Long-Term Sequential Testing (LST) of PV Modules

Stefan Kiehn
Mani TamizhMani
Global PV Component and PV Module Certification

Junction Boxes, Cables, Connectors, PV & CPV Modules, Rack and Mounting

- **Consultation**
- **Testing**
- **Certification**

**Junction Box**
DIN V VDE 0126-5; 2008

**Cable**
TÜV 2Pfg1169; 2007

**Connector**
EN 50521; 2008

**PV/CPV Module**
- IEC 61215
- IEC 61646
- IEC 61730
- IEC 62108
- **ANSI/UL 1703 (NRTL)**

- **Periodic inspection**
- **Qualified, IEC 61215**
- **Safety tested, IEC 61730**
- **Long-term sequential testing**

**Seal with Plant-ID**

1000105555

**Installer Training**

**Global PV Power Plant Certification**

- **Planning**
- **Installation**
- **Operation**
Outline

• Long-term Sequential Testing: Test Program

• Long-term Sequential Testing: Some Results
Outline

- Long-term Sequential Testing: Test Program
- Long-term Sequential Testing: Initial Results
Total Quality System (TQS)

Module Quality Cycle

- Lifetime Testing (3)
  - Qualification Testing (7)

- Longterm Sequential Testing

- Design Quality

- Production Quality

- Field Data

- Hot-Dry Climatic Condition (7)
- Cold-Dry Climatic Condition (8)
- Hot-Humid Climatic Condition (9)

Modeling (12)
- Failure Mechanism (11)
- Failure Mode (10)

Highly Accelerated Stress Audit (6)
- Supplier Quality Control (4)
Quality Cycle: Purpose of 12 Sub-Cycles

1. **Qualification Testing:** To verify design quality for minimum confidence
2. **Comparative Testing:** To verify design quality for medium confidence
3. **Lifetime Testing:** To verify design quality for maximum confidence
4. **Supplier Quality Control:** To verify supplier quality
5. **Process Quality Control:** To verify process quality
6. **Highly Accelerated Stress Audit:** To audit production quality consistency
7. **Hot-Dry Climatic Conditions:** To collect Dry-Hot conditions failure data
8. **Cold-Dry Climatic Conditions:** To collect Dry-Cold conditions failure data
9. **Hot-Humid Climatic Conditions:** To collect Hot-Humid conditions failure data
10. **Failure Mode:** To identify failure modes
11. **Failure Mechanism:** To identify failure mechanisms
12. **Modeling:** To develop appropriate physical and statistical models
Comparative Testing: Types

Sequential Testing

- DH2000
- TC400
- HF40
- Bypass Diode

Extended Testing

- TC400
- DH2000
- HF40

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<th>Extended</th>
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<td>Multi-variable &amp; variable pre-conditioning</td>
<td>Single-variable &amp; No variable pre-conditioning</td>
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One module undergoes multiple stress tests **one after another** instead of the usual certification testing case (for IEC 61215) where each module has **one** stress test **only**.

For example, one module goes through damp heat-, then thermal cycling-, then humidity freeze-, then bypass diode test.

In the usual case (IEC 61215) one module is exposed to **only** damp heat- or **only** thermal cycling- or **only** humidity freeze- or **only** bypass diode-test.

In summary this **"one after another"** explains the sequential method of testing. In addition, each test is 2-4 times the severe as that of IEC 61215.
Long-term Sequential Testing: Pre- and Post-Tests

- Pre- and post-stress tests: I-V parameters ($P_{\text{max}}$, FF etc.), dry hipot, wet resistance and visual inspection (periodical test reports).

![Graph showing Normalised Mpp vs. test sequence parameter]

- Normalised $M_{\text{pp}}$ vs. test sequence parameter
- Relative $P_{\text{max}}$
- 20% limit
- Test Block/Parameter
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**1 YEAR SEQUENCE**

LST: Test Samples (3) and Stress Test Blocks (13)
Outline

• Long-term Sequential Testing: Test Program

• Long-term Sequential Testing: Some Results
Kyocera-Case Study

• Kyocera Case- 1) Some normalized results
Kyocera Case Study

• Kyocera Case - 1) Some normalized results

After DH1750
Kyocera-Case Study

• Kyocera Case- Degradation of Sample Over the LTS Sequence

![Graph showing degradation of samples](Image)

Module 1 = -4.8% Pmax
Module 2 = -4.9% Pmax
Control = 0.0% Pmax
Normalized

FF_i = 0.75
FF_e = 0.72

FF_i = 0.74
FF_e = 0.72

FF_i = 0.74
FF_e = 0.74

Solar Energy Assessment Center (SEAC)
Kyocera-Case Study

• Kyocera Case- 1) IR Camera Thermal Degradation Checks
Visual Degradation

Module 1

Module 2

START

START
Visual Degradation of Backsheet
Long-term Sequential Tested PLUS

Ultra Violet exposure for the “Long-term Sequential Tested PLUS” gives the option to allow a dry exposure to UV light in the test sequence to simulate more severe UV light degradation.

The standard requires a pre-conditioning exposure of 15 kWh/m². This test applies 1000 h exposure.

Test Blocks
- 200 h exposure check
- 400 h exposure check
- 600 h exposure check
- 800 h exposure check
- 1000 h exposure check

These tests are performed before and after the above mentioned tests.
- Visual Inspection
- Max Power Determination
- Dielectric withstand test
- Wet leakage test
Long-term Sequential Tested PLUS

The following Plug-In modules could be applied to the base Long-term Sequential Tested program

1) Configurable extreme condition module
2) Outdoor Exposure → 3+ years
3) \( P_{\text{max}} \) degradation analysis
Acceleration Factor

Accelerated Testing
From LST sequence

Field Exposure
From LST PLUS sequence

Acceleration Factor
To be published in EU-PVSEC 2011

LST testing service is now offered by multiple TÜV Rheinland labs with varied outdoor climatic conditions

LST Locations:
- TÜV Japan (Competence)
- TÜV PTL (USA)
- TÜV Germany
- TÜV Shanghai
- TÜV Taiwan
- TÜV India

Outdoor Locations:
- Hot-Dry
- Cold-Dry
- Hot-Humid
Thanks for your attention!