

Programmes for reliability growth

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National foreword

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Programmes for reliability growth
(IEC 61014:2003)

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(CEI 61014:2003)

Programme für das
Zuverlässigkeitswachstum
(IEC 61014:2003)

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Foreword

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Annexes designated "normative" are part of the body of the standard.
In this standard, annex ZA is normative.
Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61014:2003 was approved by CENELEC as a European Standard without any modification.

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

IEC 61703	NOTE	Harmonized as EN 61703:2002 (not modified).
ISO 9000	NOTE	Harmonized as EN ISO 9000:2000 (not modified).
ISO 9001	NOTE	Harmonized as EN ISO 9001:2000 (not modified).

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INTRODUCTION

Reliability improvement by a growth programme should be part of an overall reliability activity in the development of a product. This is especially true for a design that uses novel or unproven techniques, components, or a substantial content of software. In such a case the programme may expose, over a period of time, many types of weaknesses having design-related causes. It is essential to reduce the probability of failure due to these weaknesses to the greatest extent possible to prevent their later appearance in formal tests or in the field. At that late stage, design correction is often highly inconvenient, costly and time-consuming.

Life-cycle costs can be minimized if the necessary design changes are made at the earliest possible stage.

IEC 60300-3-5, Clause 1 refers to a “reliability growth (or improvement) programme” employing equipment reliability design analysis and reliability testing, with the principal objective to realize reliability growth. Reliability design analysis applies analytical methods and techniques described in IEC 60300-3-1. Reliability design analysis is of a particular value, as it allows early identification of potential design weakness, well before design completion. This allows introduction of design modifications that are inexpensive and relatively easy to implement without consequences such as major design changes, programme delays, modification of tooling and manufacturing processes. The reliability growth testing and environmental arrangements for the test part of this programme are essentially the same as those covered by IEC 60300-3-5, IEC 60605-2 and IEC 60605-3.

The importance of the reliability growth programme, integrated into the design or product development process, and known as integrated reliability engineering, is driven by limited time to market, programme costs and striving for product cost reduction.

Although effective for disclosure of potential field problems, a reliability growth testing programme alone is typically expensive, requiring extensive test time and resources, and the corrective actions are considerably more costly than if they were found and corrected in the early stages of design. Additionally, the duration of these tests, sometimes lasting for a very long time, would seriously affect the marketing or deployment schedule of the system.

The cost-effective solution to these challenges is a reliability growth programme fully integrated in both the design and evaluation phase as well as the testing phase. This effort is enabled by strong project management, by design engineering and often by customer participation and involvement. Over the past few years, leading industry organizations have developed and applied analytical and test methods fully integrated with the design efforts for increasing the reliability during the product design phase. This reduces reliance on formal and lengthy reliability growth testing. This technology is the basis for the integrated reliability growth strategy in this standard and will be discussed further in Clause 6. Some definitions and concepts are given first in order to lay the groundwork for discussing the integrated reliability growth methodologies.

PROGRAMMES FOR RELIABILITY GROWTH

1 Scope

This International Standard specifies requirements and gives guidelines for the exposure and removal of weaknesses in hardware and software items for the purpose of reliability growth.

It applies when the product specification calls for a reliability growth programme of equipment (electronic, electromechanical and mechanical hardware as well as software) or when it is known that the design is unlikely to meet the requirements without improvement.

A statement of the basic concepts is followed by descriptions of the management, planning, testing (laboratory or field), failure analysis and corrective techniques required. Mathematical modelling, to estimate the level of reliability achieved, is outlined briefly.

