BS EN IEC 60300-3-10:2025

BSI Standards Publication

Dependability management

Part 3-10: Application guide — Maintainability and maintenance

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee DS/1, Dependability.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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EUROPEAN STANDARD

NORME EUROPÉENNE

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EN IEC 60300-3-10

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English Version

Dependability management - Part 3-10: Application guide - Maintainability and maintenance (IEC 60300-3-10:2025)

Gestion de la sûreté de fonctionnement - Partie 3-10: Guide d'application - Maintenabilité et maintenance (IEC 60300-3-10:2025)

Zuverlässigkeitsmanagement - Teil 3-10: Anwendungsleitfaden - Instandhaltbarkeit und Unterstützbarkeit (IEC 60300-3-10:2025)

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European foreword

The text of document 56/2059/FDIS, future edition 2 of IEC 60300-3-10, prepared by TC 56 "Dependability" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 60300-3-10:2025.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2026-09-30
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2028-09-30

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In the official version, for Bibliography, the following notes have to be added for the standard indicated:

IEC 60300-1	NOTE	Approved as EN IEC 60300-1
IEC 60300-3-2	NOTE	Approved as EN 60300-3-2
IEC 60300-3-3	NOTE	Approved as EN 60300-3-3
IEC 60300-3-4	NOTE	Approved as EN IEC 60300-3-4
IEC 60300-3-11	NOTE	Approved as EN 60300-3-11
IEC 60300-3-12	NOTE	Approved as EN 60300-3-12
IEC 60300-3-14	NOTE	Approved as EN IEC 60300-3-14
IEC 60300-3-16	NOTE	Approved as EN 60300-3-16
IEC 60706-5	NOTE	Approved as EN 60706-5
IEC 60812	NOTE	Approved as EN IEC 60812
IEC 61025	NOTE	Approved as EN 61025
IEC 61078	NOTE	Approved as EN 61078
IEC 61165	NOTE	Approved as EN 61165
IEC 61709	NOTE	Approved as EN 61709
IEC 62402	NOTE	Approved as EN IEC 62402
IEC 62508	NOTE	Approved as EN 62508
IEC 62740	NOTE	Approved as EN 62740
IEC 62741	NOTE	Approved as EN 62741
IEC 62960	NOTE	Approved as EN IEC 62960
ISO 9000	NOTE	Approved as EN ISO 9000

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Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cencenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 60050-192	-	International electrotechnical vocabulary - Part 192: Dependability	-	-

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IEC 60300-3-10 has been prepared by IEC technical committee 56: Dependability. It is an International Standard.

This second edition cancels and replaces the first edition published in 2001. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) more guidance is included on establishing a maintenance programme;
b) some guidance on support and supportability has been removed and has been moved to IEC 60300-3-14.

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The text of this International Standard is based on the following documents:

Draft	Report on voting
56/2059/FDIS	56/2097/RVD

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 International Standard 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.

A list of all parts in the IEC 60300 series, published under the general title *Dependability management*, can be found on the IEC website.

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, or
- revised.

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INTRODUCTION

This document provides guidance on how to identify and apply appropriate analysis and assurance techniques for maintainability and maintenance.

Maintainability relates to the ease and speed with which an item can be retained in, or restored to, a state to perform as required. Maintainability relates to the time and resources to undertake maintenance in a defined context.

For software, maintainability is the ease with which the software can be modified without major reverse engineering or redesign to address faults and changing needs. The purpose of software maintenance is to retain the functionality of software over time.

Maintenance actions are those necessary to retain or restore an item to a state to perform as required. The relative ease and economy of maintenance actions relates to the total impact resulting from the actions' frequency, timing, and duration. The impact can include economic, availability and performance impacts.

An important part of the cost of an item over its life is the total resources spent on the tasks necessary to maintain it in a satisfactory condition. This is influenced by the number of required tasks, their complexity, and duration. An item that can be maintained easily and is supported by a competent and efficient maintenance organization generally has a greater availability and a reduced life cycle cost compared to one that does not have these attributes.

