NUS National University of Singapore

SERIS Solar Energy Research Institute of Singapore

PV Modules for Urban Solar Cluster

PV Module Doctor
PV Module Reliability
PV Module Development
PV Module Recycling
PV Module Testing and Certification

NATIONAL RESEARCH FOUNDATION
PRIME MINISTER'S OFFICE
SINGAPORE

ENERGY MARKET AUTHORITY
Our Clean Energy Future

EDB: SINGAPORE

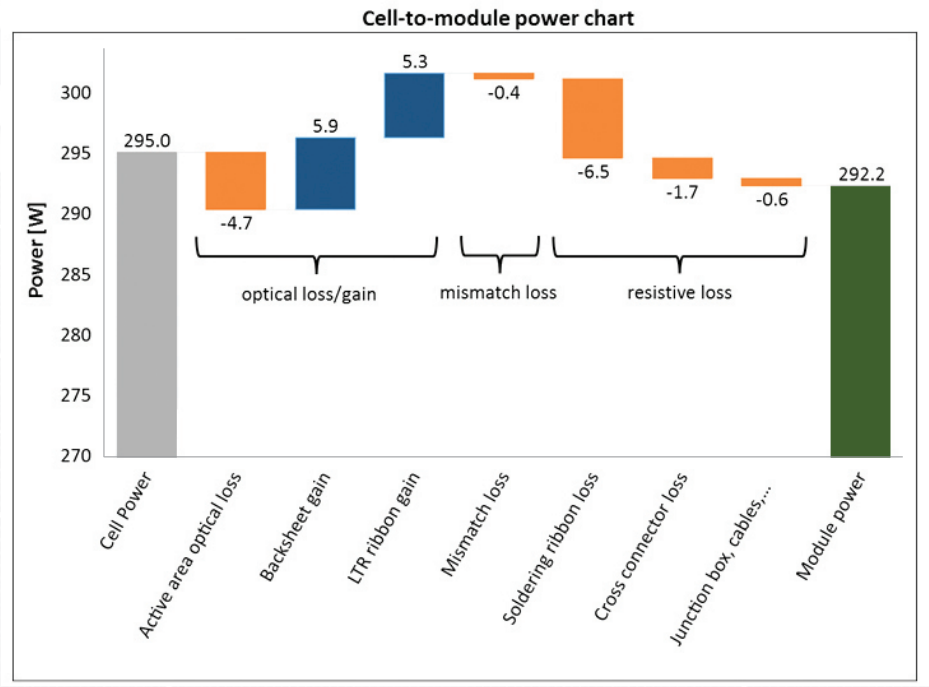
SERIS is a research institute at the National University of Singapore (NUS). SERIS is supported by NUS, the National Research Foundation Singapore (NRF), the Energy Market Authority of Singapore (EMA) and the Singapore Economic Development Board (EDB).

PV MODULE DOCTOR: CELL-TO-MODULE LOSS / GAIN "DIAGNOSIS"

SERIS developed comprehensive cell-to-module (CTM) loss analysis for Si wafer-based PV modules to minimise the CTM losses/maximise the CTM gain. Through CTM analysis, SERIS provides guidance on the module materials selection and the optimisation of the module fabrication processes, as well as extensive characterisation services to materials manufacturers to add value to their product development and product optimisation.

Selected elements of our PV module doctor service:

1. **Power loss analysis for active module area:** Quantify the reflectance loss, parasitic absorptance loss, and optical coupling gain of front encapsulation layers (glass, EVA, POE, etc.).
2. **Light harvesting analysis from inactive module area:** Quantify the light harvesting from inactive areas of a PV module (e.g. cell-gap area, ribbon).
3. **Cell mismatch analysis:** Quantify the loss occurring due to the difference in maximum power point currents (I_{mp}) of the individual series-connected solar cells.
4. **Resistive power loss analysis:** Quantify the power loss in various components used to interconnect the solar cells, as well as leakage currents at various points in the module.



