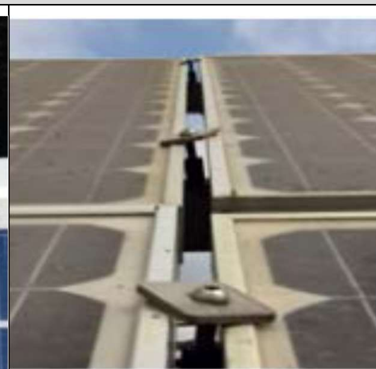
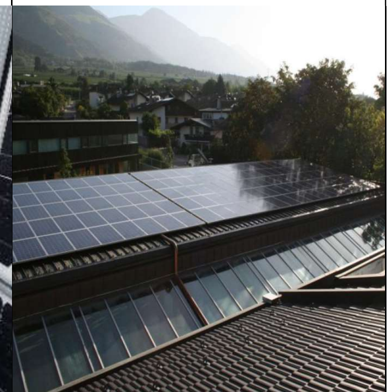
<table>
<tr><td>Component
Defect</td><td colspan="4">Mounting
Bad module clamping</td><td>PVFS 3-1vs.01</td></tr>
<tr><td>Appearance</td><td colspan="5">Inadequate fastening or damage of the module or frame by the clamp.</td></tr>
<tr><td>Detection</td><td colspan="5">VI</td></tr>
<tr><td rowspan="2">Origin</td><td colspan="5">The installation instructions of the module and mounting structure from the manufacturer are not followed. Typical errors at the planning and installation stage are: (a) use of inadequate clamps for the selected module and/or mounting structure, e.g. sharp edges damaging glass/glass modules, wrong combination of clamps and modules or mounting structure (b) too short and too narrow clamps or (c) the positions, kind or number of the clamps on the module not being chosen in accordance with the manufacturer’s manual. Other errors are too excessively or insufficiently tightened screws during the mounting phase.</td></tr>
<tr><td colspan="2">Production ■</td><td colspan="2">Installation ■</td><td>Operation ■</td></tr>
<tr><td rowspan="2">Impact</td><td colspan="5">An improperly installed clamp compromises the integrity of the mounting system and the ability of the module to stay in place under high wind or load conditions. The detachment of modules can happen as series effect because the modules share the clamps with the module next to it. Once one module is detached, the clamp immediately loses fixing force on the next module and result in series detachment. The detachment of the module/s from the mounting structure is posing a serious hazard to persons and the risk of damaging the rest of the system and/or the property in the vicinity of the installation site. Problems such as frame damage, glass breakage or cell cracks can occur compromising on the long term the performance and the electrical safety.</td></tr>
<tr><td>Safety:</td><td colspan="2">f e m e m</td><td>Performance:</td><td>1 2 3 4 5</td></tr>
<tr><td rowspan="2">Mitigation</td><td colspan="2">Corrective actions</td><td colspan="2">Preventive actions (recommended)</td><td>Preventive actions (optional)</td></tr>
<tr><td colspan="2">Modules with a safety risk or a severity of 5 should be replaced.</td><td colspan="2">Use only compatible clamps (mounting structure/ modules/ clamps) and follow manufacturer mounting instructions. Check local wind and snow loads.</td><td>Testing of non-standard mounting configurations by an accredited test laboratory (eg. facade mounting), perform regular system inspections</td></tr>
</table>

EXAMPLES (page1)			**PVFS 3-1vs.01**
Examples 1-3			
	Improper installation of clamp.	Wrong combination of clamps and modules. [Moser17]	Glass breakage caused by too tight screws. [Herrmann21] (see also PVFS 1-8)
Severity	f e e / 1	f e e / 1	f m e m / 2 3 4
Examples 4			
	Glass breakage caused by poor clamp design. [Moser17] (see also PVFS 1-8)		
Severity	f m e m / 2 3 4		

<table>
<tr><td>Component
Defect</td><td colspan="3">Mounting
Inappropriate/defect mounting structure</td><td>PVFS 3-2vs.01</td></tr>
<tr><td>Appearance</td><td colspan="4">Mechanical damages (e.g cracking, bending) or other visual defects (e.g. corrosion of frame or mounting holes) observable on the mounting structure.</td></tr>
<tr><td>Detection</td><td colspan="4">VI</td></tr>
<tr><td rowspan="2">Origin</td><td colspan="4">Typically, this failure occurs when the mounting structure is not designed to withstand the wind or snow loads which are typical for the site in which the system is installed (e.g. mounting structure does not comply with static calculations, underestimation of the environmental conditions), or if the anchorage of the mounting structure to the ground or roof is weak (e.g. ground conditions are not considered sufficiently when choosing the mounting structure). The roof strength, to withstand the added load of the PV system and include allowance for O&M activities, is not verified. Another reason for the failure of a mounting structure is the use of inappropriate materials (e.g use of corrosive materials in a corrosive environment, insufficient galvanisation, poor quality material due to a bad or missing quality assurance in production), leading to a premature degradation or mechanical failure of the mounting structure. Installation errors (e.g. missing/non-original components, excessively or insufficiently tightened screws) can be the origin of a failure of the mounting structure.</td></tr>
<tr><td>Production ■</td><td colspan="2">Installation ■</td><td>Operation ■</td></tr>
<tr><td rowspan="2">Impact</td><td colspan="4">An inappropriate or damaged mounting structure compromises the integrity of the modules mounted on it and in some cases also the substructure (e.g roof insulation). In the worst case this leads to the detachment of single modules or the whole mounting structure from the roof or ground, or roof collapses, posing a serious hazard to persons and the risk of damaging the rest of the system and/or the property in the vicinity of the installation site. Performance losses are to be expected, depending on the damage on module level (number of disconnected modules/strings, glass breakage, cell cracks, back sheet damages, damaged or detached junction box) and the time and labour needed to repair the system. Galvanic corrosion is important for the installation with two different metals in contact, for example aluminium frame fixed on steel structure, especially in humid or costal area. Direct contact of different metals generates galvanic corrosion which frequently happens around the fastening screws. Therefore insulation between two different metals is required in humid and costal area.</td></tr>
<tr><td>Safety:</td><td>f e m</td><td>Performance:</td><td>1 2 3 4 5</td></tr>
<tr><td rowspan="2">Mitigation</td><td>Corrective actions</td><td colspan="2">Preventive actions (recommended)</td><td>Preventive actions (optional)</td></tr>
<tr><td>Mounting structures with a direct safety risk should be replaced or repaired.</td><td colspan="2">Use only compatible mounting structures (ground/mounting structure/modules) and follow manufacturer mounting instructions. Check local load (conditions (wind, snow, other).</td><td>Regular system inspections.
Testing of non-standard mounting configurations by an accredited test laboratory (e.g. facade mounting), perform regular system inspections.</td></tr>
</table>

