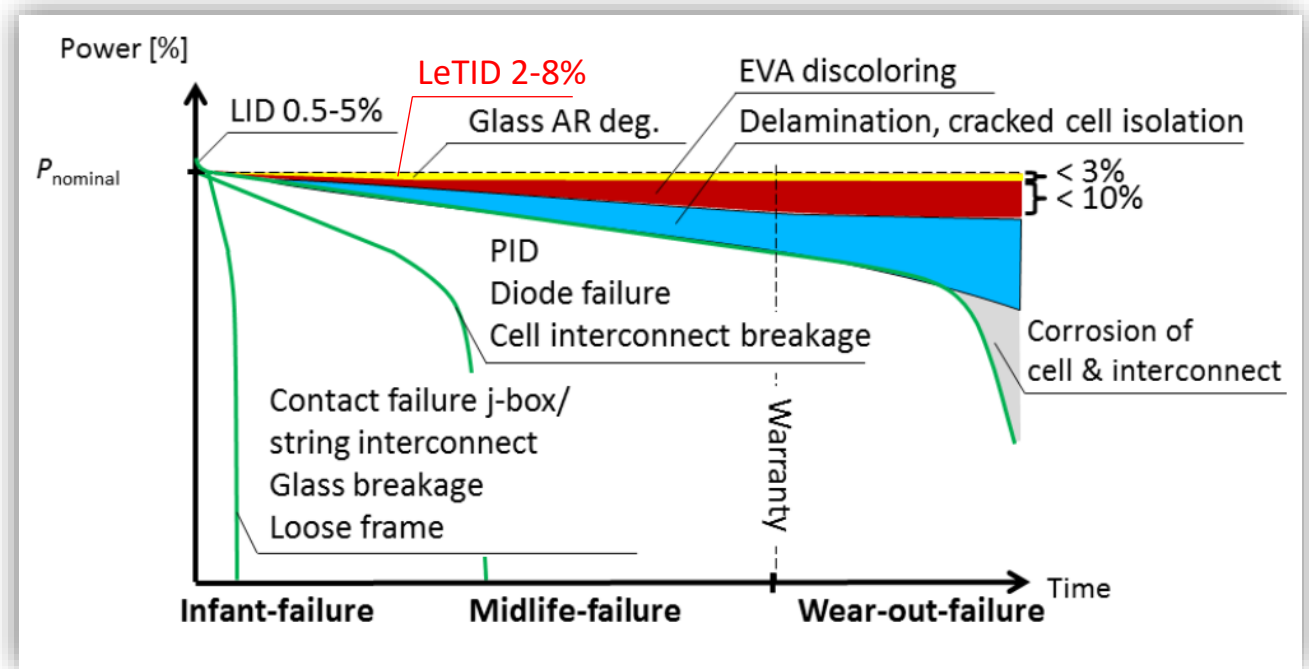
PV modules can degrade from many causes. Many of these are easy to identify, especially if they are accompanied with visual effects, and might be straightforward to claim if they fall under workmanship or serial defect warranty clauses.

However, some types of degradation, such as LeTID (Light and elevated Temperature Induced Degradation) are more difficult to diagnose and include in a warranty claim.

PID, LID and LeTID are typically not considered manufacturing or serial defects and can only be addressed under the umbrella of the limited power output warranty, with all the drawbacks regarding Pmax measurement uncertainty discussed previously.

This has many challenges to the buyer, as diagnosis and agreement with manufacturer on sampling and testing details can be hard to negotiate.

Typically, the buyer takes up the costs, so, any actions and tests should be carefully designed to achieve solid outcomes.



Source: IEA PVPS 2013, LeTID added

Case Study: LeTID (1)

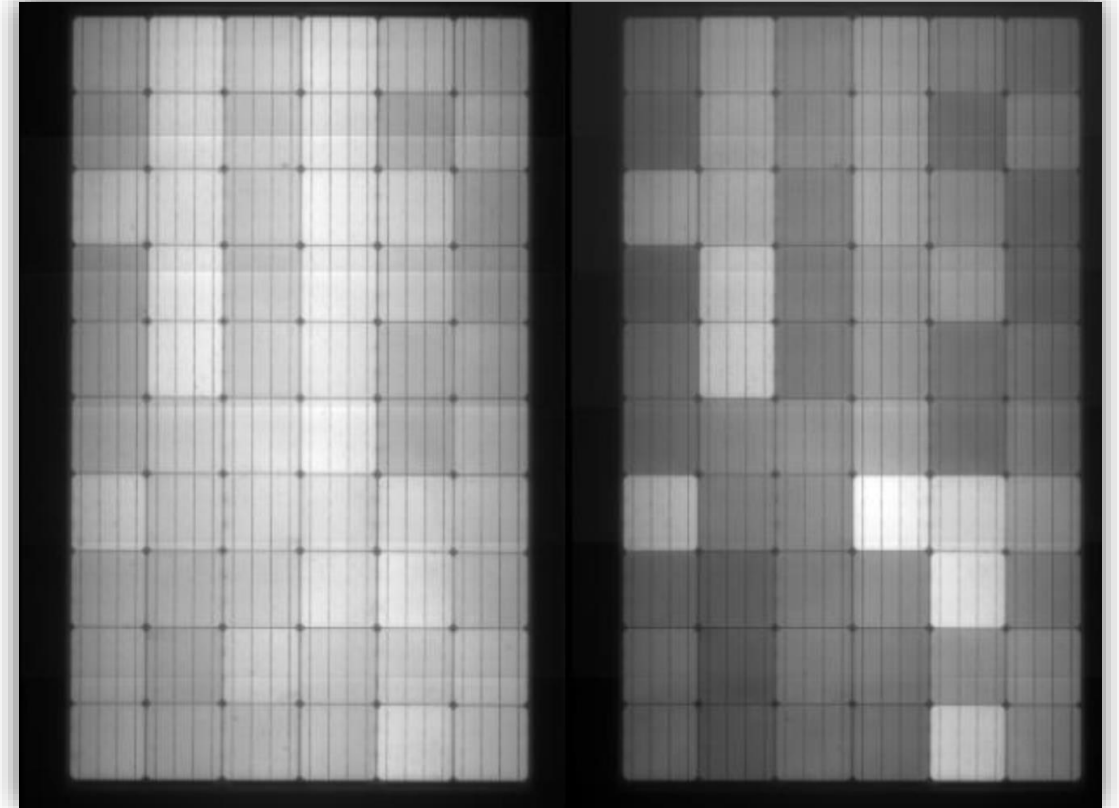
LeTID is much slower than LID and takes a few years to be detected. After reaching the maximum degradation, the regeneration sets in. The maximum degradation and speed of regeneration depend on local climate.

