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Reliability block diagrams

Diagrammes de fiabilité

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NORME INTERNATIONALE

Reliability block diagrams

Diagrammes de fiabilité

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RELIABILITY BLOCK DIAGRAMS

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International Standard IEC 61078 has been prepared by IEC technical committee 56: Dependability.

This third edition cancels and replaces the second edition published in 2006. This edition constitutes a technical revision.

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

a) the structure of the document has been entirely reconsidered, the title modified and the content extended and improved to provide more information about availability, reliability and failure frequency calculations;

b) Clause 3 has been extended and clauses have been introduced to describe the electrical analogy, the "non-coherent" RBDs and the "dynamic" RBDs;

c) Annex B about Boolean algebra methods has been extended;

d) Annex C (Calculations of time dependent probabilities), Annex D (Importance factors), Annex E (RBD driven Petri net models) and Annex F (Numerical examples and curves) have been introduced.

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

FDIS	Report on voting
56/1685/FDIS	56/1694/RVD

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INTRODUCTION

A reliability block diagram (RBD) is a pictorial representation of a system's successful functioning. It shows the logical connection of (functioning) components (represented by blocks) needed for successful operation of the system (hereafter referred to as “system success”). Therefore an RBD is equivalent to a logical equation of Boolean variables and the probabilistic calculations are primarily related to constant values of the block success/failure probabilities.

Many different analytical methods of dependability analysis are available, of which the RBD is one. Therefore, the purpose of each method and their individual or combined applicability in evaluating the availability, reliability, failure frequency and other dependability measures as may be applicable to a given system or component should be examined by the analyst prior to deciding to use the RBD. Consideration should also be given to the results obtainable from each method, data required to perform the analysis, complexity of analysis and other factors identified in this standard.

Provided that the blocks in the RBD behave independently from each other and that the order in which failures occur does not matter then the probabilistic calculations can be extended to time dependent probabilistic calculations involving non-repaired as well as repaired blocks (e.g. blocks representing non-repaired or repaired components). In this case three dependability measures related to the system successful functioning have to be considered: the reliability itself, $R_{\mathrm{S}}(t)$, but also the availability, $A_{\mathrm{S}}(t)$ and the failure frequency, $w_{\mathrm{S}}(t)$. While, for systems involving repaired components, the calculations of $A_{\mathrm{S}}(t)$ or $w_{\mathrm{S}}(t)$ can be done quite straightforwardly, the calculation of $R_{\mathrm{S}}(t)$ implies systemic dependencies (see definition 3.34) which cannot be taken into account within the mathematical framework of RBDs. Nevertheless, in particular cases, approximations of $R_{\mathrm{S}}(t)$ are available.

The RBD technique is linked to fault tree analysis [1][1] and to Markov techniques [2]:

- The underlying mathematics is the same for RBDs and fault tree analysis (FTA): when an RBD is focused on system success, the FT is focused on system failure. It is always possible to transform an RBD into an FT and vice versa. From a mathematical point of view, RBD and FT models share dual logical expressions. Therefore, the mathematical developments and the limitations are similar in both cases.
- When the availability $A_{\mathrm{i}}(t)$ of one block can be calculated by using an individual Markov process [2] independent of the other blocks, this availability, $A_{\mathrm{i}}(t)$, can be used as input for the calculations related to an RBD including this block. This approach where an RBD provides the logic structure and Markov processes numerical values of the availabilities of the blocks is called "RBD driven Markov processes".

For systems where the order of failures is to be taken into account, or where the repaired blocks do not behave independently from each other or where the system reliability, $R_{\mathrm{S}}(t)$, cannot be calculated by analytical methods, Monte Carlo simulation or other modelling techniques, such as dynamic RBDs, Markov [2] or Petri net techniques [3], may be more suitable.

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[1] Numbers in square brackets refer to the Bibliography.

RELIABILITY BLOCK DIAGRAMS

1 Scope

This International Standard describes:

- the requirements to apply when reliability block diagrams (RBDs) are used in dependability analysis;
- the procedures for modelling the dependability of a system with reliability block diagrams;
- how to use RBDs for qualitative and quantitative analysis;
- the procedures for using the RBD model to calculate availability, failure frequency and reliability measures for different types of systems with constant (or time dependent) probabilities of blocks success/failure, and for non-repaired blocks or repaired blocks;
- some theoretical aspects and limitations in performing calculations for availability, failure frequency and reliability measures;
- the relationships with fault tree analysis (see IEC 61025 [1]) and Markov techniques (see IEC 61165 [2]).

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 – Part 192: Dependability* (available at http://www.electropedia.org)

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

3 Terms and definitions

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

NOTE Some terms have been taken from IEC 60050-192 and modified for the needs of this standard.

3.1
reliability block diagram
RBD
logical, graphical representation of a system showing how the success states of its sub-items (represented by blocks) and combinations thereof, affect system success state

Note 1 to entry: The RBD technique was developed a long time ago when the term “reliability” was used as an umbrella term for “successful functioning”. This umbrella term is now superseded by “dependability”. Nevertheless it is still in use in the vernacular language and terms like “reliability engineering”, “reliability studies” or “reliability block diagram”. Therefore the term “reliability” used in RBD does not mean that this technique allows to calculate the reliability of a complex system straightforwardly from reliabilities of its constituting blocks (see 10.3.1.4).

