EL Testing: Ensuring Reliable Solar Panels

The Invisible Guard for Solar Reliability

Content Partner: J. v. G. technology GmbH

Turnkey solar module production lines — since 1997

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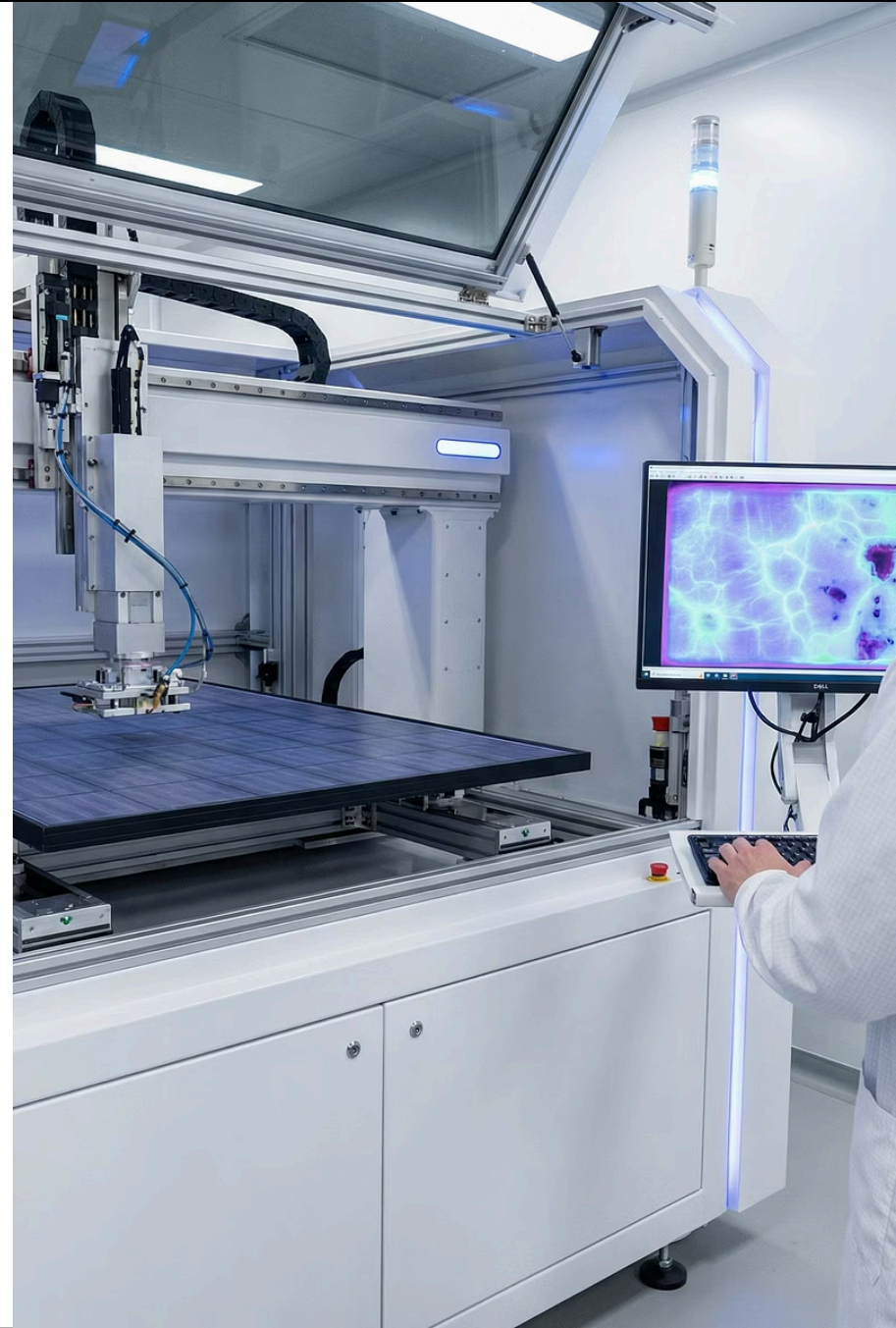

Technical overview of EL testing in PV manufacturing

Created as part of the PVKnowHow Knowledge Network

Prepared by J. v. G. Technology GmbH

European specialists in turnkey solar module production lines

Key Technical Insight

EL Ima...	Microc...	Inline ...	Reliabi...
Detection Method	**Primary Purpose**	**Primary Use**	**Key Benefit**
Electroluminescence imaging under forward bias reveals hidden cell defects	Detect microcracks and hidden defects invisible to standard visual inspection	Inline quality control integrated directly into solar module production lines	Ensures module reliability and long-term performance throughout service life

Process: EL Inspection · Application: Solar module quality control · Source: PVKnowHow / J.v.G. Technology GmbH

What Is EL Testing?

