

TECHNICAL SPECIFICATION

Terrestrial photovoltaic (PV) systems – Guidelines for effective quality assurance in PV systems installation, operation and maintenance

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IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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TECHNICAL SPECIFICATION

Terrestrial photovoltaic (PV) systems – Guidelines for effective quality assurance in PV systems installation, operation and maintenance

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**TERRESTRIAL PHOTOVOLTAIC (PV) SYSTEMS –
GUIDELINES FOR EFFECTIVE QUALITY ASSURANCE
IN PV SYSTEMS INSTALLATION, OPERATION AND MAINTENANCE**

FOREWORD

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- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

Technical Specification IEC 63049 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
82/1234/DTS	82/1283A/RVDTS

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
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- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

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INTRODUCTION

It is frequently observed that problems with PV systems may be related to the system installation in one of multiple ways. Successful completion and continuous operation of PV systems depend on appropriate training of workers, appropriate oversight of their work, and a continual improvement system to learn from identified problems.

In order to supplement multiple IEC standards for qualification of the components and to guide the design of systems, it is useful to have oversight of the installation process. Some installation companies use an ISO 9001 quality management system, but this is a relatively uncommon practice and those that do certify to ISO 9001 may omit some critical elements. Similarly, after completion of the installation, practices for operation and maintenance of a PV system vary widely with variable success.

This document was created to identify critical technical elements that should be included in Quality Assurance programs and, where useful, to provide more specific management requirements than are found in ISO 9001. This document is designed to be implemented as a self-contained certification or in conjunction with ISO 9001.

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TERRESTRIAL PHOTOVOLTAIC (PV) SYSTEMS – GUIDELINES FOR EFFECTIVE QUALITY ASSURANCE IN PV SYSTEMS INSTALLATION, OPERATION AND MAINTENANCE

1 Scope

This document provides the minimum activities deemed necessary to implement an effective Quality Assurance program for the managing and reducing of risk in the installation and operation of photovoltaic (PV) systems. This document defines requirements for certifying that an entity has and uses a Quality Assurance program to prevent, or reduce errors and learns from any new errors in:

- a) installation, and
- b) operation and maintenance of a PV system.

The object of this document is to provide more confidence in the performance and reliability of certified PV systems. By being installed and operated under a Quality Assurance program in accordance with this document, PV systems are expected to operate as designed and as expected based on product warranties.

This document is developed to facilitate implementation of the quality control scheme under the IECRE program, for those who choose to use the IECRE program ("IEC system for certification to standards relating to equipment for use in renewable energy applications").

NOTE This document has been written primarily to apply to large PV plants and similar schemes. Requirements for residential systems and smaller scale installers are being considered for a future version of this document. This document also assumes these requirements apply to the prime contractor who, in turn, is responsible to hold subcontractors and other service providers to the intent of these requirements.

This document is applicable to all PV systems independent of design and technology, i.e. flat panel, Concentrator Photovoltaic (CPV). Quality controls for CPV and nonconventional flat-plate systems will differ somewhat from those of more conventional designs; this document has not considered these differences and is expected to be generally applicable to all PV systems.

This document covers processes starting from the shipment of components out to the installation site and including the transport, unpacking, racking, construction, module installation process and processes associated with operation and maintenance of the PV system.

Compliance to a Quality Management System (QMS) such as ISO 9001 will meet many requirements in this document. The requirements that are unique to this document can be combined with the ISO 9001 audits for those organizations that are already registered to ISO 9001:2015. For the organizations who do not have ISO 9001 registration by a certified body, the entirety of this document applies.

Assessments with respect to this document may be completed to certify a Quality Assurance program for the installation process, for operations and maintenance processes or for both processes.

Clause 4 describes requirements for the installation process; Clause 5 describes requirements for operation and maintenance.

Maintenance of PV systems is often lumped into the catchall term "operations and maintenance" (O&M). This document does not address business or management operational

processes (e.g. forecasting, utility pricing incentives, etc.) or other considerations driven by factors outside of basic system working condition, safety and performance.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60364 (all parts), *Low-voltage electrical installations*

IEC 60364-7-712, *Low voltage electrical installation – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems*

IEC 61215 (all parts), *Terrestrial photovoltaic (PV) modules – Design qualification and type approval*

IEC TS 61724-2, *Photovoltaic system performance – Part 2: Capacity evaluation method*

IEC TS 61724-3, *Photovoltaic system performance – Part 3: Energy evaluation method*

IEC 61730 (all parts), *Photovoltaic (PV) module safety qualification*

IEC TS 61836, *Solar photovoltaic energy systems – Terms, definitions and symbols*

IEC 62109 (all parts), *Safety of power converters for use in photovoltaic power systems*

IEC 62446-1, *Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 1: Grid connected PV systems – Documentation, commissioning tests and inspection*

