OUTDOOR HIGH-VOLTAGE BIAS TESTING OF PV MODULES

Neelkanth G. Dhere, Ashwani Kaul

Florida Solar Energy Center, 1679 Clearlake Road, Cocoa, FL 32922-5703 USA

1. Introduction

• PV modules studies have shown that most of the degradation mechanism and reliability issues in PV cells have been determined by the tests carried out on field-deployed modules.

• Essential to understand the failure modes and mechanisms in PV modules and recommend improvements in the manufacturing technology so as to assure 25-30 year useful lifetime of field-deployed modules.

2. Degradation studies of PV Modules

• In late 80's and early 90's, array of 640 first-generation, framed, a-Si:H PV Modules were installed with a tilt of ~25^{o} towards the south by the Florida Power Corp at Orlando, FL in collaboration with researchers of the Florida Solar Energy Center. The array operational voltage was 300 V DC.

• a-Si:H thin-film PV modules were fabricated with SnO_2:F TCO layers on superstrate glass. Ground fault was created within the PV circuit of the module. Considerable degradation was observed in negatively-biased, modules (Fig. 1 showing arcing and molten glass as a result of corrosion reaching the junction box that created ~7" long gaping hole.

• Cause of degradation was thin-film circuit reaching all the way to the edge of the frame

FIGURE 1

FIGURE 2

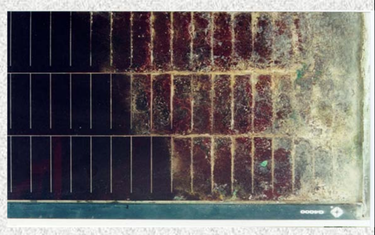
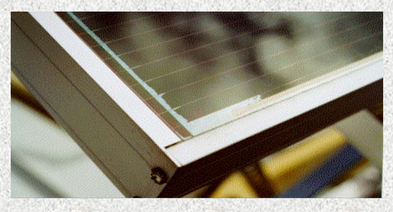


FIGURE 3

• Study of BP Solar a-Si:H (Fig. 4) PV module installed at latitude tilt at various bias voltages during 2001-2004.

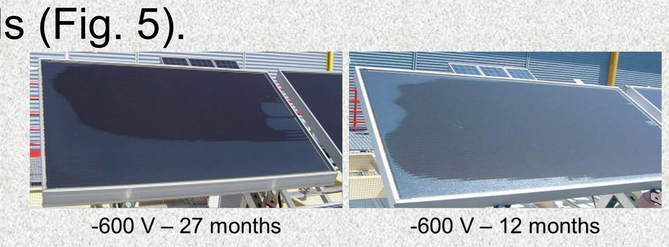
• Corrosion initiated near the southern edges of individual cell strips and moved inwards (Fig. 5).

FIGURE 4



-600 V Module – After 8 months

FIGURE 5



-600 V – 27 months

-600 V – 12 months

-300 V – 32 months

-150 V – 32 months

FIGURE 6

•Sodium diffusion seems to have resulted in severe delamination of SnO2:F layer from glass surface.

• Cells were fully destroyed due to electro-corrosion (Fig.6). Despite edge delete these modules encountered problems.

• Since PV modules are mostly mounted at latitude tilt, the role of latitude tilt is very important during the high-voltage testing at noted above the degradation begins from the bottom edges where most of the moisture and dirt accumulation takes places in actual outdoor conditions.

FIGURE 7

• Side by side testing of thin-film PV modules with maximum system voltage of ±600 V from all US manufacturers was carried out with a project from NREL (Fig. 7).

