Introduction to PV Failure Fact Sheets (PVFS)

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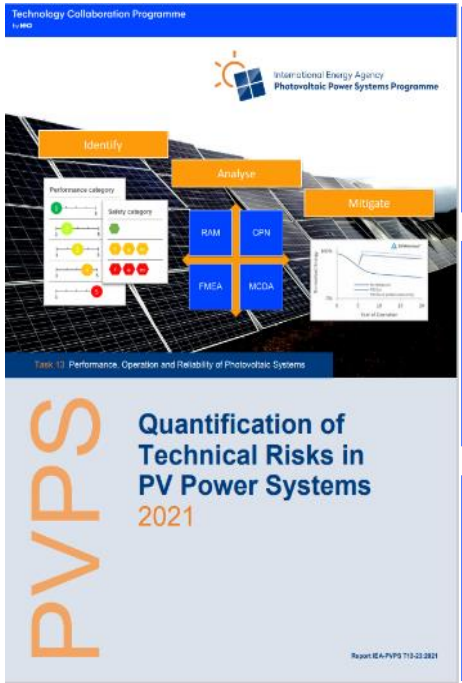
IEA PVPS Task 13 Focus Workshop/Webinar on Operation & Maintenance, Fraunhofer ISE, 30 September 2021

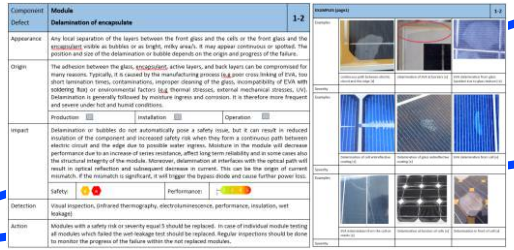
Introduction



Common Practice

Risk Database

Case Studies



PV Failure Fact Sheets (PVFS)

PV Failure Degradation Sheets

PV Cost Data

PV Failure Fact sheets

Aim

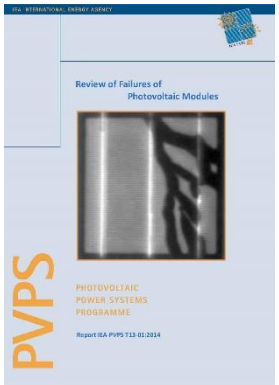
Brief description of failures with examples, an estimation of risks and suggestions for mitigation measures.

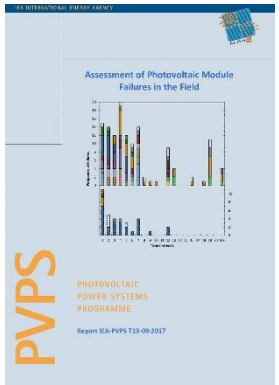
Target audience

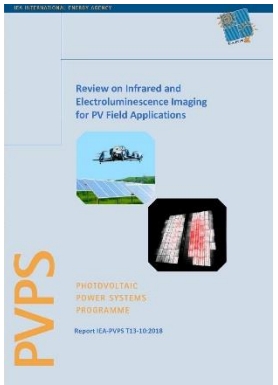
PV planners, installers, investors, independent experts and insurance companies.

Approach

Summarise the key aspects described in IEA PVPS Task 13 technical reports.



