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PV MODULE LIFE TIME FORECAST AND EVALUATION

Degradation of Power Output of Photovoltaic Modules Due to Accelerated Ageing

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INTRODUCATION

The long-term reliability and durability of installed photovoltaic (PV) modules are critical in ensuring the cost-effectiveness and commercial success of solar PV systems [1]. Hence, the need for upfront testing of materials, components, and overall systems has increased in order to improve the design and manufacturing processes of PV modules before being installed in the field [2]. However, directly observing the time-to-failure or predicting the long-term performance of PV modules in the field is difficult as most PV modules are designed to operate without failure for decades in normal use conditions. Therefore, an alternative indoor methodology based on accelerated stress tests (AST) is required to evaluate the PV module by hastening the performance degradation, so that the required reliability or durability information can be obtained quickly.

Hence, the focus of this work has been on investigating the effect of accelerated environmental stresses on c-Si PV mini-modules by extending one of the standard qualification tests in IEC-61215-2 [4] which is the damp-heat (DH) test at 85% RH/85°C, to reproduce the field failures as well as to compare whether the calculated activation energy (E_a) associated with such degradation modes, the power of humidity factor n , and the time parameter a which is related to the materials natural lifetime of the parameters of the Pan and Peck models is consistent with the range of values reported in the literature. In addition, the effect of curing time on the durability of the PV-modules has been investigated.

