Risk Mitigation, Solar Bankability and O&M Services for PV Power Plants

Nelsy Santiago, Ulrike Jahn
TÜV Rheinland
Email: nsantiago@mex.tuv.com
Email: ulrike.jahn@de.tuv.com
Web: www.tuv.com/solar
Contents

1. Overview
2. Technical risk identification
3. Assessment of technical risks
4. Mitigation of technical risks
5. Case studies of risk assessments
6. Supply chain quality assurance services
1. Overview

- **Solar bankability** is an active quality management process where all stakeholders in the approval process of a PV project attempt to identify potential legal, technical and economical risks through the entire project lifecycle.

- These risks need to quantitatively and qualitatively assessed, managed and controlled.

- Despite a wide overlap in this quality management process, the focus and the assessment criteria will vary whether the stakeholder represents an investor, a bank, an insurance or a regulatory body.
1. Overview

- Stakeholder bankability assessment
  - Investor „Investibility“
  - Bank „Bankability“
  - Insurance „Insurability“
  - Regulatory Body „Efficiency of infrastructure“

- Check list/ due diligence
  - Legal
  - Technical
  - Economical

- Project life cycle
  - Development
  - Design
  - Installations
  - Operations
  - Decommissioning

- Contracting parties
  - Building/ site owner
  - Project developer
  - EPC/ installer
  - O&M
  - Decommissioning

- Component suppliers
  - Module
  - Inverter
  - Balance of system
  - Monitoring
## 2. Technical Risk Identification

### Modules
- Improper Insulation
- Incorrect cell soldering
- Undersized bypass diode
- Junction box adhesion
- Delamination
- Arcing spots on the module
- Visually detectable hot spots
- Unclear initial degradation
- Uncertified components or production line
- Unsuitable/ uncertified Bill of Materials (BOM)
- Incorrect power rating (flash test issue)

### Inverter
- 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

### Mounting structures
- Module mishandling (glass breakage)
- Module mishandling (cell breakage)
- Module mishandling (defective backsheet)
- Incorrect connection of modules
- Bad wiring without fasteners

### Connection & distribution boxes
- 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

### Cabling
- 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

### Potential equalization & grounding, LPS
- 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

### Weather station, communication, monitoring infrastructure & environmental influence
- 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

### Storage systems
- 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

### Miscellaneous
- 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

Source: Solar Bankability

---

*06 Sep 2018 SolarPower Europe & Asolmex Workshop, Mexico City*
2. Technical Risk Identification

Examples for PV module failures

- Glass breakage
- Cell cracks
- Delamination
- Frame breakage
- Junction box failure
- Potential induced degradation
- Bypass diode failure
- Safety issues
2. Technical Risk Identification

Examples for PV module failures: 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!
3. Assessment of Technical Risks
Cost Priority Number (CPN) Approach

- Risks to which we can assign a Cost Priority Number CPN: CPN in [€/kWp/year] (e.g. module and inverter failure during O&M)

- Impact on cash flow

- 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)

- 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

Income reduction
Savings reduction

\[ C_{loss} \]

Increase in maintenance costs
Reduction of reserves

\[ C_{fix} \]
3. Assessment of Technical Risks
CPN Approach – PV Modules

- Highest risk consists of a group of installation failures (mishandling, connection failures, missing fixation, etc.)
- Variety of failures detected by different techniques (VI, IR, EL, IV-Curves)

\[ CPN = C_{\text{loss}} + C_{\text{fix}} \]
3. Assessment of Technical Risks
CPN Approach – Inverter

- Highest risk for accumulation of installation faults and overheating of ventilation.

$$\text{CPN} = C_{\text{loss}} + C_{\text{fix}} \quad [\text{€/kWp/year}]$$
### 4. Mitigation of Technical Risks

Mitigation Measures (MM)

<table>
<thead>
<tr>
<th>Mitigation Measure</th>
<th>Affected Parameter</th>
<th>Risk Mitigation Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component testing – PV modules</td>
<td>number of failures</td>
<td>α</td>
</tr>
<tr>
<td>Design review + construction monitoring</td>
<td>number of failures</td>
<td>α</td>
</tr>
<tr>
<td>Qualification of EPC</td>
<td>number of failures</td>
<td>α</td>
</tr>
<tr>
<td>Advanced monitoring system</td>
<td>time to detection</td>
<td>β</td>
</tr>
<tr>
<td>Basic monitoring system</td>
<td>time to detection</td>
<td>β</td>
</tr>
<tr>
<td>Advanced inspection</td>
<td>time to detection</td>
<td>β</td>
</tr>
<tr>
<td>Visual inspection</td>
<td>time to detection</td>
<td>β</td>
</tr>
<tr>
<td>Spare part management</td>
<td>time to repair/substitution</td>
<td>γ</td>
</tr>
</tbody>
</table>
4. Mitigation of Technical Risks
CPN Results – Best combination of MM

<table>
<thead>
<tr>
<th>Component testing</th>
<th>Design review + construction monitoring</th>
<th>Qualification of EPC</th>
<th>Advanced monitoring system</th>
<th>Basic Monitoring system</th>
<th>Advanced Inspection</th>
<th>Visual Inspection</th>
<th>Spare part management</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

**Modules - top 10 risks**

- CPN Reference without MM
- CPN Best MM Combination

- Impact of Applied Mitigation Measures on and Ranking of CPN
4. Mitigation of Technical Risks
Impact of Applied Mitigation Measures

New CPN results $C_{fix,mit}$ of mitigation measure combinations for different cost scenarios:
Preventive measures (PMM) have higher impact than corrective measures (CMM).
5. Case Studies of Risk Assessments
Field Testing and Soiling Simulation

Example: Soiling @ 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
5. Risk Assessment - Wrap Up

1. Large utility-scale PV projects under government tender schemes face severe price pressure. A **quality management programme** should ensure the technical reliability and financial viability of the PV projects.

