Development of a Visual Inspection Checklist for Evaluation of Fielded PV Module Condition

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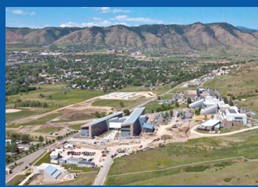


ABSTRACT

A visual inspection checklist for the evaluation of fielded photovoltaic (PV) modules has been developed to facilitate collection of data describing the field performance of PV modules. The proposed inspection checklist consists of 14 sections, each documenting the appearance or properties of a part of the module. This tool has been evaluated through the inspection of over 60 PV modules produced by more than 20 manufacturers and fielded at two different sites for varying periods of time. Aggregated data from a single data collection tool such as this checklist has the potential to enable longitudinal studies of module condition over time, technology evolution, and field location for the enhancement of module reliability models.

OVERVIEW OF VISUAL INSPECTION CHECKLIST

- Uses IEC/UL standard terminology
- Attempts to balance collection of sufficient detail for failure mode evaluation against minimizing recording time per module
- Consists of 14 sections- based on module component
- Additional detail can be found in the full NREL report

DESCRIPTION OF TEST FACILITIES

Photovoltaic modules from 2 sites served as the principle testbeds for the development of the inspection checklist, supplemented with the experience and knowledge of other professionals (identified in the Acknowledgements). Modules from Site 1 were inspected on location at the APS STAR Center ® (Arizona Public Services Solar Test and Research Center) in Tempe, Arizona USA. Modules from Site 2 were shipped from the field site at the Solar Energy Center (SEC) in New Delhi, India* to NREL for evaluation.

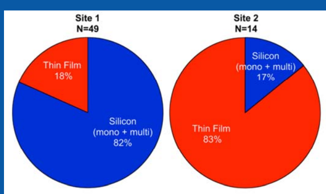


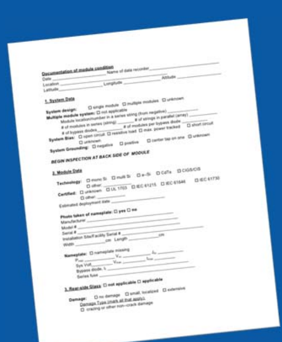
Figure 1. Composition of module sets at Site 1 and Site 2 used for early testing of the inspection checklist.

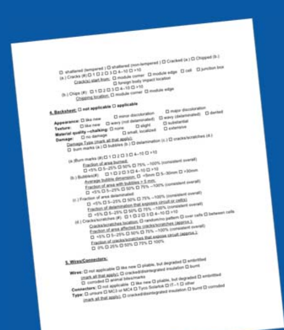
In all, more than 60 modules were inspected, representing more than 20 manufacturers. In addition to covering a broad range of technologies and manufacturers, these modules experienced different exposure times in the field: modules were fielded between 1-12+ years at Site 1 and 1-10 years at Site 2*.

*O. S. Sastry, *et al.*, "Degradation in performance ratio and yields of exposed modules under arid conditions," in *26th European Photovoltaic Solar Energy Conference and Exhibition*, Hamburg, Germany, 2011.

VISUAL INSPECTION CHECKLIST

- **Composed of 14 sections**
  - Sections 1-2: field site, system configuration, and module identification
  - Sections 3-13: individual module components, starting from the back and ending at the front of the module
  - Section 14: locations of electronic records (I-V curves, infrared images, etc.)
- Detailed instructions are given in the full report for each part of the checklist to reduce ambiguity and variation in survey responses
- **Required and optional tools:**
  - a tape measure with centimeter and millimeter gradations, a pen or other recording implement, and any personal protective equipment required by the facility (required)
  - a digital camera, an I-V curve tracer, and an infrared camera (optional)
- A full visual evaluation can be **completed in approximately 8 minutes** by a pair of experienced inspectors, though this can be reduced significantly for data sets consisting of a large number of similar modules or by the use of the abbreviated inspection list.

