SOLAR WIND

Reproducing the Effects of Wind-Induced Field Vibration on PV Modules in the Laboratory Without the Requirement of a Wind Tunnel

Herb Schueneman, Mark Escobedo, Pal Khangaldy

WESTPAK, Inc., San Jose, CA www.westpak.com

WESTPAK, INC.
EXCELLENCE IN TESTING

Presented at the 2012 PV Module Reliability Workshop, February 28 – March 1, 2012, Golden, Colorado

INTRODUCTION

- There is a 100% probability that all PV modules will be exposed to vibration during handling, transportation, installation, and exposure to high winds in the field. What is not well understood are the effects of vibration stimuli on PV modules with respect to the module's ability to produce electrical power throughout its expected lifetime.
- In order to study the effects of vibration stimuli, an efficient and economical method to reproduce the effects of vibration in the laboratory must be established and utilized.

OBJECTIVES

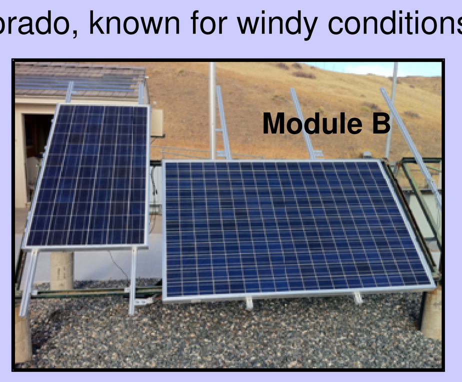
- Determine if we could adequately reproduce wind vibration response in the laboratory without a wind tunnel.
- Determine the effect vibration induced flexing has on module reliability, and to what extent a combination of environmental stresses including vibration, temperature extremes, and humidity had on PV module reliability.

APPROACH

1. Vibration sensors and data recorders were attached to two c-Si PV test modules of significantly different physical dimensions.

	Tech	No. of Cells	Pmax	Dims (L x W)	Weight
Module A	c-Si	72	170 Watts	1.6m x 0.8m	17 kg (37.5 lbs)
Module B	c-Si	216	270 Watts	1.9m x 1.3m	47 kg (104 lbs)

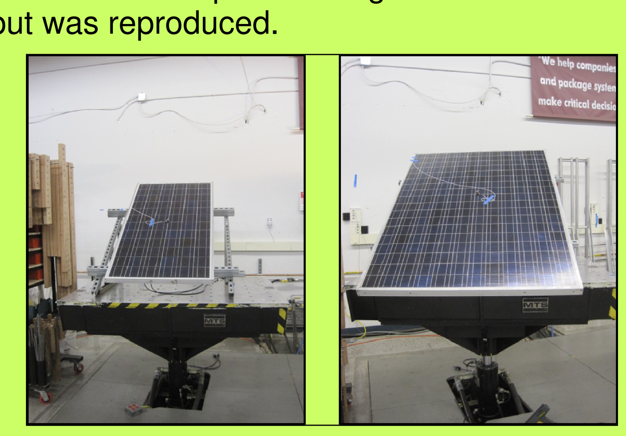
2. Modules were installed at an outdoor lab at NREL in Golden, Colorado, known for windy conditions.



Field installation at NREL

3. Wind speed and response to the wind-induced vibration of each module was monitored and recorded for a six month period.

4. Modules were returned to the test lab where the module's field response using mechanical vibration input was reproduced.



