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Quantify the impacts of cell cracking in the field

25 May 2020

4 PM – 5 PM | CEST, Berlin
10 AM – 11 AM | EDT, New York
7.30 PM – 8.30 PM | IST, India

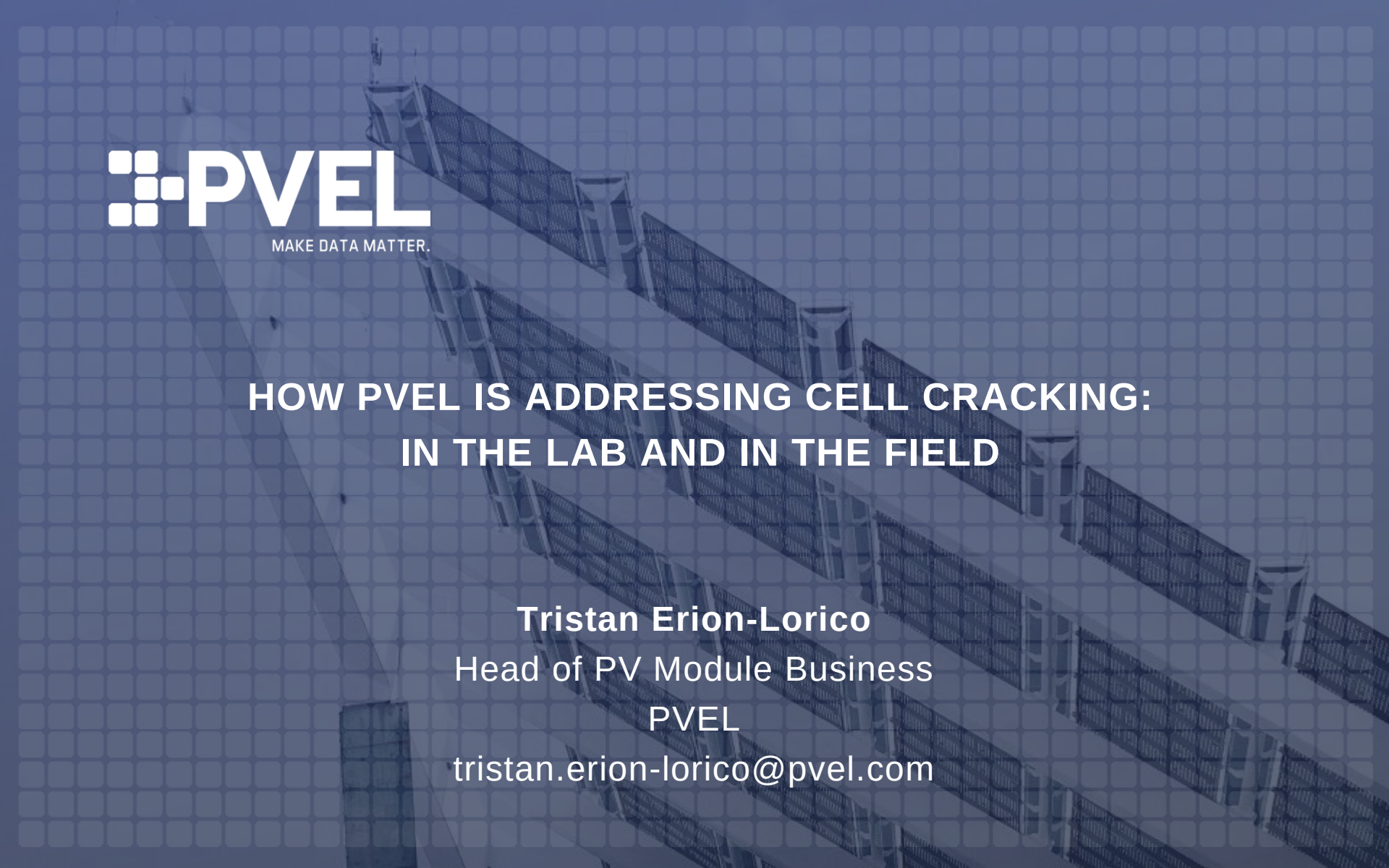
Mark Hutchins
Editor | pv magazine

Lou Trippel
First Solar

Tristan Erion-Lorico
PVEL

Anil Kottantharayil
IIT Bombay

Prakash Suratkar
PV Diagnostics



HOW PVEL IS ADDRESSING CELL CRACKING: IN THE LAB AND IN THE FIELD

Tristan Erion-Lorico
Head of PV Module Business
PVEL
tristan.erion-lorico@pvel.com