IEC 62446-2, *Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 2: Grid connected PV systems – Maintenance of PV systems (to be published)*

IEC 62446-3, *Photovoltaic (PV) systems – Requirements for testing, documentation and maintenance – Part 3: Photovoltaic modules and plants – Outdoor infrared thermography*

IEC 62548, *Photovoltaic (PV) arrays – Design requirements*

IEC TS 62738, *Ground-mounted photovoltaic power plants – Design guidelines and recommendations*

IEC 62759-1, *Photovoltaic (PV) modules – Transportation testing – Part 1: Transportation and shipping of module package units*

IEC TS 62915, *Photovoltaic (PV) modules – Retesting for type approval, design and safety qualification*

IEC TS 62941, *Terrestrial photovoltaic (PV) modules – Guideline for increased confidence in PV module design qualification and type approval*

ISO 9000, *Quality management systems – Fundamentals and vocabulary*

ISO 9001:2015, *Quality management systems – Requirements*

ISO 19011, *Guidelines for auditing management systems*

3 Terms and definitions

For the purposes of this document, the terms and definitions in ISO 9000, IEC TS 61836 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

condition adverse to quality

all-inclusive term used in reference to any of the following: failures, malfunctions, deficiencies, defective items, and non-conformances; such a condition is significant if, uncorrected, it could have a serious effect on safety or operability

4 Requirements for PV system installation

4.1 Records requirements

4.1.1 Records system

A records system(s) shall be established by the organization responsible prior to the start of installation activities. Requirements of local standards or regulations for documentation need to be considered to determine minimum documentation for PV systems.

The organization shall define the controls needed for the identification, storage, protection, retrieval, retention and disposition of records.

Records established to provide evidence of conformity to requirements and of the effective operation of the Quality Assurance program shall be controlled.

Records shall remain legible, readily identifiable and retrievable.

4.1.2 Generation of records

The applicable design specifications, procurement documents, contract documents, test procedures, operational procedures, or other documents shall specify the records to be generated, supplied, or retained by or for the project owner.

Documented information that is designated to become records shall be accurate, and completed appropriate to the work accomplished.

4.1.3 Record validation

Documented information shall be considered to be valid records only if stamped, initialled, or signed and dated by authorized personnel or otherwise authenticated, e.g. electronically validated.

4.2 Resource management

4.2.1 Training programs

4.2.1.1 General

The organization shall maintain a (periodic) training program for all personnel (not just employees) involved with the design and installation of PV projects. In addition to safety, professional, and other requirements, training should include familiarity with relevant sections of the technical photovoltaic documents described in Annex A and methods for handling modules.

4.2.1.2 Records requirements

Documented information of employee training relevant to the installation project shall include the type of training and date of completion.

4.2.2 Succession planning

The organization shall plan for succession for key functions that affect customer satisfaction, quality, reliability, safety, and performance, including the installation engineer.

4.3 PV system installation

4.3.1 General

The organization is required to implement the requirements in accordance with this document for the needed planning and development of processes for PV system installation.

In planning PV system installation, the organization shall determine the following, as appropriate:

- a) quality objectives and requirements for the installation;
- b) the need to establish processes and documents, and to provide resources specific to the installation;
- c) required verification, validation, monitoring, measurement, inspection and test activities specific to the installation and the criteria for installation acceptance;
- d) records needed to provide evidence that the installation processes and the completed installation meet requirements.

The output of this planning shall be in a form suitable for the organization's method of operations.

4.3.2 Project management

As appropriate to the organization and the project, the organization shall plan and manage PV system installation in a structured and controlled manner to meet requirements at acceptable risk, within resource and schedule constraints.

4.3.3 Determination of requirements

4.3.3.1 General

The organization shall consider requirements and guidelines contained in IEC 62548, IEC TS 62738, IEC 60364, IEC 60364-7-712, and local codes, as applicable. The final requirements shall be documented.

The installation processes shall reflect lessons learned from root cause analysis of problems with previous PV systems, and response to customer complaints or other experience with

previously installed PV systems. Input data for this process shall be proactively collected including:

- a) Analysis of performance of PV systems relative to the expected performance during the warranty period or longer.
- b) Periodic inspections of the PV systems to identify evidence of problems. Visual inspections may be supplemented by infrared and luminescent imaging.

This information may be collected and reviewed directly by the organization responsible for installation or indirectly in partnership with another entity. Regardless of the method of collection of the information, the organization shall include this proactively collected data when determining requirements.

4.3.3.2 Records requirements

Documented information shall be kept as a record of design reviews to ensure that all designs meet the requirements of IEC 62548, IEC TS 62738, IEC 60364, and IEC 60364-7-712, as applicable, before acceptance to begin construction, and to enable the information to be adequately communicated during implementation.

