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NREL PV Module Reliability and Performance R&D Status and Accomplishments

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NREL PV Module Reliability and Performance R&D Status and Accomplishments

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ABSTRACT

This paper presents a brief overview of the status and accomplishments during Fiscal Year (FY)2004 of the Photovoltaic (PV) Module Reliability and Performance R&D Subtask, which is part of the PV Module Reliability R&D Project (a joint NREL-Sandia project).

1. Objectives

The near-term objectives of this subtask are to strongly support the subcontracts involving thin-film module deployments in hot and humid climates, including active participation on the Thin Film Module Reliability Team. Direct PV industry support is also a primary objective through real-time outdoor testing, the Performance and Energy Ratings Testbed (PERT), the Outdoor Accelerated-weathering Test System (OATS), outdoor high-voltage stress, and indoor environmental chamber testing at the module level, as needed. The long-term objectives are to investigate failure mechanisms in prototype or preproduction modules and help develop accelerated stress tests that reproduce the same failures.

2. Technical Approach

Long-term testing of PV modules on an ongoing basis, both indoors and outdoors, is the most important technical approach used for determination of reliability and performance. An important adjunct to long-term testing is indoor environmental stress testing, which is used to uncover susceptibility to known failure mechanisms.

3. Results and Accomplishments

3.1 Accelerated indoor stress testing

In FY2004 we completed thermal cycling, UV exposure, humidity-freeze cycling, damp heat exposure, and controlled indoor light soaking on a number of CdTe modules as part of a testing agreement with First Solar, Inc. One result showed that the open-circuit voltage (V_{oc}) of unstressed controls declines while stored in the dark, which complicates standardized qualification testing because it is difficult to observe the effects of stress testing by comparison against controls. Note that these V_{oc} losses can be recovered by light soaking.

Thermal cycling, damp heat testing, and the surface cut test were performed on a group of crystalline-Si prototype modules from SBM Solar. These modules feature Tefzel transparent fronts rather than the conventional glass superstrate design. SBM Solar has requested additional module stress testing in the near future.

The cut test was also done on some small module coupons for SunPower Corp. that featured a fluoropolymer front surface encapsulation over glass superstrates. In all three cases, test reports were delivered to the manufacturers.

3.2 Current-voltage (I-V) curve translation

A new numerical procedure for translating I-V data to a reference condition has been developed. The procedure approximates the irradiance dependence by the sum of a dark current and a voltage-dependent photocurrent [1], but extends this method to include variations in temperature by introducing a bilinear interpolation. Comparisons with outdoor data made under a wide range of temperature and irradiance conditions have shown that the method is capable of very accurate translations, with average errors on the order of 1% or less.

3.3 Thin-film module hot & humid support

A large effort was made during FY2004 to support the thin-film module hot & humid deployment subcontracts (part of the Thin-film PV Partnership Program) to Florida Solar Energy Center (FSEC) and Texas A&M University (TAMU). This support included overseeing the baseline testing of the modules sent to the test sites for deployment, a site visit to FSEC, advice to the subcontractors, and establishment of a data archive here at NREL. We received 180 modules from First Solar, Shell Solar, Uni-Solar, and Energy Photovoltaics for baseline testing. Light and dark I-V measurements were done by the PV Measurements and Characterization Group, and hi-pot, wet insulation resistance, and forward bias infrared (IR) camera imaging were performed by our team. All data were archived, including the results from the first 150 modules obtained in FY2003.

3.4 High voltage stress testing (HVST)

The long-term outdoor high voltage (±600 V) stress test on four types of crystalline and thin-film modules continued. Also, the HVST was expanded with a unique experiment to measure the leakage currents of a string of thin-film modules connected in series. In this experiment, the high-voltage bias will be supplied by the modules themselves, which are held at the maximum power point by a programmable electronic load.

3.5 Long-term Si cell degradation

The controlled light soaking experiment designed to determine the cause of the slow degradation of short-circuit current previously observed in crystalline Si modules that was initiated in FY 2003 continues [2]. At the time of this writing, a total UV dose of about 1000 MJ/m^2 has been accumulated, and the goal of this testing is to accumulate at least 5000 MJ/m^2. Preliminary results will be presented at the 31st IEEE PV Specialists Conference in January 2005.

3.6 Ref. Meteorological and Irradiance System

This system measures and archives weather and irradiance data for the outdoor module and array field at the Outdoor Test Facility (OTF) and is used by a number of NREL groups. During this fiscal year, we have been working on an expansion of RMIS to provide a latitude-tilt diffuse measurement that is intended, when combined with the existing direct normal measurement, to be used for in situ calibrations of the numerous latitude-tilt pyranometers at the OTF. This unique measurement is difficult to perform because it requires a fixed pyranometer positioned above a two-axis solar tracker that positions a shading ball needed to block the direct solar irradiance.

3.7 Outdoor accelerated solar weathering

A major overhaul of the OATS (Fig. 1) was completed during this reporting period. The data acquisition and control systems were replaced and upgraded, along with the wiring harnesses that provide electrical connections to the two test planes in the two-axis solar tracker. Very old FORTRAN tracker control software was translated to National Instruments' LabVIEW. New UV radiometers were acquired and modified to prevent exceeding their specified 40°C maximum operating temperature. A new solar weathering experiment was initiated that includes crystalline-Si, CdTe, and Cu-In-Ga-S-Se modules.

3.8 Performance and Energy Ratings Testbed

Several modules were added to the PERT (Fig. 2) long-term monitoring program in FY2004: 1) a Sanyo a-Si/c-Si ('HIT') module, 2) a First Solar CdTe module, and 3) a Global Solar Cu-In-Ga-Se module. The PERT holds up to 45 test modules at maximum power and periodically (typically every 15 or 30 mins) measures full I-V curves. These data were used for the validation of the bilinear I-V translation procedure, and are currently being analyzed to extract temperature coefficients, which will be published in FY2005.

3.9 Module energy ratings

A subcontract with Arizona State Univ. PV Testing Laboratory has been funded for the past two years to develop a site able to perform the standard module energy ratings outdoors. This work is documented in a separate paper at this review meeting.

4. Conclusions

Long-term module testing has been performed at the OTF for more than 15 years, and during FY2004 this testing has continued and has been expanded and enhanced. All milestones that were identified in the Annual Operating Plan have been achieved.

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[2] C.R. Osterwald, J.P. Benner, J. Pruett, A. Anderberg, S. Rummel, and L. Ottoson, "Degradation in Weathered Crystalline-Silicon PV Modules Apparently Caused by UV Radiation," *Proc. 3rd World Conf. on PV Energy Conversion*, Osaka, Japan, May 11–18, 2003, ISBN 4-9901819-3-8.

MAJOR FY 2004 PUBLICATIONS

B. Marion, S. Rummel, and A. Anderberg, "Current-Voltage Curve Translation using Bilinear Interpolation," accepted for publication in *Prog. in Photovoltaics: Research Applications*, 2004.

B. Marion, J. del Cueto, and W. Sekulic, "Modeling Current-Voltage Curves Using Bilinear Interpolation," *Proc. of the 2004 World Renewable Energy Congress*, Denver, CO.

Fig. 1. The Outdoor Accelerated-weathering Test System at the NREL Outdoor Test Facility.

Fig. 2. The Performance and Energy Ratings Testbed on the roof of the NREL Outdoor Test Facility.

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