OUTDOOR FIELD TESTING AS A COMPLEMENTARY APPROACH TO ACCELERATED LIFETIME TESTS

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INTRODUCTION

PV module qualification sequences such as IEC 61215(c-Si), IEC 61646 (thin film) and IEC 62108 (CPV) consist mainly of accelerated tests performed within environmental chambers. Modules are exposed to high levels of environmental stress for a specified time period at the end of which the modules are required to maintain a certain minimum performance in order to pass. These tests have proven to be excellent indicators of faulty module designs and inadequate materials or components which has resulted in their improvements and thus reduced premature field failures. These tests do not, however, guarantee long term performance or allow for a prediction of the module service lifetime. It is essential to study the modes and mechanisms of failure and determine their acceleration factors from outdoor testing in order to verify the reliability of a specific PV module design. Real time outdoor testing allows for combinations of environmental stresses that are not achievable with accelerated testing in controlled environmental chambers. Long term test plans accompanied with extensive characterization are required to identify and understand the fundamental wear-out mechanisms in the PV module. Knowledge of these failure modes will facilitate in improving module designs and increasing the confidence levels of accelerated test results.

ACCELERATED TESTING VS. OUTDOOR TESTING

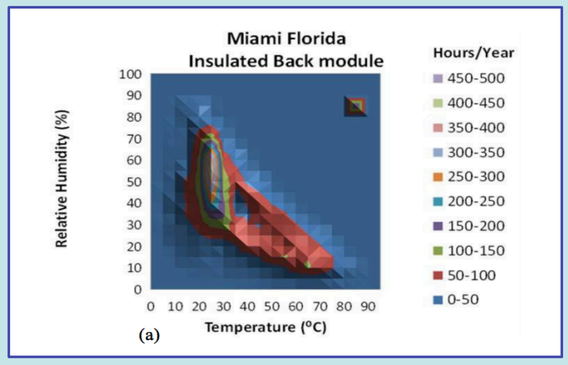
Accelerated Testing in Environmental Chamber	Outdoor Testing
Temperature	Temperature
Relative Humidity	Relative Humidity
Artificial Light	Sunlight (Visible light + UV)
Voltage	Voltage
	Rain
	Condensation
	Soiling and dust
	Pollution

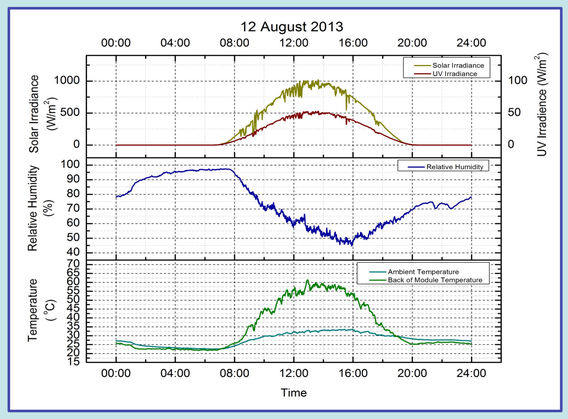
Table of environmental stresses experienced during reliability testing

In addition to having limited number of environmental parameters, some forms of accelerated testing employ unrealistic conditions such as 85 ℃ and 85% RH. It is well known that these conditions are never observed at any location on the Earth. On the other hand, outdoor testing exposes the modules to real world conditions and hence the reliability assessment based on the outdoor test is more trustworthy.

