Accelerated Test and Statistics Model Analysis of Degradation Performance for PV Module Lifetime Prediction

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Introduction

The reliability of crystalline silicon PV modules has improved dramatically in recent years. Today, manufacturers are usually asked to provide their customers with reliability information about degradation rate of PV module power. However, module power degrades very slowly at the normally used condition. Accelerated degradation tests are used widely to obtain timely information on the reliability of module.

Accelerated degradation tests for assessing the long-term reliability and performance of photovoltaic modules were conducted as follows. The damp heat tests were run at high levels of temperature and relative humidity to accelerate the hydrolytic and corrosive action of hot, humid environments and obtain degradation data more quickly. In our tests, the 2 x 2 cell modules were fabricated in the same type of crystalline Silicon cells, glass and back sheet foil. Before the damp heat tests, the modules were exposed by UV 15 KWhr as the pre-test mentioned in IEC61215. Those small modules were tested as the process flow (as Fig 1.) which are then divided into five conditions (as Fig 2.). Damp heat test were plan to keep going non-less than 2000 hrs. The tests of IV-characteristics and a visual control were carried out, and measurements were made at specific times so as to obtain the degradation ration of power loss.

The performance of a degradation model depends strongly on the appropriateness of the model describing a product's degradation path. we propose a relationship between the product's lifetime and stress variables. The method can be used for highly reliable products.

Objectives

For PV module makers, we hope to have a cost effective way but accuracy method for lifetime prediction. In this study, a general linear degradation model was proposed . The unit-to-unit variation of modules can be considered simultaneously with the time-dependent structure in degradation paths. Based on the proposed degradation model, an implicit expression of a product's lifetime distribution, and its corresponding mean-time-to-failure (MTTF) was derived. By using the profile likelihood approach, maximum likelihood estimation of parameters, a product's MTTF can be obtained. In the illustrative example, we use the accelerated degradation data for PV module to address the proposed method.

Methods

The 2 x 2 cell modules were fabricated and every module is subject to UV and Damp Heat test as the process flow.

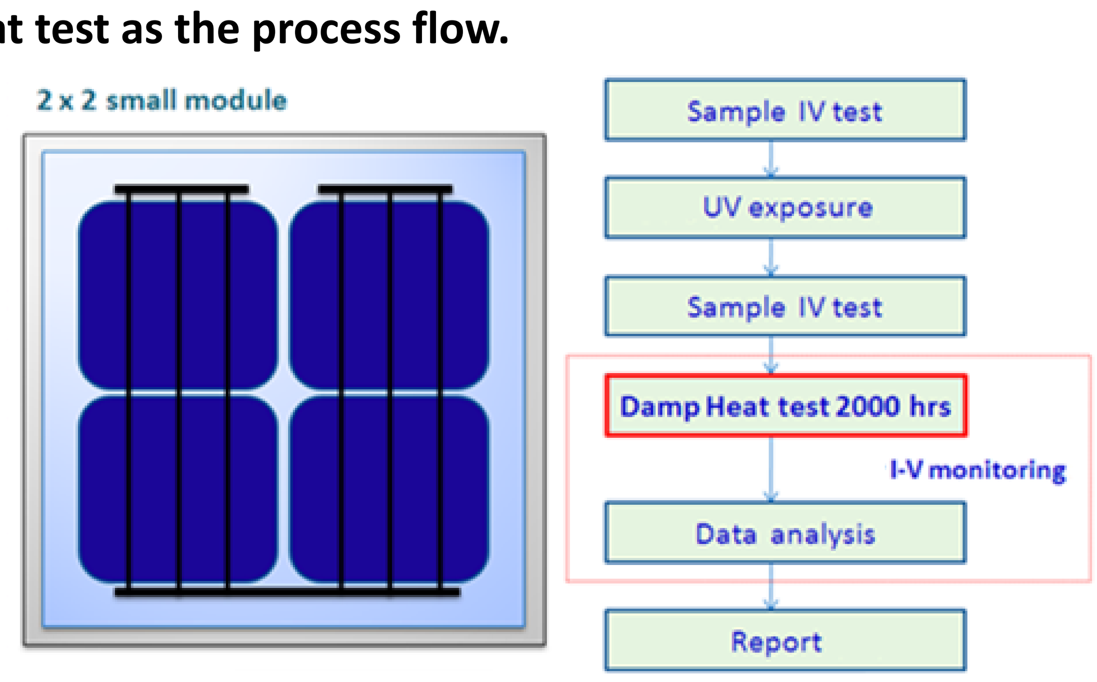

Fig 1. The 4 cells module and test flow

Five conditions of Damp and Heat accelerated degradation tests are conducted, and there are 15 test units for each test environment. In this study, the Run 1 tests had ended.

