



# Long-Term Sequential Testing (LST) of PV Modules

**Stefan Kiehn**  
**Mani TamizhMani**

# Quality Assurance Testing @ TÜV Rheinland

## 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

#### 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

検索

Installer  
Training

Global PV Power Plant Certification

Planning

Installation

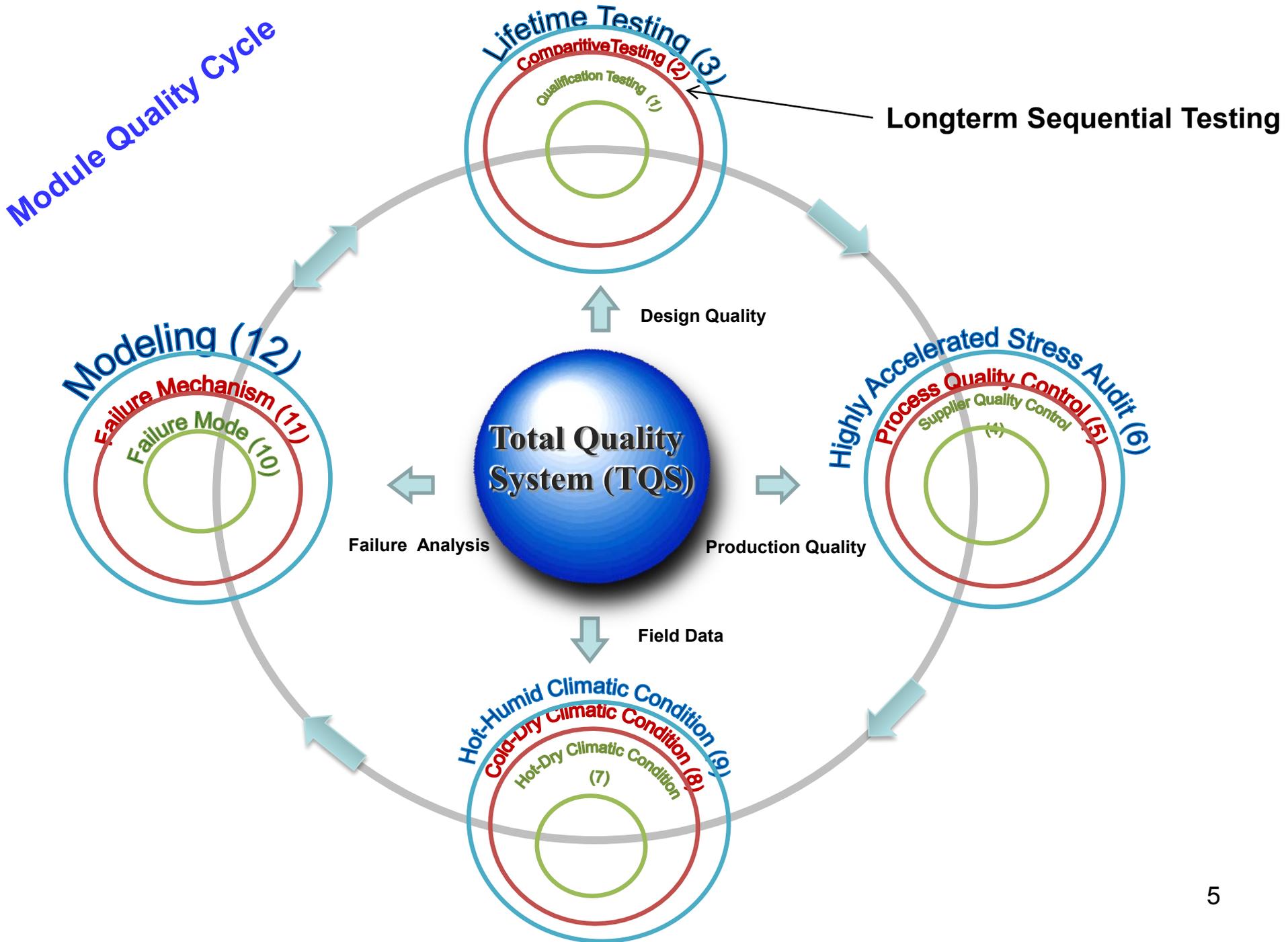
Operation

# Outline

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