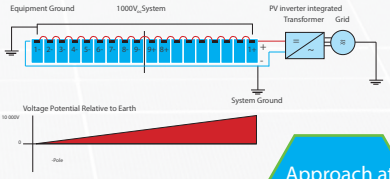
PV MODULE RELIABILITY

PID Centre of Excellence

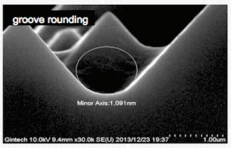
Potential-induced degradation (PID) is a major reliability issue for PV modules in the field; it can cause significant power loss within a few months.

SERIS' PID Centre of Excellence provides various services to manufacturers or research institutes for PID testing and product optimisation.

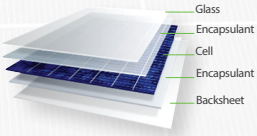
PV system voltage diagram

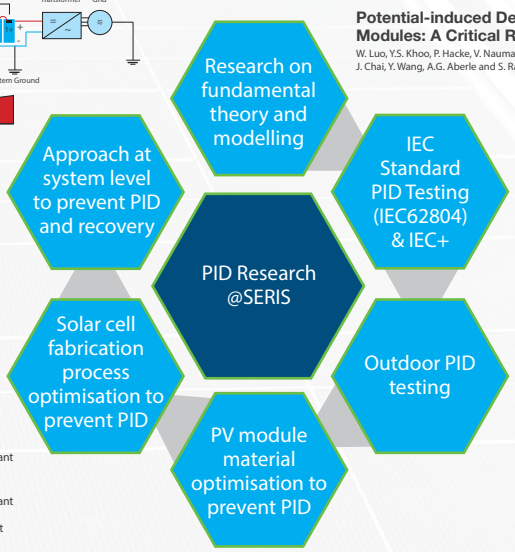


Wafer texturing



PV module materials





Energy & Environment Science

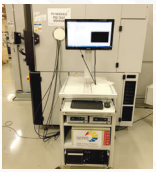
A journal linking all aspects of the chemical, physical and biotechnological sciences relating to energy conversion and storage, alternative fuel technologies and environmental science.

Impact Factor 29.518 | 12 Issues per Year | Indexed in Web of Science

Potential-induced Degradation in Photovoltaic Modules: A Critical Review

W. Luo, Y.S. Khoo, P. Hacke, V. Naumann, D. Lausch, S.P. Harvey, J.P. Singh, J. Chai, Y. Wang, A.G. Aberle and S. Ramakrishna

In-situ monitoring system



*IEEE JPV, 2016, DOI: 10.1109/JPHOTOV.2016.2621352

Outdoor PID testing system

Integrated indoor PID test station

All indoor PID testing at SERIS is performed using an in-house developed integrated PID test station that has the capability to continuously monitor the performance of PV modules under test.

Outdoor PID testing facility

SERIS' outdoor PID testing facility offers real-world testing of PV modules under Singapore's actual hot and humid climatic conditions.

PV MODULE DEVELOPMENT

SERIS operates a PV Module Development Laboratory where PV modules ranging from small single-cell modules for testing purposes up to full-size 72-cell modules can be fabricated. SERIS has been a proponent of double-glass module design since 2010. Double-glass module design with all type of bifacial cell technologies has been developed. The research of double-glass bifacial modules focuses on:

- Loss characterisation in double-glass bifacial PV modules
    - Optical loss: comparison with glass/backsheet modules
    - Resistive loss: monofacial and bifacial modules

