IEC TS 63265

Edition 1.0 2022-06

TECHNICAL SPECIFICATION

colour inside

Photovoltaic power systems – Reliability practices for operation

IEC TS 63265:2022-06(en)

IEC TS 63265

Edition 1.0 2022-06

TECHNICAL SPECIFICATION

Photovoltaic power systems – Reliability practices for operation

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 27.160 ISBN 978-2-8322-3877-6

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD 3
INTRODUCTION 5
1 Scope 6
2 Normative references 8
3 Terms, definitions and abbreviated terms 9
3.1 Terms and definitions 9
3.2 Abbreviated terms 11
4 Interrelationship of reliability, availability and maintainability 11
4.1 General 11
4.2 Information model 11
4.3 Link to IEC TS 63019 13
4.4 Benefits and justification for a robust reliability program 14
5 Development phase of a PVPS project 14
5.1 General 14
5.2 Initial reliability program plan, design for reliability 14
5.3 Critical items list 16
5.4 Preliminary failure modes and effects and criticality analysis and other fault analyses 17
5.5 High level reliability model 18
6 EPC phase of a PVPS project 21
6.1 General 21
6.2 EPC reliability program plan 21
6.3 Update FMECA, FMEA, FTA, and risk minimization approaches 22
6.4 Detailed reliability model and Monte Carlo modelling 22
6.5 Designed and specified FRACAS 23
6.6 Preliminary O&M plan 24
6.7 PVPS design and specification 24
6.8 Documentation and stakeholder guidance 25
7 O&M phase of a PVPS project 25
7.1 General 25
7.2 O&M plan for reliability 25
7.3 Failure identification 27
7.4 Failure database 30
7.5 Root cause analysis 30
7.6 Repair/replacement database 31
7.7 Pareto sorting and weak links identified 32
7.8 Reliability assessment 32
7.9 Life cycle costs (LCC) of reliability 33
Bibliography 34

Figure 1 – Clipping time decline 14
Figure 2 – Example high level reliability block diagram 20

Table 1 – Information category overview for a PVPS 12
Table 2 – Failure incident data tracking 27
Table 3 – Model report content 29

INTERNATIONAL ELECTROTECHNICAL COMMISSION

PHOTOVOLTAIC POWER SYSTEMS – RELIABILITY PRACTICES FOR OPERATION

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC TS 63265 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems. It is a Technical Specification.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
82/1993/DTS	82/2039/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Key objectives of this document are to inform users of reliability tools and assessment methods (historic, predictive, and analytical) that can satisfy the stakeholders needs for dependable PV Power System (PVPS) operation. Stakeholders will be able to use this information as a common basis for reliability assessments, effective operation and maintenance (O&M) planning and execution, reporting, communication of field data, and reliability metrics. Reliability feedback to stakeholders is an objective to be further defined by the stakeholders themselves as individual stakeholders will have differing needs for data and reporting. This document provides a fundamental process for ensuring reliability needs can be understood and met. IEC TS 63019 addresses availability which is a higher-level metric that combines reliability and maintainability, and it complements this document as a key normative standard. It should be used in combination with this document.

Many of these tools and methods can be used to consider design alternatives or to support design validation during the project phases. The ability to target critical components and discrete O&M actions will have demonstrated value in practice. The characterisation of components lifetimes is derived from real-time capability assessments, and historical records of reliability metrics. Failure estimates used in design will be replaced with recorded data over time. The overall application of reliability practices in this document is intended to be practical and reduce the costs of failures.

Using a design for reliability (DfR) approach, normative requirements are identified for the development, engineering, procurement, and construction (EPC), and (O&M) phases of PVPSs. In this document, they are defined as tasks or work products. The concept of PV plant reliability stretches into many different aspects of planning, modelling, operation, and maintenance. The use of a methodical approach using reliability and system engineering tools to apply reliability practices aid in different ways. By improving understanding of the reliability of critical and key components, informed decisions can be made regarding the trade-offs between higher reliability and system component costs, or increased maintenance with lower initial cost approaches.

