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Analysis techniques for system reliability; procedure for failure mode and effects analysis (FMEA)

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ANALYSIS TECHNIQUES FOR SYSTEM RELIABILITY - PROCEDURE FOR FAILURE MODE AND EFFECTS ANALYSIS (FMEA)

Techniques d'analyse de la fiabilité des systèmes - Procédure d'analyse des modes de défaillance et de leurs effets (AMDE)

Zuverlässigkeit von Systemen; Untersuchungstechniken; Ausfallarten- und Ausfallauswirkungsanalyse (SMEA)

BODY OF THE HD

The Harmonization Document consists of:

- IEC 812 (1985) ed 1; IEC/TC 56, not appended

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The English and French versions of this Harmonization Document are provided by the text of the IEC publication and the German version is the official translation of the IEC text. The German translation is not yet available.

According to the CENELEC Internal Regulations the CENELEC member National Committees are bound:

to announce the existence of this Harmonization Document at national level
by or before 1987-09-15

to publish their new harmonized national standard
by or before 1988-03-15

to withdraw all conflicting national standards
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INTERNATIONAL STANDARD

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Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ANALYSIS TECHNIQUES FOR SYSTEM RELIABILITY – PROCEDURE FOR FAILURE MODE AND EFFECTS ANALYSIS (FMEA)

FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This standard has been prepared by IEC Technical Committee No. 56: Reliability and Maintainability.

The text of this standard is based upon the following documents:

Six Months' Rule	Report on Voting
56(CO)85	56(CO)97

Further information can be found in the Report on Voting indicated in the table above.

The following IEC publication is quoted in this standard:

Publication No. 271 (1974): List of Basic Terms, Definitions and Related Mathematics for Reliability.

ANALYSIS TECHNIQUES FOR SYSTEM RELIABILITY — PROCEDURE FOR FAILURE MODE AND EFFECTS ANALYSIS (FMEA)

1. Scope

This standard describes Failure Mode and Effects Analysis (FMEA) and Failure Mode, Effects and Criticality Analysis (FMECA), and gives guidance as to how they may be applied to achieve various objectives, as follows:

- by providing the procedural steps necessary to perform an analysis;
- by identifying appropriate terms, assumptions, criticality measures, failure modes;
- by determining basic principles;
- by providing examples of the necessary forms.

All the general qualitative considerations presented for FMEA will apply to FMEAC, since one is an extension of the other.

2. General

The Failure Modes and Effects Analysis (FMEA) and Failure Modes, Effects and Criticality Analysis (FMECA) are methods of reliability analysis intended to identify failures which have significant consequences affecting the system performance in the application considered.

Generally, failures or failure modes of any component will affect system performance adversely. In the study of system reliability, safety and availability, both qualitative and quantitative analyses are required and these complement one another. Quantitative analysis methods allow the calculation or prediction of performance indices of the system while fulfulling a specific task or in long-term operation under specific conditions. Typical indices denote reliability, safety, availability, failure rates, MTTF (Mean Time To Failure), etc.

The FMEA is based on that defined component or sub-assembly level where the basic failure criteria (primary failure modes) are available. Starting from the basic element failure characteristics and the functional system structure, the FMEA determines the relationship between the element failures and the system failures, malfunctions, operational constraints and degradation of performance or integrity. To evaluate secondary and higher-order system and subsystem failures, the sequences of events in time may also have to be considered.

In a narrow sense, the FMEA is limited to a qualitative analysis of failure modes of hardware, and does not include human errors and software errors, despite the fact that current systems are usually subject to both. In a wider sense, these factors could be included.

The severity of the consequences of failure is described by criticality. The criticality is designated by categories or levels which are functions of the dangers and the losses of system capabilities and sometimes of the probability of their occurrence. This probability is best separately identified.

A logical extension of the FMEA is the consideration of the criticality and probability of occurrence of the failure modes. This criticality analysis of the identified failure modes is widely known as FMECA.

2.1 *Purpose of the analysis*

FMEA and FMECA are important techniques for a reliability assurance programme which can be applied to a wide range of problems and may be encountered in technical systems with varying depths and modifications to suit the purpose. The analysis is carried out in a limited way during conception, planning, and definition phases and more fully in the design and development phase. It is however important to remember that the FMEA is only part of a reliability and maintainability programme which requires many different tasks and activities. FMEA is an inductive method of performing a qualitative system reliability or safety analysis from a low to a high level.

The development of reliability block diagrams and state diagrams derived from the system structure is interrelated with the FMEA. Separate diagrams will be needed for:

- differently identified and defined criteria for system failure;
- degradation of function or reduction in assurance of function;
- safety;
- alternative operational phases:

The purposes of FMEA and FMECA may include:

a) evaluation of the effects and the sequences of events caused by each identified item failure mode, from whatever cause, at various levels of a system's functional hierarchy;

b) determination of the significance or criticality of each failure mode as to the system's correct function or performance and the impact on the reliability and/or safety of the related process;

c) classification of identified failure modes according to their detectability, diagnosability, testability, item replaceability, compensating and operating provisions (repair, maintenance and logistics, etc.) and any other relevant characteristics;

d) estimation of measures of the significance and probability of failure, subject to the availability of data.

