Long-Term Sequential Testing (LST) of PV Modules

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One-Stop Solution: From Components to Power Plants

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

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

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

Seal with Plant-ID

Installer Training

Global PV Power Plant Certification

Planning → **Installation** → **Operation**

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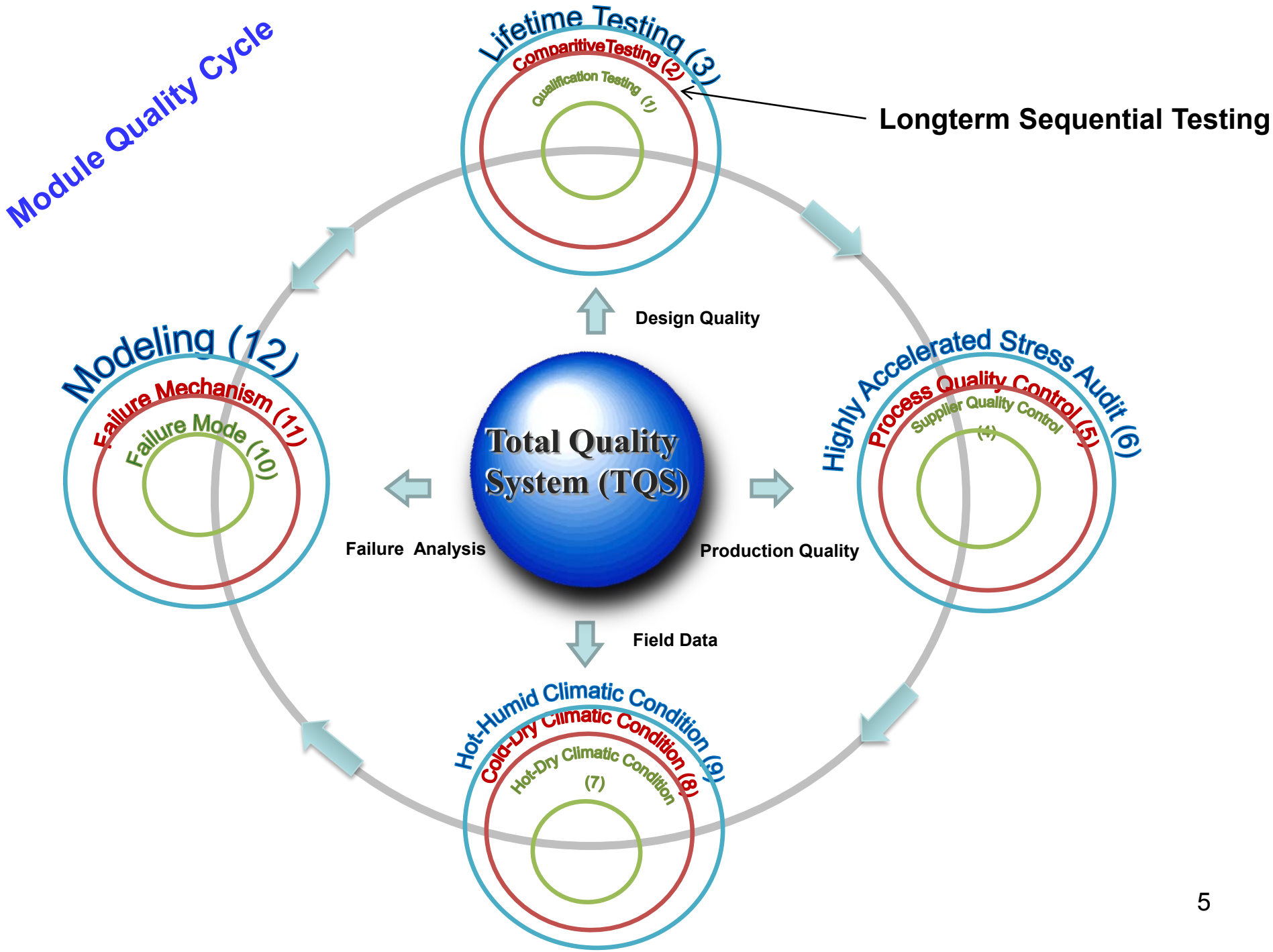
Outline

- **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**


Module Quality Cycle
Lifetime Testing (3)
Comparitive Testing (2)
Qualification Testing (1)
Longterm Sequential Testing
Design Quality
Highly Accelerated Stress Audit (6)
Process Quality Control (5)
Supplier Quality Control (4)
Production Quality
Total Quality System (TQS)
Modeling (12)
Failure Mechanism (11)
Failure Mode (10)
Failure Analysis
Field Data
Hot-Humid Climatic Condition (9)
Cold-Dry Climatic Condition (8)
Hot-Dry Climatic Condition (7)

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

vs.