Original equipment manufacturers (OEMs) are key reliability stakeholders and will receive stakeholders’ specifications addressing reliability inputs as well as field failure information. Clarity on intended function, definitions of failure, and how to implement reliability practices through the phases of PV system design, component and subsystem specification, operation and analyses are included.

PHOTOVOLTAIC POWER SYSTEMS – RELIABILITY PRACTICES FOR OPERATION

1 Scope

This document outlines methods that can be utilized to ensure reliability throughout the PVPS project phases. It is derived from a management motivation for long lasting and cost-effective energy performance, energy production, secure production and revenue, and safe function. The application of reliability practices in this document is designed to be practical and reduce the costs of unreliability.

The reliability planning documents throughout the phases include purpose, scope, limitations, schedule, reference documentation, tasks, and standards. The work products build on the documentation concurrently with the PVPS concept, design, specifications, studies, procurements, and hiring of services. They are consistent with the project implementation scheduling, including financing, insurance, underwriting, or other decisions, specification, design, operating or maintenance planning and activities.

It is a phased approach, as there are specific needs for actions by the defined phases, decision process and stakeholders involved.

This document further identifies and defines a normative minimum set of processes and tools to meet the requirements of this document. The phases are development, EPC, and O&M. These phases may not be universally applied and different parties in industry may have different nomenclature and organizing principles. It is recognized that some organizations may be vertically organized with multiple capabilities. An owner’s engineer may also have a role. The thrust here is that however organized, the reliability tools, practices, and methods are assigned with needed data collected and preserved for relevant analytics as generally outlined in this document. It includes as a minimum, the identified work products and deliverables in this document identified specifically in Clauses 5, 6, and 7. Integrated reliability products are identified in this document on a task by task progression phased throughout the project. While these tasks are part of the minimum set of actions and deliverables, it is recognized that additional specificity is required. The reliability program plans provide clarification (contractual in many cases) on approaches through the various phases. The plans are approved by the management and/or ownership at the beginning of the phases. The expert practitioners may choose to seek approval for alternate approaches as “approved equals” as the reliability program plans (RPP) are optimized, clarified, and submitted for approvals. It is also acknowledged that commercial software can be a valuable and professional aid in implementation of analyses and tracking data and the plans are where those practices can be identified.

While this document identifies normative requirements for reliability of an operating PVPS, it has functional definitions of the various tasks described above and below as the minimum set. This document performs the role of a functional specification and serves as a structure and an aid to data collection, design, and O&M decisions. It provides parent requirements for a subordinate family of documents that will describe in detail the scope and contractual elements for the design and O&M of the PVPS. The purpose is to drive improvement in the reliability of PVPS project approaches.

Some of these work products and documents are kept up to date through the phases as major decisions may necessitate. A historian system to keep, maintain data and analyses, and reports is kept for ready access of documentation needs.

Reliability metrics cannot be derived without important failure information. Determining the answers to common questions may require the PVPS operation to properly collect the requisite data, such as what equipment or portion of the plant is failing, how long, how often, and how much these failures will cost in repair and lost energy production? Asset management questions include the source of the outage (i.e., Whose clock is it on? Was the outage due to internal or external forces? What power/energy was generated? What was expected?). Effective reliability design integration should reduce overall system costs through reduction and/or mitigation of failures and their consequences. There are initial costs associated with design analyses and reviews, component selection, and analysis of reliability testing. Failure to perform reliability practices in both design/specification and operations/maintenance results in a lower reliability PVPS and resultant costs for field repairs and replacements, and the impact to energy generation.

It is important to address the OEMs' design role in the PVPS design. The scope of this document is primarily focused on the total system from a perspective of the three defined phases. Within the EPC phase falls the design and specification of components. Mitigation of the component reliability risk falls on the builder/OEMs as well as the owner/operators. After the EPC specifications, it is the OEM who designs, builds, and tests the components, considering the physics, environments, chemistry, metallurgy, and other parameters needed for robust operation, including specifications for materials and subcomponents. All aspects are considered as a "systems engineering" process (Incose) and maintaining the supplier/customer interface needs management in the warranty period and beyond in the following operations and maintenance. It is anticipated that some major components may be selected early near the time of financing the project. Failure assessments and reliability design integration of those components are made prior to specification and procurement.