The design reviews should include a constructability and a serviceability review in order to identify potential problems.

Additionally, the documented information should include information about the assembly process, especially where variability in some processes could result in subsequent field failures. A key example is the handling of modules, since poor handling can result in cracked cells or shattered glass.

4.3.4 Customer communication

4.3.4.1 General

A process shall be developed to ensure proactive communication with customers (e.g. the owner) when a problem is identified with a relevant system.

A process shall be developed to respond to customer issues during the installation process by understanding the problem, evaluating the root cause, identifying a solution, implementing that solution to the satisfaction of the customer within a reasonable timeframe.

4.3.4.2 Records requirements

Records of root cause, corrective actions, and customer communications shall be maintained as defined in the records system created in 4.1.

4.3.5 Purchasing of system components

4.3.5.1 General

All system components shall be procured to conform to specifications of the design, including assurance that manufacturing was completed to a qualified design. The manufacturer should have an effectively implemented QMS. See, for example, the relevant parts of IEC 61215, IEC 61730, IEC TS 62941 and IEC TS 62915 and how these have been considered during implementation of IEC TS 62738 and IEC 62548.

4.3.5.2 Purchasing process and associated records requirements

The organization shall ensure that purchased system components conform to specified purchase requirements and relevant standards. The type and extent of control applied to the supplier and the purchased system components shall be dependent upon the effect of the purchased system components on system performance.

The organization shall evaluate and select suppliers based on their ability to supply system components in accordance with the stated requirements. Criteria for selection, evaluation, re-evaluation, and possible disqualification shall be established.

Records of the results of supplier evaluations and any necessary actions arising from the evaluation shall be retained.

4.3.5.3 Purchasing information

Purchasing documents shall contain complete and unambiguous information describing the product ordered, including, where appropriate:

- a) the type, class, grade or other unique identification,
- b) the title or other positive identification, and applicable issues of specifications, drawing, process requirements, inspection instructions, relevant standards and other relevant technical data, including requirements for approval or qualification of product, procedures, process equipment and personnel, and
- c) the quality system standard (if applicable) to be applied.

The organization shall review and approve purchasing documents for adequacy of the specified requirements prior to release.

4.3.6 Installation process

4.3.6.1 Control of installation process

4.3.6.1.1 General

The organization shall plan and carry out the installation process under controlled conditions. Controlled conditions shall include, as applicable:

- a) the availability of information that describes the characteristics required,
- b) the availability of work standards, as necessary,
- c) consistency of assembly process, such as the handling of modules during assembly,
- d) the use of suitable facilities, tools, and equipment, including the availability and use of measuring and test equipment, and
- e) the implementation of monitoring and measurement.

4.3.6.1.2 Records requirements

Documented information of reviews of any changes made to the system design or installation process during system installation shall be retained.

This requirement is applicable to any changes in the design including:

- a) components record, including factory test report,
- b) system layout record, including size and location of components,
- c) transportation record, including on the road vibration meter report,
- d) system wiring record, including cable size and route table,
- e) storage record, including periodic temperature and humidity report (where component preservation required),
- f) module clamping record, including tightening torque check,
- g) assembly records such as module handling record, including all stages of transportation and manual handling (see IEC 62759-1).

Additionally, records should be retained to document control of the installation process, including audits, non-conformances, and corrective actions, and as defined by the records system developed in 4.1 and 4.4.

4.3.6.2 Validation of installation processes

The organization shall validate any processes for installation where the resulting output cannot be verified by subsequent monitoring, measurement or test and, as a consequence, deficiencies become apparent only after the system is in use.

NOTE Examples of such processes include welding of structure during installation, crimping of wires, riveting of structures, handling of modules, and torqueing of fasteners.

Validation shall demonstrate the ability of these processes to achieve planned results.

The organization shall establish arrangements for these processes including, as applicable:

- a) defined criteria for review and approval of the processes,
- b) approval of equipment and qualification of personnel,
- c) use of specific methods and procedures,
- d) re-validation,
- e) requirements for records.

4.3.6.3 Component identification and traceability

The organization shall identify the material/component by suitable means throughout installation.

The organization shall identify the material/component status with respect to monitoring and measurement requirements throughout installation.

Where traceability is a requirement, the organization shall control the unique identification of the material/component and retain records.

At a minimum, the organization shall record the component manufacturer and part numbers. For critical components, unique identification number (e.g. serial number) shall also be recorded, and any other required information.

4.3.6.4 Customer property

The organization shall exercise care with customer property (including intellectual property and personal data) while it is under the organization's control or being used by the organization.

The organization shall identify, verify, protect and safeguard customer property.

If any customer property is lost, damaged or otherwise found to be unsuitable for use, the organization shall report this to the customer and retain records.

