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Electromechanical elementary relays – Part 2: Reliability

Relais électromécaniques élémentaires – Partie 2: Fiabilité

IEC 61810-2:2011

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

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Email: csc@iec.ch
Tél.: +41 22 919 02 11
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMECHANICAL ELEMENTARY RELAYS –

Part 2: Reliability

FOREWORD

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International Standard IEC 61810-2 has been prepared by IEC technical committee 94: All-or-nothing electrical relays.

This second edition cancels and replaces the first edition published in 2005. This edition constitutes a technical revision.

The main changes with respect to the previous editions are listed below:

- inclusion of both numerical and graphical methods for Weibull evaluation;
- establishment of full coherence with the second edition of the basic reliability standard IEC 61649;
- deletion of previous Annex A and Annex D since both annexes are contained in IEC 61810-1.

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

FDIS	Report on voting
94/316/FDIS	94/325/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 61810 series can be found, under the general title *Electromechanical elementary relays*, on the IEC website.

This International Standard is to be used in conjunction with IEC 61649:2008.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,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

INTRODUCTION

Within the IEC 61810 series of basic standards covering elementary electromechanical relays, IEC 61810-2 is intended to give requirements and tests permitting the assessment of relay reliability. All information concerning endurance tests for type testing have been included in IEC 61810-1.

NOTE According to IEC 61810-1, a specified value for the electrical endurance under specific conditions (e.g. contact load) is verified by testing 3 relays. None is allowed to fail. Within this IEC 61810-2, a prediction of the reliability of a relay is performed using statistical evaluation of the measured cycles to failure of a larger number of relays (generally 10 or more relays).

Recently the technical committee responsible for dependability (TC 56) has developed a new edition of IEC 61649 dealing with Weibull distributed test data. This second edition contains both numerical and graphical methods for the evaluation of Weibull-distributed data.

On the basis of this basic reliability standard, IEC 61810-2 was developed. It comprises test conditions and an evaluation method to obtain relevant reliability measures for electromechanical elementary relays. The life of relays as non-repairable items is primarily determined by the number of operations. For this reason, the reliability is expressed in terms of mean cycles to failure (MCTF).

Commonly, equipment reliability is calculated from mean time to failure (MTTF) figures. With the knowledge of the frequency of operation (cycling rate) of the relay within an equipment, it is possible to calculate an effective MTTF value for the relay in that application.

Such calculated MTTF values for relays can be used to calculate respective reliability, probability of failure, and availability (e.g. MTBF (mean time between failures)) values for equipment into which these relays are incorporated.

Generally it is not appropriate to state that a specific MCTF value is “high” or “low”. The MCTF figures are used to make comparative evaluations between relays with different styles of design or construction, and as an indication of product reliability under specific conditions.

ELECTROMECHANICAL ELEMENTARY RELAYS –

Part 2: Reliability

1 Scope

This part of IEC 61810 covers test conditions and provisions for the evaluation of endurance tests using appropriate statistical methods to obtain reliability characteristics for relays. It should be used in conjunction with IEC 61649.

This International Standard applies to electromechanical elementary relays considered as non-repaired items (i.e. items which are not repaired after failure), whenever a random sample of items is subjected to a test of cycles to failure (CTF).

The lifetime of a relay is usually expressed in number of cycles. Therefore, whenever the terms “time” or “duration” are used in IEC 61649, this term should be understood to mean “cycles”. However, with a given frequency of operation, the number of cycles can be transformed into respective times (e.g. times to failure (TTF)).

The failure criteria and the resulting characteristics of elementary relays describing their reliability in normal use are specified in this standard. A relay failure occurs when the specified failure criteria are met.

As the failure rate for elementary relays cannot be considered as constant, particularly due to wear-out mechanisms, the times to failure of tested items typically show a Weibull distribution. This standard provides both numerical and graphical methods to calculate approximate values for the two-parameter Weibull distribution, as well as lower confidence limits.

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 60050-191:1990, *International Electrotechnical Vocabulary (IEV) – Chapter 191: Dependability and quality of service*

IEC 60050-444:2002, *International Electrotechnical Vocabulary (IEV) – Part 444: Elementary relays*

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

IEC 61649:2008, *Weibull analysis*

IEC 61810-1:2008, *Electromechanical elementary relays – Part 1: General requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-191 and IEC 60050-444, some of which are reproduced below, as well as the following, apply.