Vibration machines at Westpak

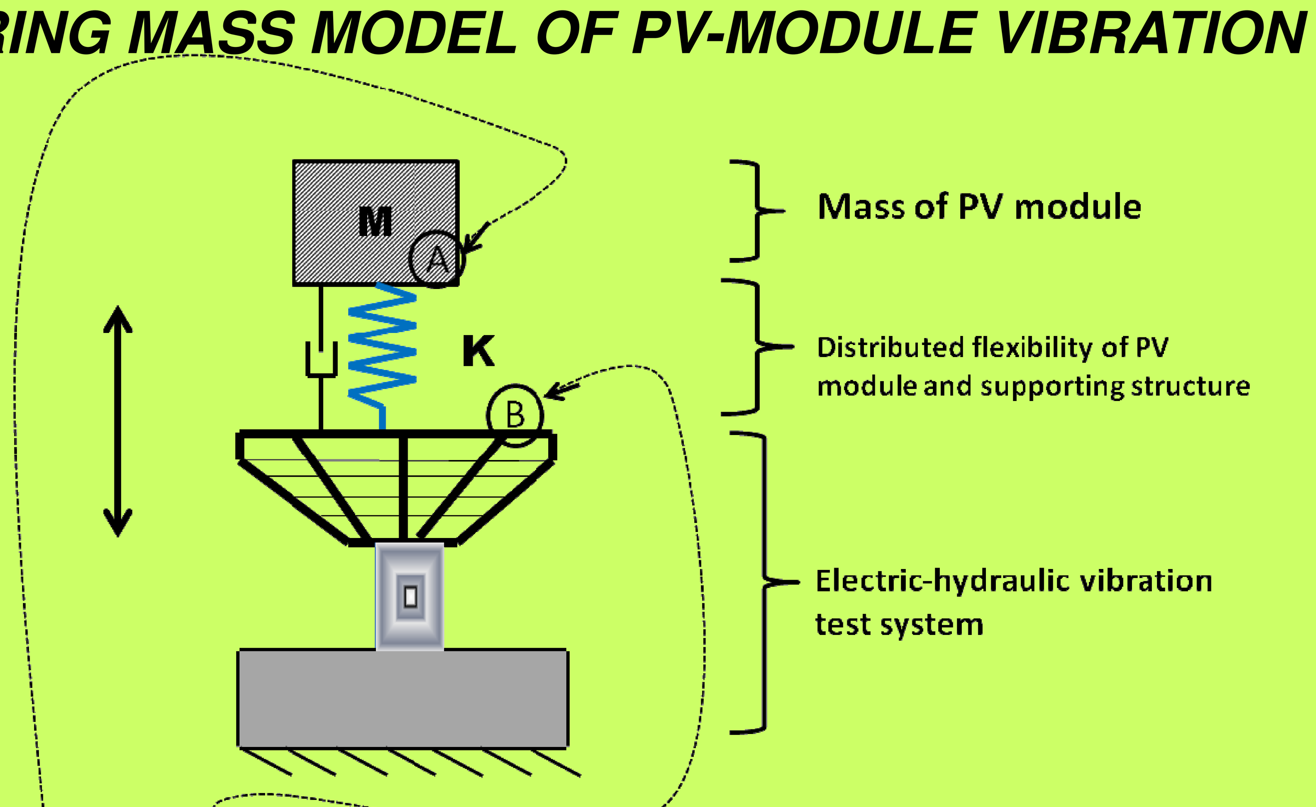
5. After initial vibration input on the machine, modules were characterized (visual, I-V, EL).

6. Modules were subjected to small amount of high intensity wind excitation, which was followed by 36 hrs of Damp Heat (+85^{o}C / 85% RH) and Thermal Cycling TC50 (-40^{o}C to +85^{o}C, no v-bias) exposure.

7. Modules characterized (visual, I-V, EL).

8. Repeat the vibration input with small increases in excitation and/or duration until significant module change is noted .

SPRING MASS MODEL OF PV-MODULE VIBRATION TEST

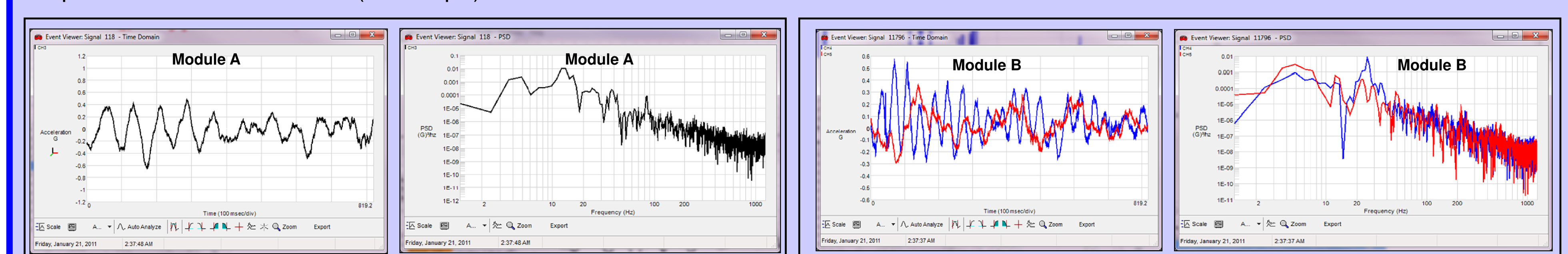


B = Platform or table or location where RESPONSE is measured for test 2.0 and the location for the DRIVE or COMMAND signal for Test 3.0.