STATISTICAL MODELLING

$$D(t) = 1 - \exp(-b * t^a)$$

Pan Model

$$b_{Peck} = A * exp\left(\frac{-E_a}{k_b * T}\right) * (RH)^n$$

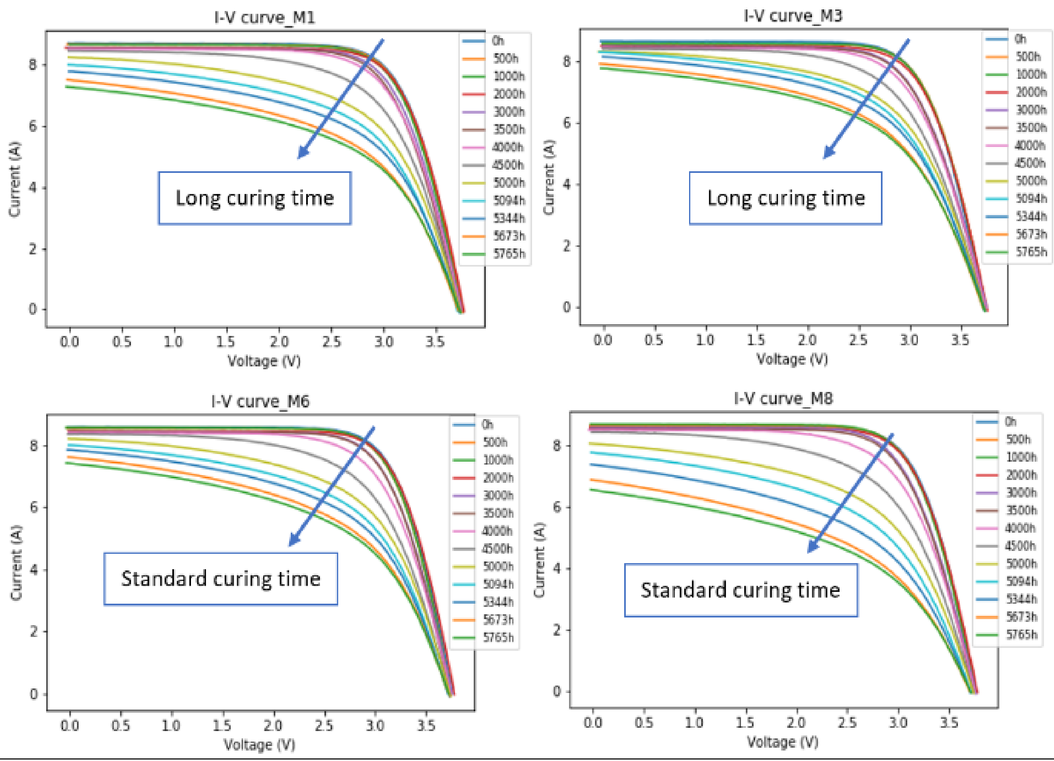
Peck Model

TEST SAMPLES

Four 6-cell PV mini-modules were prepared at CREST with module structure of glass/encapsulant/cells/encapsulant/backsheet and fabricated with two types of lamination conditions (industrial standard curing time and long curing time which is 10 and 15 min respectively.

Cell type	No. of test samples	Encapsulant	Back-sheet	No. of cells	Test condition	Test hour
Multi-crystalline Si	4	FC100011 E/A	dyMat PYE3000	6	85°C/85% R.H	5765

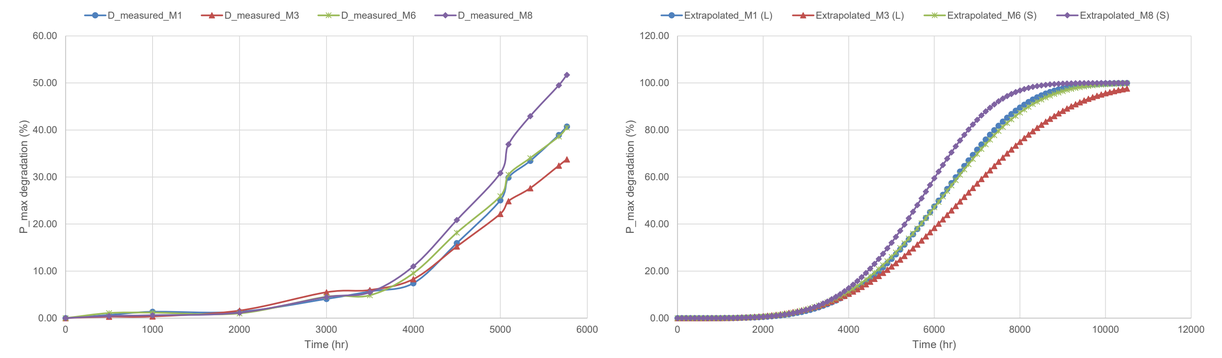
FLASH I-V MEASUREMENT



PERFORMANCE PARAMETERS

Overall 16%, 10%, 13% and 24% loss of I_{sc} and the series resistance increased by 215%, 184%, 222%, and 300% for modules 1, 3, 6, and 8 respectively.