CLIMATE FOR OUTDOOR TESTING

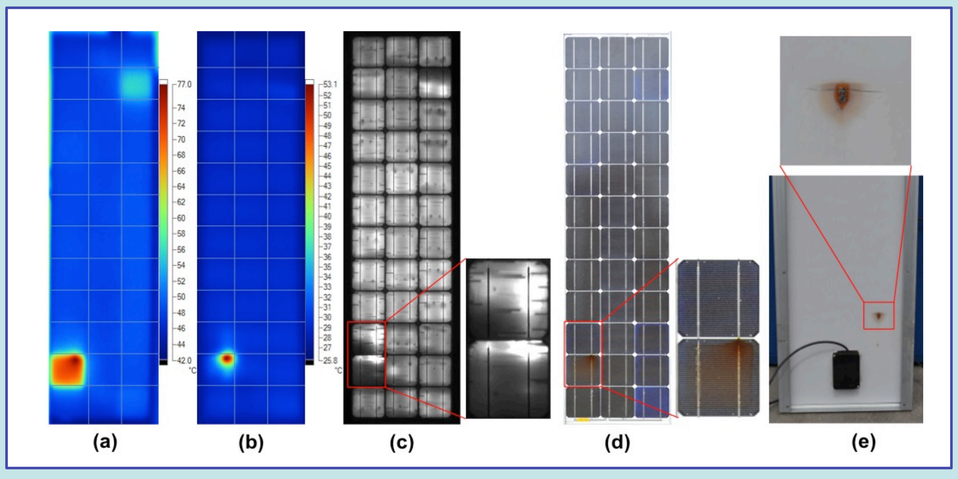
Florida's climate is known as the benchmark for outdoor weathering testing for any kind of products. Naturally, hot and humid climate of Florida is one of the harshest climates in the world for PV modules. This is because high humidity exacerbates moisture ingress within the modules. This results in higher leakage currents, enhanced corrosion and eventually performance loss. This type of degradation occurs very slowly in temperate climates such as in Golden, Colorado, or hot and dry climates found in Arizona and New Mexico. Therefore, Florida's climate is ideal for identifying the field degradation modes for specific module designs in a reasonable time frame.





MODES AND MECHANISMS OF DEGRADATION

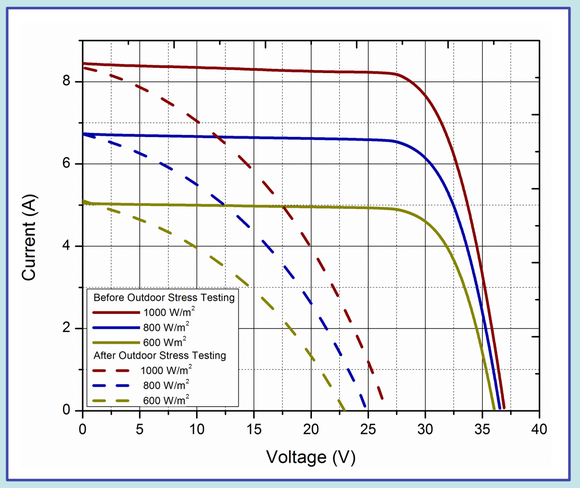
A standard series of characterization methods, known as baseline testing procedures, have been developed at the Florida Solar Energy Center for the purpose of being able to understand and predict the various failure mode and mechanisms experienced by PV modules. The goal is to be able to identify changes in fundamental materials properties that occur and relate these changes to the degradation of a specific electrical performance parameter.



Characterization of a mono-crystalline silicon module with (a) infrared image taken outdoors under short circuit conditions, (b) infrared image taken indoors under forward current of Isc, (c) electroluminescence image taken at a forward current of Isc, (d) visual image of front side, and (e) visual image from back side showing burn mark..

OUTDOOR SYSTEM VOLTAGE STRESS TESTING

High system voltages have been identified to cause degradation within PV modules in fielded systems. Due to the serial connection of modules into strings, PV systems often reach voltages such as 600 V or 1000 V. Because all module frames are grounded, a potential difference is formed between the cell circuit and frame of the module. System voltage stress is known to cause significant power loss in the field deployed modules.



Severe degradation observed in I-V characteristics after 6 months of outdoor high voltage bias testing.

In outdoor high voltage bias testing, a high voltage bias is applied between the cell circuit and frame of the outdoor deployed module and the leakage current is measured in real time. The variation of leakage current with meteorological parameters such as relative humidity, ambient and back of the module temperature, dew point temperature, rain, and wind speed is studied. Module performance characterization is performed before, during and at the end of testing to analyze degradation.

CONCLUSIONS

- Degradation in accelerated testing should be complemented with outdoor test results in order for them to be more relevant. The Florida Climate has been proven to be a suitable environment for producing results in a reasonable amount of time.
- Performing an extensive characterization sequence periodically can lead to a better understanding of the evolution of the electrical and material properties of the PV module and module components during outdoor field testing or accelerated lifetime stress testing.