

Provisional Technical Reference: Infrared Thermography for Solar PV Systems

Qualitative inspection of installed photovoltaic (PV) systems using infrared thermography

2025 Edition

Note: This Provisional Technical Reference represents current best practices and is subject to revision as further data and field feedback are incorporated.



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Foreword

This Provisional Technical Reference was prepared to establish uniform procedures and documentation requirements for qualitative infrared inspections of operating photovoltaic (PV) systems.

Infrared thermography of PV systems requires both scientific knowledge and professional judgment. This Provisional Technical Reference assumes that the user possesses foundational training and certification in infrared thermography. It is not intended as a substitute for formal training or a detailed method statement.

The Provisional Technical Reference specifies inspection responsibilities, equipment performance, environmental conditions, and report content. It applies to both ground-based and aerial inspections.

Users of this Provisional Technical Reference shall comply with applicable occupational-safety and electrical-safety regulations. The authors and publishing body accept no responsibility for any loss or injury resulting from misuse of this document.

1 Scope

1.1 This Provisional Technical Reference specifies the qualitative procedure for infrared inspection of installed and operating PV systems to detect abnormal thermal patterns in solar panels.

1.2 It applies to both ground-based and aerial (manned or unmanned) inspections.

1.3 It establishes common requirements for communication, safety, and reporting between the end user and the infrared thermographer.

1.4 This Provisional Technical Reference does not cover:

- a) Electrical conductors and components not integral to the solar panel assembly; and
- b) Quantitative measurement or structural testing.

1.5 It specifies minimum camera performance, site conditions, and report documentation for repeatable and verifiable inspection results.

2 Normative references

The following documents are indispensable for application of this Provisional Technical Reference. For dated references, only the edition cited applies; for undated references, the latest edition (including amendments) applies.

- a) Technical Reference TR 119:2024. *Qualitative Infrared Thermography for Building Facades – Code of Practice*. Enterprise Singapore, Singapore.
- b) International Electrotechnical Commission (IEC) (2017). *IEC TS 62446-3: Photovoltaic (PV)*

systems – Requirements for testing, documentation and maintenance – Part 3: Outdoor infrared thermography of PV modules and plants. Geneva, Switzerland.

- c) Occupational Safety and Health Administration (OSHA). *Occupational Safety and Health Standards for General Industry (29 CFR 1910)*. U.S. Department of Labor, Washington DC, USA.
 - d) Occupational Safety and Health Administration (OSHA). *Occupational Safety and Health Standards for the Construction Industry (29 CFR 1926)*. U.S. Department of Labor, Washington DC, USA.
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3 Terms and definitions

For the purpose of this Provisional Technical Reference, the following terms apply.

- 3.1 End user** – Person or organisation requesting an infrared inspection.
- 3.2 Exception** – Abnormally warm or cool portion of a solar panel that may indicate a potential problem.
- 3.3 Infrared thermal imager (infrared camera)** – Device that detects, displays and records apparent thermal patterns across a surface.
- 3.4 Infrared thermographer** – Individual trained and qualified to operate an infrared thermal imager.
- 3.5 Noise Equivalent Temperature Difference (NETD)** – Measure of thermal sensitivity expressed in milliKelvins; lower values indicate greater sensitivity.
- 3.6 Minimum Detectable Temperature Difference (MDTD)** – Smallest temperature difference detectable by a thermal imaging system.
- 3.7 Photovoltaics (PV)** – Method of generating electric power by converting solar radiation into direct current through semiconductors.
- 3.8 Pyranometer** – Instrument used to measure broadband solar irradiance over a 180° field of view.
- 3.9 Qualified assistant** – Person designated by the end user to assist the thermographer and familiar with system operation and safety rules.
- 3.10 Thermogram** – Recorded thermal image representing apparent surface temperature distribution.
- 3.11 Solar irradiance** – Solar power incident per unit area on a surface.
- 3.12 Solar panel** – Assembly of electrically connected solar cells mounted on a supporting structure.
- 3.13 Use of “shall”, “should”, “may”, and “can”**

- a) *shall* indicates a mandatory requirement;
 - b) *should* indicates a recommendation;
 - c) *may* indicates permission;
 - d) *can* indicates possibility or capability.
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4 Principle of thermographic inspection

A thermographic examination of photovoltaic (PV) systems comprises:

- a) determination of the relative surface temperature distribution across the solar panels, obtained from the apparent radiance temperature distribution captured by infrared thermal imaging cameras;
- b) ascertainment of whether this temperature distribution is abnormal, i.e. if it is due to defective cells, faulty wiring, partial shading, dirt or debris on the surface, or other irregular heat signatures; and
- c) estimation of the nature and extent of the observed exceptions.