3.1
item
any component that can be individually considered

[IEC 60050-191:1990, 191-01-01, modified]

NOTE For the purpose of this standard, items are elementary relays.

3.2
non-repaired item
item which is not repaired after a failure

[IEC 60050-191:1990, 191-01-03, modified]

3.3
cycle
operation and subsequent release/reset

[IEC 60050-444:2002, 444-02-11]

3.4
frequency of operation
number of cycles per unit of time

[IEC 60050-444:2002, 444-02-12]

3.5
reliability
ability of an item to perform a required function under given conditions for a given number of cycles or time interval

[IEC 60050-191:1990, 191-02-06, modified]

NOTE 1 It is generally assumed that the item is in a state to perform this required function at the beginning of the time interval.

NOTE 2 The term "reliability" is also used as a measure of reliability performance (see IEC 60050-191:1990, 191-12-01).

3.6
reliability test
experiment carried out in order to measure, quantify or classify a reliability measure or property of an item

[IEC 60300-3-5:2001, 3.1.27]

3.7
life test
test with the purpose of estimating, verifying or comparing the lifetime of the class of items being tested

[IEC 60300-3-5:2001, 3.1.17, modified]

3.8
cycles to failure
CTF
total number of cycles of an item, from the instant it is first put in an operating state until failure

3.9
mean cycles to failure
MCTF
expectation of the number of cycles to failure

3.10
time to failure
TTF
total time duration of operating time of an item, from the instant it is first put in an operating state until failure

[IEC 60050-191:1990, 191-10-02, modified]

3.11
mean time to failure
MTTF
expectation of the time to failure

[IEC 60050-191:1990, 191-12-07]

3.12
useful life
number of cycles or time duration until a certain percentage of items have failed

NOTE In this standard, this percentage is defined as 10 %.

3.13
failure
termination of the ability of an item to perform a required function

[IEC 60050-191:1990, 191-04-01, modified]

3.14
malfunction
single event when an item does not perform a required function

3.15
contact failure
occurrence of break and/or make malfunctions of a contact under test, exceeding a specified number

3.16
failure criteria
set of rules used to decide whether an observed event constitutes a failure

[IEC 60300-3-5:2001, 3.1.10]

3.17
contact load category
classification of relay contacts dependent on wear-out mechanisms

NOTE Various contact load categories are defined in IEC 61810-1.

4 General considerations

The provisions of this part of IEC 61810 are based on the relevant publications on dependability. In particular, the following documents have been taken into account: IEC 60050-191, IEC 60300-3-5 and IEC 61649.

The aim of reliability testing as given in this standard is to obtain objective and reproducible data on reliability performance of elementary relays representative of standard production quality. The tests described and the related statistical tools to gain reliability measures based on the test results can be used for the estimation of such reliability measures, as well as for the verification of stated measures.

NOTE 1 Examples for the application of reliability measurements are:

- establishment of reliability measures for a new relay type;
- comparison of relays with similar characteristics, but produced by different manufacturers;
- evaluation of the influence, on a relay, of different materials or different manufacturing solutions;
- comparison of a new relay with a relay which has already worked for a specific period of time;
- calculation of the reliability of an equipment or system incorporating one or more relays.

According to Clauses 8 and 9 of IEC 60300-3-5, for non-repaired items showing a non-constant failure rate the Weibull model is the most appropriate statistical tool for evaluation of reliability measures. This analysis procedure is described in IEC 61649.

Elementary relays within the scope of this standard are considered as non-repaired items. They generally do not exhibit a constant failure rate but a failure rate increasing with time, being tested until wear-out mechanisms become predominant. The cycles to failure of a random sample of tested items typically show the Weibull distribution.

NOTE 2 In cases where no wear-out mechanisms prevail, random failures with constant failure rate can be assumed. Then the shape parameter β of the Weibull distribution equals 1 and the reliability function becomes the well-known exponential law. For relay tests where only very few failures (or even no failures at all) occur, the WeiBayes approach of IEC 61649 might be appropriate. Another option may be the application of the sudden death method described in Clause 13 of IEC 61649.