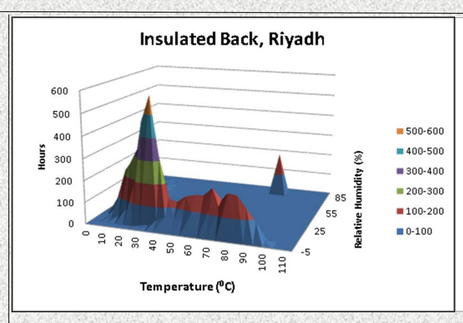


FIG. 8 (Courtesy M. Kempe)

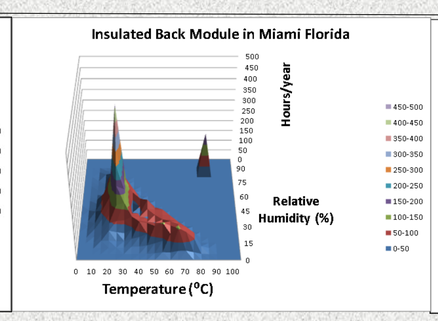


FIG. 9 (Courtesy M. Kempe)

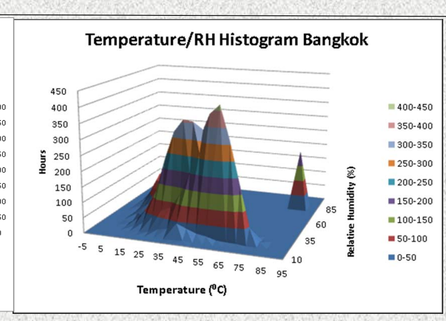


FIG. 10 (Courtesy M. Kempe)

• Typically 85°C-85%RH damp heat testing is used as the qualification test for PV modules. However, modules never see these conditions in the field (Fig 8,9,10).

•Testing PV modules outdoors with an external bias voltage is a more realistic test since it gives an opportunity to test them in nature's own laboratory where they are subjected to the actual conditions of solar irradiance, diurnal temperature variations, relative humidity.

•The acceleration factor comes from (1) higher voltage and (2) the additional biasing at night

3. CURRENT METHODS

FIGURE 11

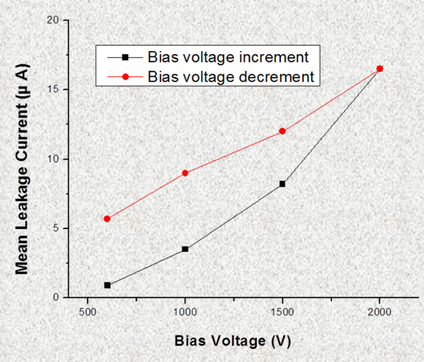


FIGURE 12

• Very high-voltage test bed was designed with the participation of graduate students. Design was approved by structural engineering firm and the entire arrangement complies with the electrical (NEC) and safety codes (OSHA).

• High-voltage bias testing (±1500 V) of c-Si PV modules, specially designed for HV applications was carried out (Fig. 11).

• Negatively biased modules showed degradation within an year.

• A new test was designed. A new module of the same type was biased at voltages up to -2000 V. The test was initiated with bias voltage at -600 V and the bias voltage was increased in steps of -600, -1000, -1500 and -2000 V with the module maintained for one week at each bias.

•Bias voltage was then decreased in same steps, again maintaining the module at each bias voltage step for one week in order to verify hysteresis.

• Figure 12 shows magnitude of mean value of leakage current at different biasing voltages for the abovementioned relative humidity and temperature range. It can be clearly seen in figure 8 that there exists a hysteresis.

4. New Plans

• To build the second high-voltage platform with improved methodology and hardware to avoid problems encountered in the past.

• PV modules from various technologies will be deployed for testing at very high voltage. Special care will be taken during the testing to avoid instantaneous irreversible degradation.

5. CONCLUSIONS

• From the studied undertaken, it is clear that high-voltage bias testing is the proper realistic test for acceleration testing of PV modules as compared to 85°C-85%RH damp heat testing.

• Therefore, outdoor high-voltage bias testing should be made an essential test for acceleration testing of PV modules.

• The chosen voltages and the latitude tilt are very important aspects of this test.