Extended Testing

↓ TC400

↓ DH2000

↓ HF40

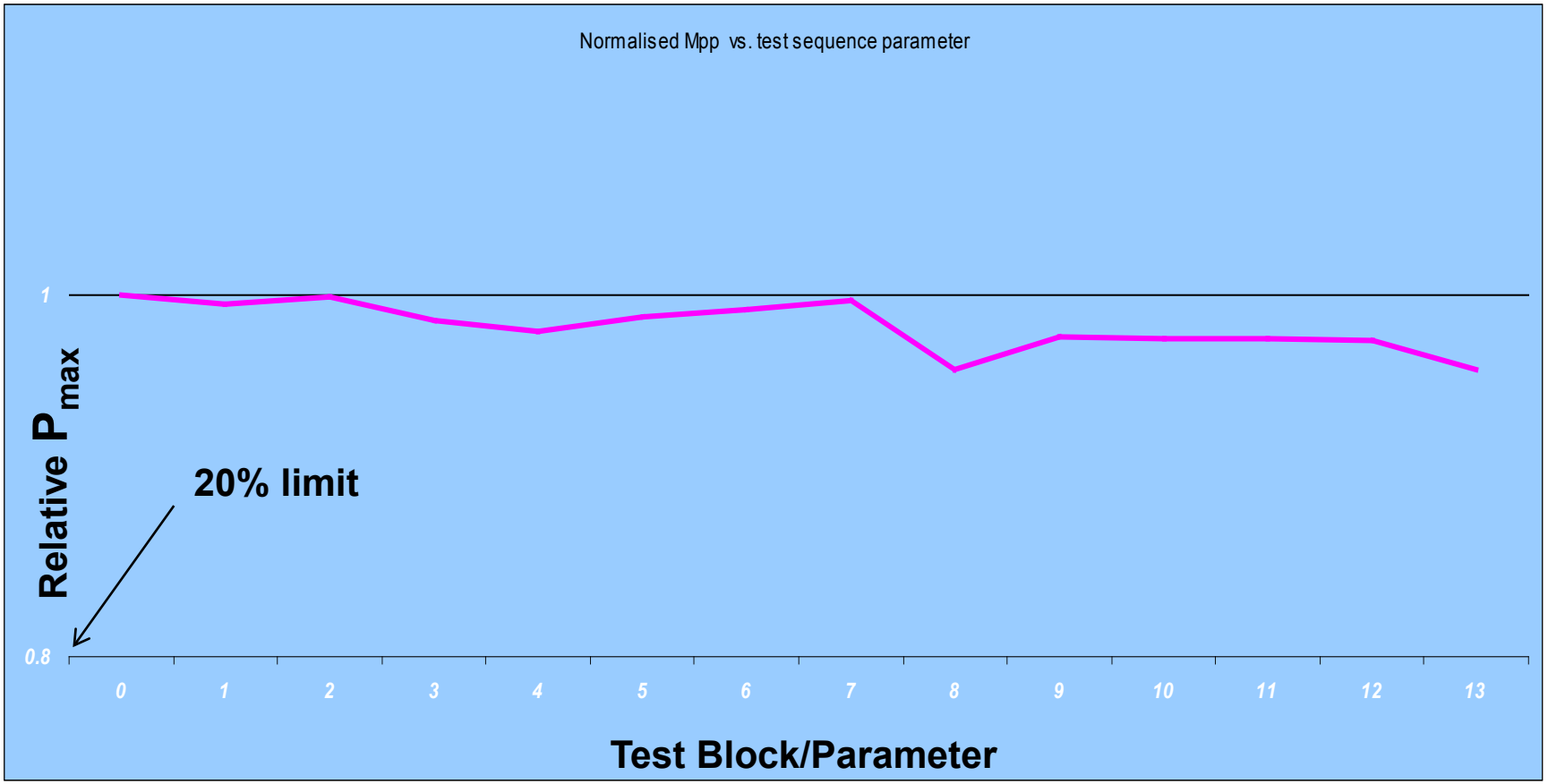
Sequential	Extended
Multi-variable & variable preconditioning	Single-variable & No variable preconditioning