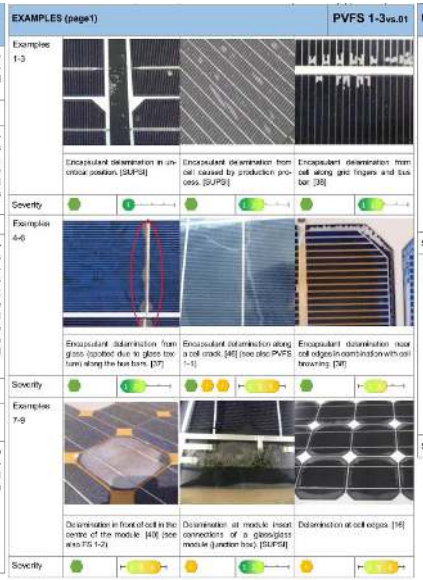


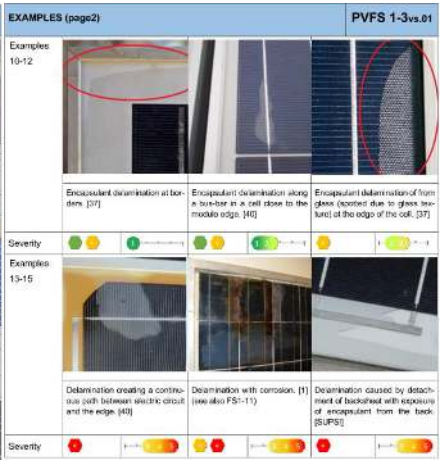


PVFS Structure

- COMPONENT
- DEFECT
- APPEARANCE
- DETECTION
- ORIGIN
- IMPACT
- MITIGATION
- EXAMPLES

Component Defect	**Module** **Front delamination**		**PVFS 1-3vs.01**
Appearance	Any local separation of the layers between (i) the front glass and the encapsulant or (ii) the cell and the encapsulant, visible as bubbles or as bright, milky area/s. It may appear continuous or in spots. The position and size of the delamination or bubble depends on the origin and progress of the failure.		
Detection	VI, (INS)		
Origin	The adhesion between the glass, encapsulant, active layers, and back layers can be compromised for many reasons. Typically, it is caused by the manufacturing process (e.g. poor cross linking of EVA, too short lamination times, too high pressure in the laminator, contaminations, improper cleaning of the glass, incompatibility of EVA with soldering flux, inadequate storage of the raw material) or environmental factors (e.g. thermal stresses, external mechanical stresses, UV). Delamination is generally followed by moisture ingress and **corrosion**. It is therefore more frequent and severe under hot and humid conditions.		
	Production ■	Installation □	Operation ■
Impact	Delamination or bubbles do not automatically pose a safety issue, but they can result in **reduced insulation** of the component and increased safety risk when they form a continuous path between electric circuit and the edge due to possible water ingress. Moisture in the module will decrease performance due to an increase of series resistance, affect long term reliability and in some cases also the structural integrity of the module. Moreover, delamination at interfaces in the optical path will result in additional optical reflection and subsequent decrease in current. This can be the origin of current mismatch. If the mismatch is significant, it will trigger the bypass diode and cause further power loss. The inverter might also shut down due to leakage current's leading to a further performance loss. Manufacturing related delamination issues often affects a relevant percentage of modules within the same production batch and consequentially has a big impact on system performance.		
	Safety: 1 2 3 S	Performance: 1 2 3 S	
Mitigation	Corrective actions	Preventive actions (recommended)	Preventive actions (optional)
	Modules with a direct safety risk or a severity of 5 should be replaced. Regular inspections should be done to monitor the status of the not replaced modules. In case of individual module testing all modules which failed the insulation and/or wet-leakage test should be replaced.	Check validity of IEC 61215 certification and BOM, ground fault detection by inverter or other devices at all time.	Extended testing (e.g. damp heat), pre-shipment inspections (e.g. cross linking level of EVA) regular visual system inspections.





Revised version of the failure sheet format proposed in the European Solar Bankability Project.

Ref: 'Technical risks in PV projects: report on technical risks in PV project development and PV plant operation', www.solarbankability.eu

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PVFS 1-03: Module front delamination

PVFS List

- COMPONENT
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30 PV Failure Fact Sheets

FAILURES	PV MODULE
PVFS 1-1	Cell cracks
PVFS 1-2	Discolouration of encapsulant or backsheet
PVFS 1-3	Front delamination
PVFS 1-4	Backsheet delamination
PVFS 1-5	Backsheet cracking
PVFS 1-6	Backsheet chalking (whitening)
PVFS 1-7	Burn marks
PVFS 1-8	Glass breakage
PVFS 1-9	Cell interconnection failure
PVFS 1-10	Potential induced degradation
PVFS 1-11	Metallisation discolouration/corrosion
PVFS 1-12	Glass corrosion or abrasion
PVFS 1-13	Defect or detached junction box
PVFS 1-14	Junction box interconnection failure
PVFS 1-15	Missing or insufficient bypass diode protection
PVFS 1-16	Not conform power rating
PVFS 1-17	Light induced degradation in c-Si modules
PVFS 1-18	Insulation failure
PVFS 1-19	Hot spot (thermal patterns)
PVFS 1-20	Soiling

FAILURES	CABLE AND INTERCONNECTOR
PVFS 2-1	DC connector mismatch
PVFS 2-2	Defect DC connector/cable
PVFS 2-3	Insulation failure
PVFS 2-4	Thermal damage in combiner box
FAILURES	**MOUNTING**
PVFS 3-1	Bad module clamping
PVFS 3-2	Inappropriate/defect mounting structure
PVFS 3-3	Module shadingure
FAILURES	**INVERTER**
PVFS 4-1	Overheating (temperature derating)
PVFS 4-2	Incorrect installation
PVFS 4-3	Complete failure (not operating)

Link for Download of PV Failure Fact Sheets (available soon!)