2 Normative references

The following referenced documents are indispensable for the application 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, *Dependability management – Part 1: Dependability management systems*¹

IEC 60300-2, *Dependability management – Part 2: Guidance for dependability programme management*²

IEC 60300-3-1, *Dependability management – Part 3-1: Application guide – Analysis techniques for dependability – Guide on methodology*

IEC 60300-3-5:2001, *Dependability management – Part 3-5: Application guide – Reliability test conditions and statistical test principles*

IEC 60605-2, *Equipment reliability testing – Part 2: Design of test cycles*

IEC 60605-3 (all parts), *Equipment reliability testing – Part 3: Preferred test conditions*

IEC 60605-4, *Equipment reliability testing – Part 4: Statistical procedures for exponential distribution – Point estimates, confidence intervals, prediction intervals and tolerance intervals*

IEC 60812, *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)*

IEC 61025, *Fault tree analysis (FTA)*

IEC 61160, *Formal design review*

IEC 61164, *Reliability growth – Statistical test and estimation methods*

¹ Second edition to be published.

² Second edition to be published.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE 1 Certain terms come from IEC 60050(191) and, where this is the case, the concept from that publication is referenced in square brackets after the definition. ISO 9000:2000 is used as referenced to quality vocabulary.

NOTE 2 For analysis of the reliability growth test data, it is important to distinguish between the terms “failure intensity” (for repaired items) and “failure rate” or “instantaneous failure rate” (for non-repaired or one-shot items) defined in IEC 60050(191).

3.1

item

entity

any part, component, device, subsystem, functional unit, equipment or system that can be individually considered

NOTE An item may consist of hardware, software or both, and may also, in particular cases, include people.

[IEC 60050, 191-01-01]

3.2

reliability improvement

process undertaken with the deliberate intention of improving the reliability performance by eliminating causes of systematic failures and/or by reducing the probability of occurrence of other failures

[IEC 60050, 191-17-05]

NOTE 1 The method described in this standard is aimed at making corrective modifications aimed at reducing systematic weaknesses or reducing their likelihood of occurrence.

NOTE 2 For any item, there are limits to practicable and economic improvement and to achievable growth.

3.3

reliability growth

condition characterized by a progressive improvement of a reliability performance measure of an item with time

[IEC 60050, 191-17-04]

NOTE Modelling (projection) and analysis of reliability improvement during the design phase is based on the standard estimation of the expected product reliability within a given time period.

3.4

integrated reliability engineering

engineering tool, consisting of a multitude of reliability/dependability methods integrated into all engineering stages and activities regarding a product, from the conceptual phase through its use in the field by a combination of contributions from all relevant stakeholders

3.5

product reliability goal

reliability goal for a product based on certain corporate targets, market requirements or desired mission success probability that is reasonably achievable according to the past history and technical evolution

NOTE For some projects, the reliability goal is set by the customer. The product specific goal is the target value of the reliability growth process.

3.6

systematic weakness

weakness, which can be eliminated, or its effects reduced, only by a modification of the design or manufacturing process, operational procedures, documentation or other relevant factors, or by replacement of substandard components by components of proven superior reliability

NOTE 1 A systematic weakness often results in a failure that is related to a weakness in the design or a weakness of the manufacturing process or documentation.

NOTE 2 Repair or replacement (or re-run in case of software) without modification is likely to lead to recurrent failures of a similar kind.

NOTE 3 Software weaknesses are always systematic.

3.7

residual weakness

weakness, which is not systematic

NOTE 1 In this case, risk of recurrent failure of a similar kind is small or even negligible, within the expected test time scale.

NOTE 2 Software weaknesses cannot be residual.

3.8

failure

termination of the ability of an item to perform a required function

NOTE 1 After failure the item has a fault.

NOTE 2 "Failure" is an event, as distinguished from "fault", which is a state.

[IEC 60050,191-04-01]

NOTE 3 The term "termination" implies that the product had the ability to perform a required function and then lost it. Once the system design is capable of meeting the specified performance requirement, then reliability failure is the termination of this capability.

3.9

failure mode

manner in which any system or component ceases to perform its respective designed operation

NOTE 1 A failure mode may be characterized by its frequency of occurrence or by probability of its occurrence to include into the system's or component's reliability.

