Quality as global standard for solar PV projects, processes and products

Dr. rer. nat. Eckart Janknecht
TÜV Rheinland Energie und Umwelt GmbH
Am Grauen Stein, 51105 Köln, Germany
Tel.: +49 221 806 4469, Fax +49 221 806 1350
E-Mail: eckart.janknecht@de.tuv.com
Internet: www.tuv.com/pv
Table of content

- Quality Assurance for PV Power Plants: Loss of Revenue Risks
- Quality Assurance for a Power Plant in different stages
- Examples of low quality projects
- Quality Assurance for a Power Plant – TÜV Rheinland approach
- Examples of low quality modules
- Product quality of PV modules within the certification process
- Summary
Introduction TÜV Rheinland
Global market leader in testing & certification of photovoltaic modules

- TÜV Rheinland operates 6 accredited PV laboratories (Cologne, Bangalore, Daya/Taiwan, Yokohama, Shanghai and Tempe/Arizona)

- More than 25 years experience in the field of photovoltaic at the head quarter in Cologne, Germany

- Approx. 60% market share in testing & certification of solar panels (global market leader)

- Team of 70 engineers and technicians in Cologne (partly > 25 years PV experience), worldwide 250 PV experts

- Active participation in the important standardization committees

- Research and development in the area of module qualification (characterization and life-time assessment)
Overview
Quality Assurance for PV Power Plants
Overview
Quality Assurance for PV Power Plants

Project Phases
- Planning
- Installation
- Operation

Quality Assurance

Loss of Revenue Risks

Risk Mitigation
- Cost Reduction
- Bankability

Investment

Yield Assurance

Stakeholder

Quality as global standard for solar PV projects, processes and products
### Loss of Revenue Risks

**Types of Risk**

<table>
<thead>
<tr>
<th>On-Site Risks</th>
<th>Technical Risks</th>
<th>Safety Risks</th>
<th>Logistical Risks</th>
<th>Political Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Wind and lightning</td>
<td>- Yield performance and degradation</td>
<td>- Electric shock</td>
<td>- Production delays</td>
<td>- Modifications of incentives</td>
</tr>
<tr>
<td>- Snow, hail and ice</td>
<td>- Malfunction</td>
<td>- Electric arc flash</td>
<td>- Shipping</td>
<td>- Permits and social acceptance</td>
</tr>
<tr>
<td>- Pollution</td>
<td>- Aging</td>
<td>- Fire</td>
<td>- Supply</td>
<td>- Financial market risks</td>
</tr>
<tr>
<td>- Dust</td>
<td>- Maintenance</td>
<td>- Static/structural</td>
<td>- Raw materials</td>
<td>- Labor unrest</td>
</tr>
<tr>
<td>- Rock fall</td>
<td>- Structural</td>
<td>- Mechanics</td>
<td>- Grid connection availability</td>
<td>- Civil strife</td>
</tr>
<tr>
<td>- Land slide</td>
<td>- Replacement</td>
<td>- Ergonomics</td>
<td>- Labor shortage and qualification</td>
<td>- Regulatotry uncertainty</td>
</tr>
<tr>
<td>- Earthquake</td>
<td>- Static Electricity</td>
<td>- Theft</td>
<td>- Tarif barriers</td>
<td></td>
</tr>
<tr>
<td>- Flood</td>
<td>- Visual appearance</td>
<td>- Vandalism</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Shading</td>
<td>- Accessibility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Animals and plants</td>
<td>- Availability of grid</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Logistical Risks**

- Production delays
- Shipping
- Supply
- Raw materials
- Grid connection availability
- Labor shortage and qualification
- Tarif barriers

**Political Risks**

- Modifications of incentives
- Permits and social acceptance
- Financial market risks
- Labor unrest
- Civil strife
- Regulatotry uncertainty

**Financial Risk**

Quality as global standard for solar PV projects, processes and products
## Loss of Revenue Risks
### Loss of Revenue Factors 1/2

<table>
<thead>
<tr>
<th>Loss of revenue factors</th>
<th>% / year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degradation (aging related output deficit)</td>
<td>0.3 – 1 %</td>
</tr>
<tr>
<td>Mismatch losses</td>
<td>0.2 – 0.5 %</td>
</tr>
<tr>
<td>Pollution (associated with yearly cleaning)</td>
<td>2 - 5 %</td>
</tr>
<tr>
<td>Line losses (wrong dimensions or planning of lines)</td>
<td>1 – 3 %</td>
</tr>
<tr>
<td>Inverter (Ø degree of efficiency at 96%)</td>
<td>3 – 4 %</td>
</tr>
<tr>
<td>Plant availability</td>
<td>1 – 5 %</td>
</tr>
<tr>
<td>Deviation of effective power</td>
<td>0 – 5 %</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>7.5 % up to 23.5 % / year</strong></td>
</tr>
</tbody>
</table>
Loss of Revenue Risks
Loss of Revenue Factors 2/2

Loss of revenue factors

- Degradation
- Mismatch losses
- Pollution
- Line losses
- Inverter
- Plant availability
- Deviation of effective power

Max.
Min.