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

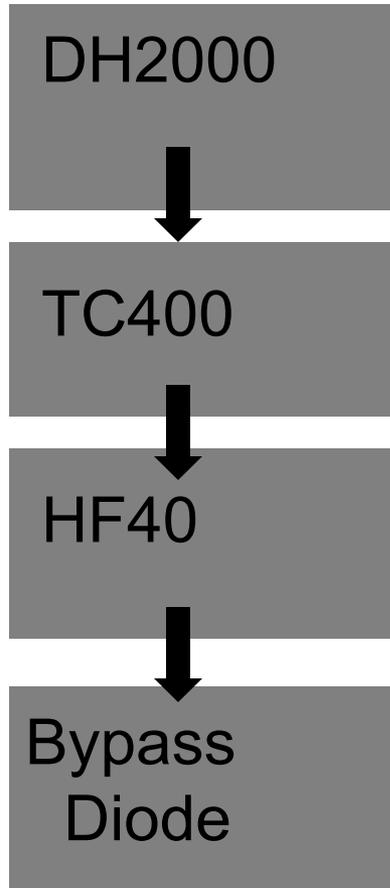


## Quality Cycle: Purpose of 12 Sub-Cycles

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

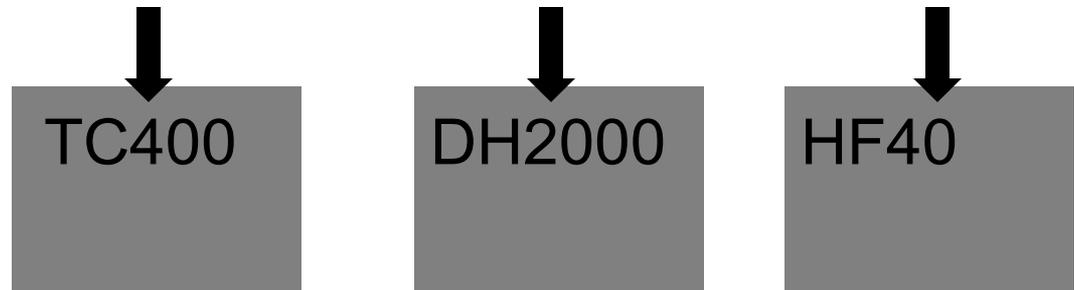
# Comparative Testing: Types

Sequential Testing



vs.

Extended Testing



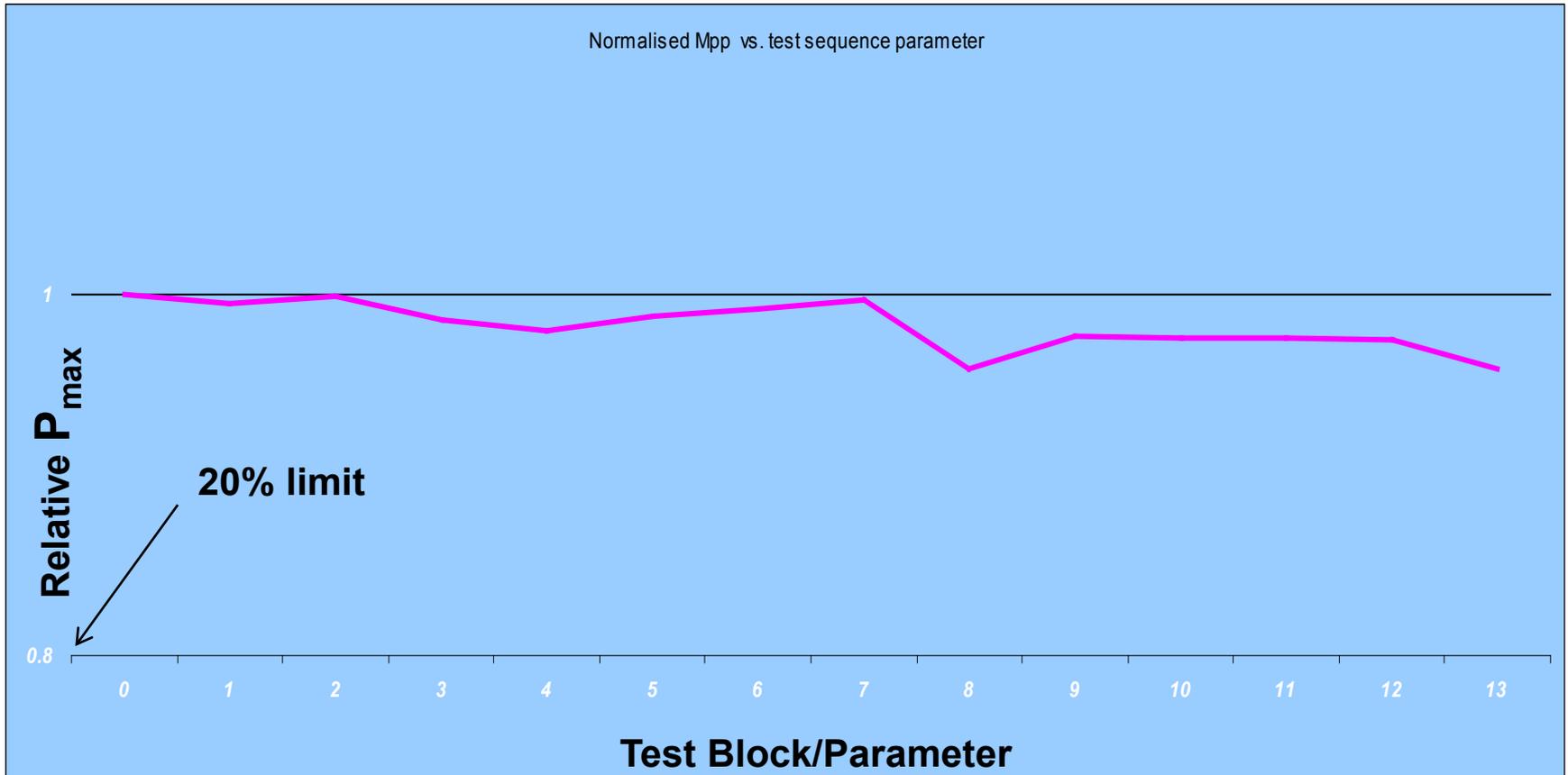
Sequential	Extended
Multi-variable & variable preconditioning	Single-variable & No variable preconditioning