NOTE 2 To address the reliability of a system, fundamentally its corresponding failure modes, the causes of these failure modes, and the frequency or probability of occurrence of these modes under the system's intended use environment need to be addressed.

3.10

relevant failure

failure that should be included in interpreting test or operational results or in calculating the value of a reliability performance measure

NOTE 1 The criteria for inclusion should be stated.

[IEC 60050, 191-04-13]

NOTE 2 The criteria for inclusion are stated in 6.4.6.

3.11

non-relevant failure

failure that should be excluded in interpreting test or operational results or in calculating the value of a reliability performance measure

[IEC 60050, 191-04-14]

NOTE The criteria for classifying failures as not relevant are stated in 6.4.5.

3.12

systematic failure

failure that exhibits, after a physical, circumstantial or design analysis, a condition or pattern of failure that may be expected to cause recurrence

NOTE 1 Corrective maintenance without modification does not usually eliminate the failure cause.

NOTE 2 A systematic failure can be induced at will by simulating the failure cause.

NOTE 3 In this standard, a systematic failure is interpreted as a failure resulting from a systematic weakness.

3.13

residual failure

failure resulting from a residual weakness

Categories of failures observed in a reliability growth test programme

3.14

failure category A

systematic failure experienced in test for which management decides not to attempt corrective modification, due to cost, time, technological constraints or other reasons

3.15

failure category B

systematic failure experienced in test for which management decides to attempt corrective modification

NOTE Failure categorization is not applicable for reliability growth in the product design phase as the view on potential failure modes is entirely different. Here, all components could potentially fail in one mode or another, but the likelihood and consequence of such an event may be very different. Failure modes and their potential causes that may be highly likely to occur are addressed first, and, if resources and schedules allow, other failure modes, less likely to occur, are addressed. A product with a high number of components where each of those might have multiple failure modes, and each of the failure modes might have multiple causes, might require a great amount of effort to classify and then re-classify each of the failure modes or causes, too cumbersome and costly to justify the classification. As the failure classification does not add any value, it is not applied during the reliability growth effort in the product design phase.

3.16

fault

state of an item characterized by inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external resources

NOTE A fault is often the result of a failure of the item itself but may exist without prior failure.

[IEC 60050, 191-05-01]

3.17

fault mode

one of the possible states of a faulty item, for a given required function

[IEC 60050, 191-05-22]

NOTE The use of the term "failure mode" in this sense is allowed for identification of a potential item or component failure.

3.18

instantaneous reliability measure

reliability measure for an item at a given point (past or present) in a reliability growth programme

NOTE 1 The reliability measure used in design analysis is the expected product reliability in a predetermined time, or its equivalent failure intensity calculated from the assessed product reliability associated with a time period of interest.

NOTE 2 Occasionally, the reliability measure can be expressed in terms of equivalent MTBF or MTTF also calculated from the assessed product reliability associated with a time period of interest.

NOTE 3 Whenever time is used in this standard, it can be substituted by other counts such as cycles, distance travelled (miles, kilometres), or copies.

NOTE 4 In this standard, the term failure intensity is used for a reliability measure of a repairable system, but terms like failure rate, instantaneous failure rate, MTBF, or MTTF can be substituted as appropriate. Further, the system is assumed repairable unless specifically stated otherwise.

NOTE 5 The reliability measures for a system commonly used in test are the (instantaneous) failure intensity (IEV 191-12-04) or the mean operating time between failures (MTBF) (IEV 191-12-09) as well as the (instantaneous) failure rate (IEV 191-12-02) or the mean time to failure (MTTF) (IEV 191-12-07).

NOTE 6 Values of reliability measures are estimated by reliability growth models determined for product improvement in the design and the test phase separately.

3.19**extrapolated reliability measure**

reliability measure for an item, predicted for a given future point in a reliability growth test programme, where the corrective modifications are promptly introduced throughout the programme

NOTE 1 The definition of the modifier “extrapolated” (IEV 191-18-03) applies here but is restricted to time.