EXAMPLES (page1)			**PVFS 3-2vs.01**
Examples 1-3			
	Corrosion due to salt water. [Köntges16]	Cracks in mounting structure due to mechanical stress. [Köntges16]	Screw canal bends due to mechanical stress. [Köntges16]
Severity	f e m / 1 2	m / 1	m / 1
Examples 4-6			
	Bracket fractured due to mechanical stress. [Köntges16]	Undersized mounting structure for local snow load conditions. [Köntges16]	Undersized mounting structure for local wind conditions. [India13]
Severity	m / 1	m / 5	m / 5

Component	**Mounting**		**PVFS 3-3vs.01**
Defect	**Module shading**		
Appearance	Depending on the position of the sun (day and time), shading can be seen either by eye when performing a visual inspection, or by comparing monitoring data of unshaded and shaded strings or by running shading simulations. The shade can have different patterns and change/move over the day and season.		
Detection	VI, (MON, IRT)		
Origin	The choice of the mounting structure and the position in which the modules are mounted influences the shading conditions. Shading can be caused by different factors or obstacles e.g trees, antennas, poles, chimneys, satellite dishes, roof or façade protrusions, near buildings, cables, or by self-shading (inter array or row-to-row shading) or soiling. Shading conditions can change over the lifetime of a PV system due to growing vegetation, new constructions or construction elements. It can be distinguished between different types of shades: direct shades hindering the direct light to reach the module or diffuse shades.		
	Production ☐	Installation ■	Operation ■
Impact	A cell or module which does not receives or receives less sunlight due to a shading obstacle, lowers the performance of a PV system. Typically, the cumulative annual shading loss of PV systems is between 1-5%, but energy losses up to 20-30% can be observed for roof top or façade systems. Due to series connection of cells and modules, the power loss is significantly higher than the shaded area. The final loss depends on the on-site implementation or shading mitigation measures like optimised string and module arrangements (landscape mounting), use of module-level power electronics (MLPEs), inverter characteristics (MPPT search algorithms, string control) or the use of shading tolerant module technologies (e.g half-cut cells, back contact cells). Shading itself does not pose a safety issue, but the **hot-spots** caused by prolonged shading can lead to follow-up failures (e.g **burn marks**, **bypass diode failures**, **glass breakage**, arcing or fire). It further can result in an acceleration of the aging process resulting into higher degradation rates. The right time to consider the impact of shading is at the system planning phase, later it is usually too late. The use of MLPEs such as micro-inverters and DC optimizers for individual modules can potentially increase performance under shading conditions, but the gain achieved by these devices do not always exceeds the loss caused by the MPLE device itself (lower efficiency), and the shading still activates the bypass diode and result in hot spot on the shaded cell, which increases the risk of reliability issues. The choice of using them only in the area where shading occurs should be considered an alternative to install them for all modules. A cost benefit analysis should be done in any case.		
	Safety: f e m	Performance: 2 3 4 5	
Mitigation	Corrective actions	Preventive actions (recommended)	Preventive actions (optional)
	Indirectly damaged modules with a safety or severity risk of 5 should be replaced or repaired. Eventual trees or vegetation responsible for the increased shading loss should be cut.	A basic shading analysis (full year solar/shade data) is recommended to identify areas and periods of major shading. Areas exposed to shading within the central part of the day or sunny season should be avoided or appropriate/cost-effective shading mitigation measure should be implemented.	A detailed shading loss analysis should be done which estimates and compares different system configurations and shading mitigation measures. Perform regular system inspections.

EXAMPLES (page1)			**PVFS 3-3vs.01**
Examples 1-3			
	Shading by pole-and-wire (poor design: too close to nearby shading objects). [Jahn18]	Shading due to bad planning or coverage by afterwards build construction element. [Moser17]	Shading by tree with seasonal changes due to foliage. [Moser17]
Severity	2 3 4	5	3 4
Examples 4-6			
	Missing maintenance on flat green roof. [SUPSI]	Vertical shading of a standard module with 3 bypass diodes. [J.Lin]	Shading by balustrade. [J.Lin]
Severity	f e m / 5	3 4 5	2 3 4
Examples 7			
	Continuous shading caused by chimney. [SUPSI]		
Severity	f e m / 3 4 5		