## 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	Sample 2	Block	Block	Block	
	Receiving	Receiving	6	TC200-Test (accumulated)	6	TC200-Test (accumulated)
	PreCon-Setup	PreCon-Setup		TC200-Teardown		TC200-Teardown
	PreCon-Test	PreCon-Test		Visual Insp		Visual Insp
	PreCon-Teardown	PreCon-Teardown		MaxPower		MaxPower
	Visual Insp	Visual Insp		DielWithstd		DielWithstd
	MaxPower	MaxPower		WetLeak		WetLeak
	DielWithstd	DielWithstd		TC300-Setup		TC300-Setup
	WetLeak	WetLeak	7	TC300-Test (+100 cycles)	7	TC300-Test (+100 cycles)
	DampHeat-Setup	DampHeat-Setup		TC300-Teardown		TC300-Teardown
1	DampHeat-Test 1000h (accumulated)	DampHeat-Test 1000h (accumulated)		Visual Insp		Visual Insp
	DampHeat-Teardown	DampHeat-Teardown		MaxPower		MaxPower
	DielWithstd	DielWithstd		DielWithstd		DielWithstd
	WetLeak	WetLeak		WetLeak		WetLeak
	Visual Insp	Visual Insp		TC400-Setup		TC400-Setup
	MaxPower	MaxPower	8	TC400-Test (+100 cycles)	8	TC400-Test (+100 cycles)
	DampHeat-Setup	DampHeat-Setup		TC400-Teardown		TC400-Teardown
2	DampHeat-Test 1250h (+250 h)	DampHeat-Test 1250h (+250 h)		Visual Insp		Visual Insp
	DampHeat-Teardown	DampHeat-Teardown		MaxPower		MaxPower
	DielWithstd	DielWithstd		DielWithstd		DielWithstd
	WetLeak	WetLeak		WetLeak		WetLeak
	Visual Insp	Visual Insp		HumFreez-Setup		HumFreez-Setup
	MaxPower	MaxPower	9	HumFreez-Test 10 (accumulated)	9	HumFreez-Test 10 (accumulated)
	DampHeat-Setup	DampHeat-Setup		HumFreez-Teardown		HumFreez-Teardown
3	DampHeat-Test 1500h (+250 h)	DampHeat-Test 1500h (+250 h)		DielWithstd		DielWithstd
	DampHeat-Teardown	DampHeat-Teardown		Visual Insp		Visual Insp
	DielWithstd	DielWithstd		MaxPower		MaxPower
	WetLeak	WetLeak		WetLeak		WetLeak
	Visual Insp	Visual Insp		HumFreez-Setup		HumFreez-Setup
	MaxPower	MaxPower	10	HumFreez-Test 20 (+10 cycles)	10	HumFreez-Test 20 (+10 cycles)
	DampHeat-Setup	DampHeat-Setup		HumFreez-Teardown		HumFreez-Teardown
4	DampHeat-Test 1750h (+250 h)	DampHeat-Test 1750h (+250 h)		DielWithstd		DielWithstd
	DampHeat-Teardown	DampHeat-Teardown		Visual Insp		Visual Insp
	DielWithstd	DielWithstd		MaxPower		MaxPower
	WetLeak	WetLeak		WetLeak		WetLeak
	Visual Insp	Visual Insp		HumFreez-Setup		HumFreez-Setup
	MaxPower	MaxPower	11	HumFreez-Test 30 (+10 cycles)	11	HumFreez-Test 30 (+10 cycles)
	DampHeat-Setup	DampHeat-Setup		HumFreez-Teardown		HumFreez-Teardown
5	DampHeat-Test 2000h (+250 h)	DampHeat-Test 2000h (+250 h)		DielWithstd		DielWithstd
	DampHeat-Teardown	DampHeat-Teardown		Visual Insp		Visual Insp
	DielWithstd	DielWithstd		MaxPower		MaxPower
	WetLeak	WetLeak		WetLeak		WetLeak
	Visual Insp	Visual Insp		HumFreez-Setup		HumFreez-Setup
	MaxPower	MaxPower	12	HumFreez-Test 40	12	HumFreez-Test 40
	TC200-Setup	TC200-Setup		HumFreez-Teardown		HumFreez-Teardown
				DielWithstd		DielWithstd
				Visual Insp		Visual Insp
				MaxPower		MaxPower
				WetLeak		WetLeak
				BypassD-Setup		BypassD-Setup
				BypassD-Test		BypassD-Test
				BypassD-Teardown		BypassD-Teardown
				Visual Insp		Visual Insp
				MaxPower		MaxPower
				DielWithstd		DielWithstd
				WetLeak		WetLeak