NOTE 2 The previous test conditions and corrective modification procedures are assumed to continue unchanged.

NOTE 3 The value of the reliability measure is estimated by a reliability growth model applied to the previous data and the same trend is assumed to apply also to the future period of the programme.

NOTE 4 The reliability measures commonly used are the (instantaneous) failure intensity (IEV 191-12-04) or the mean operating time between failures (MTBF) (IEV 191-12-09) as well as the (instantaneous) failure rate (IEV 191-12-02) or the mean time to failure (MTTF) (IEV 191-12-07).

NOTE 5 Extrapolated reliability measure is not applicable for use in a reliability growth programme during the design phase.

3.20**projected reliability measure**

reliability measure predicted for an item as a consequence of the simultaneous introduction of a number of corrective modifications

NOTE 1 The modifications are often introduced between two successive phases in the programme.

NOTE 2 The reliability measures commonly used in the formal reliability growth test are the (instantaneous) failure intensity (IEV 191-12-04) or the mean operating time between failures (MTBF) (IEV 191-12-09) as well as the (instantaneous) failure rate (IEV 191-12-02) or the mean time to failure (MTTF) (IEV 191-12-07).

NOTE 3 Reliability measure during reliability growth in the design phase is the product reliability projected for the time period of interest such as warranty period or mission duration.

NOTE 4 The values of these measures are estimated by a reliability growth model.

3.21**usage profile**

detailed information on environmental and operational aspects, their levels and content, duration, and sequence, expected to be encountered in a new product

3.22**field performance report**

summary and analysis of the field data pertinent to the product to be designed

3.23**product specification for reliability**

description of expected product performance for the specified time period under the expected usage profile

3.24**reliability and life test**

test (environmental or other stress) designed to prove or estimate probability of occurrence of failure modes or their respective causes when those estimates are difficult to make solely by analysis

NOTE Operational test (life testing) is carried out on a product to demonstrate reliability.

3.25**reliability growth planning**

plan of reliability activities such as analyses, components and materials selection and testing that would assure increase in product reliability

NOTE The same term can also refer to planning of the magnitude and the quantity of design improvements necessary to attain the product reliability goal. This planning consists of an analytical representation of the course of reliability growth in design and gives an estimate of the number and magnitude of design changes (improvements) necessary to attain the reliability goal.

3.26

preliminary reliability estimates

estimates made for new product based on inherited design

3.27

preliminary reliability allocation

reliability apportioned to the parts of design where, because of the lack of information, preliminary estimates cannot be made

3.28

design guidelines

document with design rules that point out known design criteria for reliability enhancement

3.29

continuous design reliability assessment

updating reliability assessment of the new product concurrently with the design evolution and testing of components and subsystems

3.30

FMEA and failure mode mitigation

identification of critical and/or safety-related failure modes, their causes and effects and estimation of likelihood of their occurrence regarding product usage profile, and life

NOTE Mitigation addresses causes and effects of failure modes with high severity and probability of occurrence. A very useful tool in failure mode analysis of a design is found to be fault tree analysis, which is a logical representation of hardware and associated failure modes.

3.31

key components

those components, which are determined to be essential for the intended product performance and which are evaluated and selected on the basis of available and satisfactory reliability and environmental information

3.32

final reliability report

compilation of methods, analyses, tests, results, lessons learned, mitigated consequences of failure modes, critical components and findings on their reliability, achieved reliability growth and the final reliability estimate and evaluation of the confidence in the reliability and integrity of the product

NOTE The report archives the information to be used as a source of information, references, reports, and a starting point for the next version or similar product.

3.33

reliability assessment of product changes

evaluation of changes of components, design or manufacturing process on product reliability

NOTE The changes may result from corrective actions, cost reductions on products or changes in the production process.