A = Center of PV module where the DRIVE or COMMAND signal is given to match the field response in Test 2.0 and to measure the RESPONSE of the module in Test 3.0

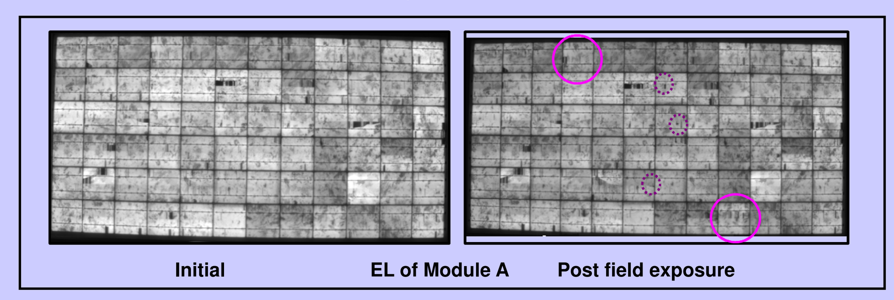
RESULTS

1. Commercially available recording devices can easily record vibration (acceleration) response levels as low as 2 m/s2 (equal to wind speed of about 8-16 km/hr (5-10 mph)

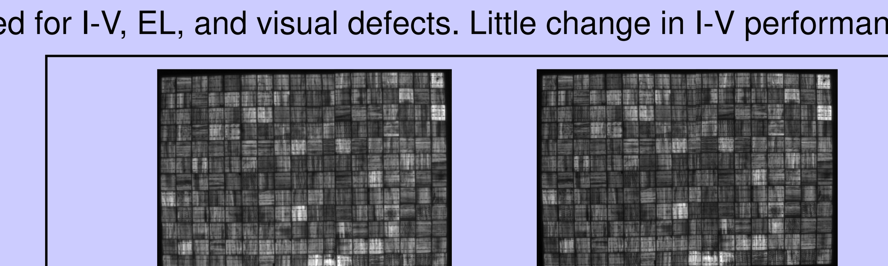


15-35 mph Wind Event (Time Domain) | 15-35 mph Wind Event (PSD) | 15-35 mph Wind Event (Time Domain) Blue: Center of Module, Red: Corner of Module | 15-35 mph Wind Event (PSD) Blue: Center of Module, Red: Corner of Module

2. After six months in the field, the test modules were characterized for I-V, EL, and visual defects. Little change in I-V performance.



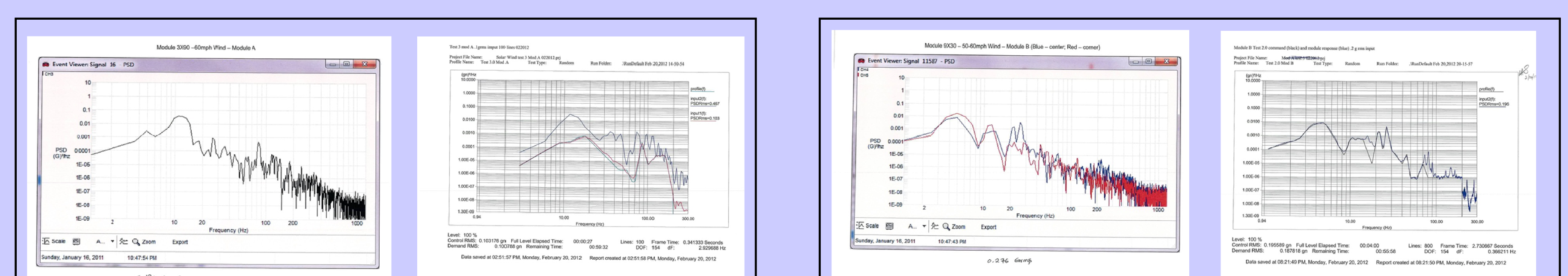
Initial EL of Module A Post field exposure



Initial EL of Module B Post field exposure

3. (Test 2.0) Using the RESPONSE spectrum from field data as the CONTROL for the vibration input command, the vibration machine reproduced the wind-induced vibration response on each module. The base table spectrum was recorded.