Long-term Sequential Testing: Simple Description

- 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_{max}, FF etc.), dry hipot, wet resistance and visual inspection (periodical test reports).**



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

Blocks	Sample 1	
	1	
	Receiving	
	PreCon-Setup	
	PreCon-Test	
	PreCon-Teardown	
	Visual Insp	
	MaxPower	
	DielWithstd	
	WetLeak	
	DampHeat-Setup	
1	DampHeat-Test 1000h (accumulated	
	DampHeat-Teardown	
	DielWithstd	
	WetLeak	
	Visual Insp	
	MaxPower	
	DampHeat-Setup	
2	DampHeat-Test 1250h (+250 h)	
	DampHeat-Teardown	
	DielWithstd	
	WetLeak	
	Visual Insp	
	MaxPower	
3	DampHeat-Test 1500h (+250 h)	
	DampHeat-Teardown	
	DielWithstd	
	WetLeak	
	Visual Insp	
	MaxPower	
4	DampHeat-Test 1750h (+250 h)	
	DampHeat-Teardown	
	DielWithstd	
	WetLeak	
	Visual Insp	
	MaxPower	
5	DampHeat-Test 2000h (+250 h)	
	DampHeat-Teardown	
	DielWithstd	
	WetLeak	
	Visual Insp	
	MaxPower	
	TC200-Setup	

Blocks	Sample 2	
	1	
	Receiving	
	PreCon-Setup	
	PreCon-Test	
	PreCon-Teardown	
	Visual Insp	
	MaxPower	
	DielWithstd	
	WetLeak	
	DampHeat-Setup	
1	DampHeat-Test 1000h (accumulated	
	DampHeat-Teardown	
	DielWithstd	
	WetLeak	
	Visual Insp	
	MaxPower	
	DampHeat-Setup	
2	DampHeat-Test 1250h (+250 h)	
	DampHeat-Teardown	
	DielWithstd	
	WetLeak	
	Visual Insp	
	MaxPower	
3	DampHeat-Test 1500h (+250 h)	
	DampHeat-Teardown	
	DielWithstd	
	WetLeak	
	Visual Insp	
	MaxPower	
4	DampHeat-Test 1750h (+250 h)	
	DampHeat-Teardown	
	DielWithstd	
	WetLeak	
	Visual Insp	
	MaxPower	
5	DampHeat-Test 2000h (+250 h)	
	DampHeat-Teardown	
	DielWithstd	
	WetLeak	
	Visual Insp	
	MaxPower	
	TC200-Setup	

6	TC200-Test (accumulated)	
	TC200-Teardown	
	Visual Insp	
	MaxPower	
	DielWithstd	
	WetLeak	
	TC300-Setup	
7	TC300-Test (+100 cycles)	
	TC300-Teardown	
	Visual Insp	
	MaxPower	
	DielWithstd	
	WetLeak	
	TC400-Setup	
8	TC400-Test (+100 cycles)	
	TC400-Teardown	
	Visual Insp	
	MaxPower	
	DielWithstd	
	WetLeak	
	HumFreez-Setup	
9	HumFreez-Test 10 (accumulated)	
	HumFreez-Teardown	
	DielWithstd	
	Visual Insp	
	MaxPower	
	WetLeak	
	HumFreez-Setup	
10	HumFreez-Test 20 (+10 cycles)	
	HumFreez-Teardown	
	DielWithstd	
	Visual Insp	
	MaxPower	
	WetLeak	
11	HumFreez-Test 30 (+10 cycles)	
	HumFreez-Teardown	
	DielWithstd	
	Visual Insp	
	MaxPower	
	WetLeak	
12	HumFreez-Test 40	
	HumFreez-Teardown	
	DielWithstd	
	Visual Insp	
	MaxPower	
	WetLeak	
	BypassD-Setup	
13	BypassD-Test	
	BypassD-Teardown	
	Visual Insp	
	MaxPower	
	DielWithstd	
	WetLeak	