PVEL is the Independent Lab for the Downstream Solar Market

Global

300+ downstream partners worldwide with 30+GW of annual buying power

Comprehensive

Testing for every aspect of a PV project from procurement to O&M

Experienced

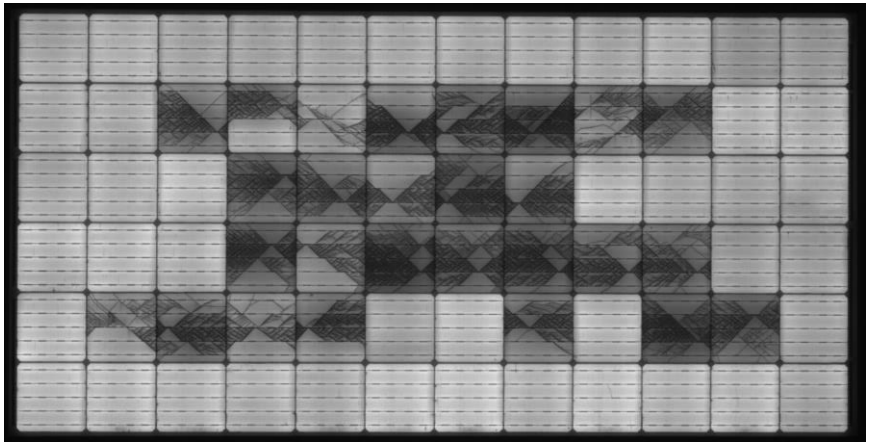
Pioneered bankability testing for PV products nearly a decade ago

Market-driven

Continuously refining test programs to meet partner needs

Understanding cell cracking in PV modules

- Cells are *quite* thin (<0.2 mm)
- Glass thickness is 3.2 mm
- Causes of cell cracks:
  - Manufacturing defects
  - Transportation and shipping
  - improper installation
  - Force majeure/extreme weather events



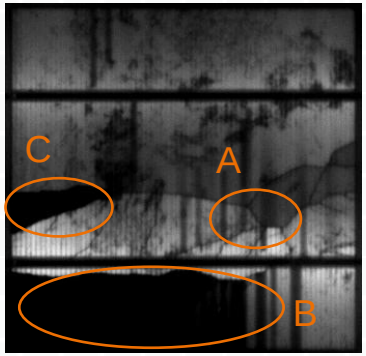
The Main Challenge:
Power loss is realized **over time** – not right away

Evaluating power loss and financial loss due to cell cracks

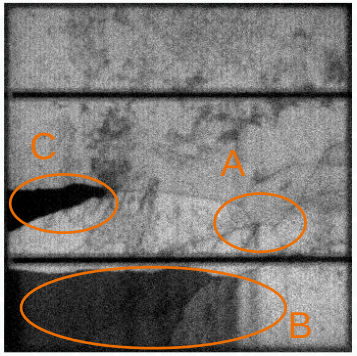
The bottom line: impact varies

- The potential for power loss varies by the type of crack
- Financial losses depend on model assumptions