(Test 3.0) The test module was then EXCITED with the table data from the previous test data from the previous test and the RESPONSE on the module was compared to field data (Test 3.0)



Module A - Wind Induced Vibration Spectrum | Module A - Lab Induced Vibration Spectrum (top trace) | Module B - Wind Induced Vibration Spectrum | Module B - Lab Induced Vibration Spectrum

Spectra of field response and vibration excitation response for Modules A and B

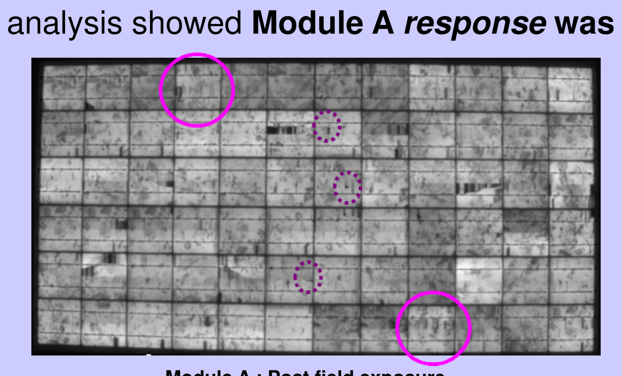
<u>Lab data is a reasonable match for field data for both modules</u>

4. (Test 3.0) Test modules were then subjected to 5 minutes of excitation equivalent to 29 m/s (65 mph) wind speed following 36 hrs DH (+85^{o}C / 85% RH) and TC50 (-40^{o}C to + 85% RH, no v-bias).

<u>SIGNIFICANT</u> degradation in Module A performance as judged from EL and visual inspection. I-V showed ~10% decrease in Pmax.

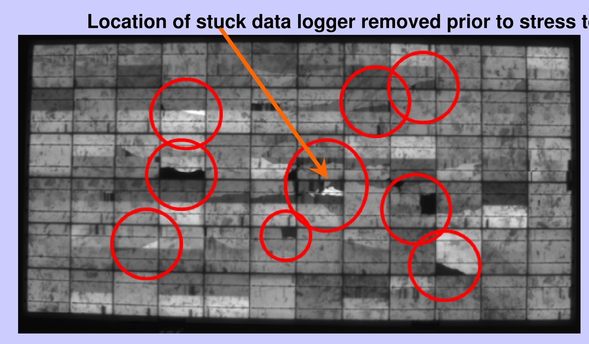
Module B showed no change in Pmax.

Later analysis showed **Module A *response* was 6 times the input** while Module B *response* was nearly equal to the input.



Module A : Post field exposure

Location of stuck data logger removed prior to stress testing



Module A : After simulation testing in lab

Module	Pmax (Watts)			Change from initial (%)	
	Initial , (data Sept 2010)	Post NREL Field, (data Nov 2011)	Post simulation testing (Dec 2011)	Post NREL fie d	Post simulation testing
Module A (control)	168.1	164.2		-2.3%	
Module A (test)	170.1	166.7	153.5	-2.0%	-9.8%
Module B (control)	280.8	283.6		1.0%	
Module B (test)	271.9	272.9	277.1	0.4%	1.9%

I-V Performance of Modules A and B

CONCLUSIONS

1. It is feasible and acceptable to reproduce field level wind-induced vibration excitation on mounted PV modules in the laboratory using standard vibration test equipment in order to help evaluate the resistance of modules to the negative effects of wind excitation.

2. When used in combination with Damp Heat and Thermal Cycling, vibration excitation <u>*may be*</u> an important tool in reliability studies for PV modules.

UN-ANSWERED QUESTIONS

1. Is it necessary to get field wind data (spectrum, Test 1.0) for each module or is there a method of determining this in the lab?

2. Can we predict the performance of a module beyond the measured input? (at 80 mph?)

3. What is the vibration excitation level suggested for possible R&D or certification tests?

4. What is a "good" combination of vibration and other tests (i.e. TC, DH, HF) to give better reliability data?

ACKNOWLEDGEMENTS

Appreciation is expressed to the following individuals for their participation and contributions:
Kent Whitfield, Solaria; Sarah Kurtz and Matt Mueller, NREL; Tanya Dhir and Brian McNamara, MiaSole; Herb Schueneman, Pal Khangaldy, Mark Escobedo, Mike Brown, and Tim Eells, Westpak, Inc.