6	TC200-Test (accumulated)	
	TC200-Teardown	
	Visual Insp	
	MaxPower	
	DielWithstd	
	WetLeak	
	TC300-Setup	
7	TC300-Test (+100 cycles)	
	TC300-Teardown	
	Visual Insp	
	MaxPower	
	DielWithstd	
	WetLeak	
	TC400-Setup	
8	TC400-Test (+100 cycles)	
	TC400-Teardown	
	Visual Insp	
	MaxPower	
	DielWithstd	
	WetLeak	
	HumFreez-Setup	
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	DielWithstd	
	Visual Insp	
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	MaxPower	
	WetLeak	
12	HumFreez-Test 40	
	HumFreez-Teardown	
	DielWithstd	
	Visual Insp	
	MaxPower	
	WetLeak	
	BypassD-Setup	
13	BypassD-Test	
	BypassD-Teardown	
	Visual Insp	
	MaxPower	
	DielWithstd	
	WetLeak	

1 YEAR SEQUENCE

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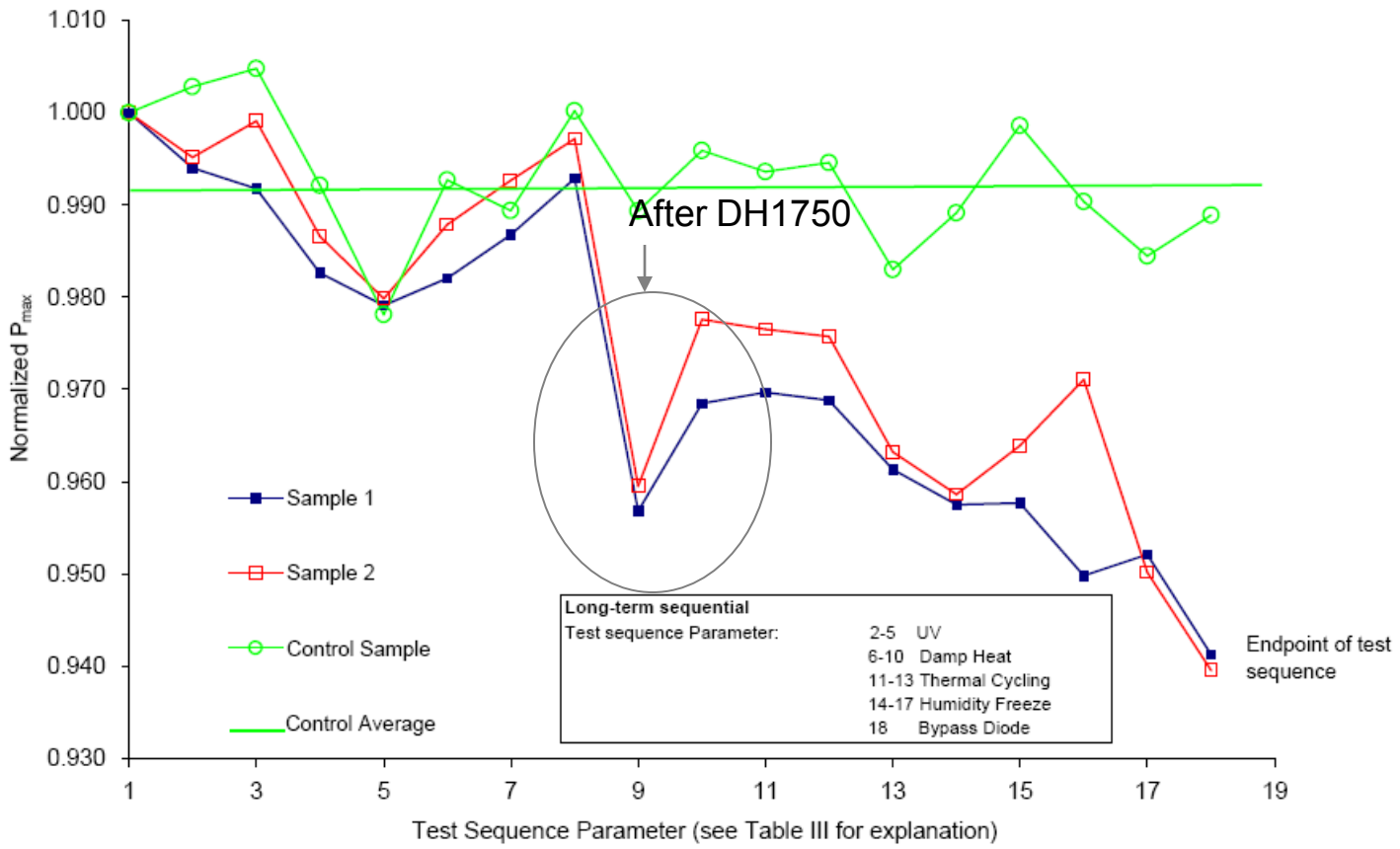
Outline