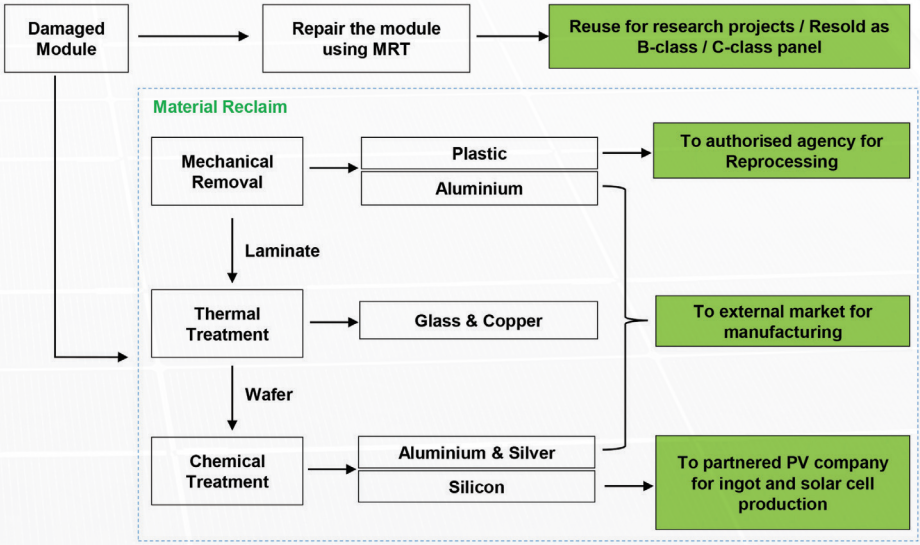
- Approaches to increase module power
    - Reduce optical loss using IR reflective coating and white selective reflective coating
    - Reduce resistive loss using half-cut cells with multi-busbars

Researcher showcasing various prototype PV modules fabricated in the lab.

PV MODULE RECYCLING

Exponential growth of PV installations in Singapore and worldwide reinforces the need of recycling for end of life PV modules and system components. PVMD group is leading the PV module recycling activities since 2014 and successfully completed its first research project on PV Module repairing and recycling in 2017. Key highlights of the PV recycling activities at SERIS are:

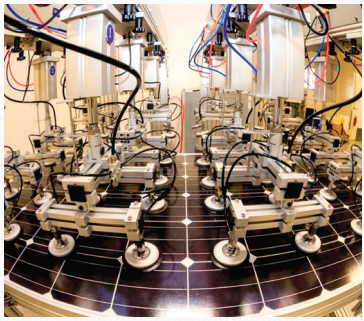
- SERIS developed a patented module repair technology (MRT) to re-use and re-characterise the partially damage/degraded modules.
- Together with other collaborators, SERIS has the capability to recover all the valuable materials from the end of life modules.
- As a next phase of recycling work, PVMD explored several new ideas for recycling of all types of PV modules (i.e. glass/backsheet, glass/glass, etc.) and system components (i.e. inverter, battery, etc.).
- In the coming years, one of the key R&D focus areas of the PVMD group will be PV module recycling. Currently, PVMD group is working on proof of concept of a viable PV recycling plan for Singapore.



PV MODULE TESTING AND CERTIFICATION

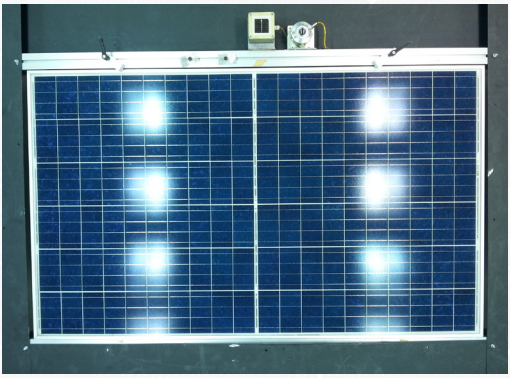
SERIS' PV Module Characterisation and Reliability Group engages in both certification and R&D activities relevant to industry. We conduct the following activities for customers:

Certification	• Latest IEC 61215, 61730 & UL1703 standards
Fault Analysis	• Detect and localise module defects
Golden Modules	• Precision measurements with Uncertainty reporting
Test-bedding	• Components and accessories e.g. smart junction boxes, etc
R&D Testing	• Industry relevant research for the tropics e.g. Fast NOCT/NMOT
SQC batch test	• Quality checking batch to batch for system installation



Measurement of NOCT or NMOT via indoor Sun Simulator

- Allows single day test instead of weeks to 3 months outdoor duration
- Small temperature variation between the outdoor vs indoor measurements of same module under test
- On-going repeat of modules of other cell technologies
- Saves time and money to industry