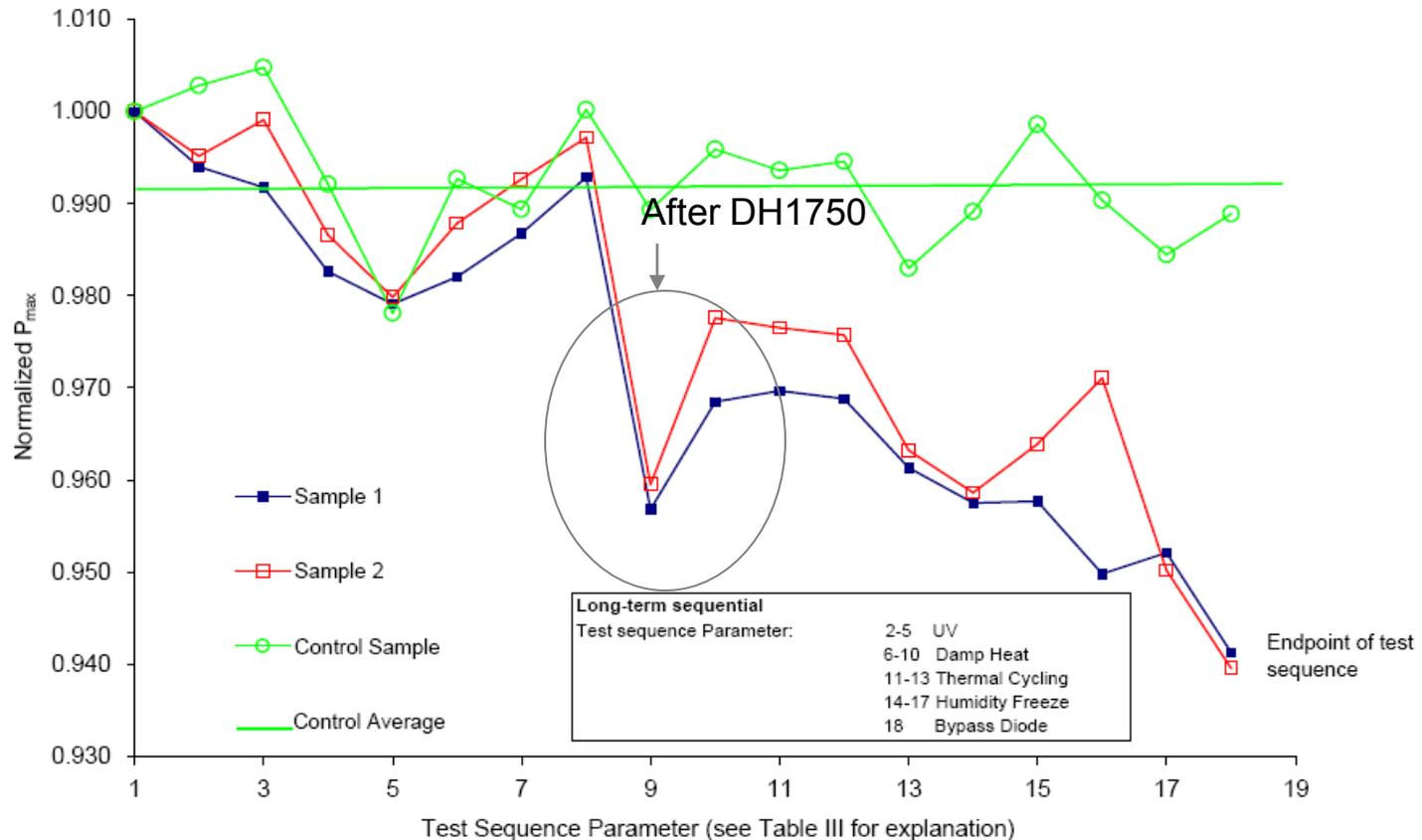
1 YEAR SEQUENCE

# Outline

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

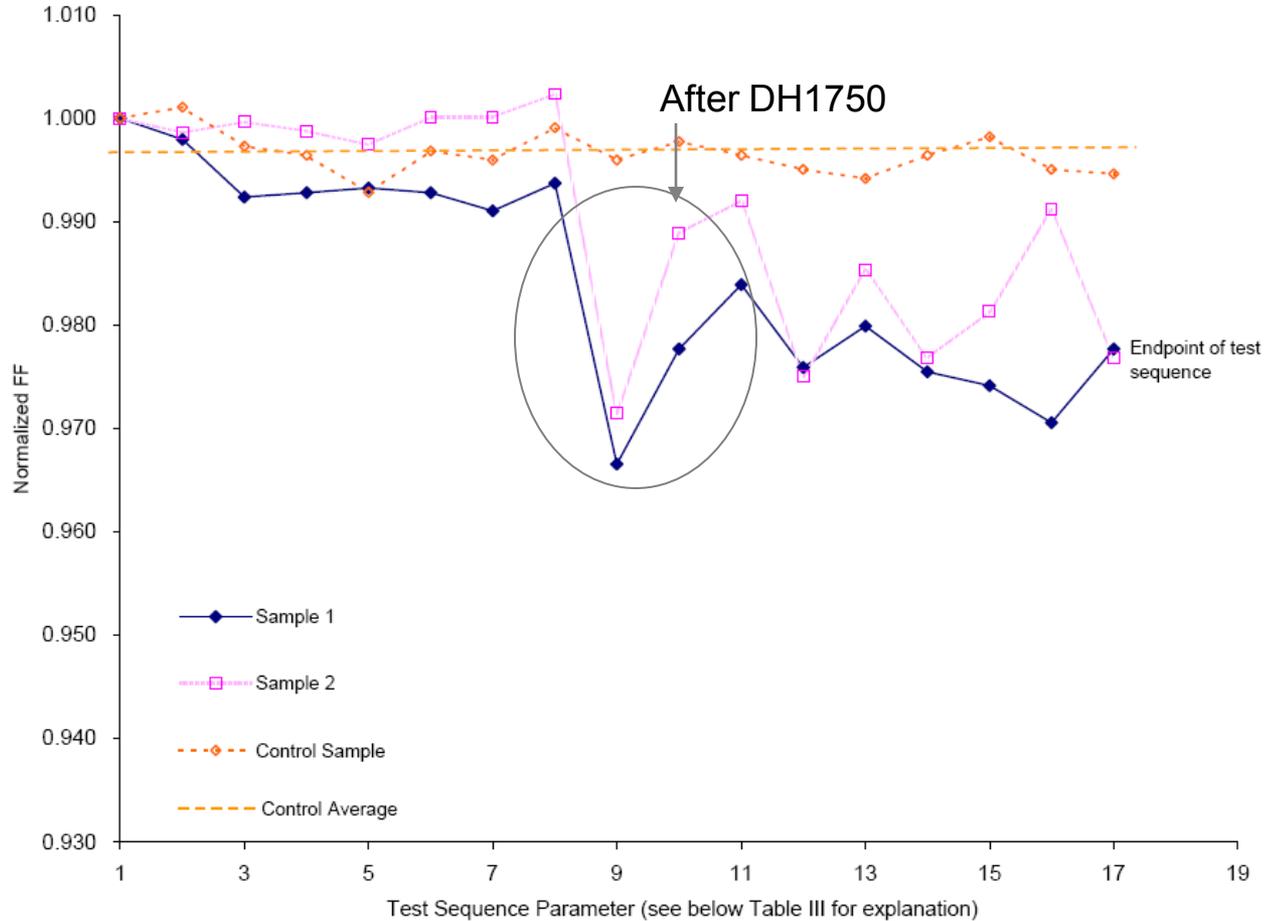
