Performance Analysis of c-Si Modules Post 10 Year Deployment Hot and Humid Climate – Cocoa, FL

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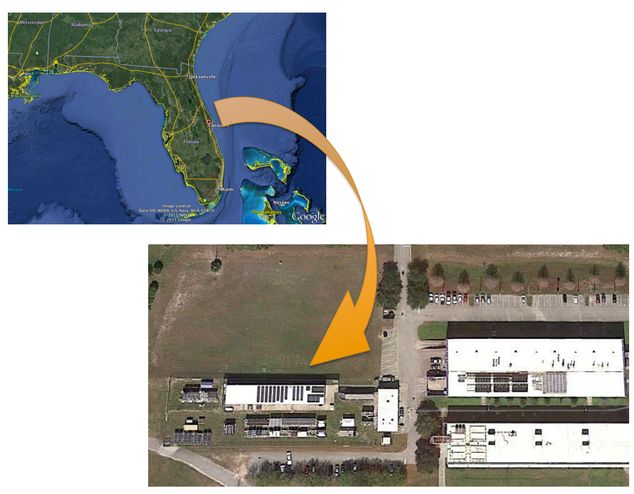
Summary

An 8.25 kW rooftop system installed in a hot and humid climate was base lined and monitored for a decade. The system consisting of over 150 solar modules was installed at the Florida Solar Energy Center (FSEC) in 2004. At the time of installation the modules were typical of the high quality modules commercially available. Prior to installation, the performance for each module was measured using an indoor solar simulator to obtain I-V measurements at standard test conditions. At the conclusion of the decade a subset of these 55W mono-crystalline solar modules were inspected and characterized. Electrical performance data of the modules was collected both before and after cleaning to understand influences of dirt accumulation. Additionally, module leads/ connectors were tested for resistive losses. Defect detection was carried out using electroluminescence imaging to provide insight into the degradation mechanisms leading to performance loss. The objective of this work is to provide valuable statistical information regarding the long-term reliability and degradation rate of c-Si modules in the hot and humid climate of Florida .

Site Installation

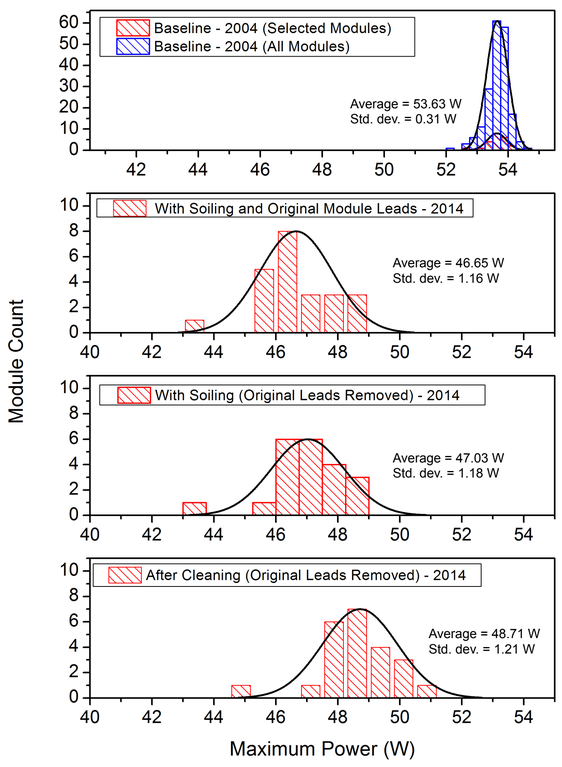
- Geographic Location:
  - 28° 23’
  - 80° 45’
  - Elevation 35’ (ground)
- Physical Address
  - 1679 Clearlake Road
  - Cocoa, FL 32922
- Environmental Stresses
  - Average hot 83.5 F in August
  - Average cold 63.8 F in January
  - 48.7” annual precipitation
  - 75% average daily humidity