- IEA PVPS homepage *https://iea-pvps.org/research-tasks/performance-operation-and-reliability-of-photovoltaic- systems/documents/*

Downloadable as:

- annex of Report IEA-PVPS T13-23:2021 "Quantification of Technical Risks in PV Power Systems"
- full PVFS package + Introduction
- individual sheets

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PVFS 1-03: Front delamination

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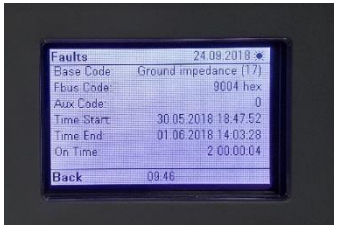
PVFS 1-03: Front delamination

Component	**Module**	**PVFS 1-3**
Defect	**Front delamination**	
Detection	VI, (INS)	

Note: Detection methods in brackets lists secondary methods, which do not detect the failure with absolute certainty or which can be used in addition to other methods.

	Detection Methods
VI	Visual inspection
IRT	Infrared thermography
EL	Electroluminescence
IV	Daylight I-V measurement
UV	UV fluorescence
STM	Signal transmission method
MON	Data monitoring
dIV	Dark I-V measurement
BYT	Bypass diode testing
VOC	V_{oc} measurement
INS	R_{iso} measurement



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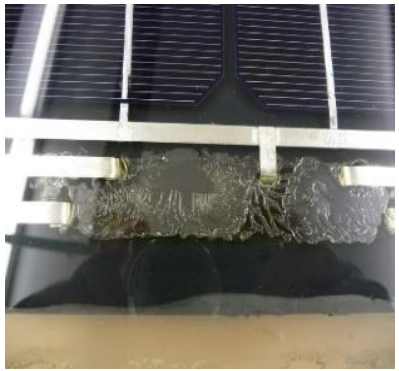
	Production ■	Installation □	Operation ■

Note: Correlations between failures are highlighted in bold. Link to other PVFS.



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- **Failure with an impact on safety**
  Failure which can lead to a danger for who is working on or staying close to a PV system.
- **Failure with an impact on performance**
  Failure which impacts negatively the energy production of a PV system.

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PVFS 1-03: Front delamination

Component	**Module**			**PVFS 1-3**
Defect	**Front delamination**			
	Safety:		Performance:	

No unique rating is possible → Spectrum covering typical field observations

RATING SYSTEM

Safety category	Description
	Failure has no effect on safety.
f e m	Failure may cause a fire (f), electrical shock (e) or a physical danger (m) if a follow-up failure and/or a second failure occurs.
f e m	Failure can directly cause a fire (f), electrical shock (e) or a physical danger (m).

Ref: 'Review of failures of photovoltaic modules', Report IEA-PVPS T13-01:2014

Performance category	Description	
1	The defect has no direct effect on performance.	*no loss (0%)*
2	The defect has a minor impact on performance.	*below detection limit <2-3%*
3	The defect has a moderate impact on performance.	*within warranty (<0.7-1%/year)*
4	The defect has a high impact on performance.	*out of warranty (>0.7-1%/year)*
5	The defect has a catastrophic impact on performance.	*catastrophic loss (>3%/year)*

Ref: 'Silicon solar module visual inspection guide: Catalogue of Defects to be used as a Screening Tool', K. Sinclair, M. Sinclair, https://www.engineeringforchange.org/wp-content/uploads/2017/09/Solar-PV-Product-Visual-Inspection-Guide.pdf