# Kyocera-Case Study

- Kyocera Case- 1) Some normalized results



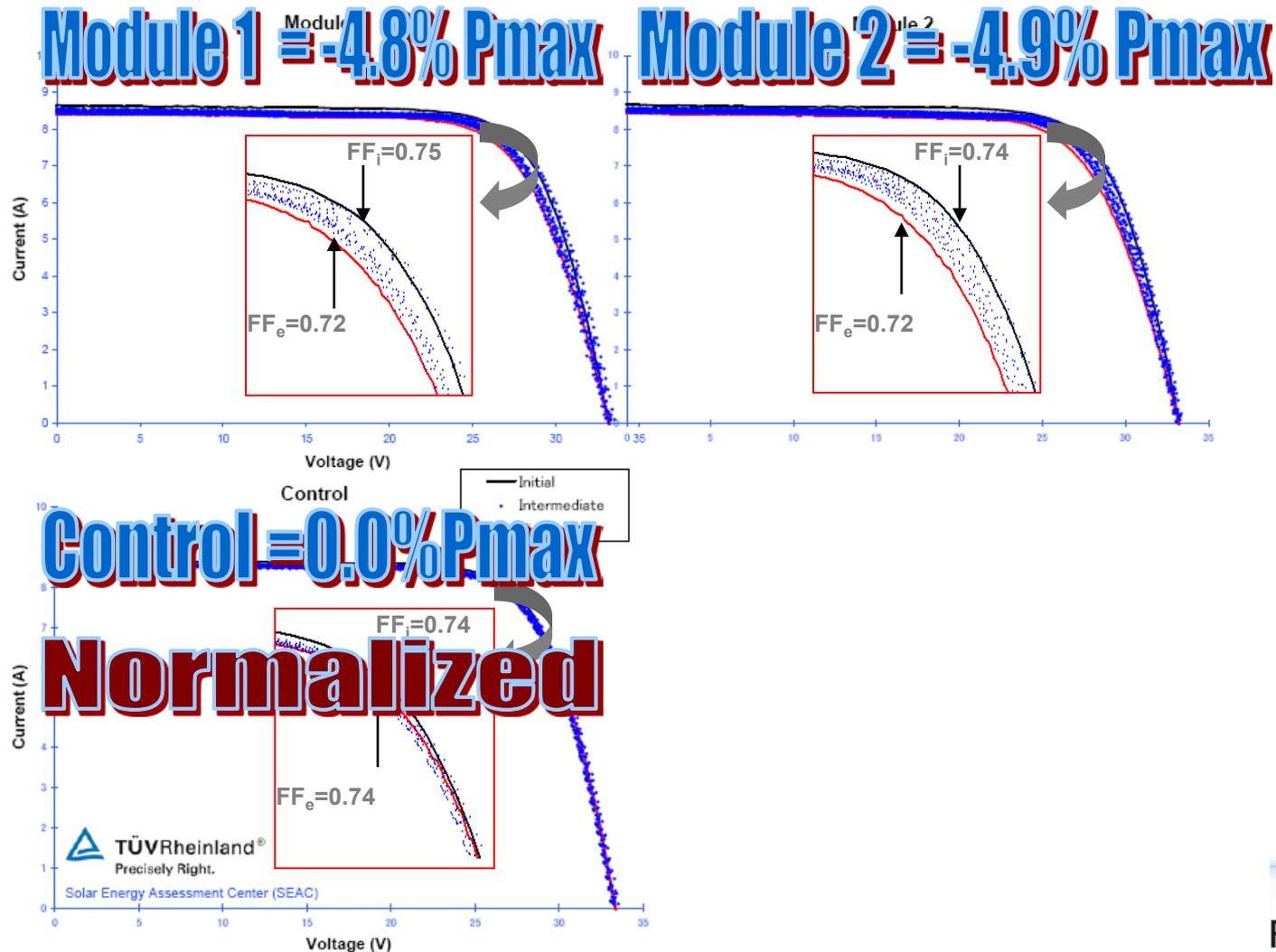
# Kyocera-Case Study

## •Kyocera