Risk Management of ground mounted Solar Parks during operation

DFBEW Solar Conference, 7 November 2017, Paris
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TÜV Rheinland – Solar Energy Worldwide

Quality, safety and reliability around the world

OUR GLOBAL PV NETWORK

No 1 in PV module and component testing worldwide

35 Years experience in PV product testing

27 Years experience in Power plant inspections

6 PV test laboratories + several outdoor test fields

> 250 Experts

> 20 GW Inspected PV projects
Failure systematics in PV Systems

- Quality assurance (QA) is crucial in order to reduce levelized cost of energy, since it contributes to ensure stability for the investors and other stakeholders.
- A development of a individual risk management strategy along the lifecycle of a PV project should contain the following steps: Risk identification; Risk assessment; Risk management; Risk controlling.
TÜV Rheinland internal Study (Data 2014/ Q1. 2015)

Cause of Defects in PV Power Plants

**Basis of the study:**
> 100 plants (100 kWp - 30 MWp)
(Main regions: Germany, Europe, RoW)

**Main findings:**
- 30 % of power plants show serious and particularly serious defects (incl. safety issues) or large number of issues
- > 50 % of defects are caused by installation errors

- Systematic quality assurance is required
- Plant inspections and maintenance are important

**Diagram:**
- Installation faults: 55%
- Documentation & planning faults: 25%
- Miscellaneous: 9%
- Environmental influence: 5%
- Product defects: 5%
- Maintenance: 5%
TÜV Rheinland internal Study: Particularly serious Defects in PV Power Plants

"Immediate Action to prevent Plant breakdown is needed"

2012 / 2013

- Cabling: 33%
- Modules: 19%
- Connection & distribution boxes: 9%
- Mounting structure: 13%
- Inverter: 11%
- Infrastructure & environmental: 8%
- Potential equalization & grounding: 7%

2014 / Q1. 2015

- Modules: 48%
- Mounting structure: 28%
- Inverter: 16%
- Connection & distribution boxes: 13%
- Cabling: 7%
- Infrastructure & environmental: 6%
TÜV Rheinland internal Study
Failure Examples (Planning, Installation, Foundation, O&M)
## Risk Identification – Technical Risk Matrix

<table>
<thead>
<tr>
<th>Modules</th>
<th>Inverter</th>
<th>Mounting structure</th>
<th>Connection &amp; distribution boxes</th>
<th>Cabling</th>
<th>Potential equalization &amp; grounding, LPS</th>
<th>Weather station, communication, monitoring</th>
<th>Infrastructure &amp; environmental influence</th>
<th>Storage system</th>
<th>Miscellaneous</th>
</tr>
</thead>
</table>
| • Improper Insulation  
• Incorrect cell soldering  
• Undersized bypass diode  
• Junction box adhesion  
• Delamination  
• Arcing spots on the module  
• Visually detectable hot spots  
• Incorrect power rating (flash test issue)  
• Uncertified components or production line  
• Unsuitable/ uncertified Bill of Materials (BOM)  
• Unclear initial degradation | • Soiling  
• Shadow diagram  
• Modules mismatch  
• Modules not certified  
• Flash report not available or incorrect  
• Special climatic conditions not considered (salt corrosion, ammonia, ...)  
• Incorrect assumptions of module degradation, light induced degradation unclear  
• Module quality unclear (lamination, soldering)  
• Simulation parameters (low irradiance, temperature...) unclear, missing PAN files | • Module mishandling (glass breakage)  
• Module mishandling (cell breakage)  
• Module mishandling (defective backsheet)  
• Incorrect connection of modules  
• Bad wiring without fasteners | • Hotspot  
• Glass breakage  
• Soiling  
• Shading  
• Snail tracks  
• Cell cracks  
• PID  
• Failure bypass diode and junction box  
• Corrosion in the junction box  
• Theft of modules  
• Delamination  
• Module degradation  
• Slow reaction time for warranty claims, vague or inappropriate definition of procedure for warranty claims  
• Spare modules no longer available, costly string reconfiguration | • Undefined product recycling procedure |

Source: Solar Bankability
Risk Identification: Soiling, Sand and Dust

Field Testing and Soiling Simulation, Thuwal/Saudi-Arabia

- High ambient dust concentration ⇒ Average daily percent decrease of - 0.5 %
- Dust storm ⇒ Max. soiling loss factor (SLF) ⇒ change per day = - 7.7 %