This document provides managers and technical professionals involved in specification, design, development, manufacture, acceptance and use of products and services with guidance on how to achieve, analyse and ensure maintainability and maintenance effectiveness.

Guidance in this document can be used at any time during the life cycle of an item or project for the planning and implementation of a maintainability or maintenance programme.

The activities described within this document can form part of an organization's asset management or quality management strategy and can therefore be aligned to, and consistent with, the organizational objectives.

The maintainability and maintenance programme content described in this document can be tailored to suit the needs of the application. Maintainability and maintenance programmes can be conducted independently or as one integrated programme.

This document is one of the 'top level' interrelated dependability standards that provides managers and technical personnel with guidance on how to effectively plan and implement dependability activities. Other documents in the suite are:

– IEC 60300-1 which highlights the importance and benefits of managing dependability. It gives guidance on dependability activities and how to integrate them into an existing management system and life cycle processes;
– IEC 60300-3-4 which provides guidance for writing dependability requirements in specifications together with a means of assuring the achievement of those requirements;
– IEC 60300-3-14 which provides guidance on how to identify and apply appropriate analysis and assurance techniques for supportability (and support);
– Standards to cover reliability and availability, which are planned.

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1 Scope

This part of IEC 60300 gives guidance to managers and technical and financial personnel on the basic principles of maintainability and maintenance activities that are applicable to any organization.

This document describes:

– the value and nature of maintainability and maintenance characteristics;
– the interfaces between maintainability and related dependability attributes of reliability, availability and supportability, as well as potential trade-offs that can be made through the interfaces during the life cycle of an item;
– the elements of maintainability and maintenance programmes;
– the application of maintainability and maintenance programmes throughout the life cycle;
– techniques to ensure maintainability and maintenance requirements are met;
– maintainability and maintenance data and information management.

This document is applicable to equipment, software, services, or structures, and gives guidance on matters of common interest to any business supplying, purchasing or sustaining products, services, or structures.

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 60050-192, *International Electrotechnical Vocabulary (IEV) - Part 192: Dependability*, available at https://www.electropedia.org/

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-192 and the following apply.

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

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

3.1.1
item
subject being considered

Note 1 to entry: The item can be an individual part, component, device, functional unit, equipment, subsystem, system, service or process.

Note 2 to entry: The item can consist of hardware, software, people or any combination thereof.

Note 3 to entry: The item is often comprised of elements that can each be individually considered.

[SOURCE: IEC 60050-192:2024, 192-01-01]

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3.1.2
off-the-shelf
OTS
item commercially available for purchase and use without the need to conduct development activities

Note 1 to entry: OTS is sometimes referred to as COTS (commercial off-the-shelf) or MOTS (modified off-the-shelf).

3.1.3
indenture level
level of sub-division within a system hierarchy

EXAMPLE System, subsystem, assembly and component.

Note 1 to entry: From the maintenance perspective, the indenture level depends upon various factors, including the complexity of the item's construction, the accessibility of sub-items, skill level of maintenance personnel, test equipment facilities, and safety considerations.

[SOURCE: IEC 60050-192:2015, 192-01-05]

3.1.4
maintenance
combination of all technical and management actions intended to retain an item in, or restore it to, a state in which it can perform as required

Note 1 to entry: Management is assumed to include supervision activities.

[SOURCE: IEC 60050-192:2015, 192-06-01]

3.1.5
maintainability
ability to be retained in, or restored to, a state to perform as required, under given conditions

Note 1 to entry: Conditions of use and maintenance impact maintainability. These include conditions such as: location for maintenance, accessibility, maintenance procedures and maintenance resources.

Note 2 to entry: Maintainability can be quantified using appropriate measures.

[SOURCE: IEC 60050-192:2024, 192-01-27, modified – Note 1 to entry has been replaced]

3.1.6
maintenance support
provision of resources to maintain an item

Note 1 to entry: Resources include human resources, support equipment, materials and spare parts, maintenance facilities, documentation and information, and maintenance information systems.

[SOURCE: IEC 60050-192:2015, 192-01-28]

3.1.7
line of maintenance
position in an organization where specified levels of maintenance are to be carried out

EXAMPLE 1st line – field; 2nd line – repair shop; 3rd line – manufacturer's facility.