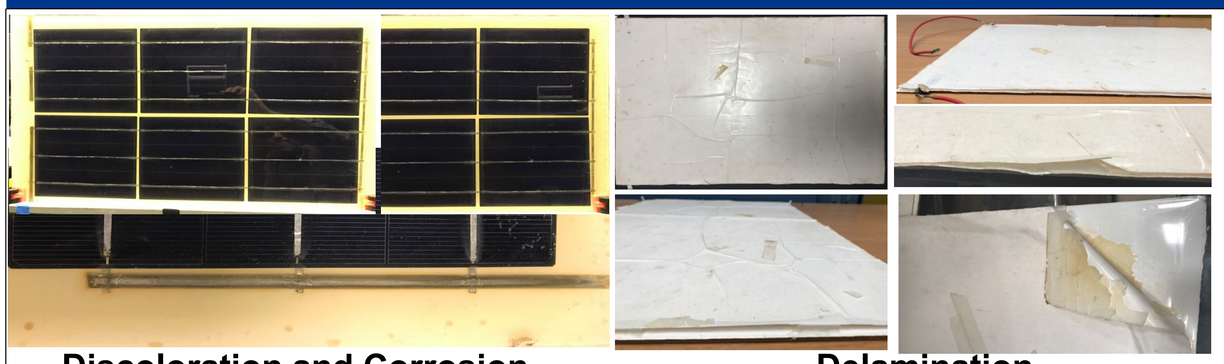
POWER OUTPUT DEGRADATION



MODEL FITTING

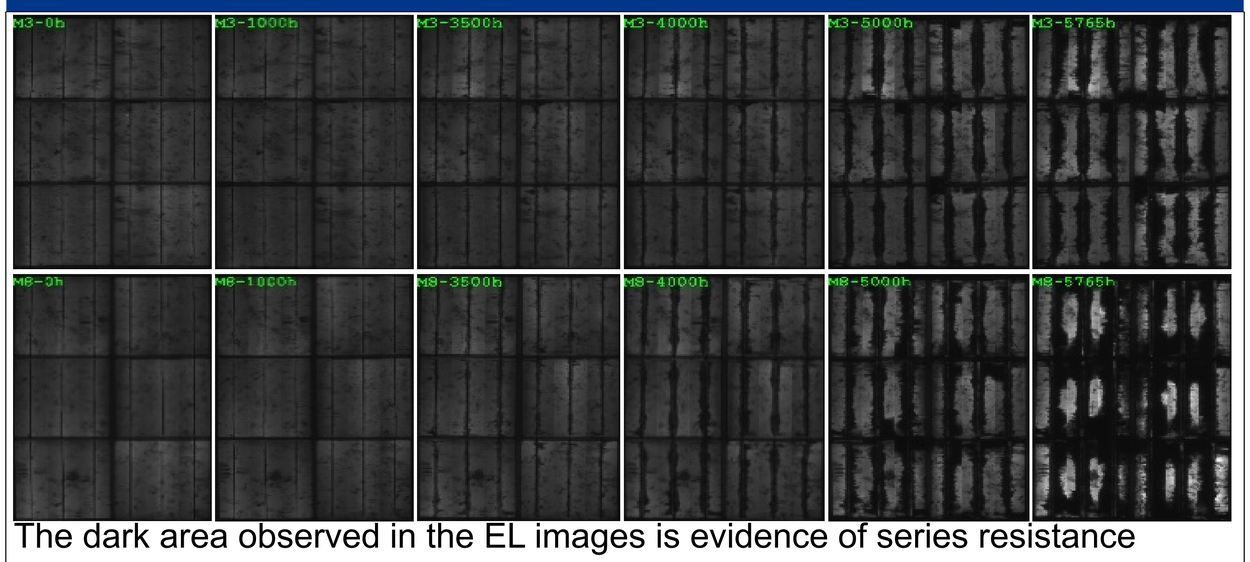
Parameters	$M_1(L)$	$M_3(L)$	$M_6(S)$	$M_8(S)$
$E_a(eV)$	1.59	1.42	1.52	1.65
A	4.90	4.91	4.90	4.89
n	2.58	2.65	2.62	2.55
a	4.36	3.65	4.10	4.66
$\sum \Delta^2$ (%)	0.25	0.11	0.22	0.21

VISUAL INSPECTION



Discoloration and Corrosion **Delamination**

ELECTROLUMINESCENCE IMAGING



The dark area observed in the EL images is evidence of series resistance increase.

CONCLUSION

- Delamination, discoloration as well as corrosion are the reproduced field failures during DH test
- Delamination and discoloration affects the I_{sc} by reducing the amount light reaching the cells
- Where as corrosion affects the over all power output by increasing the series resistances in the PV mini-modules
- All parameter's of the Pan and Peck model except E_a, have an inversely proportional effect on the degradation of power output.
- The reliability of the PV modules under the DH test is highly influenced by the value of the time parameter a rather than the power constant n and the activation energy (E_a) of the humidity and temperature factors respectively.

REFERENCES

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[3] C. R. Osterwald, "Terrestrial Photovoltaic Module Accelerated Test-to-Failure Protocol," Nrel, no. March, 2008.

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