DOE	(°C, RH%)	k	I
Run1	85/85	n1=15	I1=168 I2=336 I3=504 I4=672 I5=840 I6=1008 . . . In=2000
	95/70	n2=15	
	85/70	n3=15	
Run2	85/95	n4=15	
	90/90	n5=15	

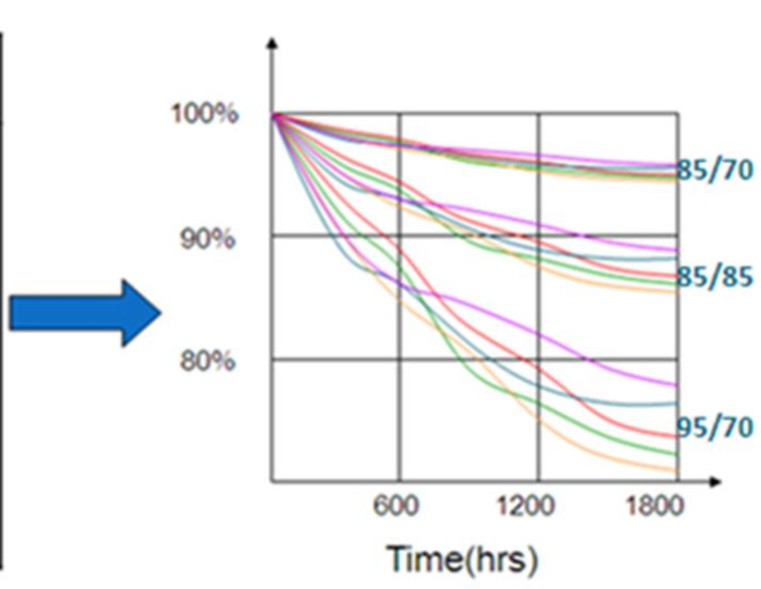

Fig 2. Five conditions of Damp Heat

Lifetime prediction of PV module was carried out by the linear degradation model. The analysis package (iDEMO: integrated degradation models) was used and it was developed by Cheng, Y. S. and Peng, C. Y. It could be downloaded freely at the website: http://www.stat.sinica.edu.tw/chienyu/demo.htm.

$$M_0: \begin{array}{l} Y(t) = L(t) + \sigma_\varepsilon \varepsilon, \\ L(t) = \Theta t + \sigma_B B(t), \end{array}$$

where

- $Y(.)$ is an observed degradation path,
- $L(.)$ is a true degradation with stochastic path,
- ε is a measurement error,
- Θ is a random effect, $\Theta \sim N(\eta, \sigma_\eta^2)$
- $B(.)$ denotes the standard Brownian motion.

- The proposed degradation model is identifiable.

Results

We use the accelerated degradation data at Run 1 to illustrate the proposed method. By Nelder-Mead's optimization algorithm, the maximum likelihood estimations of model parameters can be obtained. Furthermore, by Akaike information criterion, the random effect model with measurement error is suitable for describing the accelerated PV module degradation data. Then, given 20% power loss ($\omega = 0.2$), the estimated MTTF of PV module under (85°C,85%), (95°C,70%), and (85°C,70%) were calculated to be 1.64, 1.37, 2.08 years, respectively. Then, we can extrapolate the estimated MTTF at specific environment conditions by the following equation:

$$T_\alpha(\text{Temp},\text{RH}) = \frac{1}{24 \times 365} \exp\left(\log(\omega) - \ - \frac{b}{273.15 + \text{Temp}} - \ \log(\text{RH}) \right). \quad (1)$$