Note 1 to entry: The line of maintenance is characterized by the level of skill of the personnel, the facilities provided, the location, etc.

[SOURCE: IEC 60050-192:2015, 192-06-03]

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3.1.8
maintenance concept
definition of the maintenance objectives, line of maintenance, indenture levels, maintenance levels, maintenance support, and their interrelationships

Note 1 to entry: The maintenance concept of an item provides the basis for maintenance planning, determining supportability requirements, and developing logistic support.

[SOURCE: IEC 60050-192:2015, 192-06-02, modified – The first preferred term “maintenance policy” has been omitted and in Note 1 to entry, it has been replaced with “maintenance concept”.]

3.1.9
maintenance policy
maintenance philosophy
intentions and direction of an organization as formally expressed by its top management (as related to maintenance)

[SOURCE: ISO 55000:2024, 3.3.6, modified – In the first preferred term "maintenance" has been added, the second preferred term "maintenance philosophy" has been added and in the definition "(as related to maintenance)" has been added.]

3.1.10
testability
degree to which an item can be tested

[SOURCE: IEC 60050-192:2015, 192-09-20, modified – The domain "<of an item>" has been deleted.]

3.2 Abbreviated terms

BIT	built-in test
BITE	built-in test equipment
OTS	off-the-shelf
FMEA	failure modes and effects analysis
FMECA	failure modes, effects and criticality analysis
ILS	integrated logistic support
ILSP	integrated logistic support plan
IPS	integrated project support
LCC	life cycle cost
LORA	level of repair analysis
LRU	line replaceable unit
MLDT	mean logistic delay time
MTTM	mean time to maintain (preventive tasks)
MTTR	mean time to restoration (or repair or recovery)
OEM	original equipment manufacturer
RAM	random access memory
RCM	reliability centred maintenance
ROM	read-only memory

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4 Maintainability and maintenance overview

4.1 Description of maintainability

Maintainability relates to the ease and speed with which an item can be retained in, or restored to, a state to perform as required. It is a characteristic of the item design, construction, installation, and commissioning. Maintainability is designed into an item for defined user requirements, including the use environment. Improved maintainability can reduce life cycle cost and support preservation of the item's inherent reliability.

Maintainability can be measured as the probability that a given maintenance action, performed under stated conditions, using specified procedures and with defined support, can be completed within a specific time period. This defined support can include personnel with defined competencies, spares, tools, information, facilities, and logistics applied within a defined organizational context.

Software differs from hardware in that it does not wear out and faults originate in the specification, design logic or coding process and they can lie hidden until specific input conditions occur. For software, maintainability relates to the ease and speed with which software can be modified to change or add capabilities, to correct faults, improve performance or other attributes, or to adapt it to a different environment. From a system perspective, the time to restore a system following a software crash can be an important parameter as this has an immediate impact on operations and user experience.

4.2 Description of maintenance

Maintenance is described as the combination of all technical and administrative actions, including supervisory actions, intended to retain an item in, or restore it to, a state in which it can perform as required when required. Maintenance covers preventive and corrective maintenance. Preventive maintenance is the maintenance carried out to mitigate degradation and reduce the probability of failure and corrective maintenance is the maintenance carried out after fault detection to effect restoration.

It is necessary to identify the maintenance tasks that are required to achieve the desired availability of an item before the maintainability can be fully defined. It is not feasible or cost-effective to maintain some items. Some equipment is designed to run to failure because maintenance is ineffective in reducing the probability of failure modes or the maintenance costs are not justified by the cost of failure.

Maintenance does not include maintenance support. Maintenance is the action required to maintain, whereas maintenance support is all the resources required to maintain the item (see IEC 60300-3-14).

Clause 6 to Clause 8 detail the specifications and the programmes for maintenance.

4.3 Principles

Evaluation and control of maintainability and maintenance is founded on a set of principles. These principles should directly influence the intent of, design for, and delivery of an organization's maintenance activity.

These principles are as follows:

1) Maintenance exists to provide value.

