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GUIDE

GUIDE

Application of uncertainty of measurement to conformity assessment activities in the electrotechnical sector

Application de l'incertitude de mesure aux activités d'évaluation de la conformité dans le secteur électrotechnique

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

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CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

APPLICATION OF UNCERTAINTY OF MEASUREMENT TO CONFORMITY ASSESSMENT ACTIVITIES IN THE ELECTROTECHNICAL SECTOR

FOREWORD

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This second edition of IEC Guide 115 has been prepared, in accordance with ISO/IEC Directives, Part 1, Annex A, by IECEE/CTL. This is a non-mandatory guide in accordance with SMB Decision 136/8.

This second edition cancels and replaces the first edition published in 2007.

The main changes with respect to the previous edition are as follows:

a) editorial alignment to ISO/IEC 17025:2017 without adapting the technical content;
b) references to ISO/IEC 17025:2005 and ISO/IEC 17025:2017 in order to help for the transition to the new edition of ISO/IEC 17025.

The text of this IEC Guide is based on the following documents:

Four months' vote	Report on voting
SMBNC/8/DV	SMBNC/14/RV

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 Guide is English.

This publication has been drafted in accordance with the 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/standardsdev/publications.

INTRODUCTION

This document has been prepared by the IECEE Committee of Testing Laboratories (CTL) to provide guidance on the practical application of the measurement uncertainty requirements of ISO/IEC 17025 to the electrical safety testing conducted within the IECEE CB Scheme.

The IECEE CB Scheme is a multilateral, international agreement, among over 40 countries and some 60 national certification bodies, for the acceptance of test reports on electrical products tested to IEC standards.

The aim of the CTL is, among other tasks, to define a common understanding of the test methodology with regard to the IEC standards as well as to ensure and continually improve the repeatability and reproducibility of test results among the member laboratories.

The practical approach to measurement uncertainty outlined in this document has been adopted for use in the IECEE Schemes, and is also extensively used around the world by testing laboratories engaged in testing electrical products to national safety standards.

This document is of particular interest to the following IEC technical committees, which can decide to make use of it if necessary:

TECHNICAL COMMITTEE 13:	ELECTRICAL ENERGY MEASUREMENT AND CONTROL
TECHNICAL COMMITTEE 17:	HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR
TECHNICAL COMMITTEE 18:	ELECTRICAL INSTALLATIONS OF SHIPS AND OF MOBILE AND FIXED OFFSHORE UNITS
TECHNICAL COMMITTEE 20:	ELECTRIC CABLES
TECHNICAL COMMITTEE 21:	SECONDARY CELLS AND BATTERIES
TECHNICAL COMMITTEE 22:	POWER ELECTRONIC SYSTEMS AND EQUIPMENT
TECHNICAL COMMITTEE 23:	ELECTRICAL ACCESSORIES
TECHNICAL COMMITTEE 32:	FUSES
TECHNICAL COMMITTEE 33:	POWER CAPACITORS AND THEIR APPLICATIONS
TECHNICAL COMMITTEE 34:	LIGHTING
TECHNICAL COMMITTEE 35:	PRIMARY CELLS AND BATTERIES
TECHNICAL COMMITTEE 38:	INSTRUMENT TRANSFORMERS
TECHNICAL COMMITTEE 40:	CAPACITORS AND RESISTORS FOR ELECTRONIC EQUIPMENT
TECHNICAL COMMITTEE 47:	SEMICONDUCTOR DEVICES
TECHNICAL COMMITTEE 59:	PERFORMANCE OF HOUSEHOLD AND SIMILAR ELECTRICAL APPLIANCES
TECHNICAL COMMITTEE 61:	SAFETY OF HOUSEHOLD AND SIMILAR ELECTRICAL APPLIANCES
TECHNICAL COMMITTEE 62:	ELECTRICAL EQUIPMENT IN MEDICAL PRACTICE
TECHNICAL COMMITTEE 64:	ELECTRICAL INSTALLATIONS AND PROTECTION AGAINST ELECTRIC SHOCK
TECHNICAL COMMITTEE 65:	INDUSTRIAL-PROCESS MEASUREMENT, CONTROL AND AUTOMATION
TECHNICAL COMMITTEE 66:	SAFETY OF MEASURING, CONTROL AND LABORATORY EQUIPMENT
TECHNICAL COMMITTEE 76:	OPTICAL RADIATION SAFETY AND LASER EQUIPMENT
TECHNICAL COMMITTEE 77:	ELECTROMAGNETIC COMPATIBILITY