Case- 1) Some normalized results



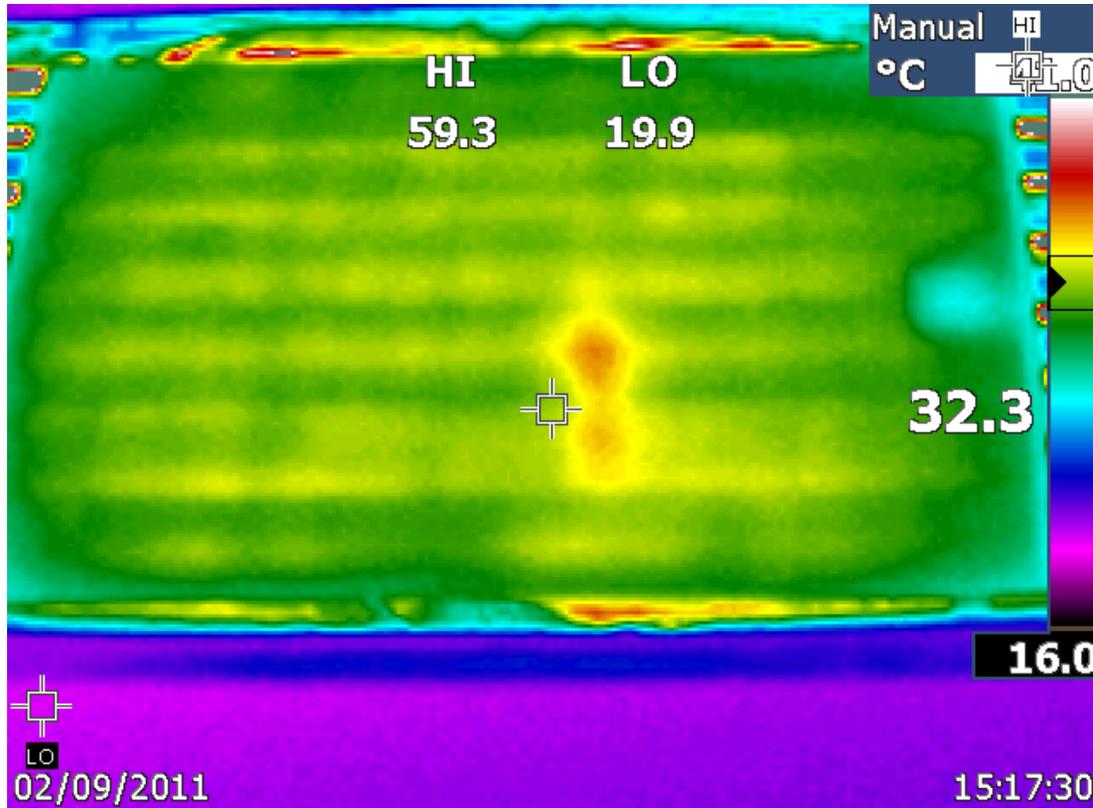
# Kyocera-Case Study

- 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





# 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<sup>2</sup>.

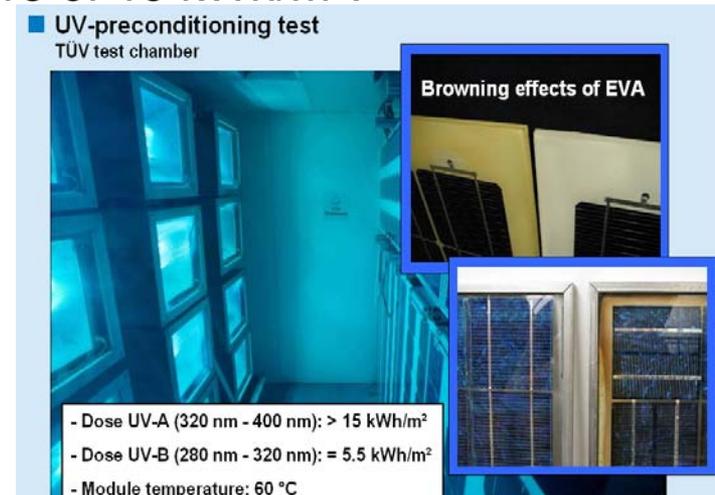
This test applies 1000 h exposure.