Reliability assessments performed during the development phase help to support common probabilities of performance exceedance where confidence levels are often stated as P50 and P90. These are statistical probability numbers often stated as 50 % or 90 % confidence. For example, the P50 figure is the annual average (statistical) level of generation over a specified interval, usually a year. The P90 figure is the confidence that the annual generation that is predicted to be met or exceeded 90 % of the time, usually over a year.

These estimates are often directed toward the variability of the resource but the health and condition of the PVPS is equally important. The general attention to reliability, probabilities, statistics, and the process of "designing reliability in" is intended to bolster the important metrics of energy production probabilities. The reliability approaches of this document should also help to support the sale of the project and subsequent potential resales.

IEC TR 63292 was written as a precursor to this document and is informative with additional descriptions on the role of individual reliability tools and techniques as well as the benefits of those approaches.

While this document identifies reliability tools, topics, methods, and procedures, there are commercial software products available to perform analyses for the mature discipline of reliability analysis. There is no assessment of those tools or recommendations for one tool over another in this document.

A word of caution. An obvious concern is that a defined reliability system appears imposing at first sight. It is not the intention that the effort to have a greater cost than its benefits. The resultant specifications and design fit the business/financial needs of the project. The cost of ensuring reliability is weighed against the costs of not ensuring reliability at achievable levels over the life of the system.

It is not within the scope of this document to determine the method of information acquisition. IEC 61724-1 has pertinent requirements and IEC TS 61724-3:2016,6.2.5 specifically identifies measured data. These standards differ on approach for different levels of system nature and size, and it is recognized that applicability is most apparent for utility scale systems. However, the reliability aspects have like applicability for systems of any size and are recommended for appropriate use. The failures and impacts will be similar.

The types of data and data collection systems are assessed for what is key and what is not while addressing the initial and future data requirements. The Pareto techniques later described allow insights to be gained on the vital few as per an 80/20 rule, where 80 % of the problems typically arise from 20 % of the components. Key data are collected for sorting by Pareto principles, and this document provides references to other documents that address data requirements.

Formulas in the referenced standards provide normative guidance for standardization. Examples and guiding principles for developing methods for calculation and estimation of reliability metrics, are subject to the knowledge and coordination for use by the involved stakeholders. Reliability aspects are critical, and the ownership and management of the projects define exactly the scope of what is to be done contractually and by whom.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes recommendations 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 60300-1:2014, *Dependability management – Part 1: Guidance for management and application*

IEC 60300-3-3, *Dependability management – Part 3-3: Application guide – Life cycle costing*

IEC 60812, *Failure modes and effects analysis (FMEA and FMECA)*

IEC 61078, *Reliability block diagrams*

IEC 61649:2008, *Weibull analysis*

IEC 61703, *Mathematical expressions for reliability, availability, maintainability, and maintenance support terms*

IEC 61724-1:2021, *Photovoltaic system performance – Part 1: Monitoring*

IEC TS 61724-3:2016, *Photovoltaic system performance – Part 3: Energy evaluation method*

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

IEC 62740, *Root cause analysis (RCA)*

IEC TS 63019:2019, *Photovoltaic power systems (PVPS) – Information model for availability*

IEC TR 63292, *Photovoltaic power systems (PVPSs) – Roadmap for robust reliability*

ISO/IEC Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995) – Supplement 1: Propagation of distributions using a Monte Carlo method*

IEEE 762-2006*: IEEE Standard Definitions for Use in Reporting Electric Generating Unit Reliability, Availability, and Productivity*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in 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

3.1.1
availability
ability of an item to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided

3.1.2
available state
where the PVPS, a subsystem, or a component is capable of providing service, regardless of whether it is actually in service and regardless of the capacity level that can be provided

3.1.3
confidence level
probability that the value of a parameter falls within a specified range of values

3.1.4
dependability
measure of the degree to which an item is operable and capable of performing its required function at any (random) time during a specified mission profile, given that the item is available at mission start

3.1.5
derating
using an item in such a way that applied stresses are below rated values or lowering of the rating of an item in one stress field to allow an increase in another stress field

