Expression of the Measurement Accuracy in Calibration with using Calmet's instruments - time and temperature influence

Calmet
Calibration

Application Note No17

What is the Accuracy and how to express it?

Accuracy is a qualitative expression of the closeness of a measurement's result to the true value. In the recent times, accuracy of measuring instruments is described using two quantitative terms:

- **limits of error** EN 60359 [1)], which is the traditional description of the accuracy used in power engineering and industries associated with it,
- **uncertainty** EA-4/02 [2)], which is a new description of the accuracy used in laboratories.

Calmet Ltd provides the broad range of calibrators, meters and testers for use in laboratories and factories as well as on site. Therefore, the accuracy of some Calmet's measuring instruments is expressed by the specification of uncertainty (mainly calibrators) and the second – the specification of the limits of error (mainly testers).

This application note presents how to calculate the uncertainty from error limits.

[1)] EN 60359 Electrical and electronic measurement equipment – Expression of performance.

[2)] EA-4/02 Expression of the Uncertainty of measurement in Calibration

Contents of the next part of this information note

1. The Caltest 300 Analyser uncertainty budget – how to calculate the uncertainty of the Caltest 300 with regard to the influence of time and temperature
2. The Measuring uncertainty budget of the Meter Test System with the Caltest 300 - how to calculate the uncertainty of the DUT's error in the Meter Test System MTS with the Caltest 300 as reference meter

The Caltest 300 Analyser

The MTS is controlled by a personal computer with *Calsoft 300 PC soft* and contains: a three phase phantom load or (power network) AC power source, the Caltest 300 as a reference meter with an error calculator. The Device Under Test DUT and Caltest 300 convert the power into performance-related impulses and then transmit these to an error calculator. The error calculator uses these impulse values to calculate the relative measuring deviation of the DUT using the error formula

$$E_X\% = \frac{E_M - E_R}{E_R} \cdot 100\%$$

where:
E_M = value of the energy measured by the DUT,
E_R = reference value of the energy.

Specification

Active power/energy accuracy of the Caltest 300 with direct inputs is expressed as limits of intrinsic error and it covers:

- reference uncertainty of standards – the traceability of the external standards used for calibration,
- stability in 12 months,
- influence of ambient temperature in range +20…+26°C,
- influence of humidity in range to 90%@+0…+30°C and to 75%@+30…+50°C,
- line regulation - influence of power supply voltage in voltage range 85…265V and frequency range 45…65Hz or DC.

Ambient temperature influence in temperature range -5…+20°C and +26…+50°C is 0.1 of the limits of intrinsic error per 1°C.

Long time stability is 0.5 of the limits of intrinsic error per $\sqrt{year}$.

Short time stability is 0.25 of limits of intrinsic error per 1 hour.

Model equation

$\delta E_X = \delta E_{SI} + \delta E_{SS} + \delta E_{ST}$

List of values

Parameter	Unit	Definition	Description
δE_X	%	Measuring uncertainty of the Caltest 300	
δE_{SI}	%	Intrinsic error from the Caltest 300 specification	Type B Rectangular distribution Intrinsic error limit: 0.050%
δE_{SS}	%	Time stability error from the Caltest 300 specification	Type B Rectangular distribution Time stability error limit: 0.025%x $\sqrt{year}$
δE_{ST}	%	Temperature error from the Caltest 300 specification	Type B Rectangular distribution Temperature error limit: 0.005%/°C

Example 1. Caltest 300 class 0.05 with direct voltage and current inputs, voltage U=3x230V, current I=3x100A, frequency 50Hz, cosφ=1 (φ=0°), t_A=+23±3°C, t ≤ 12 months from Calmet's calibration

Measuring uncertainty budgets for example 1

Parameter	Value [W]	Standard measuring uncertainty [%]	Distribution	Sensitivity coefficient	Uncertainty contribution [%]
δE_{SI}	69000 [1)]	0.0288 [2)]	Rectangle	1	0.029
δE_X	69000	0.0288 [3)]			

[1)] Output value E_{SB}=3xUxIxcosφ=3x230Vx100Ax1=69000W
[2)] Intrinsic uncertainty δE_{SI}=0.05%/√3=0.0288%
[3)] Measuring uncertainty $\delta E_X=\sqrt{(\delta E_{SI}^2)}=\sqrt{(0.0288^2)}=0.0288\%$

Results for example 1

Parameter	Value [W]	Extended measuring uncertainty *U* [%]	Coverage factor	Coverage probability [%]
δE_X	69000	0.058 [1)]	2.0	95