## 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.

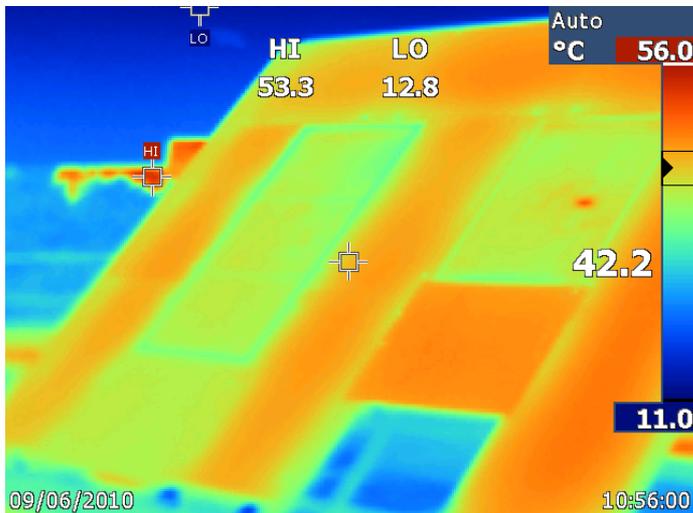
- Visual Inspection
- Max Power Determination
- Dielectric withstand test
- Wet leakage test



# 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)  $P_{\max}$  degradation analysis



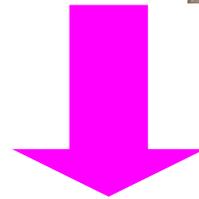
# Acceleration Factor

Accelerated Testing  
From LST sequence



+

Field Exposure  
From LST PLUS sequence

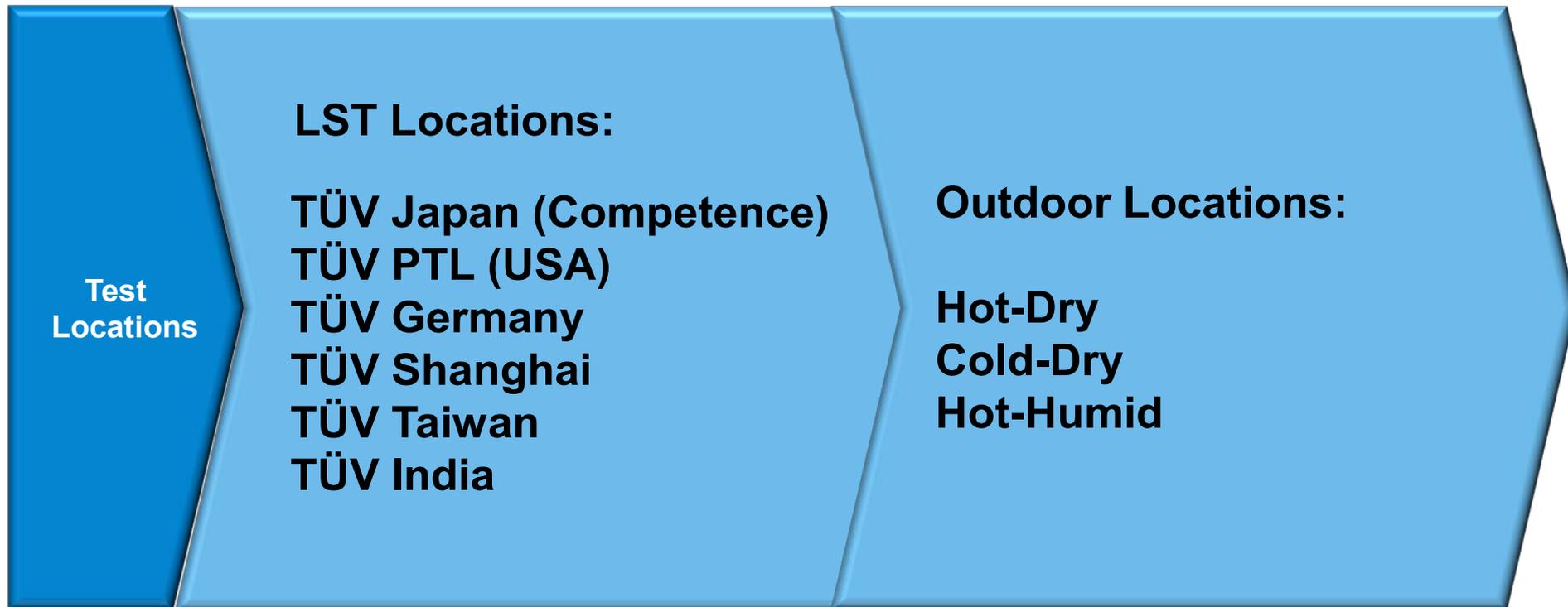


# Acceleration Factor

# 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



**Thanks for your attention!**