   Maintenance tasks, and the associated maintainability characteristics of an item, exist to provide value to stakeholders. Value is what is important to the business, reflected in organizational objectives. Value can be tangible, such as increased volume of product, or intangible, such as improved consumer confidence. It can be financial, such as reduced cost to repair an item, or non-financial, such as improved safety.

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2) Maintainability and maintenance tasks are inherent to a design solution.

   Maintainability is an inherent characteristic of a design solution. This means that it is a permanent attribute of that design which cannot be improved without a change to the design solution, the operating environment or both. Maintainability levels and maintenance tasks are inextricably linked such that maintenance tasks become a consequence of the design solution.

3) Maintainability can be balanced against other dependability attributes and stakeholder requirements to achieve organizational objectives.

   Maintainability, reliability, and supportability can be balanced and traded-off to achieve availability, a measure commonly aligned with business success. Dependability attributes can also be balanced and traded-off with other organizational considerations such as cost and assurance level required.

4) Maintainability and maintenance activities continue in-service to continuously improve and ensure that the item continues to meet stakeholder requirements.

   During the in-service phase of the item, the environment, stakeholder requirements and other factors can change and, thus, the continued evaluation of the achievement of maintainability and maintenance effectiveness is necessary.

When applying these principles to develop a maintainability or maintenance programme, activities should be tailored considering market conditions, item complexity and stakeholder definition and requirements together with the size and experience of the organization.

4.4 Benefits

Benefits of controlling maintainability and maintenance include:

– establishing an appropriate and cost-effective maintenance schedule;
– providing justified confidence that the dependability of items will be as required, when required;
– understanding and managing the risks of failure or degraded performance in an effective way to achieve a balance of cost, risk, and performance;
– enabling maintainability design weaknesses to be identified and improved with consideration for performance, risk and life cycle cost;
– providing information and data that enable continual improvement;
– preserving inherent levels of reliability and safety designed into the item;
– reducing item down time resulting in improved availability;
– reducing maintenance effort and related support resources resulting in reduced life cycle cost;
– improving timeliness of maintenance delivery;
– improving quality of maintenance resulting in higher realized levels of reliability;
– improving safety of maintenance personnel through improved access and ergonomics;
– improving sustainability by preserving the inherent characteristics of the item and increasing the life and possibility of re-use.

4.5 Interfaces

4.5.1 General

Dependability is the ability to perform as and when required. Dependability has many attributes but is usually characterized in terms of reliability, maintainability, supportability, and the resulting availability. In some cases, other characteristics such as durability and integrity are also included under the umbrella of dependability. Managing maintainability can improve dependability by reducing downtime and the level of resources necessary to ensure the item can perform as required, when required.

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4.5.2 Effect of maintainability and maintenance on reliability

Reliability is the ability of an item to provide a required function, without failure, for a given interval (e.g. time, operating cycles, distance, etc.).

The maintainability of an item does not affect its inherent reliability. In practice, the ease and speed of maintenance of an item has no effect on its reliability. In practice however, it can affect the quality of maintenance, and, in turn, poor quality of maintenance can reduce reliability below its inherent value. For example, a difficult-to-perform maintenance task with an unrealistic maintainability target can force hasty maintenance which can reduce reliability.

It is possible that additional maintenance can improve reliability. However, this can increase maintenance time thus changing the optimal balance of maintenance downtime and availability intended by the original design.

Where maintainers identify potential improvements in the design of the item or in the maintenance process, this should be fed back to developers so improvements can be made to the design to increase the reliability.

For software, maintenance includes the evolution of the software program and, therefore, maintenance can result in the improvement or degradation of both the item's inherent reliability and maintainability. This can affect the ongoing maintenance needs. If the item is highly maintainable, the probability of inducing faults through the software evolution is minimized, resulting in software which meets the reliability requirements with a reduced ongoing need for further evolution.

4.5.3 Effect of maintainability and maintenance on supportability and support

Support is the integrated set of resources, such as personnel, spares, information, training, tools, test equipment, facilities, communication systems, and transport logistics that are necessary for the item to perform as required, when required. Support includes those resources specific to maintenance but is not limited to them. Supportability is the ability to sustain the required operational capability with a defined use profile and given logistic and maintenance resources.