- Long-term Sequential Testing: Test Program
- **Long-term Sequential Testing: Some Results**

Kyocera-Case Study

•Kyocera Case- 1) Some normalized results



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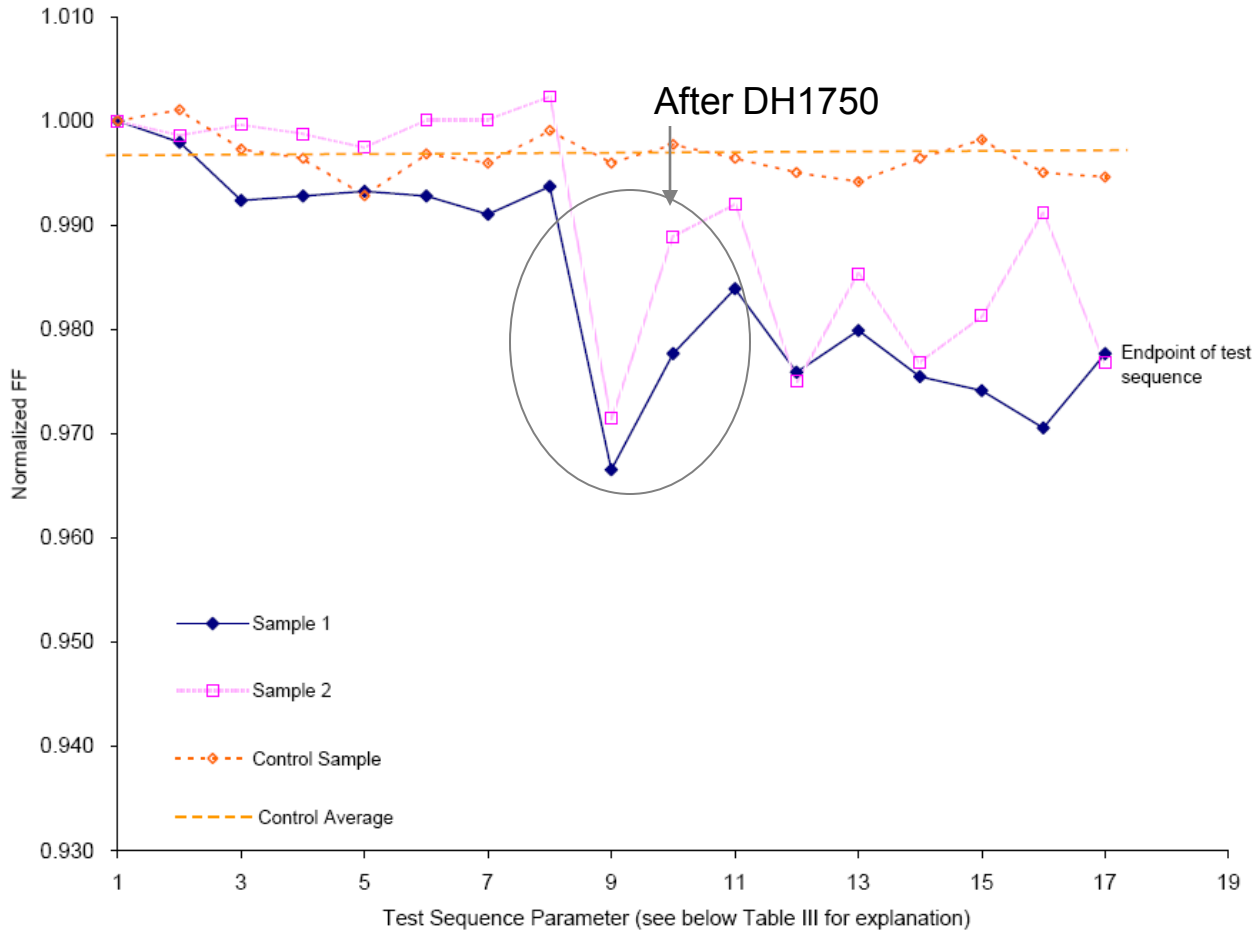
Kyocera-Case Study