07.06.2012

Quality as global standard for solar PV projects, processes and products
Loss of Revenue Risks
Cause of damage (Europe only – no severe weather)

Source: Mannheimer Versicherung

Overvoltage 45%
Technical Damage 10%
Wind 9%
Vandalism 8%
Animal interference 7%
Theft 4%
Snow Load 4%
Glass breakage 4%
Fire 2%
Hail 2%
Human Errors 2%
Other 3%

Quality as global standard for solar PV projects, processes and products
| Stage 1 | Evaluation | - Site evaluation incl. shading analysis  
|         |            | - Energy yield prediction |
| Stage 2 | Planning   | - Plan checking services  
|         |            | - Tender advisory and execution |
| Stage 3 | Installation | - Component qualification  
|         |            | - Construction supervision |
| Stage 4 | Acceptance | - Commissioning  
|         |            | - Certification incl. TÜVdotCOM-mark  
|         |            | - Yield control and assessment |
| Stage 5 | Operations | - Technical and monetary monitoring  
|         |            | - Follow-up inspections  
|         |            | - 10 year check (before end of guaranty) |

**Quality Assurance Services**

- Quality as global standard for solar PV projects, processes and products
Quality Assurance
Stage 1 – Evaluation

Meteorological Data
- Solar irradiation
- Temperatures
- Altitude
- Shading
- Wind
- Snow

Component and installation parameter
- Multivariant yield measurement
- Component parameter
- Matching of inverter, string connections, line diameter and length
- Orientation / Tracking Systems
- Shading

External factors
- Loss of revenue factors:
  - Pollution
  - Degradation
  - Loss factors of periphery

Calculation and simulation tools

Impartial component, site evaluation and yield prediction
Basics of Energy Yield Prognosis

- **weather data**
  - temperature and radiation measurements: ground based, remote sensing (satellite)

- **radiation model**
  - conversion on module plane
    - diffuse fraction, albedo, orientation

- **module model**
  - specific module parameters
    - behaviour of modules under plant specific conditions

- **inverter model**
  - MPP-tracking and efficiency
    - load range, MPP-iteration

- **energy yield**
  - cumulative energy
    - time range of inspection

**external parameters**
- environment
  - shadings, soiling

07.06.2012 Quality as global standard for solar PV projects, processes and products
# Quality Assurance

## Stage 2 – Planning

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Tender advisory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculation of solar irradiation and yield prediction</td>
<td>Definitions of minimum quality standards for the specific components</td>
</tr>
<tr>
<td>Estimation of yield degradation and pollution</td>
<td>Qualified advisory services in consideration of quality standards, requirements and international standards</td>
</tr>
<tr>
<td>Distance of the modules</td>
<td>Evaluation and weighting matrix to evaluate vendors</td>
</tr>
<tr>
<td>Verification of performance parameters by actual measurement</td>
<td>Recommended procedures based on matrix result</td>
</tr>
<tr>
<td></td>
<td>Neutral and independent advice</td>
</tr>
</tbody>
</table>

- Lightning protection, component problems, vegetation, theft

- Risk analysis

- Assessment

- Calculation of solar irradiation and yield prediction

- Estimation of yield degradation and pollution

- Distance of the modules

- Verification of performance parameters by actual measurement
Quality Assurance
Stage 3 – Installation

Quality assurance before and during installation

Random component qualification to relevant standards

- Inverter
  - EN 50 178
  - EMV EN 61000-6-3
  - EMV EN 61000-6-1
  - UL1741
  - TUV xxxx
  - …

- PV Modules
  - IEC 61215
  - IEC 61646
  - IEC 61730
  - UL1703
  - TUV xxxx
  - …

On-site supervision

- Early detection of deficiencies
  - Wiring, interconnection
  - Ground fault and short circuit safety
  - General construction and PV module installation
  - Lightning, fire and fault protection

07.06.2012 14 Quality as global standard for solar PV projects, processes and products
Quality Assurance
Stage 4 – Commissioning

- Plant safety
- Operator safety
- Compliance with agreed specifications
- Compliance with relevant standards and codes
- Function control
- Measurement and assessment of energy yield
- Compliance with requirements for grid connection
Quality Assurance
Stage 5 – Operations

Monitoring Concept

**Technical Monitoring**
- Continuous status control
- Collation of plant data
- Prompt fault repair
- Follow-up inspections on site
- Warranty related component inspections
- SmartGrid compliance verification