The thermograms obtained are analysed to determine whether the observed variations in thermal distribution are abnormal.

The condition of the PV array, the environmental conditions at the time of image capture, and any relevant system documentation shall be factored into the analysis.

Providing opinions regarding the causes of exceptions, the integrity of the system, or recommendations for corrective actions requires knowledge and skills beyond those of infrared thermography and shall not be attempted without such competence.

Infrared thermography is presented as a qualitative inspection technique to gather and document information at a specific point in time.

It shall not be promoted as a remedial measure and does not assure proper operation of the system.

Other diagnostic tests and maintenance procedures shall be conducted as necessary to ensure reliable performance of the PV installation.

5 Applicability

5.1 This Provisional Technical Reference covers procedures for conducting infrared inspections of solar panels installed in operating photovoltaic systems.

5.2 It does not cover electrical conductors and components that are not part of a solar panel.

5.3 This Provisional Technical Reference provides a common reference for end users and infrared thermographers to specify, perform, and document qualitative infrared inspections of installed

photovoltaic systems.

5.4 This Provisional Technical Reference may involve the use of equipment in hazardous or remote locations, at elevated vantage points, or on rooftops, and requires that appropriate safety and health practices be observed.

5.5 This Provisional Technical Reference also addresses criteria for imaging equipment, meteorological conditions, operator qualifications, and verification of infrared data.

5.6 It is the responsibility of the user of this Provisional Technical Reference to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

6 Responsibilities of infrared thermographers and end users

6.1 Thermographer

- a) Shall be competent in the construction, components and operation of photovoltaic (PV) systems to understand the observed thermal patterns.
- b) Shall ensure that environmental and physical conditions such as solar gain, wind, surface and atmospheric moisture, and heat transfer are favourable before conducting an inspection.
- c) Shall use infrared imaging and/or measurement equipment meeting the requirements of Clause 7 and capable of gathering accurate thermal data.
- d) Shall be accompanied by a qualified assistant who is knowledgeable in the operation of the system being inspected.
- e) Unless he or she is a licensed electrician, professional engineer, or otherwise authorised, the thermographer shall not perform tasks normally done by such personnel, and shall maintain a safe distance from energised or inspected equipment.
- f) Shall comply with all end-user safety practices, site rules, and applicable occupational-safety regulations.
- g) When requested by the end user, shall re-inspect each repaired exception to verify that the potential problem has been corrected.

6.2 End user

- a) Shall prepare or assist in preparing an inventory list and inspection route for all solar panels to be inspected in a logical and efficient manner.
- b) Shall assign a qualified assistant to accompany the thermographer. This assistant shall be knowledgeable of the system's operation and history and, unless otherwise specified, authorised by the end user to:
 - i) obtain any required access authorisations and notify facility or operations personnel of inspection activities; and

- ii) verify that the solar panels to be inspected are electrically connected to the system.
 - c) Shall ensure that panel surfaces are clean, dry, and free of dirt or debris for at least one hour prior to the infrared inspection.
 - d) Should provide drawings, layout plans, or blueprints showing the arrangement of the solar-panel arrays when available.
 - e) Accepts responsibility for all actions or decisions taken based on the inspection findings.
 - f) After repairs are completed, shall authorise re-inspection of each exception to confirm that corrective work has resolved the issue.
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7 Inspection instrument

7.1 General

- a) The infrared imaging system shall detect emitted radiation and display a real-time image, either in monochrome or multi-color.
- b) Non-imaging devices such as radiometers, line scanners, or visual infrared thermometers are not sufficient.
- c) The equipment may be hand-held, vehicle-mounted, or air-mounted, provided it is securely installed, does not interfere with safe vehicle or aircraft operation, and complies with applicable regulatory requirements.
- d) The infrared system shall permit manual adjustment of level and gain, both of which shall be independently controllable; automatic-only gain ("Auto Image") is not sufficient.

7.2 Performance requirements

Parameter	Requirement
Spectral range	2 μm to 14 μm
Detector resolution	$\geq 320 \times 240$ pixels
Thermal sensitivity (NETD)	≤ 0.05 $^{\circ}\text{C}$ (50 mK) at 30 $^{\circ}\text{C}$
Control function	Manual adjustment of level and gain independently required
Ground inspection resolution	Distinguish an individual solar cell within a panel
Aerial inspection resolution	Resolve area ≤ 0.15 m $\times$ 0.15 m per pixel
Mounting security	Equipment shall be secure and not interfere with vehicle or aircraft operation

8 Required conditions

- a) No precipitation within one hour before inspection.
 - b) Surfaces shall be free of dew, condensation, standing water, snow, ice, dirt and debris.
 - c) Wind speed shall be below 25 km/h (15 mph).
 - d) Inspections shall be conducted under direct sunlight with solar irradiance $\geq 650 \text{ W/m}^2$ measured by a pyranometer.
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9 Thermographic examinations

9.1 Types of inspection

- a) **Ground-based** – performed on foot, from an elevated vantage point, or from accessible undersides of panels where safe to do so.
- b) **Aerial** – performed from aircraft or unmanned aerial systems (drones) providing mobility and rapid coverage of large areas.