4.3.6.5 Component handling and storage

The organization shall protect the PV system components during delivery to the intended destination (including qualification of packaging to IEC 62759-1) and during on-site storage in order to maintain conformity to requirements.

Protection shall include identification, handling, packaging, storage and other protection from damage. Protection shall also apply to the constituent parts of a PV system component.

PV system components delivered to the work area shall be so positioned, or protected when necessary, to ensure that the quality of the item will not be de-graded by the construction activity or local environment at installation site.

The cleaning of important materials and equipment for the system that is necessary during receiving, storage, and handling activities shall be in accordance with applicable requirements.

Cleaning compound should not cause any environmental impact and may be subject to local regulations.

4.3.7 Construction tools, supplies and equipment

The use, location, and deployment of construction tools, supplies, and equipment shall be controlled to keep access and work areas clear and to prevent conditions that will adversely affect quality and/or safety of components and/or installation.

Depending on the local situation, it may be necessary to provide sources of power, water, communication, and transportation (including roads that are of high enough quality that traversing them will not cause damage to components). These resources should be put in place in a timely way, typically at the time when the land is prepared to begin installation.

4.3.8 Control of measuring and test equipment

4.3.8.1 General

The organization shall determine the measurement and tests to be undertaken and the measuring and test equipment needed to provide evidence of conformity of installation to determined requirements.

The organization shall establish processes to ensure that measurement and test can be carried out, and in a manner that is consistent with the measurement and test requirements.

4.3.8.2 Calibration

Measuring and test equipment shall be initially calibrated, and then maintained [verified and adjusted (as required)] at prescribed intervals or, prior to use, against certified equipment having known valid relationships to nationally or internationally recognized standards.

Calibration shall cover the intended measurement range.

If no recognized standards exist, the basis for calibration shall be documented.

4.3.8.3 Verification

The method and interval of verification for each item shall be defined, based on the type of equipment required, accuracy, intended use, and other conditions affecting measurement control.

Verification shall be performed when the accuracy of the equipment is suspected at any time within the verification interval, and the frequency reviewed.

4.3.8.4 Non-conformance

When measuring and test equipment is found to be out of calibration (OOC), an evaluation shall be made and documented of the validity of previous inspection or test results and of the acceptability of items previously inspected or tested. OOC devices shall be tagged or segregated and not used until they have been recalibrated. If any measuring or test equipment is consistently found to be out of calibration, it shall be repaired or replaced.

4.3.8.5 Commercial devices

Calibration and control measures may not be required for rulers, tape measures, levels, and other such devices, if normal commercial equipment provides adequate accuracy.

Inspection shall be performed on the condition of such devices at periodic intervals. These devices shall be replaced when they lose their functionality, e.g. the graduations wear out or are damaged.

4.3.8.6 Handling and storage

Measuring and test equipment shall be properly handled and stored to maintain accuracy.

4.3.8.7 Records requirements

Records of the results of calibration, verification, and non-conformance shall be retained and equipment shall be suitably marked to indicate calibration status.

4.4 Monitoring and measurement

4.4.1 Verification of purchased product

The organization shall establish and implement the inspection or other activities necessary for ensuring that purchased components meet specified purchase requirements.

Where the organization or its customer intends to perform verification at the supplier's premises, the organization shall state the intended verification arrangements and method of product release in the purchasing information.

4.4.2 Inspection and monitoring

Inspections required to verify conformance to specified requirements shall be planned and executed per plan. Characteristics to be inspected and inspection methods to be employed shall be specified. Inspection results shall be documented. Inspection for acceptance shall be performed by persons other than those who performed or directly supervised the work being inspected.

Inspection hold points may be required. These are points in the construction process for which it is mandatory to stop work and work shall not proceed without the specific consent of the designated representative. These specific hold points shall be indicated in documents described in 4.3.1 c) and 4.3.6.2. Consent to approve demonstrated or waive specified inspection hold points shall be recorded prior to continuation of work beyond the designated hold point.

Inspection of items in-process or under construction shall be performed for work activities, where necessary to verify conformity.

Where the conformity of the resulting output cannot be readily or economically verified, monitoring of processing methods, equipment, and personnel shall be provided.

In some instances where either inspection or monitoring is inadequate, both inspection and process monitoring should be performed.

Inspections shall be performed to verify that the prerequisites for control of construction processes such as structural bolting, and concrete measuring, mixing, transporting, placing, and curing have been accomplished. These inspections shall include verification of the following:

- a) the process has been qualified as required;

- b) process controls are in effect;
- c) approved procedures, instruction manuals, or both, if required for specific equipment, are available for use during construction;
- d) the process is suitable for the particular application;
- e) personnel, equipment (including measuring and testing equipment), and materials are readily available and adequate to perform the work in accordance with drawing and specification requirements.