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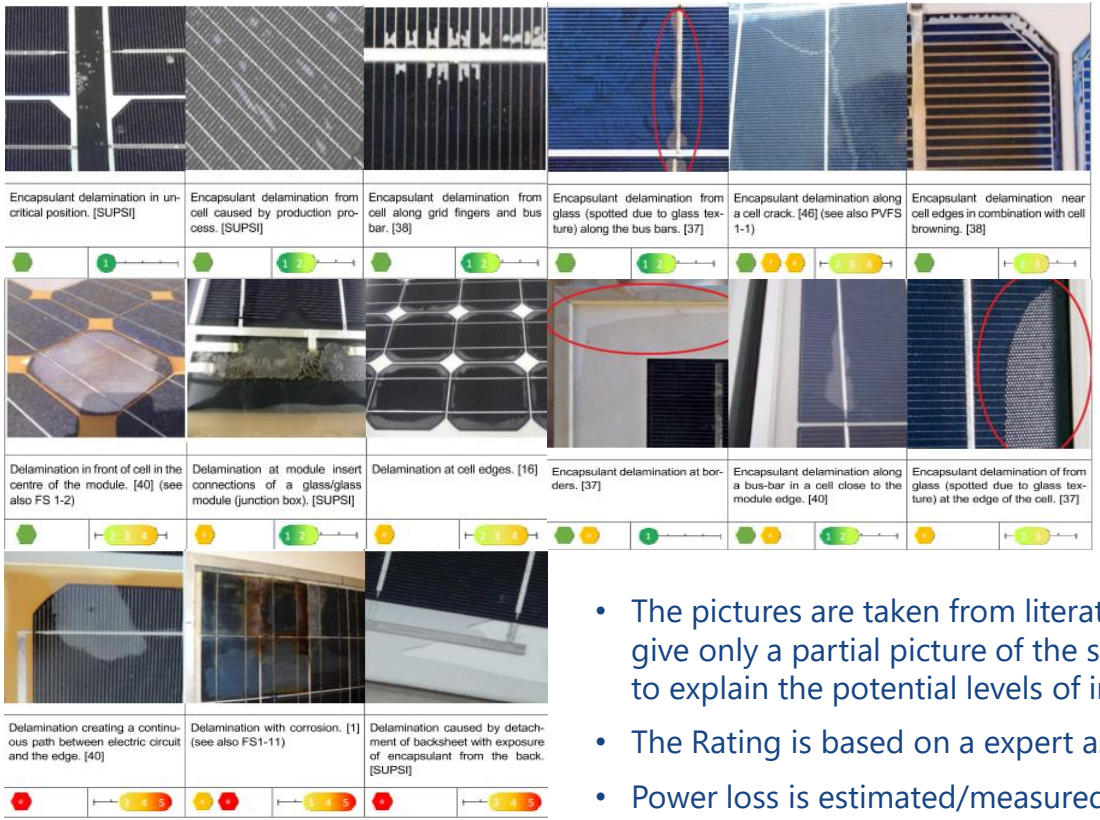

- The pictures are taken from literature or case studies and give only a partial picture of the situation. They are used to explain the potential levels of impact.
- The Rating is based on a expert assessment.
- Power loss is estimated/measured on the component level.

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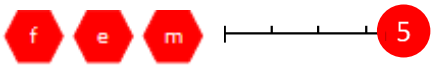
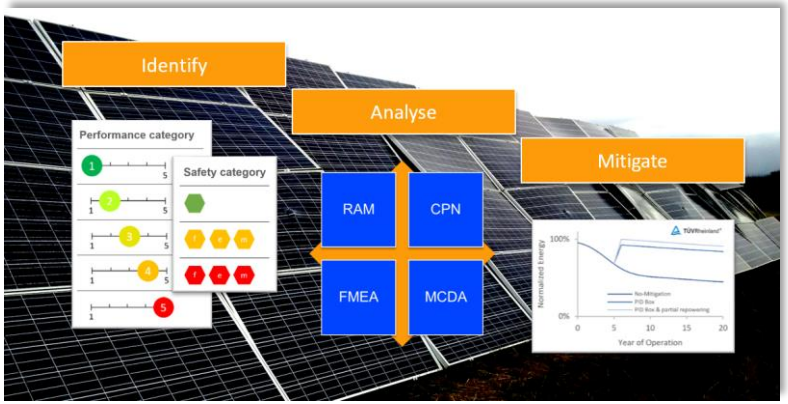
- **Repair or Replacement** of all modules rated as 

- The choice of other **Mitigation Measures** (preventive or corrective) requires a cost benefit analysis.

Summary & Conclusions

The key challenge in reacting to failures or avoiding them at a reasonable cost is the ability to quantify and manage the various risks.

The PV Failure Fact Sheets (PVFS) helps in identifying a failure, assessing the risk through a rating system and suggesting mitigation measures. Final decisions requires a case specific risk and cost-benefit analysis.



Report IEA-PVPS T13-23:2021 "Quantification of Technical Risks in PV Power Systems"
https://iea-pvps.org/research-tasks/performance-operation-and-reliability-of-photovoltaic- systems/documents/

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Thank you for your attention

A special thanks goes to all contributors

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