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TECHNICAL COMMITTEE 80:	MARITIME NAVIGATION AND RADIOCOMMUNICATION EQUIPMENT AND SYSTEMS
TECHNICAL COMMITTEE 82:	SOLAR PHOTOVOLTAIC ENERGY SYSTEMS
TECHNICAL COMMITTEE 110:	ELECTRONIC DISPLAYS

APPLICATION OF UNCERTAINTY OF MEASUREMENT TO CONFORMITY ASSESSMENT ACTIVITIES IN THE ELECTROTECHNICAL SECTOR

1 Scope

This Guide presents a practical approach to the application of uncertainty of measurement to conformity assessment activities in the electrotechnical sector. It is specifically conceived for use in IECEE Schemes as well as by testing laboratories engaged in testing electrical products to national safety standards. It describes the application of uncertainty of measurement principles and provides guidance on making uncertainty of measurement calculations. It also gives some examples relating to uncertainty of measurement calculations for product conformity assessment testing.

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.

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

3 Terms and definitions

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

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

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

3.1
coverage factor
number that, when multiplied by the combined standard uncertainty, produces an interval (the expanded uncertainty) about the measurement result that can be expected to encompass a large, specified fraction (e.g. 95 %) of the distribution of values that could be reasonably attributed to the measurand

3.2
combined standard uncertainty
result of the combination of standard uncertainty components

3.3
error of measurement
result of a measurement minus a true value of the measurand

Note 1 to entry: The error of measurement is not precisely quantifiable because the true value lies somewhere unknown within the range of measurement uncertainty.

3.4
expanded uncertainty
value obtained by multiplying the combined standard uncertainty by a coverage factor

3.5
level of confidence
probability that the value of the measurand lies within the quoted range of uncertainty

3.6
measurand
quantity subjected to measurement, evaluated in the state assumed by the measured system during the measurement itself

[SOURCE: IEC 60359:2001, 3.1.1, modified – The NOTES have been deleted.]

3.7
quantity X_i
source of uncertainty

3.8
standard deviation
positive square root of the variance

3.9
standard uncertainty
estimated standard deviation

3.10
uncertainty of measurement
parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

[SOURCE: IEC 60359:2001, 3.1.4, modified – The NOTES have been deleted.]

3.11
Type A evaluation method
method of evaluation of uncertainty of measurement by the statistical analysis of a series of observations

3.12
Type B evaluation method
method of evaluation of uncertainty of measurement by means other than the statistical analysis of a series of observations

4 Application of uncertainty of measurement principles

4.1 General

4.1.1 Qualification and acceptance of Certification Body Testing Laboratories (CBTLs), e.g. in the IECEE, are performed according to ISO/IEC 17025.

ISO/IEC 17025:2005, 5.4.6.2

"Testing laboratories shall have and apply procedures for estimating uncertainty of measurement. In certain cases, the nature of the test method may preclude rigourous, metrologically and statistically valid, calculation of uncertainty of measurement. In these cases the laboratory shall at least attempt to identify all the components of uncertainty and make a reasonable estimation, and shall ensure that the form of reporting of the result does not give a wrong impression of the uncertainty. Reasonable estimation shall be based on knowledge of the performance of the method and on the measurement scope and shall make use of, for example, previous experience and validation data.

NOTE 1 The degree of rigour needed in an estimation of uncertainty of measurement depends on factors such as:

– the requirements of the test method;
– the requirements of the client;
– the existence of narrow limits on which decisions on conformance to a specification are based.

