

Evaluation of Mechanical Stress Beyond IEC 61215



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Introduction & Motivations

- A robust and comprehensive mechanical load test protocol for evaluating new frame design and alternative mounting methods is critical to ascertaining the impact to long-term product performance and reliability.
- Developed at Yingli's state-of-the-art Photovoltaic Testing Laboratory, the Yingli Mechanical Loading Sequence is a mechanical evaluation procedure focused on systematically quantifying the performance implications from stress induced defects, such as micro-cracks, through sequential mechanical, thermal, and humidity stresses.
- Module characterization is expanded both quantitatively and qualitatively with multi-irradiance power measurement and electroluminescence (EL) imaging throughout the test process.

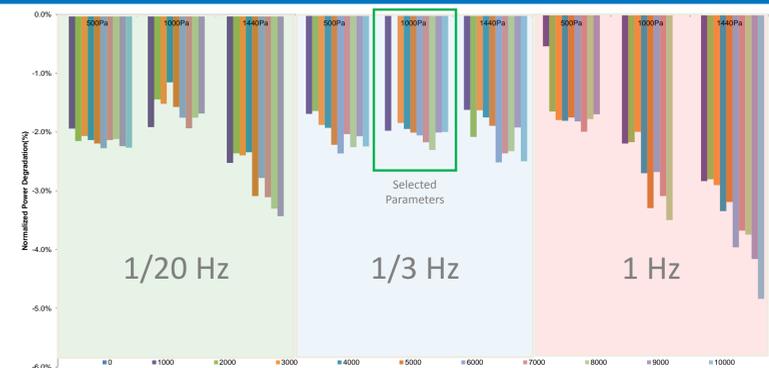
Existing Standard Review

IEC 61215 10.16 ¹	YGE Mechanical Loading Sequence	Benefits of YGE MLS
STC Power Measurement	Multi-Irradiance Testing 200-1000W/m ² in 100W/m ² Increments	Full evaluation of how the stress affects module performance at irradiances other than 1000W/m ²
Single Mounting Method	Multiple Mounting Methods	Provides module manufacturer with understanding of risk associated with different mounting methods & provides end user with more flexibility with system design
No EL Imaging	Electroluminescence Imaging at I _{sc} and 1/10 th I _{sc}	Better qualitative assessment into the type of micro-cracks being formed, with a focus on high-energy versus low-energy cracks. ²
Static Mechanical Loading	Sequential Static and Dynamic Load Testing	Stresses both the interconnect ribbons and mechanically separates the micro-cracks.
No Post Mechanical Loading Atmospheric Chamber Stress	Thermal Cycling and Humidity Stresses	Thermal and humidity induced stress allow the potential power loss from a micro-crack to be fully realized.

Dynamic Mechanical Load Protocol Development

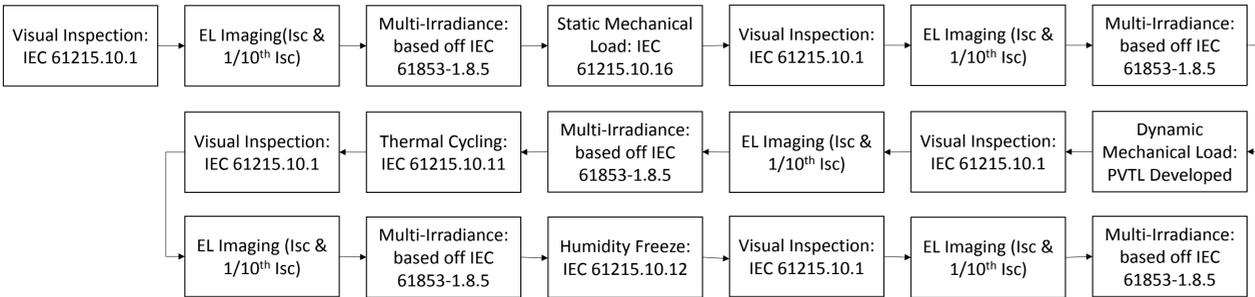
- A 3x3 factorial experiment was performed on modules for dynamic mechanical stress after static mechanical stress based off existing literature review and communication with industry experts.³