Note 2 to entry: An RBD is a directed acyclic graph (i.e. a graph without loops) representing the logical links between the success state of a system and the success states of its constituting blocks. This logical architecture is mainly represented by conventional series and parallel graphical structures (see Clause 4 and Clause 7).

Note 3 to entry: RBDs may be extended to represent multi-state (i.e. more than two states) systems but those extensions cannot be handled within the Boolean framework.

[SOURCE: IEC 60050-192:2015, 192-11-03, modified – Notes added]

3.2
Boolean related model

mathematical model where the state of a system is represented by a logical function of Boolean variables representing the states of its components

Note 1 to entry: A Boolean variable a only has two values and a logical function of several Boolean variables also has only two values. Those two values may be for example, {0, 1}, {up, down}, {true, false}, {working, failed}, etc. The underlying mathematics behind the logical functions is Boolean algebra.

3.3
RBD driven Markov process

Markov process modelled by an RBD made of blocks modelled by individual sub-Markov models behaving independently from each other

Note 1 to entry: The underlying logic of an RBD allows to combine the individual availabilities of the blocks to obtain the system availability. When the block are modelled by small individual Markov processes (e.g. with less than 10 states) the RBD is equivalent to the Markov process related to the system which may encompass millions of states. This is the basis for most of the probabilistic calculations achieved with RBDs. Such Markov process built through the use of the RBD as guideline is called "RBD driven Markov process".

Note 2 to entry: The independent Markov process is developed in [2].

3.4
dynamic RBD
DRBD

reliability block diagram where the assumption of independency between the blocks is not fulfilled

Note 1 to entry: The blocks of a DRBD can have interactions with elements external to the RBD itself.

3.5
non-coherent RBD

reliability block diagram modelling a non-monotonic logical function

Note 1 to entry: A non-coherent RBD is an RBD where the blocks may appear both in direct and inverted states (see Table 3). In this case, some of the minimal success path (see definition 3.15) may have some blocks in down state and some minimal failure paths, some blocks in up state. The concepts of minimal tie and cut sets are no longer valid and have to be replaced by the concept of prime implicants.

Note 2 to entry: In a non-coherent RBD, a minimal success path may become a failure path by the repair of a block in down state and a minimal failure path may become a success path by a further failure of one block in up state. This is why they are named "non-coherent".

3.6
item

subject being considered

Note 1 to entry: In this International Standard the word “item” covers mainly the system modelled by the RBD and the “blocks” in the RBD.

[SOURCE: IEC 60050-192:2015, 192-01-01, modified – Notes to entry have been deleted, Note 1 to entry has been added]

3.7
block

basic element used to build an RBD

Note 1 to entry: A block has only two states (up and down) and may represent any item with two states (e.g. components, functions, subsystems) repaired or not repaired. By analogy and to simplify the wording, a repaired/non-repaired block represents a repaired/non-repaired item, the failure/repair of a block represents the failure/repair of the modelled item and the up/down state of a block represents the up/down state of the modelled item.

Note 2 to entry: The number of states may be extended to more than two states in order to represent multi-state (i.e. more than two states) systems but those extensions cannot be handled within the Boolean framework.

Note 3 to entry: For the purposes of this standard, the blocks are divided between "elementary blocks" – or more simply, "blocks" – and "composite blocks" comprising several "elementary blocks". This is illustrated in Table 3.

3.8
repeated block

block appearing more than once in an RBD

Note 1 to entry: Repeated blocks represent the same physical items. This should not be confused with duplicated blocks which represent different but similar physical items used to implement redundancy.

Note 2 to entry: Repeated blocks can appear in the direct or inverted state (i.e.; the block appears in up state in a part of the RBD and down state in another part, or vice versa). They are very useful to represent RBDs related to a complex system or for representing RBDs in the form of success or failure paths (see 8.2).

3.9
up state
available state

state of being able to perform as required

Note 1 to entry: The absence of necessary external resources may prevent operation, but do not affect the up state.

Note 2 to entry: Up state relates to availability of the item.

Note 3 to entry: An item may be considered to be in an up state for some functions and in a down state for others, concurrently.

Note 4 to entry: The adjectives "up" and “available” designate an item in an up state.

Note 5 to entry: Within the context of RBDs, the state of a block is identical to the state of the component modelled by this block. Therefore a block in up state refers to a component in up state. The same concept applies to the RBD and the corresponding system.

Note 6 to entry: Within an RBD and by analogy with an electrical circuit, a block in the up state can be considered as a virtual switch in closed position and a block in the down state as a virtual switch in open position.

[SOURCE: IEC 60050-192:2015, 192-02-01, modified – Note 5 to entry and Note 6 to entry have been added]

3.10
up time

time interval for which the item is in an up state

[SOURCE: IEC 60050-192:2015, 192-02-02]

3.11
mean up time
MUT

expectation of the up time

[SOURCE: IEC 60050-192:2015, 192-08-09]

3.12
down state
unavailable state

state of being unable to perform as required, due to internal fault, or preventive maintenance

Note 1 to entry: “Down” state relates to unavailability of the item.

Note 2 to entry: The adjectives “down” or “unavailable” designate an item in a down state.