SLOVENSKI STANDARD
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High-voltage test techniques - Part 2: Measuring systems - Amendment 1

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Hochspannungs-Prüftechnik -- Teil 2: Meßsysteme

Techniques des essais à haute tension -- Partie 2: Systèmes de mesure

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High-voltage test techniques
Part 2: Measuring systems

Techniques des essais à haute tension
Partie 2: Systèmes de mesure

Hochspannungs-Prüftechnik
Teil 2: Meßsysteme

This amendment A11 modifies the European Standard EN 60060-2:1994; it was approved by CENELEC on 1997-07-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this amendment the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This amendment exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

This amendment was prepared by CENELEC Reporting Secretariat SR 42.

The text of the draft was submitted to the formal vote and was approved by CENELEC as amendment A11 to EN 60060-2:1994 on 1997-07-01.

The following dates were fixed:

- latest date by which the amendment has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 1998-08-01
- latest date by which the national standards conflicting with the amendment have to be withdrawn (dow) 1998-08-01

Add the following annex H:

Annex H (informative)

A procedure for estimating uncertainty of high-voltage measurements

H.1 Introduction

This part of IEC 60 gives additional procedures for estimating the uncertainty of high-voltage measurements and calibrations of high-voltage measuring systems especially by comparison with reference measuring systems.

The evaluation and expression of uncertainty in measurement is described in detail in the ISO/TAG 4/WG3, Jan. 1993: "Guide to the expression of uncertainty in measurement" /1/. This Annex is closely related to this guide, and it forms the basis for demonstrating that HV measurements are carried out with uncertainties not higher than specified in this standard.

H.2 General principles

The uncertainty of a measurement or calibration result is a parameter characterising the dispersion of the values that could reasonably be attributed to the measurand. The parameter used is the half-width of a confidence interval (see : IEC 60-1: 1989; Annex A), which covers the true (but unknown) value related to the result of the measurement (calibration) with a specified probability (called "confidence level") of preferably 95 %.

Note 1: If it is shown that the uncertainty U of the scale factor of a measuring system is 2 % at a confidence level of P = 95 %, a voltage value measured with this system including its uncertainty can be given by, e.g., 420,1 kV ± 8,4 kV. Then different measurements, performed on the same measurand with the same procedure and the same uncertainty, could produce results in the range from 411,7 kV to 428,5 kV.

Formally the uncertainty is defined by

$$U = k \cdot s \qquad \text{(H.1)}$$

where: s standard deviation
k coverage factor.

The coverage factor, k, denotes the confidence level of the measurement result. A preferred value for calibrations and tests is k = 2, corresponding to a confidence level of 95 %.

In most measurements, the overall uncertainty is the sum of several contributions. It is positive and given without sign. The contributions are grouped in the following two categories, Type A and Type B, according to the method used to evaluate their numerical values.

Note 2: In some publications, especially former ones, uncertainty components are categorised as "random" and "systematic". Such a categorisation can be ambiguous or misleading and should therefore not be used for the uncertainty.

Note 3: Uncertainty must not be confused with the tolerance of a voltage value or a parameter given in IEC 60-1. The tolerance describes accepted deviations from given values, e. g., for an impulse test voltage of 500 kV with a tolerance of ± 3 %, each value between 485 kV and 515 kV has to be considered as the acceptable test voltage.

H.2.1 Type A evaluation of uncertainty

The type A evaluation of uncertainty includes all types of statistical analysis of series of measurements with random results. In the following such a uncertainty contribution is called "type A uncertainty". It is characterised by the following set of parameters for the random variable.

H.2.1.1 Arithmetic mean

In most cases, the best available estimate of the random variable is the arithmetic mean x_m:

$$x_m = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad \text{(H.2)}$$

where n number of measurement
x_i measured values for i= 1 to n.

H.2.1.2 Experimental standard deviation

A measure of the dispersion of the random variable is the experimental standard deviation s_e of the measured results x_i:

$$s_e = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - x_m)^2}. \qquad \text{(H.3)}$$

Note: The quadratic value of the standard deviation, s_e^2, is called (experimental) variance.

H.2.1.3 Experimental standard deviation of the mean

When a measurement (or calibration) is repeated several times, the arithmetic mean will also show a dispersion, which is characterised by the experimental standard deviation of the mean s_m:

$$s_m = \frac{s_e}{\sqrt{n}}. \qquad \text{(H.4)}$$

Note: The quadratic value of the standard deviation of the mean, s_m^2, is called variance of the mean.

H.2.1.4 Type A uncertainty

The type A uncertainty, U_A, is the half-width of the confidence interval for the arithmetic mean on the assumption of Gaussian (randomly) distributed variables and a pre-selected confidence level P.

a) Small number of measurements

When the number of measurements is small (e.g., n = 10 as required in clause 6 of this standard), the type A uncertainty U_A is given by

$$U_A = t \cdot s_m = \frac{t \cdot s_e}{\sqrt{n}} \qquad \text{(H.5)}$$

where t is the Student factor obtained from Table H.1.

b) Large number of measurements (n >> 10)