EL Image at Isc



EL Image at 1/10 Isc



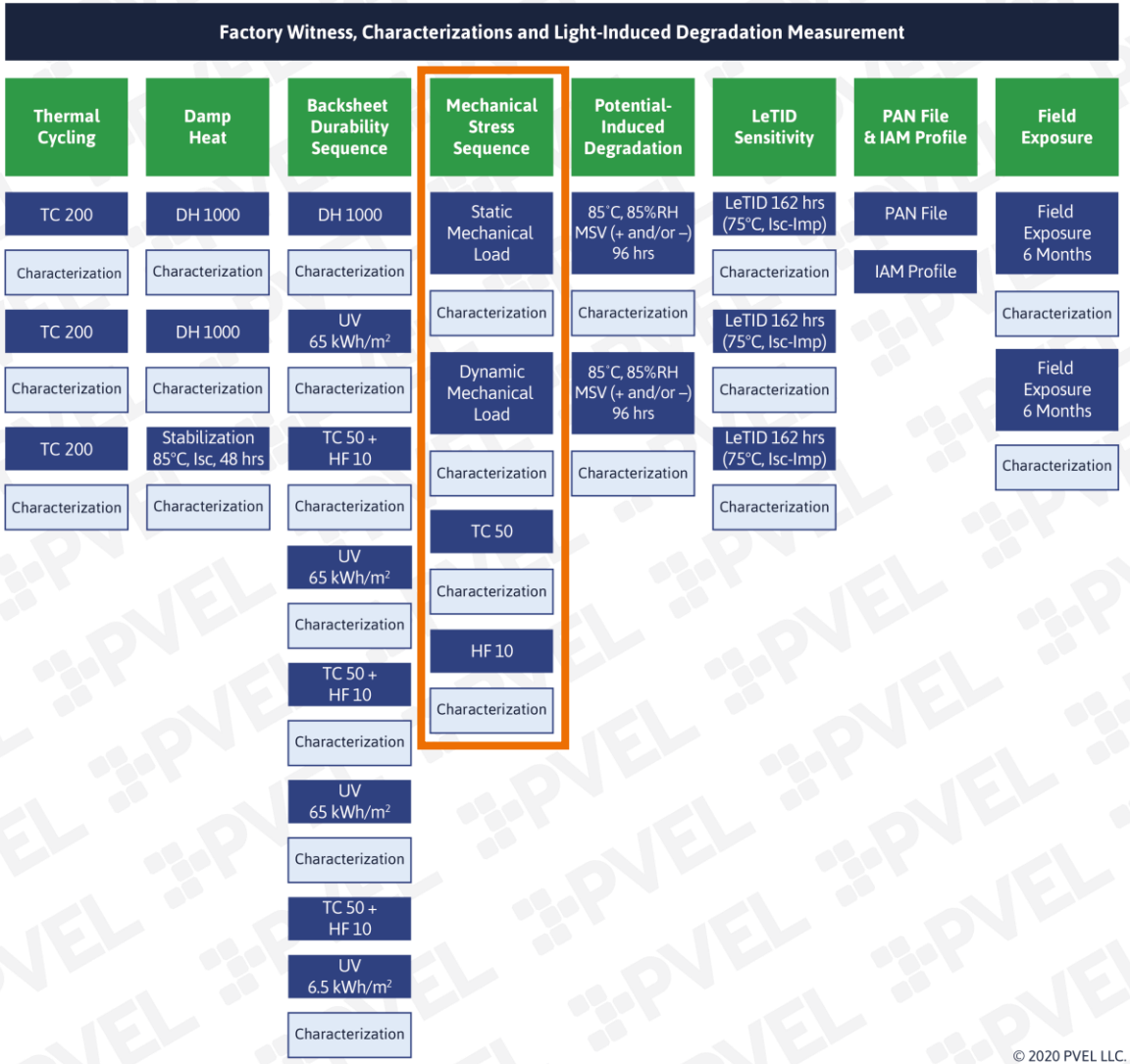
A: No resistance across crack
B: Degraded, still connected, but increased resistance
C: Isolated, inactive cell area

Source: Köntges et al., “Crack statistic of crystalline silicon photovoltaic modules,” Institute for Solar Energy Research Hamelin, (2010)