NOTE 2 In those cases where a well-recognized test method specifies limits to the values of the major sources of uncertainty of measurement and specifies the form of presentation of calculated results, the laboratory is considered to have satisfied this clause by following the test method and reporting instructions (see 5.10)."

ISO/IEC 17025:2017, 7.6

"7.6 Evaluation of measurement uncertainty

7.6.1 Laboratories shall identify the contributions to measurement uncertainty. When evaluating measurement uncertainty, all contributions that are of significance, including those arising from sampling, shall be taken into account using appropriate methods of analysis.

7.6.2 A laboratory performing calibrations, including of its own equipment, shall evaluate the measurement uncertainty for all calibrations.

7.6.3 A laboratory performing testing shall evaluate measurement uncertainty. Where the test method precludes rigorous evaluation of measurement uncertainty, an estimation shall be made based on an understanding of the theoretical principles or practical experience of the performance of the method.

NOTE 1 In those cases where a well-recognized test method specifies limits to the values of the major sources of measurement uncertainty and specifies the form of presentation of the calculated results, the laboratory is considered to have satisfied 7.6.3 by following the test method and reporting instructions.

NOTE 2 For a particular method where the measurement uncertainty of the results has been established and verified, there is no need to evaluate measurement uncertainty for each result if the laboratory can demonstrate that the identified critical influencing factors are under control."

4.1.2 ISO/IEC 17025:2005, 5.10.3.1 c) states:

"c) where applicable, a statement on the estimated uncertainty of measurement; information on uncertainty is needed in test reports, when it is relevant to the validity or application of the test results, when a customer's instruction so requires, or when the uncertainty affects compliance to a specification limit;".

ISO/IEC17025:2017, 7.8.3.1 c) states:

"c) where applicable, the measurement uncertainty presented in the same unit as that of the measurand or in a term relative to the measurand (e.g. percent) when:

– it is relevant to the validity or application of the test results;
– a customer's instruction so requires, or

– the measurement uncertainty affects conformity to a specification limit;".

4.1.3 ISO/IEC 17025 was written as a general use document, for all industries. Uncertainty of measurement principles are applied to laboratory testing and presentation of test results to provide a degree of assurance that decisions made about conformance of the products tested according to the relevant requirements are valid. Procedures and techniques for uncertainty of measurement calculations are well established. This document is written to provide more specific guidance on the application of uncertainty of measurement principles to reporting of testing results under the CB Scheme.

4.1.4 Clause 4 of this document focuses on the application of uncertainty of measurement principles under the CB Scheme, while Clause 5 provides guidance on making uncertainty of measurement calculations and includes examples.

4.2 Uncertainty of measurement principles

A challenge to applying uncertainty of measurement principles to conformity assessment activities is managing the cost, time and practical aspects of determining the relationships between various sources of uncertainty. Some relationships are either unknown or would take considerable effort, time and cost to establish. There are a number of proven techniques available to address this challenge. These techniques include eliminating from consideration those sources of variability which have little influence on the outcome and minimizing significant sources of variability by controlling them.

4.3 Background

4.3.1 Test methods used under the IECEE CB Scheme are in essence consensus standards. Criteria used to determine conformance with requirements are most often based on a consensus of judgment of what the limits of the test result should be. Exceeding the limit by a small amount does not result in an imminent hazard. Test methods used can have a precision statement expressing the maximum permissible uncertainty expected to be achieved when the method is used. Historically, test laboratories have used state-of-the-art equipment and not considered uncertainty of measurement when comparing results to limits. Safety standards have been developed in this environment and the limits in the standards reflect this practice.

4.3.2 Test parameters that influence the results of tests can be numerous. Nominal variations in some test parameters have little effect on the uncertainty of the measurement result. Variations in other parameters can have an effect. However, the degree of influence can be minimized by limiting the variability of the parameter when performing the test.