Improved maintainability can improve supportability by:

– reducing the number of personnel and associated competencies required to maintain the item due to decreased complexity of preventive actions, fault finding and repair processes;
– minimizing the sparing, transport logistics, supply management and information requirements, for example by arranging commonality in components and tooling;
– optimizing the requirements for the facilities, their locations and associated supporting elements by simplifying the maintenance requirements. For example, designing modular systems can allow items to be easily and effectively replaced on site, with failed modules transported to a central facility for repair.

These elements can affect the timeliness and cost of maintenance support.

Timeliness of maintenance support delivery refers to the time delay between the identification of the requirement for support and the completion of all preparatory activity necessary before conduct of the maintenance task. For unplanned repair tasks this period can include:

– notification of task;
– permit to work;
– assembly of material, spares, tools, and task information;
– travel to site;
– unloading and transport to work position of any required support equipment.

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Cost of maintenance support delivery refers to the cost-effectiveness of all actions required for maintenance support. Excessive cost of ownership can result in future costs of maintenance being unaffordable and, hence, threaten achievement of inherent characteristics of reliability and maintainability, as well as the intended useful life.

4.5.4 Effect of maintainability and maintenance on availability

Availability is the ability to be in a state to perform when called upon to do so. It is often quantified as a ratio of up time to total time. It is a key performance metric that reflects the readiness and operational efficiency of an item over time.

Maintainability directly influences availability by determining how quickly and effectively maintenance tasks can be performed. High maintainability means that maintenance tasks are easier, quicker, and require fewer resources, which minimizes downtime and enhances the overall availability of the item. Conversely, poor maintainability can lead to prolonged maintenance activities, increased downtime, and reduced availability.

Maintenance practices also impact availability. Efficient and well-planned preventive maintenance can prevent unexpected failures and retain the item in a state of readiness. Inefficient maintenance practices, such as delayed or inadequate corrective maintenance, can extend downtime and adversely impact availability.

Feedback from maintainers regarding potential improvements in maintenance processes or design can support continuous improvement of maintenance, reducing downtime and increasing availability.

4.5.5 Effect of maintainability and maintenance on life cycle cost

Life cycle cost is the total cost associated with all stages of the item's life. It encompasses initial acquisition costs, operating costs, maintenance costs and end-of-life disposal costs.

Maintainability affects life cycle costs by influencing the frequency, duration, and complexity of maintenance activities. High maintainability can lead to reduced maintenance time, lower labor costs, and minimized need for specialized tools and spares. This lowers the overall maintenance cost and contributes to reduced life cycle cost.

Effective maintenance practices impact life cycle cost through mitigating the risk of costly unplanned failures and extending the operational life of the item. Poor maintenance practices can lead to frequent failures, higher repair costs, and potentially premature replacement, increasing life cycle cost.

Feedback from maintenance can lead to design improvements that enhance reliability and maintainability, resulting in lower maintenance requirements and costs over the item's life cycle.

5 Manager responsibility

5.1 Overview

Managers are responsible for the coordination and organization of activities to ensure the desired outcomes of maintainability and maintenance programmes are achieved. Responsibilities and authorities should be assigned so that the programmes can be implemented effectively and efficiently. Manager responsibilities include:

– establishing a maintenance policy;
– articulating the organization's risk appetite (or attitude towards risk) in reference to the maintainability and maintenance programmes – this will influence the level of effort applied;
– assigning responsibility for maintainability or maintenance to a competent person(s);

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– providing adequate resources, including analysis tools, to undertake the programme;
– maintaining sound communication with internal and external stakeholders through enabling feedback between maintainers and designers and maintaining good relationships with suppliers, contractors, and customers;
– integrating the programmes into overall product development, production, utilization and improvement;
– establishing controls with programme suppliers.

It is the responsibility of managers to ensure that system maintainability and maintenance characteristics are balanced with other measures of system effectiveness and constraints such as cost and risk. Managers should ensure that criteria for trade-offs are in line with organizational objectives.