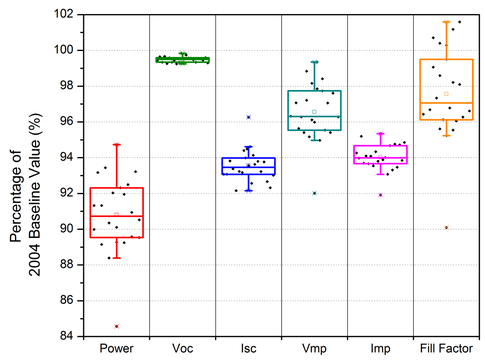
Experimental

- Pre Exposure:
  - All module were characterized at STC prior to installation at the FSEC site
  - A small subset of module (~5) were left unexposed during this period
- Post Exposure:
  - A subset of 25 modules were selected for removal.
  - Modules were characterized with a SPIRE solar simulator at STC in three stages
    - Before cleaning with original MC3 leads
    - Before cleaning (Bypassing original MC3 leads)
    - After cleaning (Bypassing original MC3 leads)
  - Electroluminescence imaging was carried out on selected modules

Power Degradation



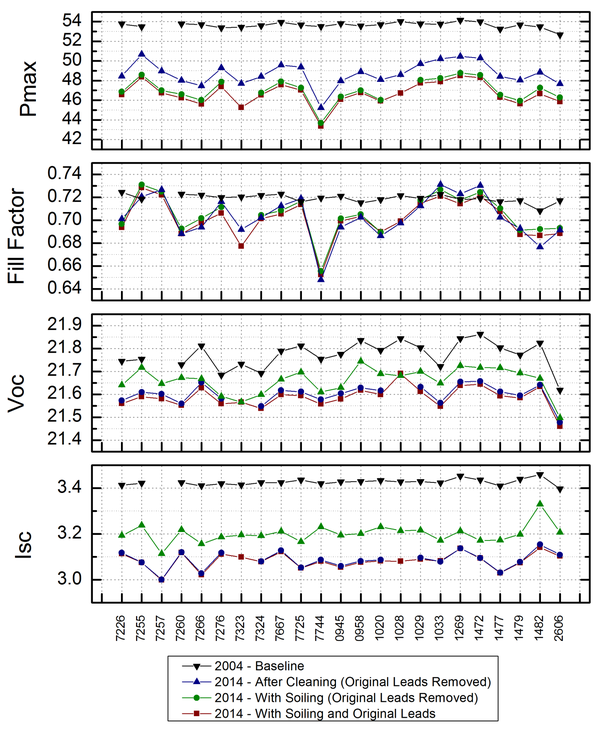
The initial performance variation was relatively small with a standard deviation of 0.31 W. After the 10 year exposure, the variation among the modules increased as seen in the histogram plots to the left. The average module power decreased by 4.92 W, or 90.82 % of the original value. This is equivalent to an average degradation rate of 0.908% per year over the 10 year period. As shown in the figure below, the degradation is a combination of a reduction in I_{sc} and Fill Factor.