2.2 *Application*

2.2.1 *FMEA field of application*

FMEA is a method which is primarily adapted to the study of material and equipment failures and which can be applied to categories of systems based on different technologies (electrical, mechanical, hydraulic, etc.) and combinations of technologies. FMEA may also be used for the study of software and human performance.

2.2.2 *FMEA application within the framework of a project*

The user should determine how and for what purposes he uses FMEA within his own technical discipline. It may be used alone or to complement and support other methods of reliability analysis. The requirements for FMEA originate from the need to understand hardware behaviour and its implications for the operation of the system or equipment. The need for FMEA can vary widely from one project to another.

FMEA is a technique for design review support and for assurance and assessment which should be put into use from the very first steps of system and subsystem design. FMEA is appropriate to all levels of system design. Special training of personel performing FMEA is required, and they must have the close collaboration of systems engineers and designers. The FMEA must be updated as the project progresses and as designs are modified. By the end of the project, FMEA is used to check the project design and may be essential for demonstration of conformity of a designed system to required standards, regulations, and user's requirements.

Information from the FMEA identifies priorities for process controls and inspection tests during manufacture and installation, and for qualification, approval, acceptance and start-up tests. It provides essential information for diagnostic and maintenance procedures.

In deciding on the extent and the way in which FMEA should be applied to an item or design, one should consider the specific purposes for which FMEA results are needed, the time phasing with other activities, and the importance of establishing a predetermined degree of awareness and control over unwanted failure modes and effects. This leads to the planning of FMEA in qualitative terms at specified levels (system, subsystem, component, item) to relate to the iterative design and development process.

To ensure that it is effective, FMEA shall be identified in the reliability programme.

2.2.3 *Uses of FMEA*

Some of the detailed applications and benefits of FMEA are listed below:

a) to identify failures which, when they occur alone, have unacceptable or significant effects, and to determine the failure modes which may seriously affect the expected or required operation. Such effects may include secondary failures;

b) to determine the need for:
- redundancy;
- designing features which increase the probability of "fail safe" outcomes of failures;
- further derating and/or design simplification;

c) to determine the need for selecting alternative materials, parts, devices, and components;

d) to identify serious failure consequences and hence the need for design review and revision;

e) to provide the logic model required to evaluate the probability of anomalous operating conditions of the system;

f) to disclose safety hazard and liability problem areas, or non-compliance with regulatory requirements;

g) to ensure that the test programme can detect potential failure modes;

h) to establish duty cycles which anticipate and avoid wear-out failures;

i) to focus upon key areas in which to concentrate quality, inspection and manufacturing process controls;

j) to avoid costly modifications by the early identification of design deficiencies;

k) to establish the need for data recording and monitoring during testing, check-out and use;

l) to provide information for selection of preventive or corrective maintenance points and development of trouble-shooting duides, built-in test equipment and suitable test points;

m) to facilitate or support the determination of test criteria, test plans and diagnostic procedures, for example: performance testing, reliability testing;

n) to identify circuits requiring worst case analysis (frequently required for failure modes involving parameter drifts);

o) to support the design of fault isolation sequences and to support the planning for alternative modes of operation and reconfiguration;

p) to facilitate communication between:
- general and specialized engineers;
- equipment manufacturer and his suppliers;
- system user and the designer or manufacturer;

q) to enhance the analyst's knowledge and understanding of the behaviour of the equipment studied;

r) to provide a systematic and rigorous approach to the study of system facilities.

2.2.4 *Limitations and drawbacks of FMEA*

FMEA is extremely efficient when it is applied to the analysis of elements which cause a failure of the entire system.

However, FMEA may be very difficult and tedious for the case of complex systems which have multiple functions consisting of a number of components. This is because of the quantity of detailed system information which must be considered. This difficulty can be increased by the number of possible operating modes, as well as by considerations of the repair and maintenance policies.

Another limitation is that the results of human error are not usually included. Studies of man-machine interactions are the subject of specific methods (task analysis, for example). Generally, human errors appear during operation of systems in a sequential mode and the study of their impact has to be made by methods such as, for example, cause-consequence analysis. Nevertheless, the FMEA can identify components most sensitive to human factors. A further limitation is apparent when the effects of the environment are significant. The consideration of these effects requires a thorough knowledge of the characteristics and performances of the different components of the system.

It should be noted that human error and environmental effects constitute a major source of common mode or common cause failure. This question is dealt with in Sub-clause 3.6.1.

3. Basic principles of FMEA

3.1 *Terminology*

All terminology, except where specifically identified, is in accordance with IEC Publication 271: List of Basic Terms, Definitions and Related Mathematics for Reliability.