4.3.3 A frequent way of accounting for the effects of test parameters on test results is to define the acceptable limits of variability of test parameters. When this is done, any variability in measurement results obtained due to changes in the controlled parameters is not considered significant if the parameters are controlled within the limits. Examples of the application of this technique require:

a) input power source to be maintained: voltage ±2 %, frequency ±0,5 %, total harmonic distortion maximum 3 %;
b) ambient temperature: 23 °C ± 2 °C;
c) relative humidity: 93 % ± 2 % (RH);
d) personnel: documented technical competency requirements for the test;
e) procedures: documented laboratory procedures;
f) equipment accuracy: instrumentation with accuracy according to CTL OD-5014.

NOTE The acceptable limits in items a) through c) are given as examples and do not necessarily represent actual limits established.

4.3.4 The end result of controlling sources of variability within prescribed limits is that the measurement result can be used as the best estimate of the measurand. In effect, the uncertainty of measurement about the measured result is negligible with regard to the final pass/fail decision.

4.4 Uncertainty of measurement principles – Application of procedures

4.4.1 When a test results in measurement of a variable, there is uncertainty associated with the test result obtained.

4.4.2 Procedure 1, see Figure 1, is used when calculation of uncertainty of measurement is required by ISO/IEC 17025:2017, 7.6.3 and 7.8.3.1 c). Calculate the uncertainty for measurement (see Clause 5) and compare the measured result with the uncertainty band to a defined acceptable limit. The measurement complies with the requirement if the probability of its being within the limit is at least 50 %.