3.1.6
failure
event or inoperable condition in which a PVPS, a subsystem, or a component did not, or could not, perform as intended when required

3.1.7
forced outage
damage, fault, failure or alarm that has disabled a system or component

3.1.8
failure reporting and corrective action system
FRACAS
closed loop experience process used to improve dependability of current and future designs by feedback of testing, modification, and use

3.1.9
incident
event or inoperable condition in which a PVPS, a subsystem, or a component did not, or could not, perform as intended, or was prevented from operation due to external constraints

3.1.10
lowest level of repair
lowest level of item (component, assembly, module, card, box, or subsystem) that is repaired or replaced as the result of failure of the end item

3.1.11
maintenance action
element of a maintenance event. One or more tasks (i.e., fault localization, fault isolation, servicing, and inspection) necessary to retain an item in or restore it to an operable condition

3.1.12
mean time between failure
MTBF
statistically based parameter (usually expressed in hours) that allows comparisons to be made between the reliability of different products

3.1.13
mean time to failure
MTTF
basic measure of reliability for non-repairable items. The total number of life units of an item population divided by the number of failures within that population, during a particular measurement interval under stated conditions

3.1.14
mean time to repair
MTTR
basic measure of maintainability assuming that all parts, equipment and personnel are immediately available

3.1.15
reliability
probability that an item (component, assembly, or system) can perform its intended function for a specified period of time under stated conditions per IEC TS 63019 as modified from IEEE 762

3.1.16
repair
to restore equipment damaged, faulty or worn to a serviceable condition

3.1.17
repowering
planned event in the service life of a plant wherein the plant is repopulated with the latest generation of PV modules/panels, new inverters, other power components, or mechanical items to increase energy production to original or greater levels

3.1.18
service life
time that any manufactured item can be expected to be economically serviceable or supported by its manufacturer

3.1.19
scheduled maintenance
planned repair or replacement of items before expected failure based on strong historical evidence. Includes predictive maintenance which is performance of maintenance before a known failure mechanism or mode can occur by periodic inspection, test or measurement

3.1.20
systems engineering
transdisciplinary and integrative approach to enable the successful realization, use, and retirement of engineered systems, using total systems principles and concepts, and scientific, technological, and management methods

3.1.21
unavailability
operational state when the equipment is not capable of operation because of operational or equipment failures, external restrictions, testing, work being performed, or some adverse condition

3.2 Abbreviated terms

DfR	Design for Reliability
EPC	Engineering, Procurement, Construction
FMECA	Failure Modes Effects and Criticality Analysis [sometimes referred to as Failure Modes and Effects Analysis (FMEA) in common or partial usage]
FRACAS	Failure Reporting and Corrective Action System
IEEE	Institute of Electrical and Electronics Engineers
FTA	Fault Tree Analysis
LLC	Life Cycle Cost
McT	Mean Corrective Time
MTBF	Mean Time Between Failure (repairable item)
MTTF	Mean Time to Failure (replaceable item)
MTTR	Mean Time to Repair
O&M	Operations and Maintenance
OEM	Original Equipment Manufacturer
RAM	Reliability, Availability, Maintainability
RBD	Reliability Block Diagram
RCA	Root Cause Analysis
RPP	Reliability Program Plan

4 Interrelationship of reliability, availability and maintainability

4.1 General

The discipline of reliability analysis is mature and often uses the acronym RAM derived from the combination of reliability, availability, and maintainability. The RAM attributes can be assessed using commercial tools and standard methodologies that provide for the assessment and understanding of the current and future state of the PVPS. In addition, this data provides a means to make improvements in the current plant and provide the basis for improved specification for future plants. Availability is a higher-level metric and a mathematical function of both reliability and maintainability.

4.2 Information model

Availability, as shown in IEC TS 63019:2019, Table 1 is an important aspect of PVPS. As indicated by the definitions of availability and available state in that document, there are multiple reasons for availability loss. IEC TS 63019 has identified and information model to map these causes. Energy availability alone, as viewed as performance, does not allow one to determine or assess the status of the system with respect to underlying equipment failures, maintenance, and trends. To determine the state of the plant as a design metric and or during operation