•Kyocera Case- 1) Some normalized results



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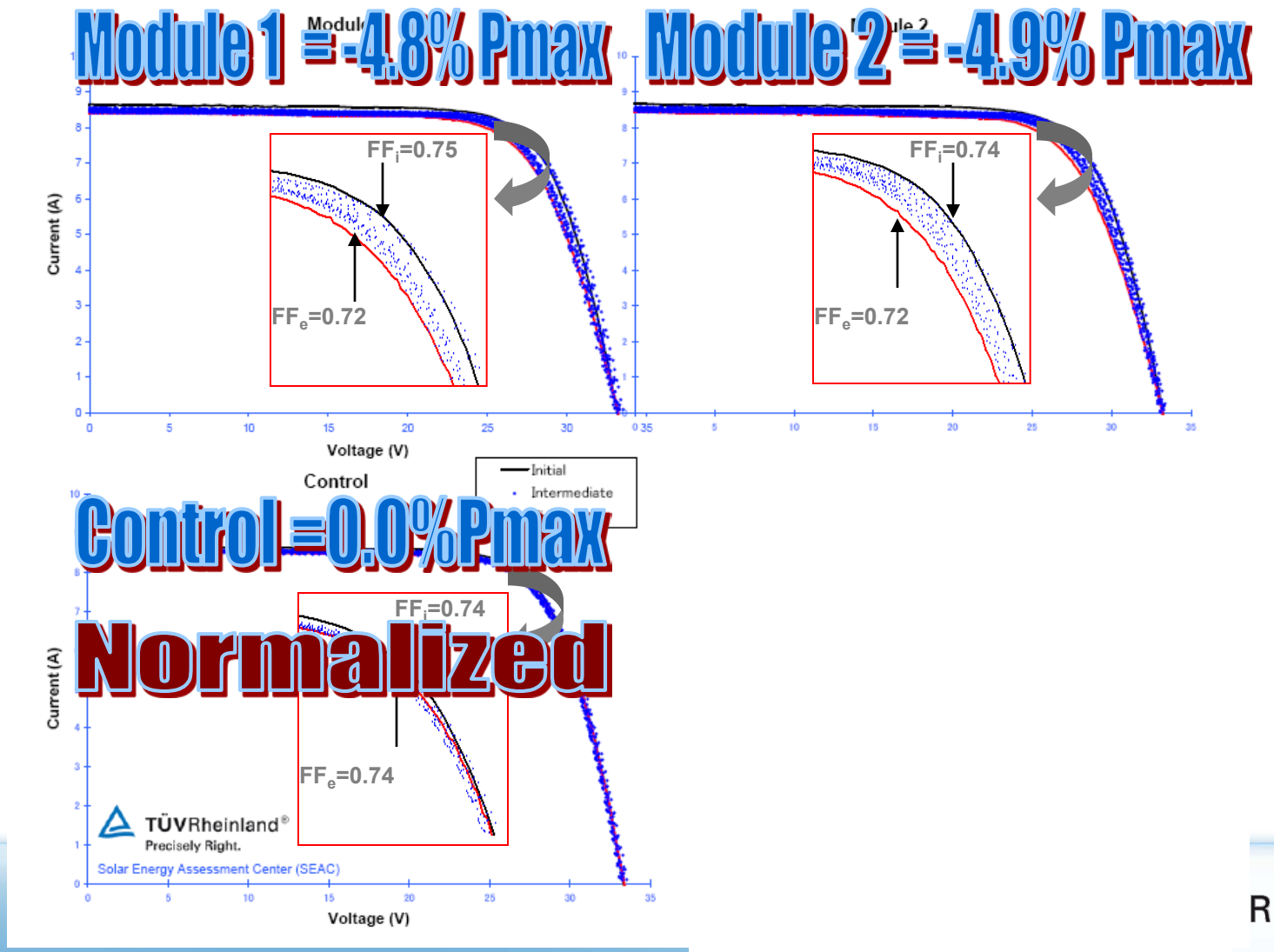
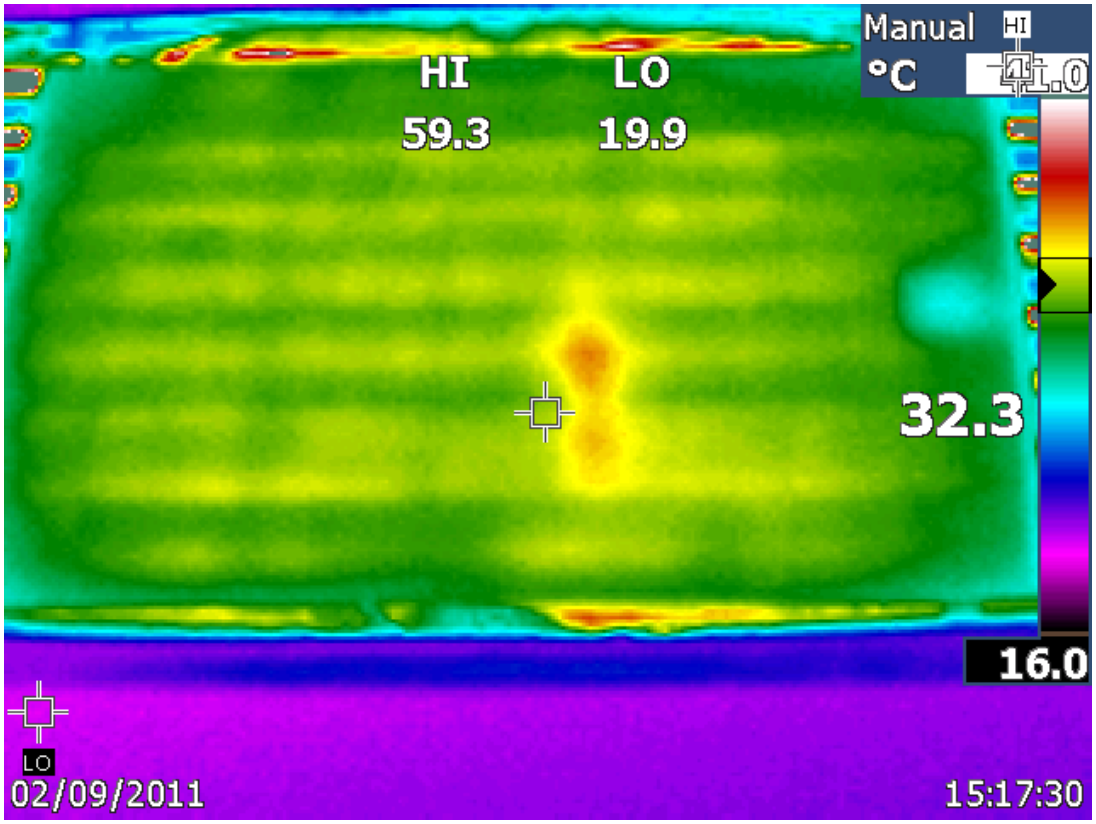
Kyocera-Case Study

