Uncertainty of register test by TE30 & TS33 analysers and TB41 test bench station

CALMET Smart Calibration Devices

Application Note No42

1. Description of the process of testing the energy meter counter (register).

A reference meter is connected in parallel (voltages in parallel, current in series) to the meter connected to the grid, measuring the flow of energy over a specified period of time (Fig.1.). The test consists of reading the energy value from the counter of the meter being tested (E_{start}), waiting a time for a sufficiently large energy flow (getting the appropriate resolution) simultaneously recorded by the reference meter (E_{ref}), reading the energy value again from the counter of the meter being tested (E_{stop}). The difference of the counter readings is compared with the energy registered by the reference meter and the meter error ε is calculated. The error ε can be calculated as:

$$\varepsilon = \frac{(E_{stop} - E_{start}) - E_{ref}}{E_{ref}} \times 100\% \quad (1)$$

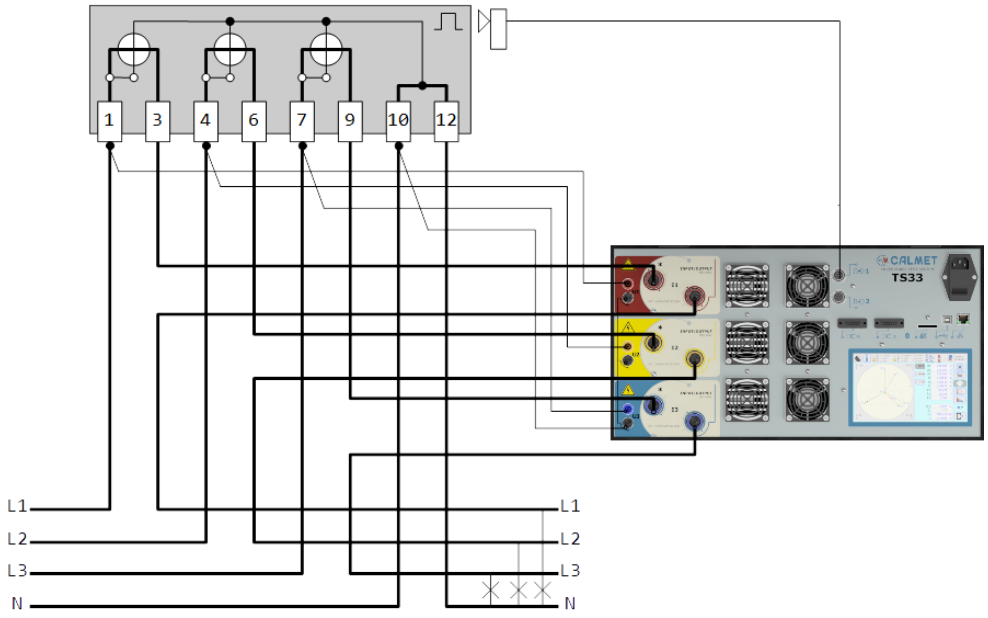


Fig.1. Typical register test connection of DUT to reference meter

According to the standard IEC62052-11 for checking the relationship between the test output and the energy meter register, the difference of the value between test output and register content shall not exceed ±1/10th of the meter accuracy class. What means that the meter constant should be evaluated with accuracy for meters class: 2 – 0.2%, 1 – 0.1%, 0.5 – 0.05%, 0.2 – 0.02%. Getting resolution on mentioned above level requires eg. 1000 pulses for 0.1% (500 pulses for 0.2%, 2000 for 0.05%, 5000 for 0.02%) what requires for meter constant 500 pulses/kWh minimum energy flow of 2.0 kWh. The accuracy of energy reading from register is related also to the number of register digits and decimals after dot. There are a few kinds of registers usually in kWh (MWh): without decimal point or with 1, 2 or 3 digits after decimal point. For example for meter with one decimal digit the minimum amount of energy to get 1% of readout accuracy (according to the IEC62058-31) is 11.1kWh. Given that all the conditions mentioned above are met at the time of measurement, one can proceed to the selection and evaluation of parameters affecting uncertainty.

2. Uncertainty budget

An uncertainty budget for a register test in an electricity meter (DUT – **D**evice **U**nder **T**est) involves identifying and quantifying the sources of uncertainty that contribute to the total uncertainty of the measurement. Each uncertainty component is added to a budget. In the equation of meter error (1) calculated by the method of comparison of energy register readings, the influences quantities must be taken into account:

- δE_{ref} - correction related to the limit error of the standard – reference meter,
- δER_{ref} - correction related to the readout resolution of the standard – reference meter,
- δER_{start} - correction related to the readout resolution of the calibrated DUT,
- δER_{stop} - correction related to the readout resolution of the calibrated DUT,

Environmental errors due to temperature, humidity and time can be eliminated because the test is carried out in the laboratory under reference conditions for which both the errors of energy meters and reference meters are determined. If the test conditions differ significantly from the reference conditions, their impact should be additionally taken into account in the uncertainty budget.

Thus, the error equation ΔE is given by the formula (2):

$$\Delta E = (E_{stop} + \delta ER_{stop}) - (E_{start} + \delta ER_{start}) - (E_{ref} + \delta E_{ref} + \delta ER_{ref}) \qquad (2)$$

and the measurement $u^2(\Delta E)$ uncertainty equation (the square of the standard complex uncertainty) is given by the formula (3):

$$u^2(\Delta E) = u^2((E_{stop}-E_{start})-E_{ref})/E_{ref}) + u^2(\delta E_{ref}) + u^2(\delta ER_{ref}) + u^2(\delta ER_{stop}) + u^2(\delta ER_{start}) \quad (3)$$

where:

$u^2((E_{stop}-E_{start})-E_{ref})/E_{ref})$ - type A measurement uncertainty of DUT counter readings (experimental standard uncertainty of the mean of the indications); at least 3 measurements must be made to calculate this uncertainty; this uncertainty can be calculated as the ratio of the standard deviation ***s*** from ***N*** measurements to the square root of the number of measurements ($= \frac{s}{\sqrt{N}}$).