For some items, this responsibility begins and remains with the original designer or manufacturer generally titled as “designated design authority”. For others, the designer or manufacturer has initial responsibility for identifying likely support needs but the end user or operator takes final responsibility for completing the planning process and implementing the results.

5.2 Maintenance policy

The organization responsible for maintenance and its associated support should establish a maintenance policy. The maintenance policy details the organization’s commitments and expectations for decisions, activities, and behaviours concerning maintenance management. It should be aligned to, and demonstrate support for, the organizational objectives and should articulate the principles by which the organization is going to define and manage maintenance to achieve those organizational objectives.

The maintenance policy guides the planning, execution, assessment, analysis and improvement of maintenance and maintenance support. Consequently, the maintenance policy also informs the required maintainability characteristics and the subsequent design effort.

NOTE An organizational objective to balance expenditure can result in a maintenance policy statement requiring quantitative risk-based approaches to maintenance planning.

The maintenance policy can include guiding principles for maintenance activity, such as:

– provision of service delivery targets to guide maintenance practices and decisions;
– long-term goals, sustainable outcomes and stakeholder requirements;
– applicable laws, legislation, and regulations;
– prioritisation of maintenance strategies and approval of approaches to determine maintenance strategies for different equipment;
– provision of resources to ensure achievement of maintenance objectives;
– decision making criteria used to define maintenance schedules and to plan and execute their implementation, for example, the tools required to be used to determine the maintenance tasks and their periodicities;
– reporting on item performance and associated maintenance activities;
– general repair policies and constraints such as those approved by engineering and design authorities;
– context in which maintenance is required, for example during shutdown periods;
– continual improvement of the maintenance system and its plans

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6 Specifying for maintainability and maintenance

6.1 Defining requirements

The maintainability requirements within an item's dependability specification provide the basis of understanding between the asset owner, supplier and other key stakeholders involved with the product's design and use. Maintainability requirements should be clearly defined in qualitative and quantitative terms to allow for proper planning and implementation of design.

The development of a specification should be conducted in accordance with IEC 60300-3-4 and the quantitative and qualitative measures designated to represent the maintainability and testability (i.e. the ability to detect, analyze and isolate faults) requirements should be decided (see 6.3). The methods for verifying that the requirements have been satisfied should be stated, as should the existence of any constraints that can affect the maintainability characteristics of the item.

Maintainability requirements are determined through analysis of stakeholder needs and include consideration of:

– expected operating time (or cycles) per unit of calendar time;
– maximum downtime or required availability;
– operational environment and mission profile;
– skill types and skill levels of maintenance personnel;
– types of diagnostics to aid detectability of faults;
– existing maintenance support equipment, plant, and facilities available to support the product.

For complex systems, once quantitative system requirements have been determined, they are allocated or apportioned to lower levels. This allocation ensures a balanced target for each developmental item and provides design or procurement targets. The allocation should be based on the relative complexity of the units involved (see 7.3.2).

There is a progressive link between requirement, specification, and contract.

– The requirement is the initial statement of performance characteristics which can be assured. It can be produced by an asset owner, to which a potential supplier can submit a bid. It can also be put out from within a supplier organization as a result of market research on a future product.
– The specification is the collation of the requirements for an item. The specification includes the context, such as expected demand and operating environment, as this can affect the dependability performance, and maintainability and maintenance requirements.
– The specification can be used as the basis of a contract, which will include how the requirements are to be assured.

The actual use of an item can deviate from the envisaged use and environment. In this case, it is necessary for the user to modify the maintainability specifications and procedures to cover the changed use circumstances. For example, if a product designed for use in an easily accessible building is used instead on top of a wind turbine at sea.