	500 Pa	1000 Pa	1440 Pa
1/20 Hz	10,000 Cycles, with power & EL characterization every 1,000 Cycles		
1/3 Hz			
1 Hz			

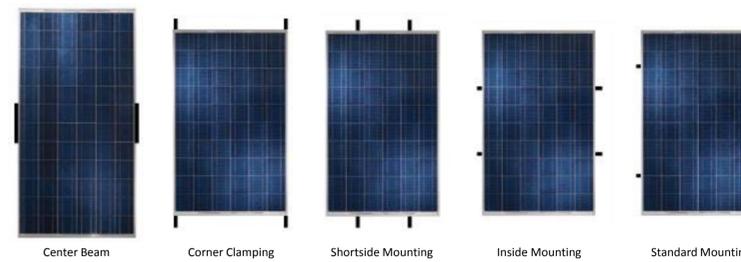


Yingli Solar Mechanical Load Testing Sequence

Test Process Flow

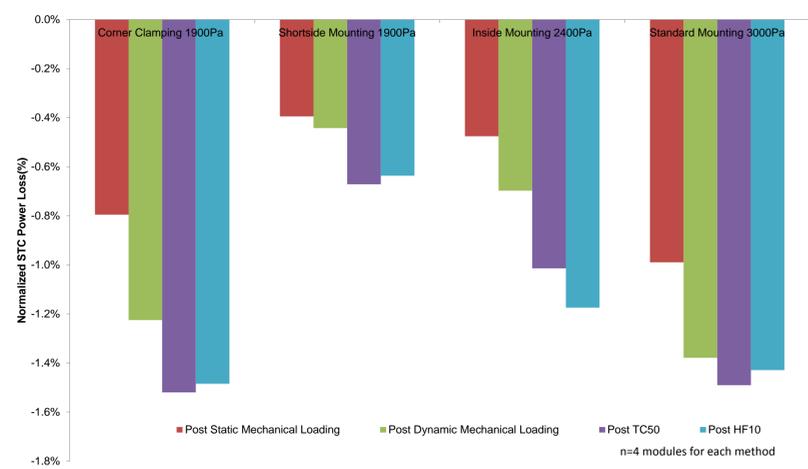


Different Mounting Methods

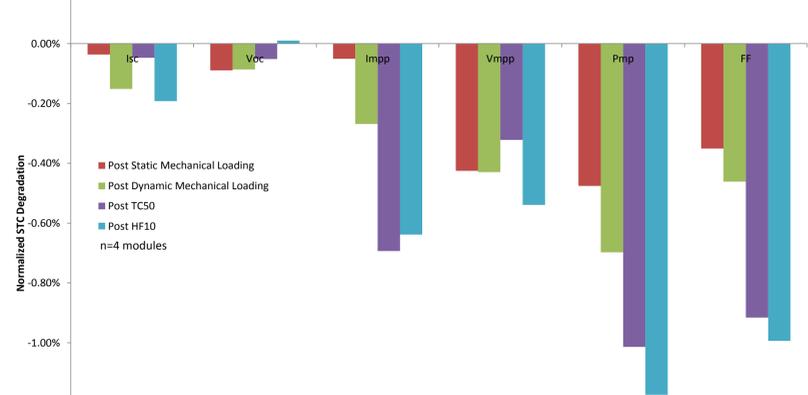


Example of Test Results

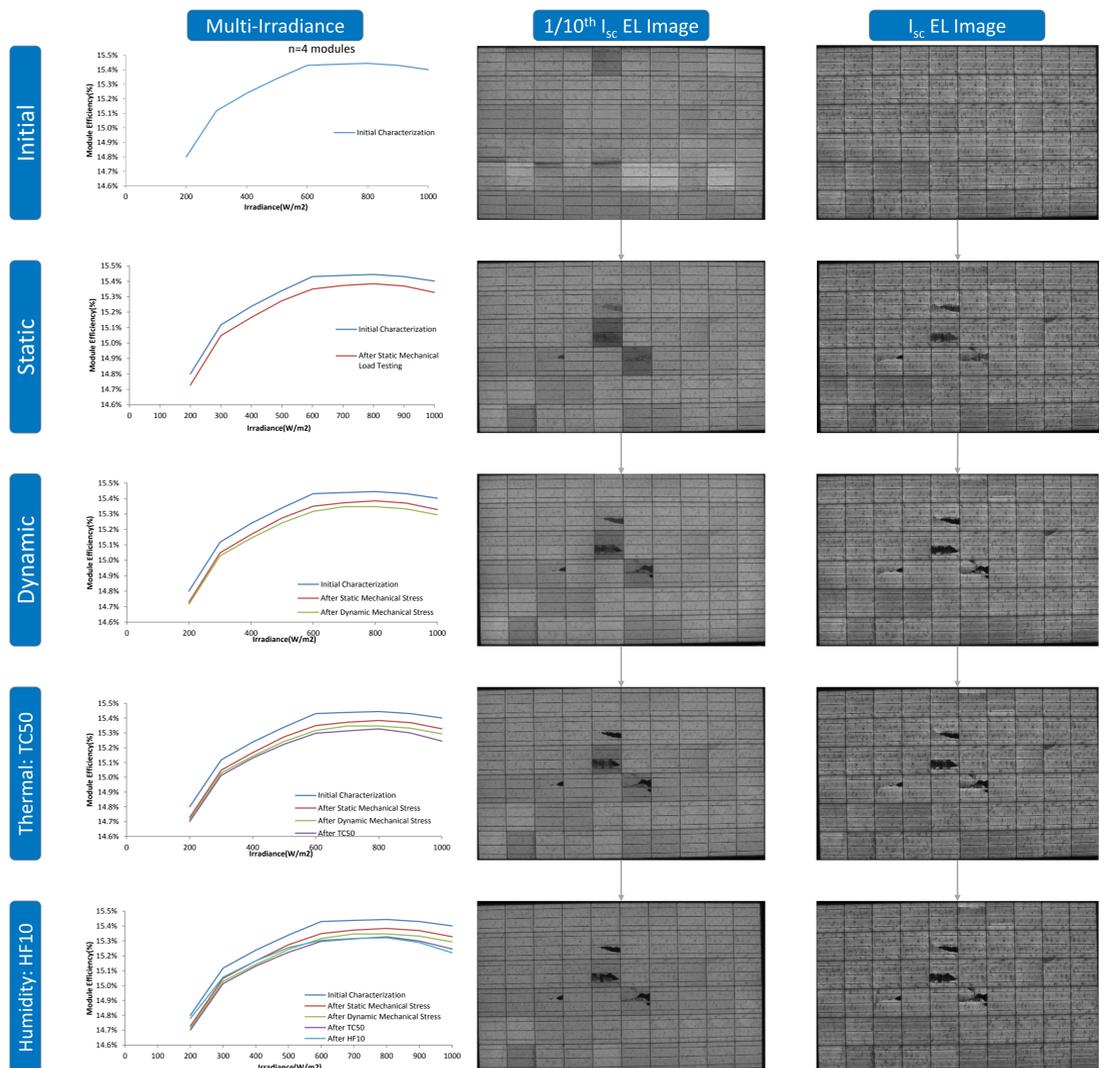
Comparison of Mounting Methods



Inside Mounting Method: In Detail



Inside Mounting Method: Progression of Micro-cracks



¹IEC 61215, "Crystalline Silicon Terrestrial Photovoltaic Modules- Design Qualifications and Type Approval" edition 2, 2005
²Körtges et al., "Origins and Consequences of (Micro)-Cracks in Crystalline Silicone Solar modules", NREL PV Module Reliability Workshop(2011)
³ Wohlgemuth, J. "Dynamic Mechanical Load Test Protocols" Email to the author. 30 July 2012. E-mail