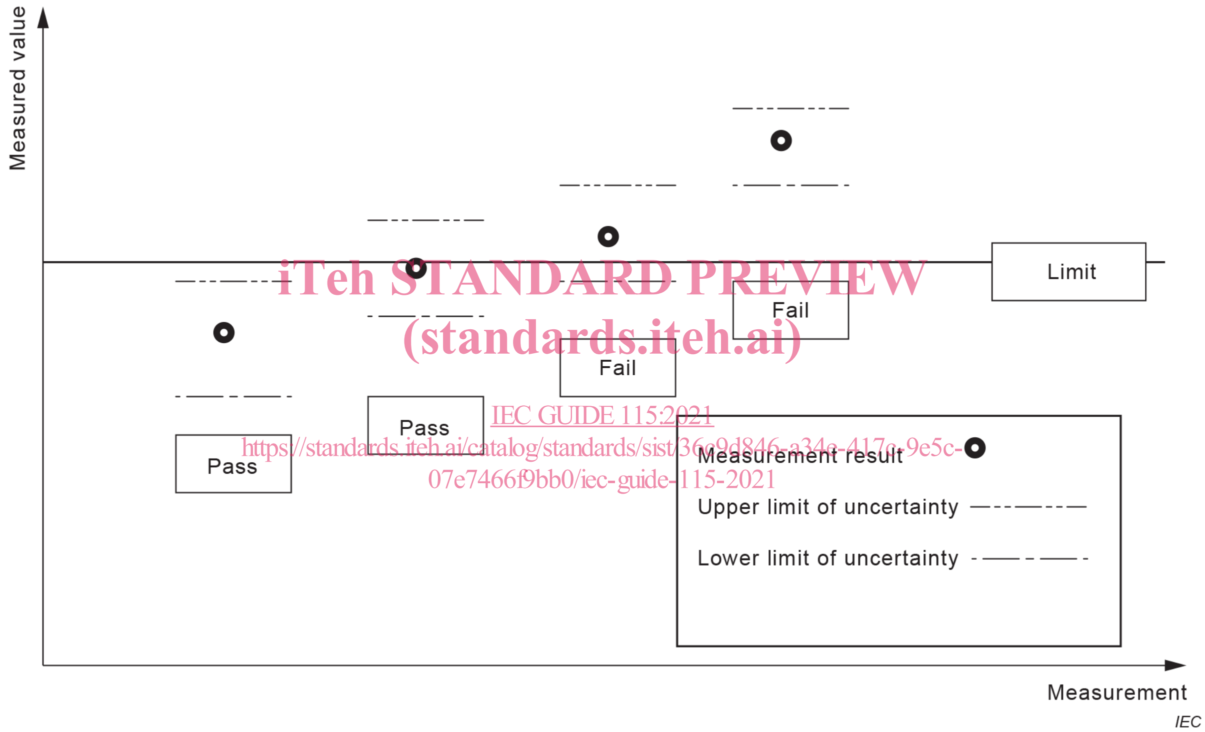

Figure 1 – Procedure 1: uncertainty of measurement calculated

4.4.3 Procedure 2, see Figure 2, is used when ISO/IEC 17025:2017, 7.6.3, Note 2, applies. Procedure 2 is the traditional method used under the CB Scheme and has been referred to as the "accuracy method". The test performed is routine. Sources of uncertainty are minimized so that the uncertainty of the measurement need not be calculated to determine conformance with the limit. Variability in test parameters is within acceptable limits. Test parameters such as power source voltage, ambient temperature and ambient humidity are maintained within the defined acceptable limits for the test. Personnel training and laboratory procedures minimize uncertainty of measurement due to human factors. Instrumentation used has an uncertainty within prescribed limits.

NOTE The name, accuracy method, comes from the concept of limiting uncertainty due to instrumentation by using instruments within prescribed accuracy limits. For this purpose, the accuracy specification for an instrument is considered the maximum uncertainty of measurement attributable to the instrument.