Effect of Soiling and Contact Leads

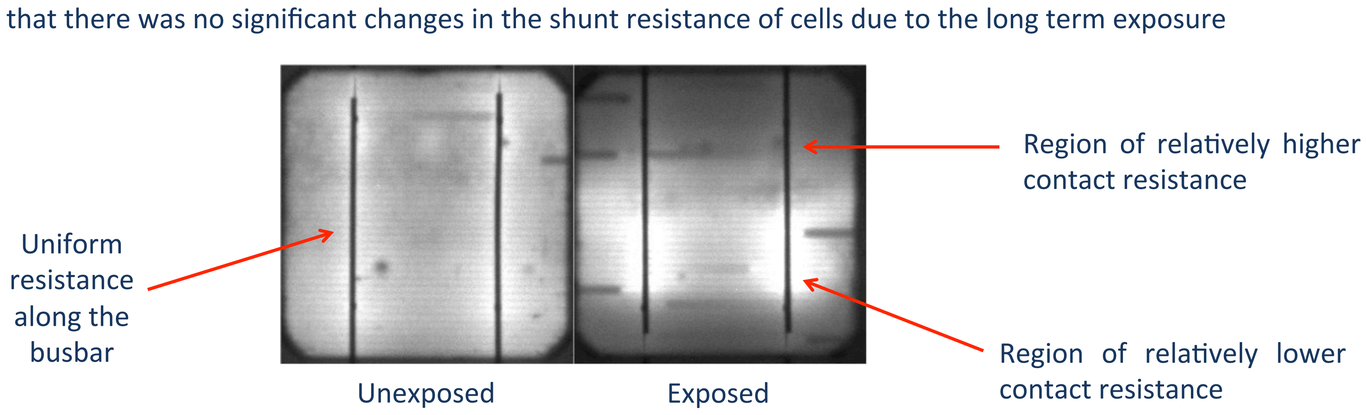
The resistance of the leads and the effect of soiling were captured using a series of I-V measurements. The original MC3 connector were removed bypassed, and measurements were taken directly from the terminal contacts. The figure to the right shows the performance parameters for each module, plotted for each measurement stage.

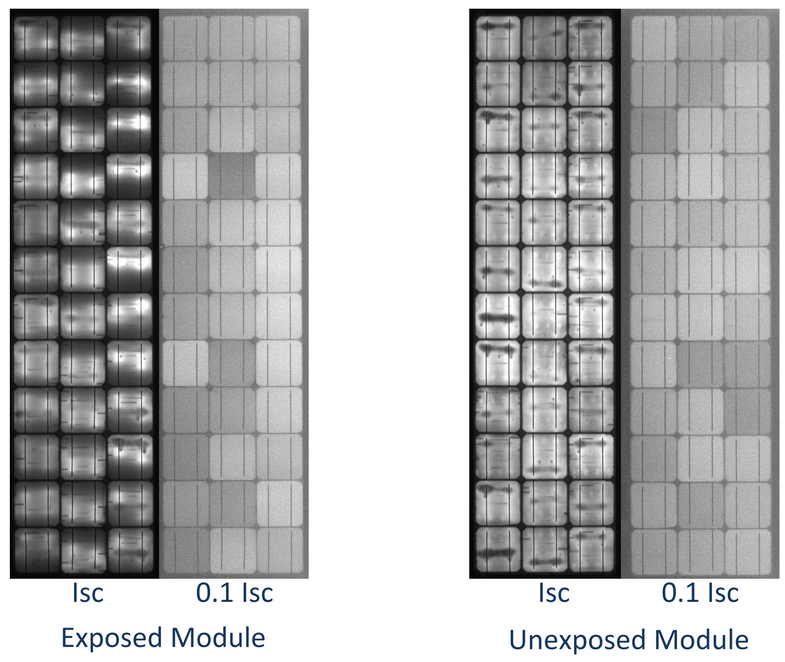
- Average power loss due to the leads
  - 0.31 W at Max Power
- Average loss due to Soiling
  - 1.75 W at Max Power
  - 0.115 A at I_{sc}



Electroluminescence Analysis

Electroluminescence imaging was carried out on selected modules including several unexposed modules. Two images were taken for each module at a forward current of I_{sc} and 0.1 I_{sc}. A variation in the contact resistance between the interconnecting busbar and the cell was consistently observed within cell of the exposed modules. An example from two modules is shown in the following figures. The low current images confirmed that there was no significant changes in the shunt resistance of cells due to the long term exposure





Conclusion

This long-term study identifies the degradation rate of standard c-Si modules deployed in the hot and humid climate of Florida. The degradation rate was determined to be just under 1 % per year, with the modules retaining an average of 90.8% of there original measured value. The effect of soiling and resistance of the contact leads was investigated and attributed to an additional loss of 3.84%. The modules in their operational state (including soiling and original leads) were performing at 87% of there original measured value. Electroluminescence imaging was used to identify any defects that developed during operation. These results represent only the preliminary performance evaluation of this system, with future investigations planned. This system remains in service at the Florida Solar Energy Center.

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