At the preferred confidence level of 95 % for a sample n >> 10 measurements, *t* in equation (H.5) can be replaced by k = 2. The uncertainty of the mean of the samples, x_m, then becomes:

$$U_A = 2 \cdot s_m \qquad \text{(H.6)}$$

Table H.1 - Student *t* distribution
Values of *t* for specified confidence level *P* in %
as a function of the number of measurements, *n*

n \ *P* %	68,3	90,0	95,0	99,7
2	1,84	6,31	12,7	-
3	1,32	2,92	4,30	-
4	1,20	2,35	3,18	9,22
5	1,14	2,13	2,78	6,62
6	1,11	2,02	2,57	5,51
7	1,09	1,94	2,45	4,90
8	1,08	1,89	2,36	4,53
9	1,07	1,86	2,31	4,28
10	1,06	1,83	2,26	4,09
20	1,03	1,73	2,09	3,45
[1]	k = 1,00	k = 1,65	k = 1,96[2]	k = 3,00

[1] When $n \to \infty$, $t \to$ k
[2] For *P* = 95 %, *k* is rounded to 2 [1].

NOTE- In statistics, *n*-1 is called the number of degrees of freedom of the distribution

c) Previously established large number of measurements

If a value of s_e has been obtained from a large number of measurements (e. g., $n_1 \geq 20$ for a confidence level of 95 %) for a Measuring System to which no significant change has been made, then the uncertainty in a subsequent single (or repeated) measurement is:

$$U_A = \frac{k\, s_e}{\sqrt{n_2}} \qquad \text{(H.7)}$$

where n_2 = 1 (or 2, etc.) and $n_2 << n_1$.

H.2.2 Type B evaluation of uncertainty

The type B evaluation of uncertainty includes the evaluation of uncertainty by means other than statistical analysis of series of measurements. This evaluation is based on special knowledge or estimation of the potential influence any parameter might exert on the measurement. In the following such uncertainty contributions are called "type B contribution", their combination is called "type B uncertainty".

Note 1: However, if the influence of a parameter is well known, the measurand should first be corrected for it as far as possible, e.g., the influence of ambient temperature. Often, such a correction cannot fully compensate for the influencing parameter, e.g., the temperature of large HV dividers is uncertain within a few degrees due to temperature variations and gradients in most HV halls. The small remaining influence of the parameter will then contribute to the uncertainty.

The pool of information for the type B evaluation may include:

- uncertainties provided in calibration and other certificates of the measuring system used;
- experience or general knowledge of the behaviour (e. g., drift of the scale factor due to ageing or temperature variations);
- manufacturer's specifications (e. g., resolution of instruments).

Note 2: Once a Measuring System (or a component) has been calibrated and then is used in a test, the uncertainty of the calibration is treated in the estimation of the uncertainty of the test result as one of the Type B contributions.

The type B contributions may have different distributions as described below.

H.2.2.1 Contributions by normal (Gaussian) distribution

Normal distribution can be assumed when this is explicitly stated or when a confidence level is indicated as, e.g., in:

- calibration certificates
- manufacturer's specifications.

The known standard deviation s_{Bg} or the known uncertainty U_{Bg}, both linked by

$$U_{Bg} = k \cdot s_{Bg} \qquad \text{(H.8)}$$

(k = 2 for P = 95 %) are used for further calculations. When a number of *n* normally distributed contributions has to be considered, the total value is

$$s_{Bg} = \sqrt{s_{Bg1}^2 + s_{Bg2}^2 + \ldots + s_{Bgn}^2} \qquad \text{(H.9)}$$

or

$$U_{Bg} = \sqrt{U_{Bg1}^2 + U_{Bg2}^2 + \ldots + U_{Bg3}^2}\,. \qquad \text{(H.10)}$$

H.2.2.2 Contributions by rectangular distribution

Rectangular distribution is assumed when only lower and upper limits of the measurand can be estimated, i.e. any measured value between the estimated limits is assumed to be of equal likelihood. This is the case especially for the

- resolution of instruments in a single measurement,
- drift of the scale factor.

A rectangular distribution with the lower limit a_l and the upper limit a_u is characterised by its half-width:

$$a = \frac{1}{2}(a_u - a_l), \tag{H.11}$$

its mean value:

$$a_m = \frac{a_u + a_l}{2} \tag{H.12}$$

and the standard deviation:

$$s_{Br} = \frac{a}{\sqrt{3}}. \tag{H.13}$$

When a number of n uncorrelated rectangular contributions has to be considered, the total standard deviation is given by

$$s_{Br} = \sqrt{\frac{a_1^2}{3} + \frac{a_2^2}{3} + \ldots \frac{a_n^2}{3}} \tag{H.14}$$

and the corresponding uncertainty by:

$$U_{Br} = k \cdot s_{Br} \tag{H.15}$$

Note: The resultant distribution of three and more rectangular contributions resembles a random distribution.

H.2.2.3 Combination of type B contributions

On the assumption that the contributions are not correlated, the standard deviation of all type B contributions is calculated from eqs. (H.9) and (H.14):

$$s_B = \sqrt{s_{Bg}^2 + s_{Br}^2} \tag{H.16}$$

and the type B uncertainty from eqs. (H.10) and (H.15):

$$U_B = \sqrt{U_{Bg}^2 + U_{Br}^2}\ . \tag{H.17}$$

Both values are linked by

$$U_B = k s_B \tag{H.18}$$

or, in detail, with eqs. (H.8), (H.10), (H.14), to (H.18)