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6.2 Characteristics of maintainable items

Maintainability characteristics are an inherent characteristic of design and operating environment. The greatest opportunity to influence maintainability is where decisions and modifications only affect a ‘theoretical’ item and no materials have been committed, such as the concept or design stages of the life cycle. Activities at this stage therefore offer the ability to identify and analyze trade-off opportunities with the other dependability attributes and stakeholder goals. While maintainability characteristics are generally determined during design, characteristics such as accessibility can be influenced by the installation or configuration as determined by the user

A high level of maintainability can be achieved by:

– designing the item such that maintenance is performed without interrupting operation, resulting in reduced financial impact of conducting maintenance;
– providing redundancy to allow for a specified period of maintenance, which can be conducted on one of the redundant components without shutting down the entire system. This is important when the impact of interrupted operation is more significant than the cost of designing in redundant components;
– standardizing components, restoration and repair processes, and special tools and equipment which support streamlined maintenance conduct;
– modularization of discrete components such that they can be changed with minimal effect on other components;
– the ability to detect, analyse and isolate faults;
– increasing accessibility to reduce time to conduct the maintenance, as well as minimize the probability of inadvertent impact on surrounding items;
– an adequate level of labelling (e.g. for cables and hoses) to expedite correct identification of components;
– increasing modifiability, where items can be efficiently and effectively modified without introducing defects;
– refining test and fault criteria and increasing effectiveness of testing for the criteria so as to reveal the underlying failure mechanism.

How maintainability is addressed is dependent on the context. Item designers and manufacturers are generally responsible for the maintainability characteristics however the item can be:

– OTS, where the manufacturer has no knowledge of the final application and interfaces;
– a bespoke design for a known application allowing for specific design characteristics to support the user;
– a combination, using OTS items with inherent maintainability characteristics in a design for a known application.

Testability is the degree to which an item can be tested and is a primary contributor to maintainability characteristics. Ensuring that an item is testable requires adherence to some basic testability design principles (IEC 60706-5). A brief description of the most common testability design principles are below.

a) Physical and functional partitioning. The ease or difficulty of fault isolation depends to a large extent upon the size and complexity of the units that are replaceable. Partitioning the design such that components are grouped by function (i.e. each function is implemented on a single replaceable unit), or by technology (e.g. analogue, digital) whenever possible enhances the ability to isolate failures (hardware and software).
b) Electrical partitioning. Whenever possible, a block of circuitry being tested should be isolated from circuitry not being tested via blocking gates, tristate devices, relays, etc. (hardware).

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c) Initialization. The design should allow an item to be initialized to a known state so it will respond in a consistent manner for multiple testing of a given failure (hardware and software).

d) Controllability. The design should allow external control of internal component operation for the purpose of fault detection and isolation. Special attention should be given to independent control of clock signals, the ability to control and break up feedback loops, and tri-stating components for isolation (hardware and software).

e) Observability. Sufficient access to witness points (see IEC 61850-10:2012, 3.16), test points, resource use, error conditions, outputs, data paths and internal circuitry should be provided to allow the test system (machine or human) to gather sufficient signature data for fault detection and isolation (hardware and software).

f) Accessibility. Critical items should be accessible for testing, with physical and hazardous obstacles being easily removable.

g) Test system compatibility. Each item to be tested should be designed to be electrically and mechanically compatible with selected or available test equipment to eliminate or reduce the need for a large number of interface device designs (hardware).

6.3 Measures of maintainability

6.3.1 Overview

Maintainability measures should be chosen appropriate to the operating environment and organisational requirements. Quantitative and qualitative measures enable maintainability requirements to be specified unambiguously and provide a measure of programme success.

The measures that are used will affect what activities are undertaken in the programme and how they are performed.

Maintainability is related to the ease and speed with which maintenance is undertaken and, therefore, can be measured as the maintenance duration, maintenance effort and other qualitative factors which represent the ease of the task. Maintainability can be measured as a probability distribution of defined maintenance task times or as the probability of achieving a maintenance action within a defined time.

The specification of each maintainability requirement as a quantitative or qualitative measure should detail the life cycle stages at which conformity will be verified and the means and procedures (analytical methods, simulations, tests, etc.) by which this will be carried out. The interdependence between requirements should be clearly described.

The required confidence in the assessed measure determines the amount of resources (i.e. people, money, time) which are necessary to demonstrate achievement of programme outcomes.