• Yield losses > 5 % within 1 week are possible

• Site specific cleaning concept is required
Risk Identification: Potential induced Degradation

- Performance killer number one: potential induced degradation (PID)
  (occurs in cases of high voltage, sensitive module/material combinations and damp environments – e.g. caused by condensation, high humidity)
- Reversible process through grounding or counter-potential (investments required)

Test results of PID tests of PV modules from a large-scale PV system

Knowledge of PID sensitivity of used PV modules is necessary. All material combinations of a module type must be considered to declare it PID-free!
Risk Identification: Degradation, Delamination

Degradation of Backsheet

Delamination, Browning

Significant amount of arrays (Gigawatt level) show early degradation
Risk Assessment

Introduction of Cost Priority Number (CPN in €/kWp/year)

a) Economic impact due to downtime and/or power loss (kWh to Euros)
   - Failures might cause downtime or % in power loss
   - Time is from failure to repair/substitution and should include: time to detection, response time, repair/substitution time
   - Failures at component level might affect other components (e.g. module failure might bring down the whole string)

b) Economic impact due to repair/substitution costs (Euros)
   - Cost of detection (field inspection, indoor measurements, etc)
   - Cost of transportation of component
   - Cost of labour (linked to downtime)
   - Cost of repair/substitution

Source: Solar Bankability
Risk Assessment

Ranking of Cost Priority Number CPN, Impact of Applied Mitigation Measures

Modules - top ten risks with & without mitigation measures in CPN

Examples of mitigation measures

- Vendor qualification
- Component testing (pre-tests and/or batch related)
- Design, contract and EY-prediction review
- Qualification of EPC
- Advanced Inspection
- Advanced Monitoring

To avoid or strongly mitigate risks early mitigation measures during project development and procurement phase are most effective, e.g. component tests
## Risk Assessment

### Quantification of the Economic Impact of Technical Risks – PID. Example: 40 MWp- Plant

<table>
<thead>
<tr>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential induced degradation is a performance loss in PV modules, caused by so called stray currents</td>
<td>8 % (failure rate 40 %, 20 % power loss of affected modules)</td>
</tr>
<tr>
<td>Performance losses</td>
<td>160 kWh/kWp/a (spec. yield 2,000 kWh/kWp)</td>
</tr>
<tr>
<td></td>
<td>700,000 €/a for 40 MWp plant (0.1 €/kWh) → 16 €/kWp/a</td>
</tr>
<tr>
<td>Repair method</td>
<td>Installation of PV grounding kits</td>
</tr>
<tr>
<td>Cost to fix and repair</td>
<td>100,000 € (2,200 € per inverter x 40; incl. installation cost)</td>
</tr>
<tr>
<td></td>
<td>→ 0.12 €/kWp/a</td>
</tr>
<tr>
<td>Mitigation measure</td>
<td>Testing of the PV modules to avoid use of PID sensitive modules</td>
</tr>
<tr>
<td>Cost of mitigation measure</td>
<td>Testing of modules;</td>
</tr>
<tr>
<td></td>
<td>10,000 € for sample testing for PID resistivity</td>
</tr>
<tr>
<td></td>
<td>0.25 €/kWp</td>
</tr>
</tbody>
</table>

| ! 1.5 Mio € loss after 2 years incl. repair costs versus 10 k € mitigation costs (during procurement process) |

CPN = 16.12 €/kWp/a
Conclusion

• Technical risks can have a major impact on the total project risk rating scheme. Technical risks can be systematically organized in a risk matrix.

• Currently main risk on module level are (Installation failures, PID, degradation of back sheet, module underperformance, class breakage, delamination, arcing of BIPV, unexpected soiling)

• Mitigation measures have been identified along the value chain

• A professional risk management strategy should become integral part of each PV investment

• The risk management function should be hierarchically independent and can be provided by qualified in-house or external third party experts

• Mitigation measures, which prevent risks or allow early detection are most effective:
  a. Qualification of Vendor and EPC
  b. Component testing prior to installation
  c. Advanced monitoring system for early fault detection
Thank you for your attention

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Save the Date
All Quality Matters - PV Module Technology & Applications Forum
We are very pleased to invite you to attend the first “All Quality Matters Forum” in Europe introducing the topic PV Module Technology & Applications on
29 and 30 January 2018 at TÜV Rheinland in Cologne/Germany
www.tuv.com/pv-module-forum

Strategy to improve Quality on PV Power Plants = Risk Management