The statistical procedures of this standard are valid only when at least 10 relevant failures are recorded.

Upon special agreement between manufacturer and user, the test may be performed with even less than 10 relays, provided the uncertainty of the estimated Weibull parameters is acceptable to them. In such a case the minimum number of tested relays shall be specified; this number then replaces the minimum number of 10 relays wherever prescribed in this standard. However, it shall be noted that this reduction of relay specimens is only acceptable where the graphical methods of A.5.1 are applied. For the numerical method of A.5.2 at least 10 failures are required, since the maximum likelihood estimation (MLE) is a computational method for larger sample sizes, i.e. when at least 10 relevant failures are recorded (see 9.3 of IEC 61649).

The first step in the analysis of the recorded cycles to failure (CTF) of the tested relays is the determination of the two distribution parameters of the Weibull distribution. In a second step, the mean cycles to failure (MCTF) is calculated as a point estimate. In a third step, the useful life is determined as the lower confidence limit of the number of cycles by which 10 % of the relay population will have failed (B_{10}).

With a given frequency of operation these reliability measures expressed in number of cycles (MCTF) can be transformed into respective times (MTTF), see Annex B for an example.

The statistical procedures require some appropriate computing facility. Software for evaluation of Weibull distributed data is commercially available on the market. Such software

may be used for the purpose of this standard provided it shows equivalent results when the data given in Annex B are used.

Since the number of cycles to failure highly depends on the specific set of test conditions (particularly the electrical loading of the relay contacts), values for MCTF and useful life derived from test data apply only to this set of test conditions, which have to be stated by the manufacturer together with the reliability measures.

5 Test conditions

5.1 Test items

As a minimum of 10 failures need to be recorded to perform the analysis described in this standard, 10 or more items (relays) should be submitted to the test. This allows the test to be truncated when at least 10 relays have failed. When the test is truncated at a specific number of cycles, all relays that have not yet failed may be considered to fail at that number of cycles (worst case assumption). However, at least 70 % of the tested relays shall fail physically. This allows the test to be carried out with 10 relays only, even when the test is truncated before all relays have physically failed (with a minimum of 7 physical failures recorded).

The items shall be selected at random from the same production lot and shall be of identical type and construction. No action is allowed on the test items from the time of sampling until the test starts.

Where any particular burn-in procedure or reliability stress screening is employed by the manufacturer prior to sampling, this shall apply to all production. The manufacturer shall describe and declare such procedures, together with the test results.

Unless otherwise specified by the manufacturer, all contacts of each relay under test shall be loaded as stated and monitored continuously during the test.

The test starts with all items and is stopped at some number of cycles. At that instant a certain number of items (minimum: 10 items) have failed. The number of cycles to failure of each of the failed items is recorded.

Items failed during the test are not replaced once they fail.

5.2 Environmental conditions

The testing environment shall be the same for all items.

– The items shall be mounted in the manner intended for normal service; in particular, relays for mounting onto printed circuit-boards are tested in the horizontal position, unless otherwise specified.
– The ambient temperature shall be as specified by the manufacturer.
– All other influence quantities shall comply with the values and tolerance ranges given in Table 1 of IEC 61810-1, unless otherwise specified.

5.3 Operating conditions

The set of operating conditions

– rated coil voltage(s);
– coil suppression (if any);
– frequency of operation;
– duty factor;

– contact load(s)

shall be as specified by the manufacturer.

Recommended values should be chosen from those given in Clause 5 of IEC 61810-1.

The test is performed on each contact load and each contact material as specified by the manufacturer.

All specified devices (for example, protective or suppression circuits), if any, which are part of the relay or stated by the manufacturer as necessary for particular contact loads, should be operated during the test.

The contacts shall be continuously monitored to detect malfunctions to open and malfunctions to close, as well as unintended bridging (simultaneous closure of make and break side of a changeover contact).

The contacts are connected to the load(s) in accordance with Table 12 of IEC 61810-1 as specified and indicated by the manufacturer.

5.4 Test equipment

The test circuit described in Annex C of IEC 61810-1 shall be used, unless otherwise specified by the manufacturer and explicitly indicated in the test report.

6 Failure criteria

Whenever any contact of a relay under test fails to open or fails to close or exhibits unintended bridging, this shall be considered as a malfunction.