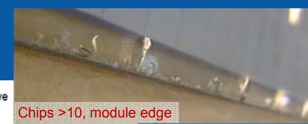




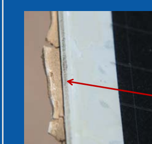
EXAMPLES

Section 3: Rear side glass

Damage: ☐ no damage ☑ small, localized ☐ extensive
Damage Type (mark all that apply):
☐ crazing or other non--crack damage
☐ shattered (tempered) ☐ shattered (non-tempered) ☐ Cracked (a.) ☑ Chipped (b.)
(a.) Cracks (#): ☐ 1 ☐ 2 ☐ 3 ☐ 4--10 ☐ >10
Crack(s) start from: ☐ module corner ☐ module edge ☐ cell ☐ junction box
(b.) Chips (#): ☐ 1 ☐ 2 ☐ 3 ☐ 4--10 ☑ >10
Chipping location: ☐ module corner ☑ module edge



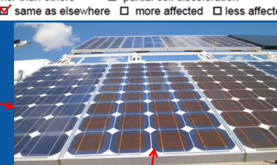
Section 9: Frameless Edge Seal



Appearance: ☐ like new ☐ discoloration (a.) ☑ visibly degraded
(a.) Fraction affected by discoloration:
☐ <5% ☐ 5--25% ☐ 50% ☐ 75% --100% (consistent overall)
Material problems:
☑ squeezed/pinched out ☐ shows signs of moisture penetration
Delamination: ☐ local only ☐ widespread
Fraction Delaminated: ☐ <5% ☐ 5--25% ☐ 50% ☐ 75% --100% (consistent overall)

Section 12: Silicon (mono or multi) module

Discoloration: ☐ none/like new ☐ light discoloration ☑ dark discoloration
Number of cells with any discoloration: 36
of those, average % discolored area:
☐ <5% ☐ 5-25% ☐ 50% ☐ 75% ☑ 100% (consistent overall)
Discoloration location(s) (mark all that apply):
☐ module center ☐ module edges ☑ cell centers ☐ cell edges
☐ over gridlines ☐ over busbars ☐ over tabbing ☐ between cells
☐ individual cell(s)darker than others ☐ partial cell discoloration
Junction box area: ☑ same as elsewhere ☐ more affected ☐ less affected



Section 13: Thin film module

Damage: ☑ no damage ☐ small, localized ☐ extensive
Damage Type (mark all that apply): ☐ burn mark(s) ☐ cracking
☐ possible moisture ☐ foreign particle embedded
Delamination: ☐ no delamination ☐ small, localized ☑ extensive
Location: ☐ from edges ☐ uniform ☐ corner(s) ☐ near junction box ☑ near busbar
☑ along scribe lines
Delamination Type: ☑ absorber delamination ☐ AR coating delamination ☐ other

PRELIMINARY RESULTS

We have not yet developed a large enough database to make conclusive statements about climate-zone dependent degradation but a preliminary analysis illustrates the types of data that become available through visual inspection.

Most frequently observed issues at Sites 1 & 2

Site 1 Observation	% of Modules	Site 2 Observation	% of Modules
Glass (front): Lightly soiled	55%	Glass (front): Small, localized damage	50%
Glass (front): Bird droppings	24%	Wires: Pliable but degraded	43%
Connectors: Pliable but degraded	22%	Glass (front): Lightly soiled	43%
Encapsulant: Major discoloration	20%	Junction box: seal will leak	36%
Backsheet: Small, localized damage	20%	Thin film module: Distance between frame and cells <10mm	36%

If visually observable defects can be correlated or conclusively linked with the measured electrical performance degradation rates, visual inspection may provide a relatively low impact method for assessing which PV installations may be more likely to see accelerated degradation based on the frequency and types of defects that develop.

FUTURE

- Availability of the checklist, a data collection spreadsheet, and NREL report with detailed instructions for using the checklist
- Availability of a database for compiling user-submitted field data

Please contact Corinne Packard if you are interested in participating in data collection

ACKNOWLEDGEMENTS

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