9.2 Ground-based procedure

- a) Conduct a daylight visual survey to locate access points, heat sources, and hazards.
- b) Exercise care on rooftops to avoid damaging membranes or fixtures.
- c) Inspect panel surfaces at angles greater than 45° from the surface; ensure complete coverage including underside areas where accessible.
- d) Where accessible, the underside of panels shall be visually inspected, and any obstructions such as HVAC equipment, vents or structural supports that may affect thermal patterns shall be noted.
- e) Capture focused thermograms of exceptions or representative panels and corresponding visible-light images for correlation.

9.3 Aerial procedure

- a) Comply with all aviation, flight-safety, and regulatory requirements.
- b) Maintain altitude and flight parameters to meet the resolution requirements of Clause 7.2.
- c) Operate the imaging system to view thermal imagery live during flight, ensuring complete

coverage at viewing angles greater than 45°.

- d) Record thermal data and visible imagery digitally for subsequent analysis.

9.4 Inspection methodology

- a) Inspections shall be qualitative and performed using a thermal imager or imaging radiometer.
 - b) Compare panels under similar solar exposure to identify anomalies.
 - c) Panels exhibiting abnormal patterns shall be classified as exceptions.
 - d) Each exception shall be documented with focused thermograms and corresponding visible-light images aligned in perspective and stored electronically.
-

10 Thermographic report

The report shall include:

- a) Name, qualification and certification number of thermographer.
- b) Name and address of end user.
- c) Names of assistant(s).
- d) Equipment manufacturer, model and serial number.
- e) List of panels inspected and any that were not included.
- f) Date(s) of inspection and report issue.
- g) For each exception, the following are to be provided:
 - i) Location and description;
 - ii) Time of observation;
 - iii) Ambient conditions (temperature, wind speed, solar irradiance, sky conditions);
 - iv) Thermogram and visible image;
 - v) Field-of-view and optics used;
 - vi) Aircraft altitude if applicable;
 - vii) Notes on special conditions affecting results.
 - viii) Narrative summary of inspection procedures and findings.
 - ix) Scaled site layout showing orientation and location of exceptions.

Reports shall also include information on the field-of-view of the lens, any infrared filters or external optics used, and the sky conditions at the time of inspection.

Annex A (informative)

Example inspection procedures and coverage

Activity	Description
Pre-inspection planning	Review inventory list, obtain site permits, confirm weather forecast and solar irradiance criteria.
On-site visual survey	Identify access routes and safety hazards; verify panel condition.
Ground inspection	Scan rows systematically left-to-right to avoid overlap or omission.
Aerial inspection	Flight lines should maintain approximately 80 % forward and 20 % side overlap to ensure complete thermal coverage.
Data review	Compare thermal patterns across panels with similar orientation and irradiance.
Verification	Cross-check thermal anomalies with visual images and system records.

Annex B (normative)

Qualification requirements for thermographers

Level	Minimum qualification
Level I	Certified infrared thermographer with formal training in infrared imaging and basic PV principles.
Level II	Experienced thermographer qualified to interpret thermograms and prepare reports.
Assistant	Trained in site safety and operation of PV systems under supervision of the thermographer.

Annex C (informative)

Typical inspection checklist and report template

A. Checklist

- Weather conditions and irradiance verified ($\geq 650 \text{ W/m}^2$)
- Panel surfaces clean and dry
- Wind $< 25 \text{ km/h}$
- Camera settings (Level/Gain, Emissivity) recorded
- Visible photo captured for each thermogram
File names include panel row and column number
- Safety measures confirmed

B. Report Template

Item

- Project Title
 - Location
 - Client
 - Thermographer (Name/Level/Cert No.)
 - Date of Inspection
 - Equipment (Brand/Model/Serial No.)
 - Weather & Irradiance
 - Exceptions Observed
 - Remarks / Observations
 - Thermograms and Visual Images (Appended)
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Feedback Form

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Type of comment (GE – General; TE – Technical; ED – Editorial)	Clause/Subclause/ Table/Figure (e.g. 4.1, Table 2)	Proposed changes (Exact wording of recommended changes should be given.)	Reasons for the changes

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