By using the experimental conditions and lifetimes, the estimates of a, b, and c can be obtained as $\hat{a} = -1.37$, $\hat{b} = -5466.41$ and $\hat{c} = 1.23$, respectively. Fig 3. shows the contour plot of the equation in (1) under the various combinations of temperature and humility. If the normally used condition is (50°C,70%), then the lifetime can be evaluated as follows:

$$T_\alpha(50,70) = \frac{1}{24 \times 365} \exp\left(\log(0.2) - \hat{} - \frac{\hat{b}}{273.15 + 50} - \hat{}\log(70) \right)$$
$$= 10.86.$$

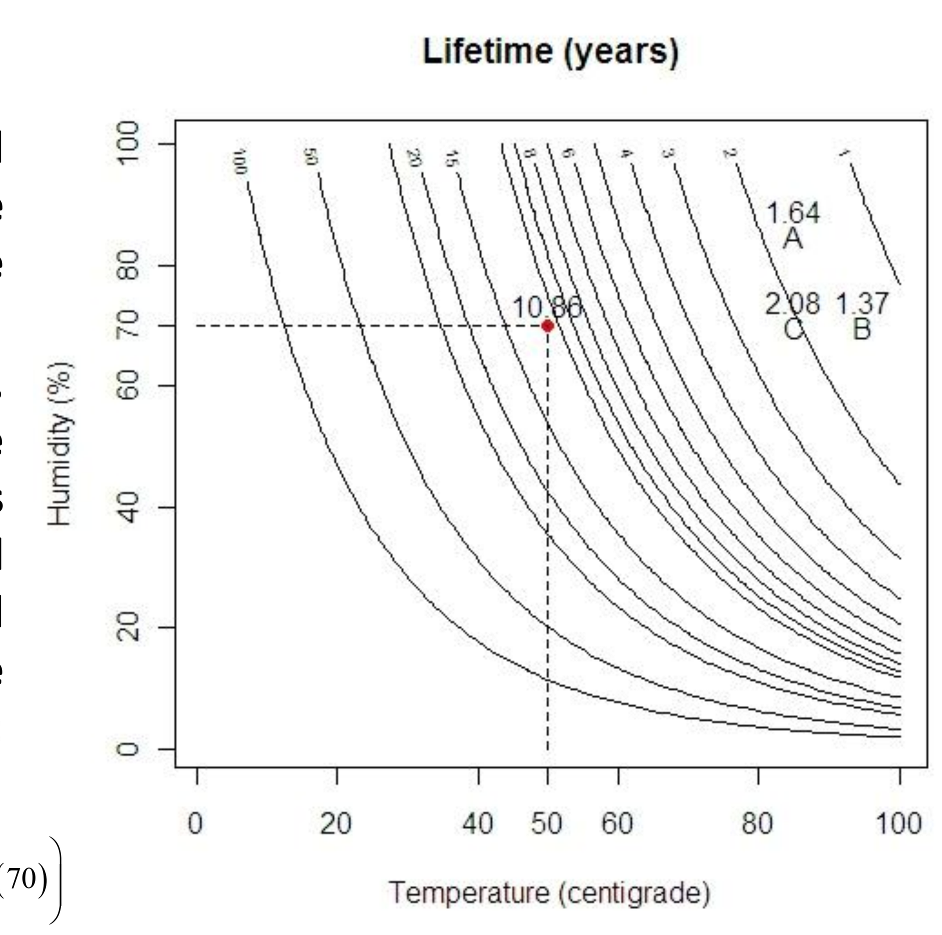

Fig 3. The contour plot of Temp and RH

Conclusions

In this study, motivated by the data of PV module power loss, a general linear degradation model which takes "unit-to unit variation", "time-correlated structure", and "measurement error" into considerations simultaneously was proposed. The product's lifetime under the normally used conditions can be obtained. The estimates are reasonable for practical condition from the experiences of engineering and the viewpoint of material property.

The following two issues are worthwhile for further research: (1). We will implement Run 2 tests with longer testing time around 3000 hrs for Damp Heat testing which will give more clearer accelerated degradation path. (2). We will develop a statistical degradation model for the outdoor testing of PV module.

References

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