6.3.2 Quantitative measures of maintainability

Quantitative maintainability characteristics normally define the time that an item is in an inoperable state due to being under maintenance. There are a number of criteria that can be used to define this, a selection of which are given in Table 1. Many of these measures can be expressed as a mean, median or maximum, representing statistical characteristics from any applicable distribution. The difference between the measures is that they express different priorities between related item properties and they allow for flexibility concerning trade-offs to be made later in the programme. It is important that such factors are considered before a specific requirement is included in the specification. Limits can also be specified for the preventive maintenance tasks (see 8.4 for maintenance descriptions).

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When specifying the measures of maintainability, the following questions should be considered to determine suitable metrics.

– Does failure stop operation? If a failure causes the item to stop functioning, the time required to restore operation and complete corrective maintenance should be measured. This helps ensure that downtime is minimized and operations can resume quickly after a failure.

– Can failures be repaired during operation? If the item can continue to operate while repairs are being made, focus should be on measuring the effort required for restoration. This includes the maintenance person hours, tools, and resources needed to fix the issue without halting operations, ensuring minimal disruption.

– Does preventive maintenance stop operation? If preventive maintenance activities require the item to be shut down, measure the time needed to perform these maintenance tasks. This helps in planning and scheduling maintenance to minimize operational downtime. If preventive maintenance can be performed without stopping the item, measure the effort required, such as the person-power and resources needed to maintain operational efficiency.

Table 1 – Examples of quantitative maintainability measures (hardware)

Term	Definition	Statistical characteristic	Verification method
Active maintenance time	The amount of time required for diagnosis, technical delays, planned maintenance, restoration and final check or testing, over a defined period	Mean, median or maximum[a]	Design evaluation, demonstration, or operational evaluation
Active corrective maintenance time	The amount of time required for diagnosis, technical delays, restoration and final check or testing, over a defined period	Mean, median or maximum[a]	Design evaluation, demonstration, or operational evaluation
Active preventive maintenance time	The amount of time required for technical delays, planned maintenance and final check or testing, over a defined period	Mean, median or maximum[a]	Design evaluation, demonstration, or operational evaluation
Access time	The amount of time required to access the item requiring maintenance	Value, mean, maximum[a]	Design evaluation, demonstration, operational evaluation
Maintenance person-hours	The number of maintenance person-hours, considering the effort of all technicians involved, over a defined period	Value	Design evaluation, operational evaluation
Time between all maintenance	The operational time between any maintenance action; planned or corrective	Mean, median or minimum[c]	Design evaluation, operational evaluation
Time between planned maintenance	The operational time between planned maintenance actions	Mean, median or minimum[c]	Design evaluation, operational evaluation
Time between restoration	The operational time between corrective maintenance actions	Mean, median or minimum[c]	Design evaluation, operational evaluation
Number of maintenance hours per operating hour[b]	Ratio of maintenance to operating time	Mean, median or maximum	Design evaluation, operational evaluation
Number of appropriately skilled personnel per maintenance action	Number of personnel required to complete each maintenance action	Mean, maximum or minimum	Design evaluation, operational evaluation

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Term	Definition	Statistical characteristic	Verification method
Time to restoration	Time taken for disassembly, maintenance actions, reassembly, and alignment	Mean, median or maximum[a]	Design evaluation, demonstration, or operational evaluation

[a] The maximum value shall be associated with a percentile – a commonly used value is 95 %.

[b] Other time bases may be selected as appropriate, e.g. day, month, year, operating cycle.

[c] The minimum value shall be associated with a percentile – a commonly used value is 5 %.

The active maintenance time is often used to specify maintainability and includes the following sub-elements:

– diagnosis (failure detection, fault detection and isolation, localization of cause, etc.);
– technical delays (typical technical delays include setting time, cooling, interpretation and supplication of information, interpretation of displays, read out);
– restoration (disassembly, insert software patch, interchange, modify control code, re-assembly, alignment, etc.);
– final check (testing procedures as necessary).

The active maintenance time does not include administration and logistic delays. These are addressed in IEC 60300-3-14.

The time to restore an item following a software crash can be an important parameter as this has an immediate impact on operations and user experience.

Examples of quantitative software maintainability measures are given in Table 2. Some measures commonly used for software can be applied to hardware e.g. modularity.

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