Inspection of soils and earthwork shall include preparations for earthwork, as well as in-process inspections of placing and compacting operation, to ensure conformance to applicable requirements.

Controls, where required, shall be established and documented for the coordination and sequencing of these activities at established inspection points, and during successive stages of construction.

4.4.3 Measurement and test

4.4.3.1 General

The organization shall apply suitable methods for measurement and, where applicable, test of the installation processes.

When determining suitable methods, the organization shall consider the type and extent of measurement or test appropriate to each of its processes in relation to their impact on the conformity to installation requirements.

- Calibrated torque wrenches shall be used when tightening clamps and connections that are required by the design to be tightened to a specified torque.

When conformity is not achieved, correction and corrective action shall be taken, as appropriate.

4.4.3.2 Test

Tests required to verify conformance to specified requirements and to demonstrate satisfactory performance for operation shall be planned and executed. Characteristics to be tested and corresponding test methods shall be specified. Test results shall be documented and their conformance with acceptance criteria shall be evaluated.

Tests required to collect data, such as for siting or design input, shall be planned, executed, documented, and evaluated.

4.4.4 Ongoing installation monitoring

In addition to the items above, the organization shall define an ongoing/periodic monitoring program during installation to ensure that critical specifications are met. For example (where applicable), that:

- a) The right PV modules are used per drawing (ratings, cable ratings, orientation).
- b) PV module clips and attachment devices are correct, including torque.
- c) PV module inter row distance is correct.
- d) PV module spacing is correct and flatness of module support structures is within design specification.
- e) Appropriate PV connectors are used to ensure compatible mating and connections are made properly.
- f) Inter module wiring, connectors and DC cables are correct.

- g) Cables are supported at specified distances, not taut and stressed and bend radii are adequate.
- h) If cable tray is used, thermal and corrosion protection provisions are in place.
- i) Cable test certificates are in place.
- j) Electrical connections are torqued appropriately.
- k) Electrical connections made with dissimilar metals are compliant with requirements to minimize corrosion.
- l) Material quality reviews for the foundation and mounting structures are completed.
- m) Caution markers are used near trenches.
- n) Adequate cable protection and cable spacing are used within trenches.
- o) Compaction tests are completed before closing off trenches.
- p) Cable trenches are documented before/after placing of the cables.
- q) Manufacturer test certificates are completed for all cables.
- r) The right module/pallet unpacking techniques are used.
- s) Conduit is properly installed and glued where required, openings are sealed.
- t) Expansion/contraction joints are integrated as required for cable runs.
- u) String scheme is implemented correctly with appropriate labelling.
- v) Labels are done according to Single-Line Diagram (SLD) drawing and local codes.
- w) Grounding installations are complete according to drawings to ensure continuity.
- x) Wiring terminations are done per drawings and equipment manufacturer guidelines.

The monitoring program shall include definition of the information recorded. Completion of monitoring may be indicated as a check mark or “pass”. However, when monitoring involves a measurement, the measured value should be recorded. Where appropriate, photographs should be used as evidence of the monitoring.

Photographs may be the best way to document certain types of monitoring. For example: documenting underground cables or grounding connections that may no longer be visible for inspection after completion of the plant.

4.4.5 Commissioning upon installation completion

The organization shall define a final inspection program that is compliant with IEC 62446-1 and may use IEC 62446-2 and IEC 62446-3.

4.4.6 Internal audit

4.4.6.1 General

The organization shall conduct internal audits at planned intervals to determine whether the processes implemented and their activities:

- a) conform to the planned arrangements and requirements established by the organization and, to the requirements of this document, and
- b) are effectively implemented and maintained.

An audit program shall be planned, taking into consideration the status and importance of the processes and areas to be audited, as well as the results of previous audits. The audit criteria, scope, frequency and methods shall be defined.

The selection of auditors and conduct of audits shall ensure objectivity and impartiality of the audit process. Auditors shall not audit their own work.

The organization shall define the responsibilities and requirements for planning and conducting audits, establishing records and reporting results.

The management responsible for the area being audited shall ensure that any necessary corrections and corrective actions are taken without undue delay to eliminate detected nonconformities and their causes.

4.4.6.2 Records requirements

Documented information shall be retained as evidence of the implementation of the audit program and the audit results.

Audit records shall include audit plans, audit reports, corrective action response, and the record of completion of corrective action including objective evidence.

4.4.7 Control of non-conformances

4.4.7.1 General

The organization shall ensure that system components which do not conform to requirements are identified and controlled to prevent unintended use.

The organization shall ensure that installation activities that do not conform to requirements are identified and quarantined until remediated.

The organization shall define the controls and related responsibilities and authorities for dealing with nonconforming system components and installation activities.