3.34

continuing reliability testing

reliability testing on ongoing lot of production to verify that the product reliability has not been compromised by the manufacturing processes or a lot of components of inferior quality

3.35

FRACAS

failure reporting analysis and corrective action system, closed loop system for tracking and bringing design issues to closure

NOTE As a database, it is a source of information on test and field experienced failure modes on products related to the new design. The analysis may then address potential of existence of those failure modes in the design being analysed.

3.36

system

set of interrelated or interfacing elements

[ISO 9000:2000, definition 3.2.1]

NOTE 1 In the context of dependability, a system should have

- a) a defined purpose expressed in terms of required functions; and
- b) stated conditions of operation/use (see IEV 191-01-12).

NOTE 2 The structure of a system is hierarchical.

3.37

component

item on the lowest level considered in the analysis

3.38

allocation

procedure applied during the design of an item intended to apportion the requirements for performance measures for an item to its sub-items according to given criteria

3.39

integrated reliability growth

reliability growth achieved through joint efforts of analysis, testing, design engineering and other information and activities for identification and mitigation of potential item failure modes

3.40

intermittent failure

failure that may not be reproducible every time the item is tested for it and that appears sporadically

3.41

recurrent failure

failure that appears repetitively

3.42

action list

list prepared to outline actions necessary to be taken for achievement of reliability growth

3.43

condition or pattern of failure

manner in which some failures occur

3.44

circumstantial analysis

analysis of the circumstances in which some failures occur

3.45

equivalent failure rate

failure rate of a component or an item calculated from its achieved reliability for the corresponding time period with an assumption of a constant failure rate in the course of that time period

NOTE The obtained value of the equivalent failure rate is valid for the particular time period only.

4 Basic concepts

4.1 General

The basic concepts for reliability growth of a product are similar, whether the product weaknesses are discovered through design, analysis, or test.

In a programme of reliability growth design analysis, the product design is analysed to determine whether any of its components and their interactions constitute potential weaknesses when subjected to the expected operational and environmental stresses and their potential extremes. Results of the design analysis may be compared with the product reliability goals or requirements, and recommendations are made for the necessary improvements. Here, the design stress and component weakness analysis regarding their respective failure modes are instrumental for determination of potential failures, improvements and the reliability growth.

Design analysis should not be limited to electronics, as mechanical components and software are also subject to failure. For that reason, the appropriate reliability measure is the probability of survival or probability of failure, rather than the failure rate or failure intensity, as the mechanical components often cannot be related to a failure rate especially to a constant failure rate, but rather to a failure probability (wear-out).

All reliability analytical methods can be applied, including testing specifically designed to detect potential failure modes, especially those where the analysis would be too complex, or would be likely to produce uncertain results. Failure modes, or their causes, found to have a high probability of occurrence are addressed through design improvement, and the new design reliability is reassessed. In that manner, reliability growth is monitored and the progress is recorded. Design reliability analysis also includes imbedded software, as well as the hardware-software interactions.

In a programme of reliability growth testing, laboratory or field testing is used to stimulate the exposure of weaknesses and to improve the reliability of a system, module, sub-assembly or component. When a failure occurs it shall be diagnosed, repair and/or replacement shall be carried out and testing shall be continued. Concurrently with testing, past failures shall be analysed to find their basic causes and, where appropriate, corrective modifications shall be introduced into design or other procedures, resulting in progressive reliability growth. This procedure applies equally to pure hardware and to embedded software.

A reliability growth programme on non-repairable, or one-shot, items or component only shall provide for successively modified samples, each of a more reliable design than the one before.

4.2 Origins of weaknesses and failures

4.2.1 General

Weaknesses are normally unknown in product use until they are revealed by failures. However, a weakness may be created long before the occurrence of an observable failure by an unconscious human error in some operation affecting an item such as excessive operational or environmental stress, or inadequate component derating such that the component strength is inadequate to withstand the expected stress or combination of stresses. Alternatively, it may be inherent in a material or component due to a process not being under complete control.