Basic Principle

- A non-destructive inspection technique using the electroluminescence phenomenon of PV cells
- A forward bias current is applied to the solar module, causing cells to emit near-infrared light
- A specialized camera captures the emitted light to produce a high-resolution image of the module
- Defective areas emit less or no light — appearing as dark regions in the EL image

Why It Is Unique

- Reveals internal cell conditions invisible to the naked eye or standard visual checks
- Non-invasive — modules are not damaged during testing
- Applicable at multiple stages: cell, module, and field inspection
- Detects defects that only appear under electrical operation conditions

Why EL Testing Matters

Quality Assurance

Ensures only defect-free modules leave the production line — preventing costly field failures

Reliability

Detects hidden defects that cause power loss, hot spots, and premature module degradation

Warranty Protection

Provides documented baseline evidence for warranty validation and dispute resolution

Microcracks and hidden defects identified early in production prevent significant financial loss and ensure module performance over a 25+ year service lifetime.

Detection of Microcracks and Defects

Microcracks

- Tiny cracks in silicon cells — can lead to power loss, diode activation, or hot spots
- Caused during manufacturing, shipping, or installation
- Not detectable by standard visual inspection or IV curve analysis

Cell & Soldering Defects

- Cell cracks isolate regions of cells, disrupting current flow
- Poor soldering connections cause power loss and potential fire hazards
- Broken gridlines and bus bar contact failures are clearly visible in EL imaging

Electrical Anomalies

- Potential Induced Degradation (PID) — voltage stress reducing output over time
- Dead cells, short circuits, and disconnection faults
- Cell contamination and uneven doping from manufacturing process

EL Inspection Process Steps

1

1 — Dark Room Setup

Module placed in a light-controlled or dark environment

Eliminates ambient light interference for accurate near-infrared imaging

2

2 — Voltage Application

Forward bias current applied to the module terminals

Causes solar cells to emit electroluminescent near-infrared light

3

3 — Image Capture

Specialized high-resolution camera captures the emitted light pattern

Full-module image produced in seconds at production-line speed

4

4 — Image Analysis

Dark spots and irregular patterns indicate defective cell areas

Manual review, automated software, or AI-assisted classification applied

5

5 — Pass / Fail & Reporting

Modules graded based on defect type, severity, and location

Results logged for traceability, warranty records, and process feedback

Role in the Production Line: Inline vs. Offline

Criterion	Inline EL Testing	Offline EL Testing
Integration	Fully integrated into production conveyor	Separate station; modules removed from line
Speed	Matches production throughput — no line stoppage	Slower; used for sampling or detailed analysis
Best Suited For	High-volume production; 100% inspection coverage	R&D, audit inspections, failure analysis
Defect Response	Real-time rejection and process feedback	Post-process review; slower corrective loop
Cost Impact	Higher upfront; lower cost per inspection at scale	Lower initial investment; higher per-unit cost

Key Benefits of EL Testing

Quality Assurance

- 100% non-destructive inspection of every module
- Detects defects invisible to visual or IV curve methods
- Reduces scrap rates and rework costs at the production stage

Production Efficiency

- Inline systems match line throughput with zero disruption
- Automated classification reduces operator dependency
- Real-time data feeds continuous process improvement

Warranty Validation

- Creates documented proof of module condition at shipment
- Supports manufacturer warranty claims with image evidence
- Enables root cause differentiation: manufacturing vs. transport damage

Key Features of EL Testers

High-Resolution Imaging

- Near-infrared sensitive cameras capture full-module images at high resolution
- Precise spatial resolution identifies microcrack location and orientation
- Consistent image quality maintained across production speed variations