Where applicable, the organization shall deal with nonconforming system components and installation activities by one or more of the following ways:

- a) by taking action to eliminate the detected nonconformity;
- b) by authorizing its use, release or acceptance under concession by a relevant authority (process and designated relevant authority shall be documented) and, where applicable, approved by the customer;
- c) by taking action to preclude its original intended use or application;
- d) by taking action appropriate to the effects, or potential effects, of the nonconformity when nonconforming product is detected after delivery or use has started.

Non-conformances to design requirements dispositioned use-as-is or repair shall be subject to design control measures commensurate with those applied to the original design.

When nonconforming system components and installation activities are corrected they shall be subject to re-verification to demonstrate conformity to the requirements.

4.4.7.2 Records requirements

Documented information describing the nature of nonconformities and any subsequent actions taken, including concessions obtained, shall be retained.

The disposition (such as use-as-is, reject, repair, or rework) of nonconforming items shall be identified and documented.

Technical justification for the acceptability of a nonconforming item (dispositioned repair or use-as-is) shall be documented.

The as-built records and relevant ongoing inspection or maintenance records shall reflect the accepted disposition and ongoing management as a result of the disposition, if appropriate.

4.4.8 Corrective action

4.4.8.1 General

The organization shall take action to eliminate the causes of existing nonconformities in order to prevent recurrence.

Conditions adverse to quality shall be identified promptly and corrected.

In the case of a significant condition adverse to quality, the cause of the condition shall be determined and corrective action taken to preclude recurrence at all impacted installations.

The identification, cause, and corrective action for significant conditions adverse to quality shall be documented and reported to appropriate levels of management; follow-up action shall be taken to verify implementation of this corrective action at all impacted installations.

Corrective actions shall be appropriate to the effects of the nonconformities encountered.

The organization shall define requirements for:

- a) reviewing nonconformities,
- b) determining the causes of nonconformities,
- c) evaluating the need for action to ensure that nonconformities do not recur at all impacted installations,
- d) determining and implementing action needed for all impacted installations,
- e) records of the results of action taken; and
- f) reviewing the effectiveness of the corrective action taken at all impacted installations.

4.4.8.2 Records requirements

The identification, cause, and corrective action for significant conditions adverse to quality shall be documented and reported to appropriate levels of management; including follow-up action to verify implementation of this corrective action.

4.4.9 Preventive action

4.4.9.1 General

The organization shall determine action to eliminate the causes of potential nonconformities in order to prevent occurrence.

Preventive actions shall be appropriate to the effects of the potential problems.

The organization shall define requirements for:

- a) determining potential nonconformities and their causes,
- b) evaluating the need for action to prevent occurrence of nonconformities,
- c) determining and implementing action needed at all impacted installations,
- d) records of results of action taken, and
- e) reviewing the effectiveness of the preventive action taken at all impacted installations.

4.4.9.2 Records requirements

The identification, cause, and corrective action for significant conditions adverse to quality shall be documented and reported to appropriate levels of management; including follow-up action to verify implementation of this corrective action.

4.4.10 Continual improvement

4.4.10.1 General

The organization shall continually improve the effectiveness of the Quality Assurance program through the use of the audit results, analysis of data, corrective and preventive actions. Data collection for input into the continual improvement process shall include proactively collected data as described in 4.3.3 and as described in 4.4.10.3.

4.4.10.2 Records requirements

Documented information should be retained to document any reported failures at previous installations, the root cause analysis that was completed, and the actions that were taken to prevent recurrence of the problem across the fleet.

These records should include collected data and associated analysis for proactively collected data from completed systems as described in 4.3.3 in order to demonstrate that the organization responsible for installation proactively learns from past projects (rather than learning from past projects only when a customer identifies a serious problem) and applies the learning across the fleet.

4.4.10.3 Collection of systems performance data to aid in continual improvement

4.4.10.3.1 General

Toward the purpose of identifying whether the design has been successfully implemented and whether there are opportunities to improve the installation quality, the organization shall compare the predicted (based on historical weather data), expected (based on measured weather data, if available), and measured energy production (see IEC TS 61724-3) for each system installed.

This shall cover at least the installation warranty period and preferably at least the first 5 years of operation (to provide a benchmark for module and system degradation), but preferably should be done for the life of the installation per agreement with the owner/operator.

If complete data for the first 5 years are not available, data should be available for at least 50 % of the time period, or for portfolios with multiple similar projects, preferably for at least 50 % of the projects.

Data shall include at least the annual total energy production; however, more frequent and more detailed measurements are recommended.

4.4.10.3.2 Records requirements

Documented information shall be retained to compare the predicted (based on historical weather data), expected (based on measured weather data, if available), and measured energy production (see IEC TS 61724-3) for each system that has been constructed with the purpose of using the results of this data to improve future systems, as described in 4.3.3.