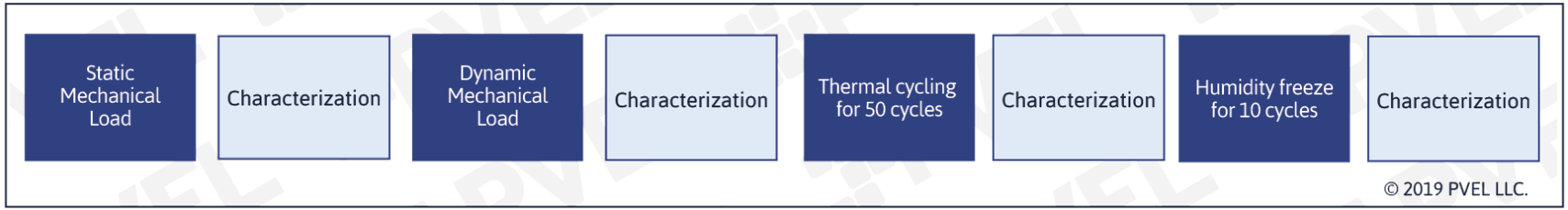
Certification testing for cell cracks

- IEC 61215
  - Static mechanical load testing at 2400 Pa with options for up to 5400 Pa
  - Includes minimum hail testing: 1” hail balls at 50 mph
- Challenges
  - No thermal cycling after stress
  - No dynamic mechanical loading
  - A pass means:
    - <5% power loss
    - No physical damage
    - **EL imaging not required**

PVEL's Module Product Qualification Program (PQP) Test Sequences



PVEL's mechanical stress sequence for cell cracking



Step 1:
Creates cell cracks in susceptible modules

Step 2:
Articulate cracks, opening them in susceptible modules

Step 3:
Reduces power output in susceptible modules

Module types at PVEL queued for MSS testing: monofacial, bifacial, n-type, p-type, 5bb, 6bb, 9bb, 12bb, IBC, MWT, thin film, full cell, half-cut, shingled, 156.75 mm, 158.75 mm, 161 mm , 166 mm, glass//backsheet, glass//glass

Improving Cell Cracking Resistance

Lower Crack Risk

- Glass/glass – no tensile stress
- More interconnect wires – smaller disconnected areas
- Conductive adhesive (some shingled) – fewer microcracks
- Parallel wiring – cells less likely to enter reverse bias
- Better packaging
- More EL quality control testing – factory, pre and post install
- Thin film – inherently impervious to cell cracks

Higher Crack Risk

- Laser cut cells (half-cut, shingled) – microcracks
- Larger modules – more deflection and tensile stress
- Thinner wafers – easier crack propagation

(thanks to Brightspot Automation for this list!)

New Incident Response testing combines advanced field and aerial inspection to safeguard against financial losses

Hypothetical: A 100 MW site is hit by major wind and hail storm

- 270,000 370W modules on site are visually inspected
- 5% show visible damage and must be replaced – 13,500 modules
- Assumptions:
  - $0.25 USD/watt for PV modules
  - $50/module for labor

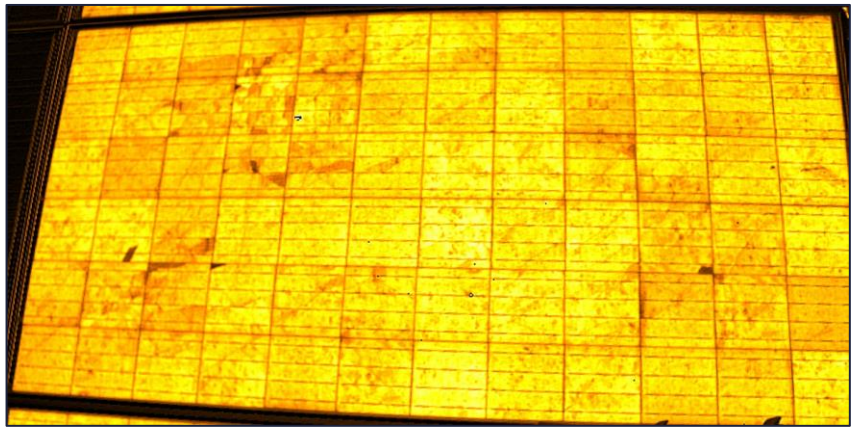
Value of insurance claim for visually inspected PV modules:
$1.92M

100 MW site damaged by major wind and hail storm
(Image Source: Heliolytics)

Insurance payout based on Incident Response

- EL imaging reveals that 15% of the modules on site have significant cell cracks
- An additional 40,500 modules must be replaced

Total payout for all damaged PV modules:
$6.35M – over 3x



EL image of cell cracked PV module in the field

PVEL
MAKE DATA MATTER.

QUESTIONS, AND THANKS!

Tristan Erion-Lorico
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