Die Methode zur Risikobewertung und Risikominimierung bei PV Anlagen

PV Magazine Webinar: TÜV Rheinland - Die CNP Methode für die monetäre Bewertung des Schadensrisikos bei Modulen und Verkabelung

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TÜV Rheinland – Solar Energy Worldwide

Quality, safety and reliability around the world

>35 years of experience in PV

20,000 employees

250+ Solar Experts

6 PV Laboratories

> 20 GW inspected PV projects
Content

Cost Priority Number

Risk Identification

Risk Assessment

Risk Mitigation

Conclusion
OBJECTIVES

- Reduce the monetary risks in PV projects
- Standardized Reproducible and transparent technique
- Reacting to failures and preventing failures at a reasonable cost
- Make the best decisions from a cost-benefit perspective

Severity Criteria

<table>
<thead>
<tr>
<th>Rank</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>1</td>
<td>Performance loss &lt; 0.5%</td>
</tr>
<tr>
<td>2</td>
<td>Performance loss &lt; 1%</td>
</tr>
<tr>
<td>3</td>
<td>Performance loss &lt; 3%</td>
</tr>
<tr>
<td>4</td>
<td>Performance loss &lt; 5%</td>
</tr>
<tr>
<td>5</td>
<td>Performance loss &lt; 10%</td>
</tr>
<tr>
<td>6</td>
<td>Performance loss &lt; 25%</td>
</tr>
<tr>
<td>7</td>
<td>Performance loss &gt; 25%</td>
</tr>
<tr>
<td>8</td>
<td>Safety risk without perf. loss</td>
</tr>
<tr>
<td>9</td>
<td>Safety risk with perf. loss</td>
</tr>
<tr>
<td>10</td>
<td>Death, fire, total loss</td>
</tr>
</tbody>
</table>

FMEA Rating of PV Module Failures

- Module frame damaged
- Snail tracks
- Plant components not working
- Delamination of PV module
- Unprotected connector
- Heavy soiling of PV module
- Module unprotected against reverse current
- Module back side damaged
- Connector not properly connected
- Breakage of front glass

Initial Risk → Avoid → Mitigate → Transfer → Residual Risk
DEVELOPMENTS

- First approach to implement a cost-based FMEA to the PV sector
- Based on statistical analysis and assumptions
- Cost of loss from system downtime ($C_{\text{down}}$)
- Cost for detection and mitigation ($C_{\text{fix}}$)
- Further factors: occurrence, irradiance, power loss, PPA, costs

IMPROVEMENTS

- Updated and adapted to the needs of O&M operators
- Identify the adjustments needed to a fully automatized approach
- Key Performance Indicators (KPIs) were revisited and reformulated:
  - Detect time
  - Response time
  - Repair time

\[ \text{CPN} = \frac{t_{\text{detect}} + t_{\text{response}} + t_{\text{repair}}}{t_{\text{ref}}} \times \frac{n_{\text{fail}} \times C_{\text{PL}} \times M \times P_{\text{nom}} \times y \times \text{PPA}}{n_{\text{comp}} \times P_{\text{nom}} \times n_{\text{years}}} + \frac{(C_{\text{det}} + C_{\text{rep}} + C_{\text{sub}} + C_{\text{transp}}) \times n_{\text{fail}} + t_{\text{fix}} \times C_{\text{lab}} \times n_{\text{fail}}}{P_{\text{nom}} \times n_{\text{years}}} \]
CPN = \( \frac{t_{detect}+t_{response}+t_{repair}}{t_{ref}} \times \frac{n_{fail} \times C_{PL} \times M \times P_{nom} \times y \times PPA}{n_{comp} \times P_{nom} \times n_{years}} + \frac{(C_{det}+C_{rep}+C_{sub}+C_{transp}) \times n_{fail} + t_{fix} \times C_{lab} \times n_{fail}}{P_{nom} \times n_{years}} \)
# Risk Identification – Technical Risk Matrix

<table>
<thead>
<tr>
<th></th>
<th>Design</th>
<th>Procurement</th>
<th>Construction</th>
<th>Acceptance</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Modules</td>
<td></td>
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<tr>
<td>Inverters</td>
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<tr>
<td>Mounting system</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cabling/Connectors</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Transformer</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Combiner Boxes</td>
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</tr>
</tbody>
</table>

- Delamination
- Glass breakage
- Backsheet brittleness
- Backsheet “chalking”
- PID
- LeTID
- Cable corrosion
- Cross-connection

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Potential induced degradation

LeTID
# Risk Assessment: Potential induced Degradation (PID)

<table>
<thead>
<tr>
<th>Risk</th>
<th>Failure Rate plants</th>
<th>Failure Rate components</th>
<th>Initial Power Loss</th>
<th>Power Degradation rate</th>
<th>Occurrence degradation rate</th>
<th>PPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>PID</td>
<td>10%</td>
<td>20%</td>
<td>20%</td>
<td>5%</td>
<td>5%</td>
<td>0.10 €/kWh</td>
</tr>
</tbody>
</table>