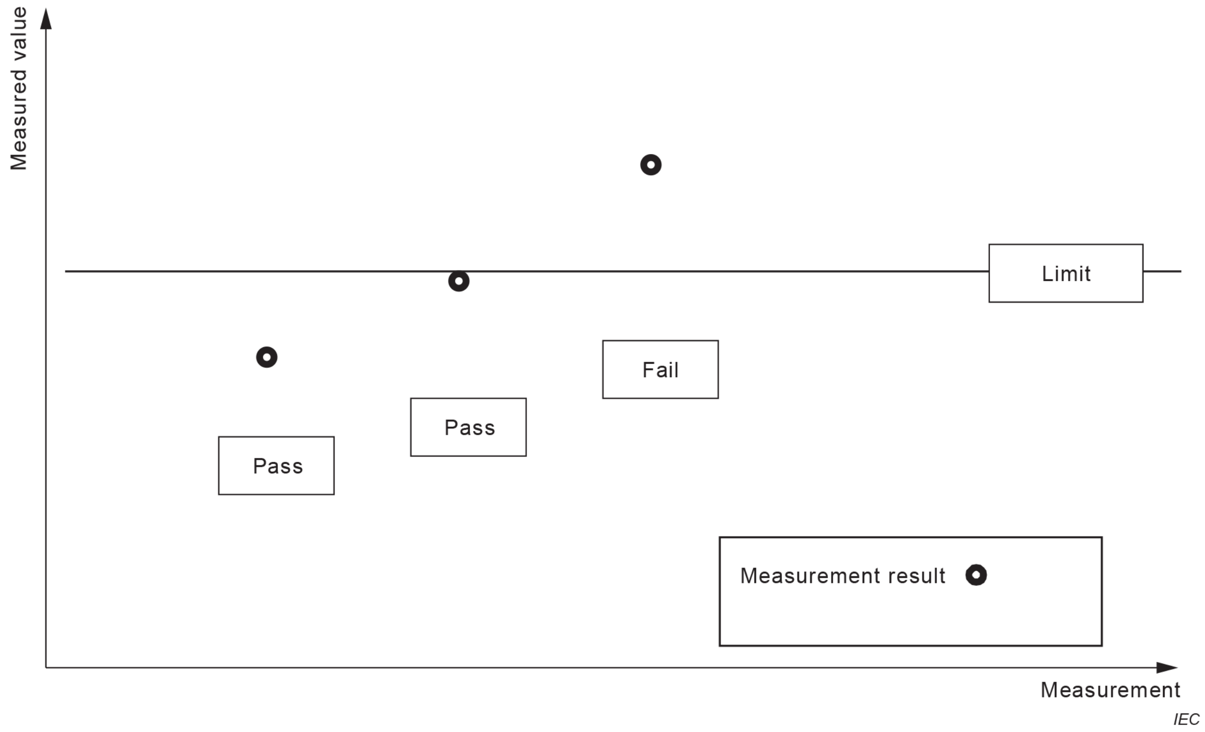

Figure 2 – Procedure 2: accuracy method

4.4.4 The measurement result is considered in conformance with the requirement if it is within the prescribed limit. It is not necessary to calculate the uncertainty associated with the measurement result.

4.4.5 Example – Procedure 2

- Power supply output voltage measurement test
  a) Method

  Connect the power supply to a mains source of rated voltage, ±2 %, and rated frequency. Measure output voltage from power supply while loaded to rated current, ±2 %, with a non-inductive resistive load. The test is to be performed in an ambient temperature of 23 °C ± 2 °C.

  Use meters having an accuracy conforming to CTL OD-5014.

  The power supply conforms to the requirements if the output voltage is ±5 % of rated value.

  b) Results

  Power supply rating: 240 V, 50 Hz input; 5 V d.c., 2 A output. See Table 1.

Table 1

Input		**Output**	
U V	**Frequency** Hz	I A	U V
242	50	2,01	5,1

Test ambient temperature: 24 °C.

The accuracy of the instruments used is shown in Table 2.

Table 2

Meter	Calibrated accuracy for scale used for measurement	CTL decision 251A, max.
Thermometer	±1,0 °C	±2,0 °C
Voltmeter	±0,5 %	±1,5 %
Frequency meter	±0,2 %	±0,2 %
Current meter	±0,5 %	±1,5 %

The conclusion of the test is that the power supply conforms to the requirement.

4.5 Conclusion

4.5.1 The traditional approach to addressing uncertainty of measurement for conformity assessment activities under the CB Scheme has been the application of the accuracy method. This method minimizes sources of uncertainty associated with the performance of routine tests so that the measurement result can be directly compared with the test limit to determine conformance with the requirement. This method conforms to the requirements in ISO/IEC 17025. The accuracy method takes less time and costs less to implement than detailed uncertainty of measurement calculations and the conclusions reached are valid with regard to the final pass/fail decision.

4.5.2 In situations where the traditional accuracy method does not apply, uncertainty of measurement values are calculated and reported along with the variables results obtained during testing.

5 Guidance on making uncertainty of measurement calculations including examples of how to perform the calculations

5.1 General principles

5.1.1 Clause 5 is meant to be a short and simplified summary of the steps to be taken by a CBTL when the need to estimate uncertainties arises. It also includes examples of how to perform the calculations.

5.1.2 It is by no means a comprehensive paper about measurement uncertainty (MU), its sources and estimation in general, but is supposed to offer a practical approach for most applicable circumstances within a CBTL in the IECEE CB Scheme.

5.1.3 No measurement is perfect and the imperfections give rise to error of measurement in the result. Consequently, the result of a measurement is only an approximation to the measured value (measurand) and is only complete when accompanied by a statement of the uncertainty of that approximation. Indeed, because of measurement uncertainty, a true value can never be known.

5.1.4 The total uncertainty of a measurement is a combination of a number of component uncertainties. Even a single instrument reading may be influenced by several factors. Careful consideration of each measurement involved in the test is required to identify and list all the factors that contribute to the overall uncertainty. This is a very important step and requires a good understanding of the measuring equipment, the principles and practice of the test and the influence of environment.

5.1.5 ISO/IEC GUIDE 98-3:2008 has adopted the approach of grouping uncertainty components into two categories based on their method of evaluation: Type A and Type B. This categorization of the methods of evaluation, rather than of the components themselves, avoids certain ambiguities.