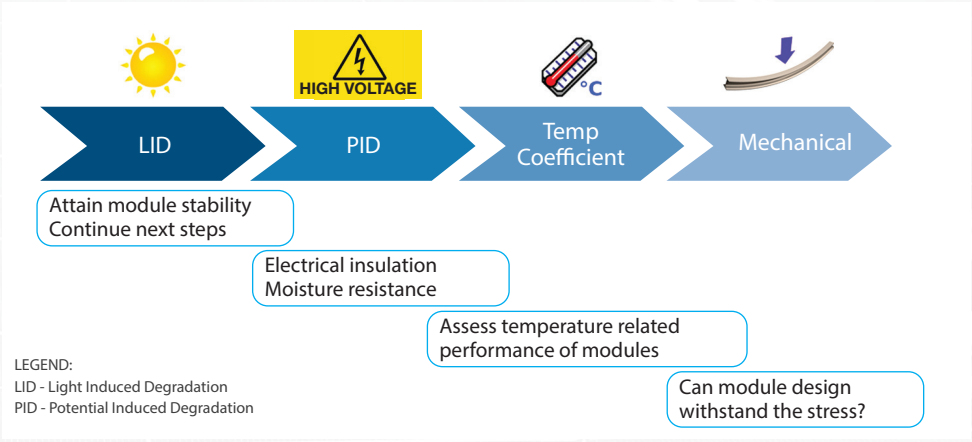
Indoor Simulated Fast NOCT (also NMOT) test

SERIS Quality Check Service (SQC)

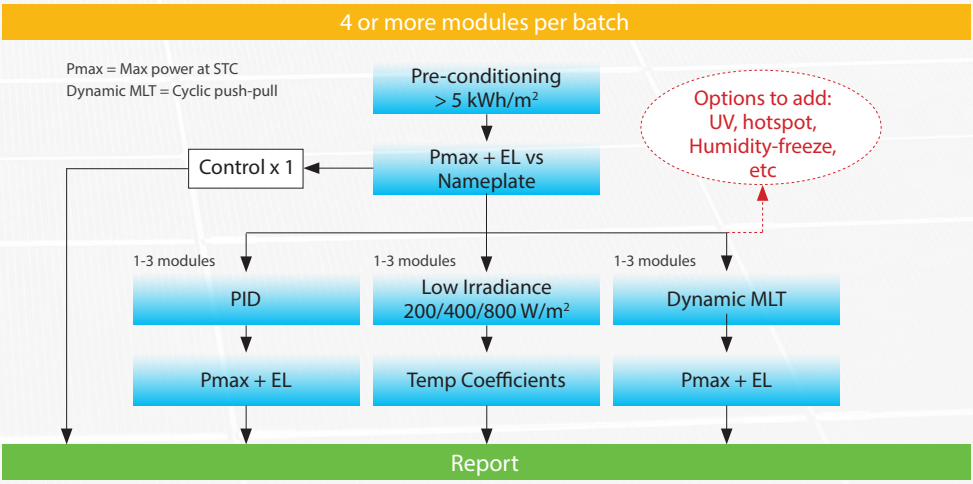
The SQC provides PV system owners, EPC operators, finance companies and stakeholders a means to qualify and quantify the quality of the PV modules delivered in batches.

Rationale and benefits of SQC:

- Address industry concerns of PV module reliability (i.e. LID, PID)
- Performance and durability
- Applicable to EPCs, finance & insurance companies, module makers and other stakeholders
- Compliments standard IEC and UL certification tests
- Timely - less than a month for basic framework
- Scalable and customisable



SERIS QC Test Plan



ABOUT THE PV MODULES FOR URBAN SOLAR CLUSTER AT SERIS

Located off campus at CleanTech One, the PV Modules for Urban Solar Cluster of SERIS comprises the PV Module Development Group and the PV Module Characterisation and Reliability Group.

Research areas:

- Develop baseline module fabrication process for advanced solar cell structures
- Decreasing cell-to-module loss to increase module power
- Outdoor performance simulation & PV module optimisation
- Developing new module designs and fabrication processes for cost reduction
- Degradation study to improve module reliability and durability
- PV product development for urban applications

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