Hotter climates can lead to quicker, higher degradation, but also faster regeneration.

However, if the degradation is high enough, a reasonable strategy for the buyer would be to file a warranty claim, documenting the degradation and proving the mechanism.

Besides degradation, LeTID affected modules develop characteristic “checkered” EL image patterns, due to the uneven degradation of individual cells (easy to distinguish from similar PID-related patterns by excluding PID).

If other causes can be excluded (LID, PID, mixed cell power classes), this can be a strong indicator for LeTID.



EL images @ 0.1 Isc, before and after 690 h LeTID testing
LeTID test: Current injection (Isc-Imp) at 75 °C
Source: Fraunhofer CSP, 36 EU PVSEC

Case Study: LeTID (2)

Field facts

Buyer suspected underperformance of several PV plants 2-3 years after installation, using same type of modules.

Field inspection and further analysis excluded PID, LID, cell cracks and other causes. Module degradation was identified in sample testing.

Cell power inhomogeneity was identified by thermography and EL imaging.

Quality assurance records of pre-shipment tests showed that modules were shipped without cell mismatch, LID or PID.

Testing

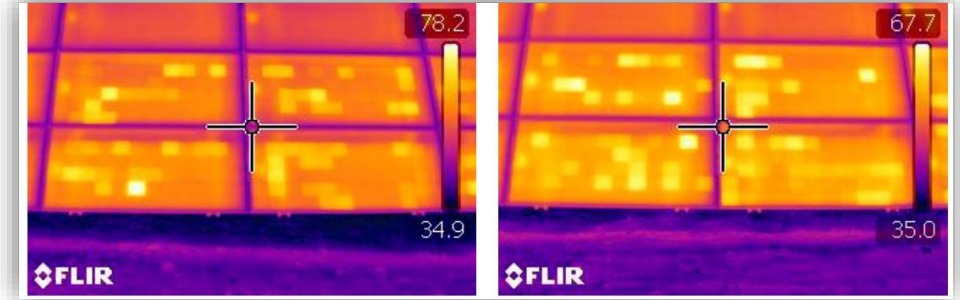
LeTID testing of uninstalled spares and installed degraded modules can prove the LeTID mechanism by exhibiting degradation of spares and regeneration of degraded modules.

Sampling, testing method and degradation percentage have been agreed with manufacturer.

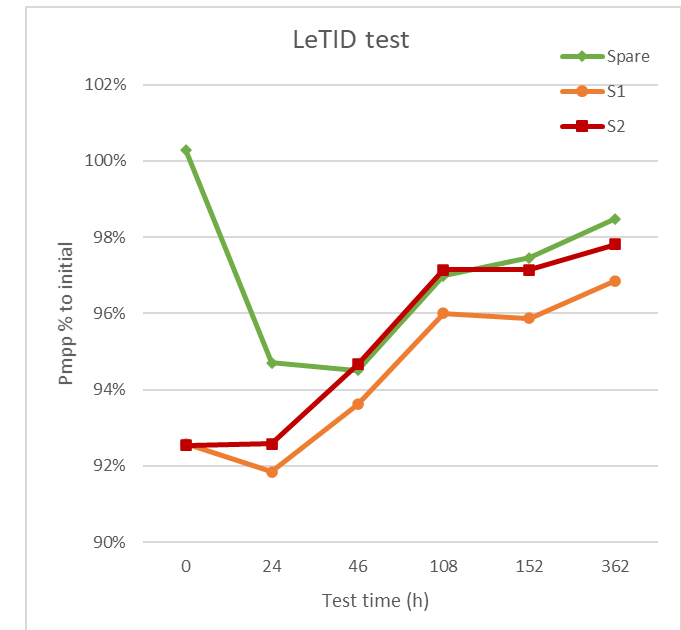
LeTID testing (per draft IEC 61215) has shown that spares degraded and installed modules show regeneration.

Options

Remedies under power output warranty, field regeneration, serial defect clauses and other options are under negotiation.



Thermography of short-circuited strings revealing cell mismatch



Thank you

Company: Clean Energy Associates

Website: www.cea3.com

Email: info@cea3.com

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