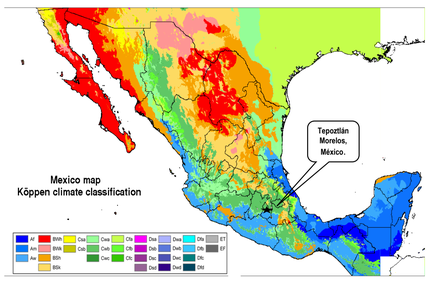
Electrical Performance and degradation analysis of a 25 Year Old Silicon PV Module

D. Martínez Escobar, R. Santos Magdaleno, P. A. Sánchez-Pérez, A. Sánchez Juárez and J. Ortega Cruz

Renewable Energy Institute UNAM, Addreess: Privada Xochicalco S/N Col Centro Temixco Morelos México. ZC 62580
Corresponding author: damae@ier.unam.mx

Background

Two stand alone systems were installed in Tepoztlan, Morelos in 1990. The first system was designed with 16 modules (16S x 1P) for lighting applications with ***Arco Solar M75*** modules. The second system has a 1S x 8P configuration for pumping application with ***Arco Solar M55*** modules. The objective of this analysis is to establish a dependence between degradation effects and climate conditions in the north part of Morelos.



Site of installation	Tepoztlan Morelos, Mex 18° 54' N, 99°01' W 1706 meters above sea level
Climate condition	Maritime temperate climates, Cwb (Köppen classification)
Manufacturer name:	Arco Solar Inc M55 & M75
Name plate data: M55	Pmax= 55 W, Isc= 3.35 A, Voc= 21.7 V, Imax= 3.13 A, Vmax= 17.6 V. Pmax= 50 W, Isc= 3.35 A, Voc= 19.8 V, Imax= 3.11 A, Vmax= 17.6 V.
Years exposed in Mexico	25 years

NIST National Institute of Standards and Technology U.S. Department of Commerce

3rd Atlas/NIST Workshop on Photovoltaic Materials.

Test methods

Crystalline silicon modules were removed and taken to our facilities for their characterization. Degradation analysis was carried out by:

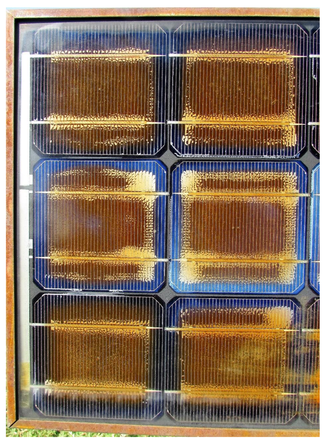
- ❖ Visual Inspection
- ❖ Infrared thermography
- ❖ IV curves with outdoor natural sun light

IV curves obtained were normalized following the procedure 1 described in IEC-60891, with the translation parameters α y β, supplied by the PV modules manufacturer.

Results

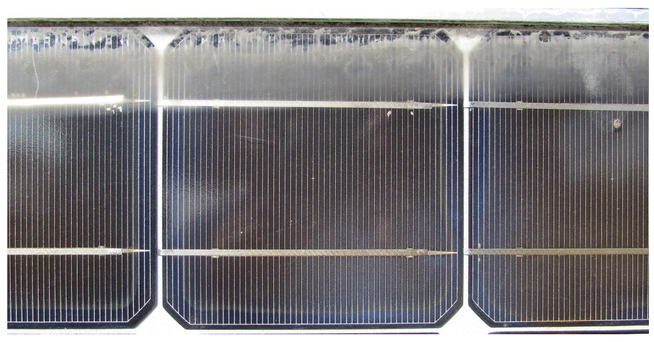
Visual Inspection:

Various types of defects were detected after a thorough visual inspection of the modules:



Arco Solar M55 module:

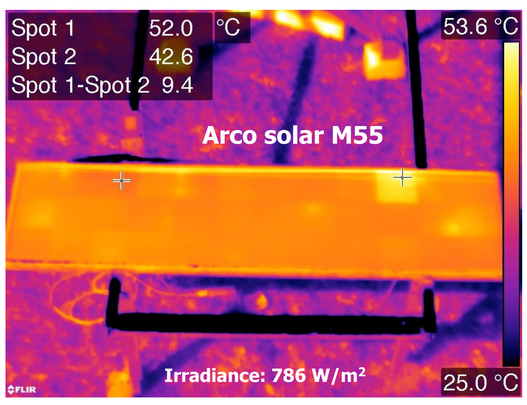
- ✓ Dark discoloration at cell center
- ✓ Delamination between Semiconductor /Encapsulant near the busbars and edges.
- ✓ Oxidation in the frame
- ✓ Crack cells

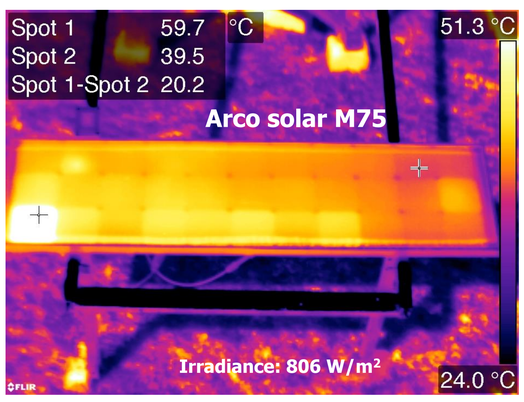


Arco Solar M75 module:

- ✓ Light discoloration at the cell center
- ✓ Soiled near the frame.
- ✓ Crack cells

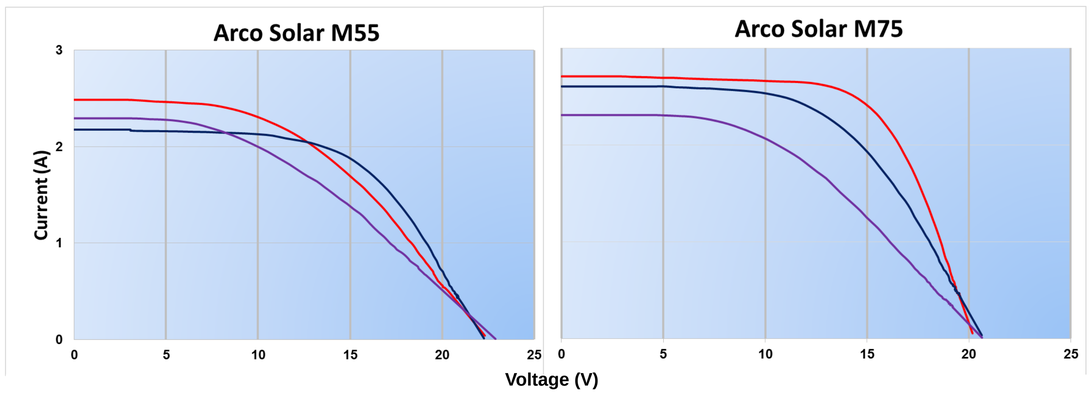
Infrared Images:





Thermal non-uniformity was found in both models. Multiple hot spots were detected near the positive junction box in Arco Solar M55 and near the negative junction box in Arco Solar M75.

Electrical performance:



Test Condition	M55					M75				
	Voc (V)	Isc (A)	Vmp (V)	Imp (A)	Pm (W)	Voc (V)	Isc (A)	Vmp (V)	Imp (A)	Pm (W)
Rated @ STC	21.7	3.35	17.60	3.13	55.00	19.80	3.35	15.9	3.11	50
Measured @ STC *	22.9	2.31	13.19	1.64	21.64	20.64	2.31	11.69	1.86	21.74
Measured vs Rated	-1.2	1.04	4.41	1.49	33.56	-0.84	1.04	4.21	1.25	28.26
Measured vs Rated (%)	-5.53	31.04	25.06	47.60	60.65	-4.24	31.04	26.48	40.19	56.52
Anual degradation Rate (%)	-0.22	1.24	1.00	1.90	2.43	-0.17	1.24	1.06	1.60	2.26

Electrical series resistance is calculated using outdoor IV curve; for M55 model it was obtained a value for Rs of 5.74 Ω, and 4.57 for M75 module. Since there was no control module, only the values of Rs are presented

Conclusions

- ➢ The power degradation rate is approximately 2 % per year for the worst module.
- ➢ Power degradation is due Isc drop and series resistance increases.
- ➢ Although it can not be obtain Rs increases rate, it can be suggest the increase due the IV curve shape.
- ➢ Severe corrosion was found in all the M55 modules.

References

[1] Packard, C. E., Wohlgemuth, J. H., & Kurtz, S. R. (2012). *Development of a visual inspection data collection tool for evaluation of fielded PV module condition* (No. NREL/TP-5200-56154). National Renewable Energy Laboratory (NREL), Golden, CO.
[2]Jordan, D. C., & Kurtz, S. R. (2013). Photovoltaic degradation rates—an analytical review. *Progress in photovoltaics: Research and Applications*, *21*(1), 12-29.
[3] Sánchez-Friera, P., Piliougine, M., Pelaez, J., Carretero, J., & Sidrach de Cardona, M. (2011). Analysis of degradation mechanisms of crystalline silicon PV modules after 12 years of operation in Southern Europe. *Progress in photovoltaics: Research and Applications*, *19*(6), 658-666.
[4] Chandel, S. S., Naik, M. N., Sharma, V., & Chandel, R. (2015). Degradation analysis of 28 year field exposed mono-c-Si photovoltaic modules of a direct coupled solar water pumping system in western Himalayan region of India.*Renewable Energy*, *78*, 193-202.
[5] Ndiaye, A., Charki, A., Kobi, A., Kébé, C. M., Ndiaye, P. A., & Sambou, V. (2013). Degradations of silicon photovoltaic modules: A literature review. *Solar Energy*, *96*, 140-151.

Acknowledges:
The present work was supported by the Renewable Energy Institute (IER-UNAM), through the funding of the Mexican Center for Innovation in Solar Energy (CeMIE-Sol), with the Strategic Project No P29 and the FORDECYT project No. 190603. The author want to thank Ing. Amilcar Reyes Roldán for his support in electrical characterization.