**Monetary Monitoring**
- Complete yield documentation
- Domain independent information integration
- Custom real time reporting
- Multi-plant integration
- Deviation analysis
- Sealed and calibrated yield data collection and web based presentation (trusted data concept)

Continuous yield control, review and assurance
Examples of low quality - projects
Examples of low quality - projects
Customer Benefits

- Avoidance of planning and installation faults
- Progression of efficiency and yield return
- Assurance of investment
- Assurance of “Bankability”
- Optimization of plant performance
- Risk minimization of potential damages (e.g. lightning)
- Optimal utilization of warranty
- Exoneration of additional tasks, concentration on core business
- Facilitation of argumentation in case of warranty or insurance related damages
Quality Assurance –
external inspection using the example of TÜVdotCOM approach

- Commissioning of the PV power plant using a predefined checklist (safety aspects, compliance with law and codes, functionality and performance)
- A unique TÜVdotCOM-ID will be allocated to your PV power plant(s), giving clients, operators, regulators or investors insight in bankability parameters. The portal can serve a number of communication functions and link to the real time monitoring.
- Periodic follow-up inspections ensure continued adherence with specifications (yearly and 3-years-inspections) and monitoring data integrity.
- Quality assurance for investors
- Ensuring “Bankability” – precise, reliable and independently audited
- The public and institutions trust TÜVdotCOM, independence and impartiality for 140 years
Quality Assurance
TÜVdotCOM service

- Verification of energy yield
- Functionality verified
- Verified plant design
- Component specification verification/performance and reliability tested
- Safety verified
- Measurement of string performance
- Thermography & connection verification
- Inspection of mounting system
- Inspection of lightning protection system
- Follow-up inspections

Internet-Service
www.tuv.com

Enter Plant-ID

Quality information and inspection criteria:
- Safe and compliant with laws and codes
- Functional
- Performance verified

Additional Information:
- Inspection certificate
- Links to websites of project partners or producers
- Inspection report, etc.
- Monitoring portal

21 07.06.2012 Quality as global standard for solar PV projects, processes and products
Overview
Quality Assurance for PV Power Plants

- Project Phases
  - Planning
  - Installation
  - Operation

- Stakeholder

- Yield Assurance

- Quality Assurance

- Loss of Revenue Risks

- Risk Mitigation
  - Cost Reduction
  - Bankability

- Investment

Quality as global standard for solar PV projects, processes and products
Examples of low quality – PV modules 1/2
Examples of low quality – PV modules 2/2
Product quality:
IEC 61215, Error distribution within the certification of crystalline PV modules

- Damp Heat: 16.6%
- Temperature Cycling TC200: 20.5%
- Temperature Cycling TC50: 4.0%
- Bypass Diode: 4.0%
- Cut Test: 2.8%
- Robustness of Termination: 1.8%
- Reverse Current: 0.7%
- Outdoor: 0.8%
- Mechanical Load: 8.8%
- Impulse Voltage: 1.4%
- Isolation: 3.1%
- Hot-Spot: 7.8%
- Hail Impact: 1.4%
- Initial Measurements: 15.2%
Product quality:
IEC 61646, Error distribution within the certification of thin-film PV-modules

Distribution of test failures for thin-film PV modules 2007-2011

- Damp heat test: 22%
- Reverse current test: 11%
- Mechanical load test: 12%
- Initial measurement: 10%
- Hot-spot test: 10%
- Light-soaking: 9%
- Thermal cycling test (200 cycles): 8%
- Humidity freeze test: 6%
- Thermal cycling test (50 cycles): 4%
- Robustness of terminations test: 2%
- Other: 7%

Distribution of test failures for thin-film PV modules 2007-2011

- Damp heat test: 22%
- Reverse current test: 11%
- Mechanical load test: 12%
- Initial measurement: 10%
- Hot-spot test: 10%
- Light-soaking: 9%
- Thermal cycling test (200 cycles): 8%
- Humidity freeze test: 6%
- Thermal cycling test (50 cycles): 4%
- Robustness of terminations test: 2%
- Other: 7%
Failure rate for IEC 61215/61646 certification

Percentage of projects with at least one test failure
Check of the certificates – How to avoid fake certificates

www.tuvdotcom.com
Summary

- Only use certified components such as modules, inverters, ...
- Check the Energy yield prediction and the loss of revenue factors
- Quality control during the evaluation, planning and installation phase is the cheapest way to ensure high quality photovoltaic power plants
- Especially for bigger PV projects an external quality assurance is the best way to ensure the quality
- During the operation period active monitoring of the PV power plant is essential to detect faults as soon as possible
- Follow-up inspections during the operation period make sense to avoid safety problems and to make warranty related inspections
Thank you for your interest!