2. A professional **risk management strategy** as suggested in this project should become integral part of each PV investment.

3. The risk management function should be hierarchically independent and can be provided by qualified in-house or **external third party experts**.
6. Supply Chain Quality Assurance Services

Along each procurement step

**Sourcing**
- Factory audits

**Production**
- Pre-production inspection
- DuPro inspection
- Reference module creation
- Reliability Tests

**Post-Production**
- Pre-shipment inspection
- Loading supervision
- Fast random verification test
- Final product control test
- Post-shipment inspection
Fast random verification tests at third party laboratory

@ TÜV Rheinland Laboratory
During Planning

- Site feasibility
- Tender development
- Product qualification
- Vendor qualification/bankability services
- Technical DD
- Specific yield prediction
- Risk assessment
- Financial sensitivity analysis

Development, Planning  Commissioning  Operation and Maintenance
Our Service at all Stages of PV Power Plant Investment

During construction:
- Pre-shipment testing and inspections
- Factory acceptance testing
- Construction monitoring & supervision
- Cost review
- Punch list
- Mechanical completion inspection
- Performance acceptance testing & verification
- Provisional and final acceptance report
- O&M concept, contract & manual review
6. Our Service at all Stages of PV Power Plant Investment

<table>
<thead>
<tr>
<th>After construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
</tr>
<tr>
<td>Commissioning</td>
</tr>
<tr>
<td>Performance Ratio (PR) verification &amp; Independent energy analysis</td>
</tr>
<tr>
<td>Periodic inspection</td>
</tr>
<tr>
<td>First year capacity test</td>
</tr>
<tr>
<td>Warranty inspections</td>
</tr>
<tr>
<td>Technical Due Dilligence</td>
</tr>
<tr>
<td>Module status (quality) analysis</td>
</tr>
<tr>
<td>Performance optimization</td>
</tr>
<tr>
<td>Monitoring, data analysis &amp; sensor calibration</td>
</tr>
<tr>
<td>Arbitration services</td>
</tr>
</tbody>
</table>

06 Sep 2018 SolarPower Europe & Asolmex Workshop, Mexico City
6. PV Power Plant O&M Contractor Certification

Application

- Application Form
- ISO 9001 Certificate
- List of O&M service
- List of PVPP under service
- Business license (initial application)

Submission

Step 1: Application

Step 2: Creation of audit plan and quotation

Step 3:
- Documentation review
- On-site O&M audit

Step 4: Evaluation of the audit results

Step 5: Re-audit / Review after correction

Step 6: Reporting and certificate application

Step 7: Certification

Step 8: Annual audit

6 month lead time

at least 2 PVPP units

2 months correction period

3 years of validity

SolarPower Europe & Asolmex Workshop, Mexico City
6. PV Power Plant O&M Contractor Certification

TÜV Rheinland O&M Contractor Certification

**Index**

- **General Requirement**
  - Service Definition
  - Structure
  - Personnel Qualification
  - Confidentiality
  - QM documentation

- **Operation**
  - DMS
  - Supervision and Control
  - Grid Code Compliance
  - Performance Forecast
  - Change Management
  - Reporting
  - Optimization

- **Maintenance**
  - Preventative Maintenance
  - Corrective Maintenance
  - Extra Maintenance
  - Additional Maintenance

- **Spare Parts Management**
  - Responsibility
  - Insurance Management
  - Stock level
  - Storage

- **Security, EHS and PPE**
  - Site Security
  - Staff/PVPP Insurance
  - EHS
  - PPE

- **Contract Fulfillment**
  - Conformity
  - Client Satisfaction
  - Performance Evaluation

- **Local Requirement**
  - Legal
  - Industrial
  - Others

**Criteria**

- **Service Definition**
- **Supervision and Control**
- **Grid Code Compliance**
- **Performance Forecast**
- **Change Management**
- **Reporting**
- **Optimization**
- **Responsibility**
- **Insurance Management**
- **Stock level**
- **Storage**
- **Site Security**
- **Staff/PVPP Insurance**
- **EHS**
- **PPE**
- **Conformity**
- **Client Satisfaction**
- **Performance Evaluation**

7 **indexes**

30 **main criteria**

100+ **sub-criteria**
6. Supply Chain Services for all Stakeholders of PV Plant Investments

- Increase confidence for PV investments.
- Minimize investment risks and increase profits (bankability).
- Take advantage of national and international subsidy programmes.
PV Power Plant and Supply Chain Services.

Your investment. Our commitment.

TÜV Rheinland

Nelsy Santiago
nsantiago@mex.tuv.com
044 (55) 2057 4242

Ulrike Jahn
Ulrike.jahn@de.tuv.com

www.tuv.com/solar