Records shall be kept in accordance with the organization's policy.

NOTE Such records may be transferred to the succeeding entity claiming ownership of the installation to facilitate long term trending of system performance. The installer may make arrangements with the owners to gather ongoing feedback about system performance even after the transfer for continuous improvement long term.

4.5 System documentation for owner

Documented information (e.g. as-built drawings) needed for long-term maintenance and operation of the system shall be transferred to the owner or the party maintaining the system with clear communication of the importance of these documents being retained in a readily identifiable and retrievable way for the life of the system. Any irregularities or deviations during the construction process should be included in the information package transferred to the owner.

These records include as-built drawings, electrical schematics, component data sheets, any installation and owner's manuals, any available recommended maintenance and emergency procedures, and contact information for the system designer and installer.

5 Requirements for PV system operations and maintenance (O&M)

5.1 Records requirements

5.1.1 Records system

A records system(s) shall be established by the organization responsible for the O&M at the time when the O&M support is initiated and in compliance with the requirements of this document, IEC 62446-2, and any other applicable contractual and regulatory requirements.

A records system(s) shall be established by the organization responsible prior to the start of O&M activities.

Records established to provide evidence of conformity to requirements and of the effective operation of the Quality Assurance program shall be controlled.

The organization shall define the controls needed for the identification, storage, protection, retrieval, retention and disposition of records.

Records shall remain legible, readily identifiable and retrievable.

5.1.2 Generation of records

The applicable O&M procedures, operational procedures, or other documents shall specify the records to be generated, supplied, or retained by or for the owner, using IEC 62446-2 as a guide.

Documented information that is designated to become records shall be accurate, and completed appropriate to the work accomplished.

5.1.3 Record validation

Documented information shall be considered valid records only if stamped, initialled, or signed and dated by authorized personnel or otherwise authenticated, e.g. electronically validated.

5.2 Resource management

5.2.1 Training programs

5.2.1.1 General

The organization shall maintain a training program that includes training identified to be critical to success, including familiarity with relevant sections of the technical documents described in Annex B.

5.2.1.2 Records requirements – training

Documented information of employee training relevant to the relevant O&M activities shall include the type of training and date of completion.

5.2.2 Succession planning

The organization shall plan for succession for key functions that affect customer satisfaction, quality, reliability, safety, and performance, including the O&M personnel.

5.3 PV system operation and maintenance

5.3.1 General

The organization is required to implement the requirements in accordance with this IEC document for the needed planning and development of processes for PV system operation and maintenance.

5.3.2 As-built information

Documented information (e.g. as-built drawings) needed for long-term maintenance and operation of the system shall have been transferred to the owner or the entity maintaining the system with clear communication of the importance of these documents being retained in a readily identifiable and retrievable way for the life of the system.

These records include as-built drawings, electrical schematics, component data sheets, any installation and owner's manuals, any available recommended maintenance and emergency procedures, and contact information for the system designer and installer.

5.3.3 Determination of requirements

The organization shall determine applicable operational guidelines based on component manufacturers' requirements (e.g. cleaning requirements) and from relevant IEC publications and local codes for documenting O&M processes using IEC 62446-2 as a guide.

The O&M processes shall also reflect lessons learned from O&M records and analysis as described in 5.6, and response to customer complaints or other interested parties.

Input data for this process shall be proactively collected including:

- a) Analysis of performance of PV systems relative to the expected performance during the warranty period or longer.
- b) Periodic inspections of the PV systems to identify evidence of problems, as described in IEC 62446-2:–, Clauses 10 and 11. Visual inspections may be supplemented by infrared and luminescent imaging (see IEC 62446-3).

This information may be collected and reviewed by the O&M entity, by the system owner, or by another entity. Regardless of the method of collection of the information, the organization shall include this proactively collected data when determining requirements.

These determined requirements shall be complied with through the establishment of O&M procedures and processes.

5.3.4 Customer communication

A process shall be developed to ensure proactive communication with customers (e.g. the owner) when a problem is identified with a relevant system.

A process shall be developed to respond to customer issues during operation by understanding the problem, evaluating the root cause, identifying a solution, and implementing that solution to the satisfaction of the customer.

5.3.5 Spare and replacement parts

All parts purchased for the purpose of performing maintenance on the system shall conform to specifications of the as-built design.

If replaced parts differ from the original, the replacement parts shall go through qualifications using a reasonable change-management process and approved by the customer prior to being substituted.

All change management program procedures and results shall be retained in the records system including the specifications of the new part that was installed.

5.3.6 Tools, measuring, and test equipment

5.3.6.1 General

The organization shall determine the measurements and tests to be undertaken and the tools, measuring, and test equipment needed to adequately provide O&M services.