- Kyocera Case- Degradation of Sample Over the LTS Sequence



Kyocera-Case Study

•Kyocera Case- 1) IR Camera Thermal Degradation Checks



Visual Degradation

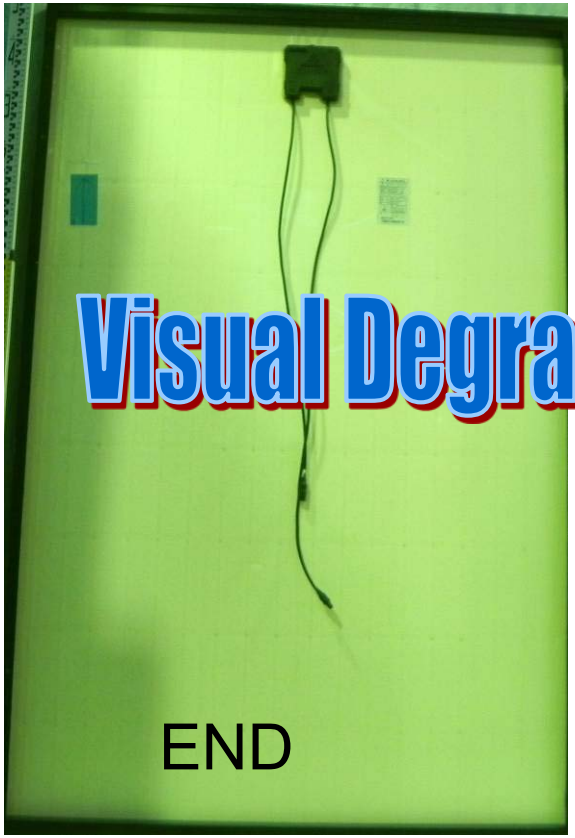
Module 1

Module 2

Module 1

Module 2

Visual Degradation of Backsheet

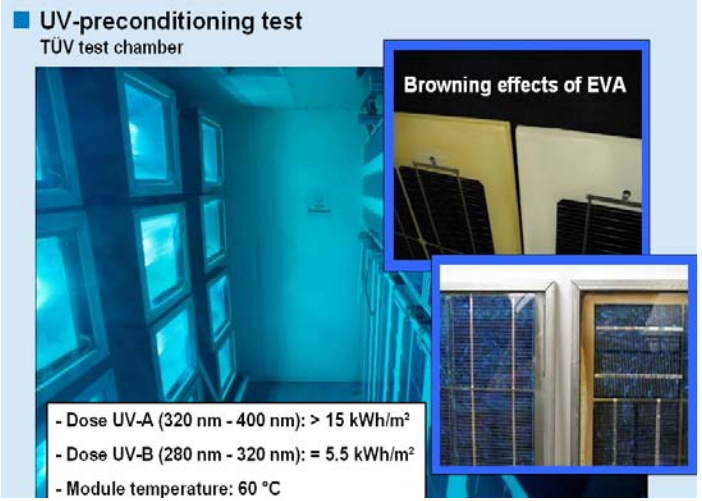


Long-term Sequential Tested PLUS

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/m^2.

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

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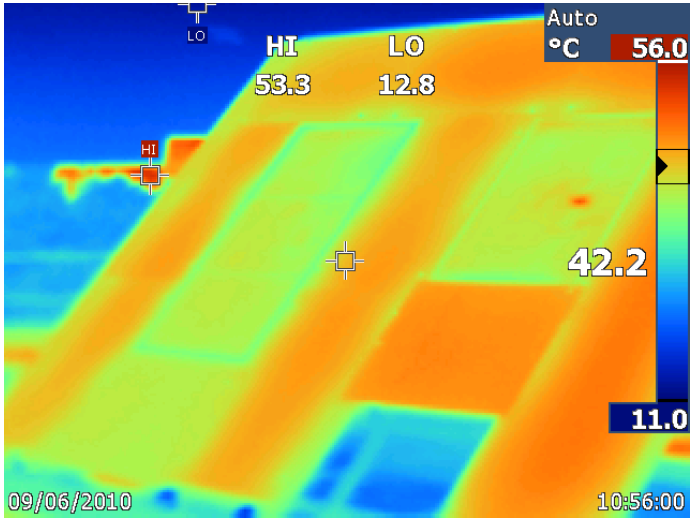
Long-term Sequential Tested PLUS

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

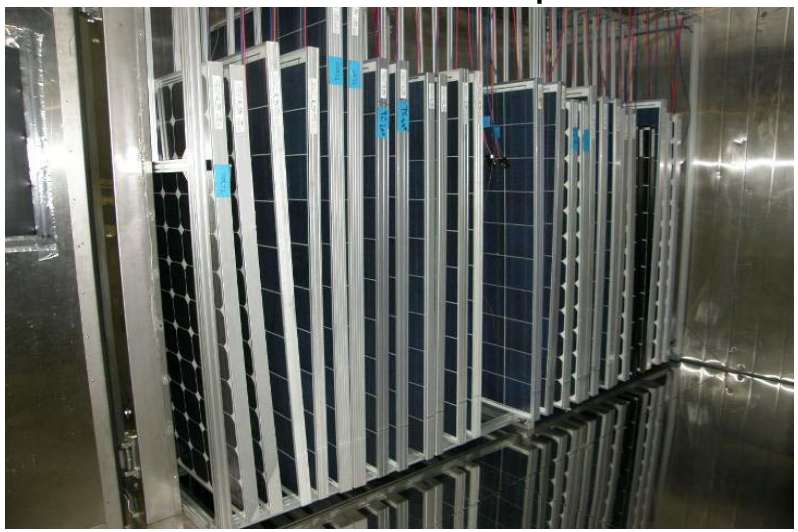
1) Configurable extreme condition module
2) Outdoor Exposure → 3+ years
3) P_{max} degradation analysis



Acceleration Factor

Accelerated Testing

From LST sequence



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Field Exposure

From LST PLUS sequence

Acceleration Factor

LST: Publication & Locations

§To be published in EU-PVSEC 2011

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

Test Locations

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!