- **CPN (5y) = 7€/kWp**
- **Revenue Loss = 70k€**
- **0.7% of investment**

- **CPN (10y) = 25€/kWp**
- **Revenue Loss = 250k€**
- **2.5% of investment**

**Example:**
- 10 MW PV Portfolio (100 x 100kW)
- 10 PID affected PV plants
- CAPEX ~10 Mio€
Risk Mitigation: Potential induced Degradation (PID)

**Mitigation**

- **Mitigation cost (year 0)**: 0.6 €/kWp
- **CPN after 10 years**: ~1 €/kWp
- **Savings after 10 years**: ~24 €/kWp

**PID Box**

- **Mitigation cost (year 0)**: 2 €/kWp
- **CPN after 10 years**: 9 €/kWp
- **Savings after 10 years**: 16 €/kWp

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**Graphs and Diagrams**

- **CPN Losses PID**
  - PID = Potential Induced degradation
  - Mitigated PID with preventive Mitigation

- **Detection time**, **Response time**, **Repair time**

- **Year of Operation vs. Normalized Energy**
  - No-Mitigation vs. PID Box
Risk Assessment: Light and elevated Temperature Induced Degradation (LeTID)

### Example:
10 MW PV Portfolio (100 x 100kW)
20 LeTID affected PV plants
CAPEX ~10 Mio€

### Table: LeTID Test Mitigation Costs

<table>
<thead>
<tr>
<th>Mitigation</th>
<th>Mitigation cost (year 0)</th>
<th>CPN after 10 years</th>
<th>Savings after 10 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>LeTID Test</td>
<td>2 €/kWp</td>
<td>2 €/kWp</td>
<td>1 €/kWp</td>
</tr>
</tbody>
</table>

### Diagram:
- **Light elevated Temperature induced degradation (LeTID)**
- **Light induced degradation (LID)**
- **Light cycles of 5 kWh/m², 50°C ± 10°C**
- **Temperature chamber cycles of 162 hrs, 75°C, current flow of I_{sc}^{Lmpp}**

### Table: Risk Assessment

<table>
<thead>
<tr>
<th>Risk</th>
<th>Failure Rate plants</th>
<th>Failure Rate components</th>
<th>Max. Power Loss</th>
<th>PPA</th>
<th>CPN after 10 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>LeTID</td>
<td>20%</td>
<td>100%</td>
<td>4%</td>
<td>0.10 €/kWh</td>
<td>3 €/kWp</td>
</tr>
</tbody>
</table>
Risk Mitigation: CPN Results - PV Modules

MITIGATION MEASURES

- Component testing
- Design review
- Qualification of EPC
- Monitoring system
- Inspection
- Spare part management

### Modules - top 10 risks

<table>
<thead>
<tr>
<th>Risk Description</th>
<th>CPN Reference without MM</th>
<th>CPN Best MM Combination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improperly installed</td>
<td>10.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Glass breakage</td>
<td>9.0</td>
<td>7.0</td>
</tr>
<tr>
<td>PID = Potential induced degradation</td>
<td>7.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Defective backsheet</td>
<td>6.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Delamination</td>
<td>5.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Hotspot</td>
<td>3.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Soiling</td>
<td>2.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Shading</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Failure bypass diode</td>
<td>0.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Overheating junction box</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

### Data collection is biased by
- Locations
- Technologies
- Reason for inspections
Risk Mitigation: Random verification tests at third party laboratory

In TÜV Rheinland’s laboratory

- Highly Accurate STC Measurement
- EVA Gel Content & Peel-Off
- Thermal Cycling / Damp Heat Potential induced degradation
- Mechanical Load Test
- Light Induced Degradation
- Thermographic Inspection
- UV Test
- Hail Test
Risk Mitigation through Quality Assurance Concept for PV Power Plants

**Development**
- Energy yield prediction, glare assessment
- Technical rating of PV module and PV inverter suppliers
- Pre-production factory inspection of - PV modules - Components (inverter, transformer, mounting system, cables, etc.)
- Pre-production testing of project-relevant equipment (reliability and performance)

**Procurement**
- During production inspection (DUPRO), pre-shipment inspections of PV modules
- During production tests of PV modules
- During production factory acceptance test (FAT) of inverters

**Construction and Commissioning**
- Joint construction supervision, project monitoring (onsite)
- Confirmation of mechanical completion
- Grid conformity assessment

**Confirmation of Acceptance**
- Confirmation of provisional acceptance
- Confirmation of final acceptance
- Certification (optional)
The CPN Method gives an indication of the economic impact of a failure due to downtime and investment cost. A professional risk management strategy should become integral part of each PV investment.

Technical risks can be systematically classified in a Risk Matrix and need to be defined using a standardized nomenclature.

There is a strong need of risk mitigation measures in all stages of PV power plant investment. Mitigation measures, which are allow early detection are most effective.
Thank you for your attention


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PV Module Forum 2020

The world’s leading forum for PV module technologies and applications from 18th to 19th February 2020, TÜV Rheinland headquarter, Cologne/Germany

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