Three severity levels are specified:

– severity A: the first detected malfunction is defined as a failure;
– severity B: the sixth detected malfunction or two consecutive malfunctions are defined as a failure;
– severity C: as specified by the manufacturer.

The severity level used for the test shall be as prescribed by the manufacturer and stated in the test report.

7 Output data

The data to be analysed consists of cycles to failure (CTF) for each of the items put on test. These CTF values have to be known exactly. However, it is not necessary to gather the CTF values for all items under test, as the test may be stopped before all items have failed, provided at least 10 CTF values from different failed items are available.

8 Analysis of output data

The evaluation of the CTF values obtained during the test shall be carried out in accordance with the procedures given in Annex A.

9 Presentation of reliability measures

The basic reliability measures applicable to elementary relays as described in this standard and obtained from the data analysis shall be provided.

However, since the values obtained for these reliability measures using the procedures of Annex A depend to a great extent on the basic design characteristics of the relay, the test conditions of Clause 5 and the failure criteria of Clause 6, the following information shall also be provided together with the test results:

– relay type for which the results are valid:
  a) contact material;
  b) deviations from standard types (if any);
  c) type of termination;
– set of operating conditions (see 5.3):
  a) rated coil voltage(s);
  b) coil suppression (if any);
  c) frequency of operation;
  d) duty factor;
  e) contact load(s);
  f) ambient conditions;
– test schematic selected (see Clause C.3 of IEC 61810-1, or test circuit details, if different from the circuit described in Clause C.1 of IEC 61810-1);
– severity level (see Clause 6).

In addition basic data of the test and the related analysis (see Annex A) shall be given in the test report:

– number of items (n) on test;
– number of failed items (r) registered during the test (minimum 10);
– time (given in number of cycles) when the test was stopped (T);
– confidence level, if other than 90 %.

The test results are applicable to the samples specifically tested and variants, as stipulated by the manufacturer, provided that the relevant design characteristics remain the same.

NOTE Acceptable examples are coil variants with the same ampere-turns. Unacceptable examples are variants with AC in place of DC coils, or different contact dynamics.

When test results for various operating conditions (for example, contact loads) are available, they may be compiled as a family of curves or in suitable tables. However, it shall be ensured that a sufficient number of points are determined when plotting such curves.

Annex A
(normative)

Data analysis

A.1 General

This annex has been derived from the reliability standard IEC 61649:2008 with certain modifications necessary to adopt the procedures to elementary relays. The distribution considered in the reliability standard is of the Weibull type, which has been empirically recognized to correspond to an appropriate data analysis for elementary relays.

The graphical method, as well as the numerical method are covered in IEC 61649. In addition, not only the Weibull probability analysis but also the Weibull hazard analysis is taken up in the graphical method. Here, Weibull hazard and Weibull probability analyses are applied to complete and incomplete data, respectively. The latter is especially useful for the reliability analysis of relays because many data sets obtained from life tests are incomplete (censored tests).

NOTE 1 Incomplete data are the data sets obtained from the test after either a certain number of failures or a certain number of cycles, when there are still items functioning, whereas complete data are the data sets without censoring.

This annex deals with the Weibull probability plot and the Weibull hazard plot for the graphical method based upon median rank regression (MRR) principles, and the maximum likelihood estimation (MLE) for the numerical method in accordance with the provisions of IEC 61649.

When more in-depth information is required, IEC 61649 is to be consulted.

The concept “time” is to be understood as “cycles” in the case of relays. However, with a given frequency of operation, the values indicated in numbers of cycles can be transformed into respective times.

NOTE 2 Whereas the variable “time” (symbol: t) is used within IEC 61649, this standard therefore is based on the variable “cycles” (symbol: c).

For the sake of consistency, the following symbols and equations are reproduced in accordance with IEC 61649.

A.2 Abbreviations

CDF Cumulative distribution function

MRR Median rank regression

MLE Maximum likelihood estimation

MCTF Mean cycles to failure

PDF Probability density function

A.3 Symbols and definitions

The following symbols are used in this Annex A, and in both Annex B and Annex C. Auxiliary constants and functions are defined in the text.

$f(c)$ probability density function

$F(c)$ cumulative distribution function (failure probability)