Tools, measuring, and test equipment used by the O&M personnel or contractors performing work at the system shall have the appropriate ratings, capabilities, and current certifications to perform the work required safely and accurately.

Personnel using the equipment shall wear appropriate safety gear and be adequately trained and qualified to use the tools, measuring, and test equipment on the system equipment being serviced.

5.3.6.2 Calibration

Measuring and test equipment shall be initially calibrated, and then maintained [verified and adjusted (as required)] at prescribed intervals or, prior to use, against certified equipment having known valid relationships to nationally or internationally recognized standards, including IEC 62446-2, where applicable.

If no recognized standards exist, the basis for calibration shall be documented.

5.3.6.3 Verification

The method and interval of verification for each item shall be defined, based on the type of equipment required, accuracy, intended use, and other conditions affecting measurement control.

Verification shall be performed when the accuracy of the equipment is suspected at any time within the verification interval, and the frequency reviewed.

5.3.6.4 Non-conformance

When measuring and test equipment is found to be out of calibration (OOC), an evaluation shall be made and documented of the validity of previous inspection or test results and of the acceptability of items previously inspected or tested. OOC devices shall be tagged or segregated and not used until they have been recalibrated. If any measuring or test equipment is consistently found to be out of calibration, it shall be repaired or replaced.

5.3.6.5 Commercial devices

Calibration and control measures may not be required for rulers, tape measures, levels, and other such devices, if normal commercial equipment provides adequate accuracy.

Inspection shall be performed on the condition of such devices at periodic intervals. These devices shall be replaced when they lose their functionality, e.g. when the graduations wear out or are damaged.

5.3.6.6 Handling and storage

Measuring and test equipment shall be properly handled and stored to maintain accuracy.

5.3.6.7 Records requirements

Records of the results of calibration and verification shall be maintained and equipment shall be suitably marked to indicate calibration status.

5.3.7 Maintenance planning and tracking

5.3.7.1 General

The organization shall determine the required maintenance (e.g., predictive, preventive, corrective, etc.) to be undertaken and an appropriate system to document and report on such maintenance needed to adequately provide O&M services, using IEC 62446-2 as a guide.

5.3.7.2 Planning and scheduling

The organization shall have an effective method for planning and scheduling the required maintenance to be undertaken and an appropriate system to document and report on such planning and scheduling methods to adequately provide O&M services.

5.3.7.3 Maintenance management system

The system(s) used for maintenance management shall be capable of accurately recording, tracking, and reporting on:

- failures, causes, and corrective actions
- corrective and preventive maintenance required and performed
- parts and material usage and cost
- resource usage and cost
- open and closed work orders
- spare parts inventory
- equipment information
- warranty information and work performed
- vendor and subcontractor information

5.3.7.4 Records requirements

- a) Failure tracking and reporting, including that the identification, cause, and corrective action for significant conditions adverse to quality shall be documented and reported to appropriate levels of management; including follow-up action to verify implementation of this corrective action.
- b) The disposition (such as use-as-is, reject, repair, or rework) of nonconforming items shall be identified and documented. Technical justification for the acceptability of a nonconforming item (dispositioned repair or use-as-is) shall be documented. Non-conformances to design requirements dispositioned use-as-is or repair shall be subject to design control measures commensurate with those applied to the original design. The as-built records, if such records are required, shall reflect the accepted disposition.
- c) Documented information shall be retained of:
 - Reviews of any changes made to the O&M procedures
 - Components record for replacement parts, including factory test report
 - Modifications to the system
 - Storage record for spares, including periodic temperature and humidity report
 - Equipment testing
 - Data collection

5.4 System monitoring

The organization shall have a method of remotely and/or locally monitoring the systems to adequately identify fault or low-performance conditions and provide O&M services.

The system monitoring shall be capable of reporting the status of available points for all critical system equipment including: network communications, protective, metering, safety, and environmental devices in time intervals to adequately provide O&M services, as appropriate for the size of the system.

5.5 Internal audit

5.5.1 General

The organization shall conduct internal audits at planned intervals to determine whether the processes implemented and their activities:

- a) conform to the planned arrangements and requirements established by the organization and, to the requirements of this document, and
- b) are effectively implemented and maintained.

An audit program shall be planned, taking into consideration the status and importance of the processes and areas to be audited, as well as the results of previous audits. The audit criteria, scope, frequency and methods shall be defined.

The selection of auditors and conduct of audits shall ensure objectivity and impartiality of the audit process. Auditors shall not audit their own work.

The organization shall define the responsibilities and requirements for planning and conducting audits, establishing records and reporting results.

The management responsible for the area being audited shall ensure that any necessary corrections and corrective actions are taken without undue delay to eliminate detected nonconformities and their causes.

The audit program may be combined with the continual improvement program described in 5.6.