[1)] $U=2\times\sqrt{(\delta E_{SI}^2)}$

The calibration result is: δE_X = 69000W±0.058%

Example 2. Caltest 300 class 0.05 with direct voltage and current inputs, voltage U=3x230V, current I=3x100A, frequency 50Hz, cosφ=1 (φ=0°), t_A=+28°C, t = 18 months from Calmet's calibration

Measuring uncertainty budgets for example 2

Parameter	Value [W]	Standard measuring uncertainty [%]	Distribution	Sensitivity coefficient	Uncertainty contribution [%]
δE_{SI}	69000 [1)]	0.0288 [2)]	Rectangle	1	0.029
δE_{SS}	0	0.0102 [3)]	Rectangle	1	0.010
δE_{ST}	0	0.0058 [4)]	Rectangle	1	0.006
δE_X	69000	0.0311 [5)]			

[1)] Output value E_{SB}=3xUxIxcosφ=3x230Vx100Ax1=69000W
[2)] Intrinsic uncertainty δE_{SI}=0.05%/√3=0.0288%
[3)] Time stability uncertainty δE_{SS}=[(0.025%/√3)]x√[(18-12)/12]=0.0102%
[4)] Temperature uncertainty δE_{ST}=[(0.005%/√3/°C)]x(28°C-26°C)=0.0058%
[5)] Measuring uncertainty $\delta E_X=\sqrt{(\delta E_{SI}^2+\delta E_{SS}^2+\delta E_{ST}^2)}=\sqrt{(0.029^2+0.010^2+0.006^2)}=0.0311\%$

Results for example 2

Parameter	Value [W]	Extended measuring uncertainty *U* [%]	Coverage factor	Coverage probability [%]
δE_X	69000	0.062 [1)]	2.0	95

[1)] $U=2\times\sqrt{(\delta E_{SI}^2+\delta E_{SS}^2+\delta E_{ST}^2)}$

The calibration result is: δE_X = 69000W±0.062%

Calculator of uncertainty

Model equation $dE_X = dE_{XMTS} + dE_S + E_{CON} + dE_{SRES} + dE_{XRES} + dE_{IMP}$

No.	Observation	
1	-0,0092	
2	0,0111	
3	-0,0098	
4	0,0163	
5	0,0095	
6	0,0196	
7	-0,0011	
8	0,0011	
9	0,0022	
10	0,0096	
	0,0049	*mean*
	0,0100	sample standard deviation *s*

List of values				Measuring uncertainty budgets				
Parameter		Description		Value [%]	Standard measuring uncertainty [%]	Distribution	Sesitivity coefficient	Uncertainty contribution [%]
dE_{XMTS}	Relative measuring deviation of the DUT in % as calculated by the Error Calculator	Type A Normal distribution						
		Number of observations	10					
		Mean		0,0049				
		Sample standard deviation *s* [%]	0,0100					
		Standard deviation of mean [%]	0,0032		0,0032	Normal	1	0,0032
dE_S	Uncertainty of the reference meter Caltest 300	Type B Normal distribution						
		Half-width of limits [%]	0,0580		0,0290	Normal	-1	-0,0290
dE_{CON}	Connection losses (e.g. cable losses)	Type B Rectangular distribution						
		Half-width of limits [%]	0,0010		0,0006	Rectangle	-1	-0,0006
dE_{SRES}	Resolution of the reference meter	Type B Rectangular distribution						
		Half-width of limits [%]	0,0010		0,0006	Rectangle	-1	-0,0006
dE_{XRES}	Resolution of the measuring value for the test sample	Type B Rectangular distribution						
		Half-width of limits [%]	0,0010		0,0006	Rectangle	1	0,0006
dE_{IMP}	Distortion during transmission of the impulses (e.g. irregularities)	Type B Rectangular distribution						
		Half-width of limits [%]	0,0010		0,0006	Rectangle	1	0,0006
dE_X	Relative measuring deviation (percentage error)			0,0049	0,0292			

U	Extended measuring uncertainty at k=2	0,0584

Examples of an uncertainty *U* for different sample standard deviation *s*

U =0,0580 @ *s* =0,0000

U =0,0581 @ s=0,0050

U =0,0584 @ s=0,0100

U =0,0594 @ s=0,0200

U =0,0661 @ s=0,0500

Result: Error of the DUT is 0,0049% with uncertainty 0,0584% @ k=2

Calmet Ltd
Kukulcza 18, 65-472 Zielona Gora, Poland
Phone +48 68 324 04 56 Fax +48 68 324 04 57
E-mail: mail@calmet.com.pl Web access: http://www.calmet.com.pl