Automation & Integration

- Automated loading, testing, and unloading on inline systems
- PLC-based control with HMI interface for operator management
- Customizable test parameters: voltage, current, exposure time

Software & Reporting

- Defect classification software with configurable pass/fail thresholds
- Full traceability: image archiving linked to module serial number
- Compliance with IEC and ASTM testing standards

Integration into Manufacturing Stages

Cell Fabrication

EL testing identifies defects or process variations at the individual cell level before module assembly begins

Pre-Lamination (Module Assembly)

Critical inspection point — defects detected here can still be corrected; rework is impossible after lamination

Post-Lamination QC

Final confirmation of module integrity and performance classification before shipment to customer

Manufacturers frequently perform EL testing twice during production: once before lamination (corrective) and once after lamination (confirmatory). Pre-lamination is the more critical intervention point.

Types of EL Testers

Production-Integrated Systems

- **Inline EL Tester:** Fully integrated into conveyor line; 100% module coverage; matches production throughput
- **High-Throughput EL Tester:** Designed for large-volume factories; automated loading/unloading; minimal cycle time

Flexible & Field Systems

- **Offline / Benchtop EL Tester:** Standalone station for sampling, R&D, and detailed defect analysis
- **Portable EL Tester:** Compact kit for on-site field inspections; can test installed modules without removal

Maintenance & Reliability Considerations

Camera & Optics

- Regular calibration of near-infrared camera required for consistent image quality
- Lens cleanliness critical — contamination degrades resolution and defect detection
- Periodic sensitivity checks against reference modules recommended

Electrical Components

- Power supply stability essential — voltage fluctuations affect emission uniformity
- Contact probes and connectors require regular inspection for wear
- PLC software and test parameter records should be backed up and version-controlled

System Uptime

- Inline EL systems are on the critical production path — unplanned downtime stops the line
- Preventive maintenance schedules reduce risk of unplanned failures
- Spare camera and light source modules recommended for high-volume facilities

Future Trends in EL Testing

AI & Machine Learning

- Automated defect classification with up to 99% accuracy reported
- AI models trained on large defect datasets for faster, consistent grading
- Reduces operator subjectivity in pass/fail decisions

Automation & IoT

- Full integration with Manufacturing Execution Systems (MES) for end-to-end traceability
- IoT-enabled remote monitoring of tester status and test result data
- Closed-loop feedback directly to upstream process equipment

Advanced Imaging

- Hyperspectral EL imaging for deeper material characterization
- Higher camera resolutions enabling sub-cell defect mapping
- Combined EL + IR thermography for multi-modal defect analysis

Applications of EL Testing

Production Line Quality Control

- Inline 100% inspection during cell-to-module manufacturing
- Pre-lamination correction and post-lamination confirmation
- Real-time process feedback to reduce defect recurrence

Research & Development

- Evaluation of new cell technologies (TOPCon, HJT, perovskite)
- Process optimization studies comparing encapsulants and cell formats
- Failure mode analysis and accelerated degradation testing

Field Inspection

- On-site inspection of installed modules without uninstalling panels
- Baseline documentation at commissioning; periodic condition monitoring
- Evidence collection for warranty disputes and insurance claims

Conclusion: EL Testing as a Manufacturing Standard

Quality Gateway

EL testing is the most effective non-destructive method for detecting internal module defects at production speed

Reliability Anchor

Systematic EL inspection throughout production directly supports 25+ year module lifetime performance targets

Industry Standard

From sporadic cross-check to mandatory inline QC — EL imaging is now a baseline requirement in modern PV manufacturing

An experienced turnkey production line provider integrates EL testing know-how into full-line process methodology — ensuring quality assurance from cell fabrication through final module shipment.

About the Content Partner

J. v. G. technology GmbH — The DESERT Company

Founded in 1997 in Bavaria, Germany. Family-owned engineering company specializing in turnkey solar module production lines.

More than 90 factory projects delivered worldwide. On-site team training included — no prior manufacturing experience required.

Key areas:

Turnkey PV manufacturing lines | DESERT Technology® | TÜV-certified module designs | Factory planning to production

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