$u^2(\delta E_{ref})$ – uncertainty related to the limit error of the standard – reference meter ***a*** (accuracy class defined in reference meter data sheet for testing point); this uncertainty can be calculated as the ratio of reference meter accuracy ***a*** mentioned in data sheet or calibration certificate to the square root of 3 ($= \frac{a}{\sqrt{3}}$).

$u^2(\delta ER_{ref})$ – uncertainty related to the readout resolution of the standard – reference meter; this uncertainty can be calculated on base of data sheet as the ratio of the ½ least significant digit d_{ref} of the result to the square root of 3 ($= \frac{dref}{2\sqrt{3}}$).

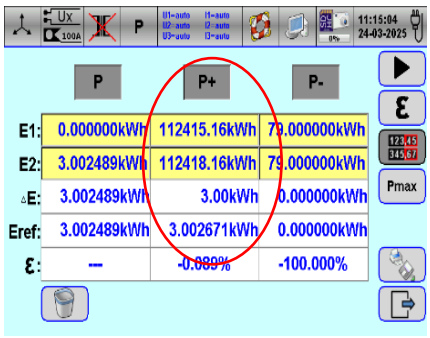
$u^2(\delta ER_{stop})$ - uncertainty related to the readout resolution of the calibrated DUT; this uncertainty can be calculated on base of data sheet as the ratio of the ½ least significant digit d_{stop} of the result to the square root of 3 ($= \frac{dstop}{2\sqrt{3}}$). Usually the resolution of energy meters are 1kWh, 0.1kWh, 0.01kWh or 0.001kWh (also kvarh).

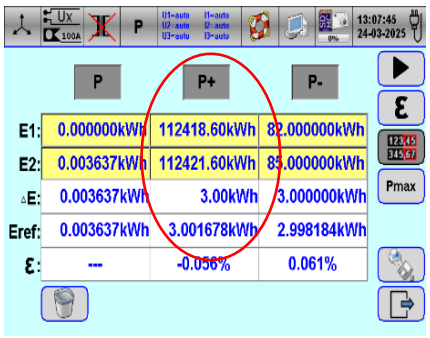
$u^2(\delta ER_{start})$ - uncertainty related to the readout resolution of the calibrated DUT; it is usually equal to $u^2(\delta ER_{stop})$; this uncertainty can be calculated on base of data sheet as the ratio of the ½ least significant digit d_{start} of the result to the square root of 3 ($= \frac{dstart}{2\sqrt{3}}$).

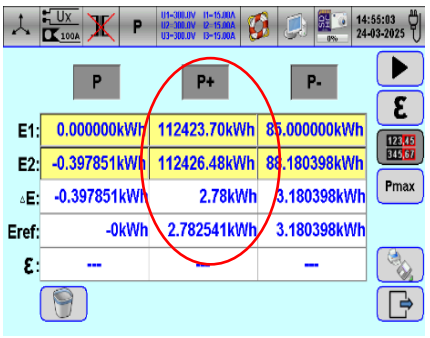
The calibration standard uncertainty u_c of the energy meter counter is given by formula $u_c = \sqrt{u^2\ (\Delta E)}$ and the expanded uncertainty is $U = 2 \times u_c$.

3. Practical example

The calibration was carried out for a Landis & Gyr type E550 class 1 meter with an exported active energy indication resolution of 0.01kWh (OBIS register 1.8.0). The calibration meter is a TS33 automatic test system with an accuracy class of 0.02% at the measurement points to be checked. Three tests of one hour each were conducted (to ensure sufficiently high energy flow) , the results of which are presented in the figures below.







The meaning of the symbols are: **P+** - export of active energy; **E1** = E_{start} – value of energy register before start of calibration; **E2** = E_{stop} – value of energy register after stopping the calibration; E_{ref} – value of energy measured by reference meter during the calibration process.

In the Table below are presented final calculations for the example.

Measurement no	1	2	3	Comment
Estart	112415,16 kWh	112418,16 kWh	112423,70 kWh	Register value before test
Estop	112418,16 kWh	112421,16 kWh	112426,48 kWh	Register value after test
Eref	3,002671 kWh	3,001678 kWh	2,782541 kWh	Reference meter energy
ε	-0,0890 %	-0,0559 %	-0,0913 %	Register error
ε ***ave***		-0,0787 %		Average register error
sEstop-Estart		0,0198 %		Standard deviation of ε
u2(sε)		0,0114 %		Uncertainty of DUT counter readings
u2(δE*ref*)		0,0115 %		Uncertainty of reference error limit
u2(δER*ref*)		0,0000 %		Uncertainty of reference resolution
u2(δER*stop*)		0,0962 %		Uncertainty of E*stop* readings
u2(δER*start*)		0,0962 %		Uncertainty of E*start* readings
uc		0,1370 %		Standard uncertainty
U		**0,2741** %		Expanded uncertainty
Result of test	**-0,0787 +/-**	**0,2741 %**	extended uncertainty under confidence level of 95%	

Conclusion: as can be seen from the example, the greatest influence on the value of uncertainty is the resolution of the energy value reading from the meter register related to the amount of energy flow. This uncertainty can be reduced by increasing the power and/or increasing the test time.