# Efficiency of test bench station in meter testing

CALMET
Smart Calibration Devices

**Application Note** No22

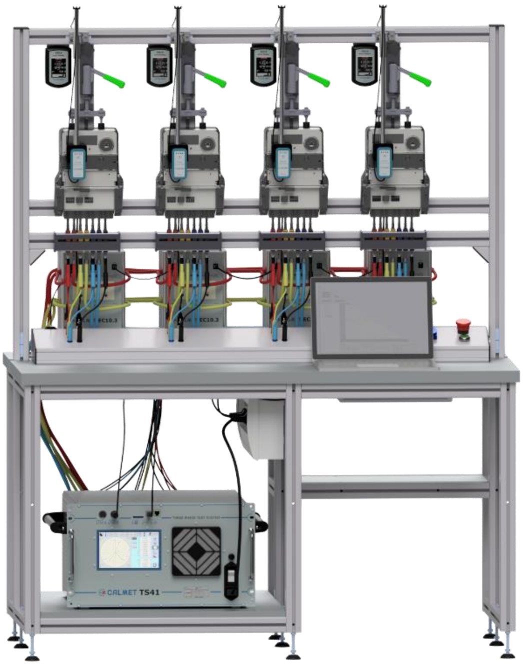
**Simple, smart and economic test bench station can test up to 160 meters a week (one work shift).**

## 1. How long does it take to test an energy meter?

The efficiency of a meter test bench station can be defined as the total time required to test an energy meter to verify its parameters, mainly accuracy for compliance with standards. The answer to the simple question above is complicated because it depends on many factors:

- the kind of test we want to perform;
- the number of load points we want to test;
- the value of load power in the testing point;
- meter under test constant;
- meter accuracy;
- meter register resolution;
- meter connection: single or three-phase.

All the factors are discussed below in detail and then analysed based on the Calmet TB41 Test Bench Station (see picture below).



## 2. What tests are required by standards?

There are sets of standards issued by IEC, ANSI, OIML, EN/MID that describe testing procedures for energy meters, e.g.:

- **IEC 62052 - 11** Electricity metering equipment (a.c.) - General requirements, tests and test conditions – Part 11: Metering Equipment;
- **IEC 62053 - 11** Electricity metering equipment (a.c.) - Particular requirements – Part 11: Electromechanical meters for active energy class 0.5, 1and 2;
- **IEC 62053 - 12** Electricity metering equipment (a.c.) - Particular requirements – Part 12: Electromechanical meters for reactive energy class 2 and 3;
- **IEC 62053 - 21** Electricity metering equipment (a.c.) - Particular requirements – Part 21: Static meters for active energy class 1 and 2;
- **IEC 62053 - 22** Electricity metering equipment (a.c.) - Particular requirements – Part 22: Static meters for active energy class 0.2 S and 0.5 S;
- **IEC 62053 - 23** Electricity metering equipment (a.c.) - Particular requirements – Part 23: Static meters for reactive energy class 2 and 3;
- **IEC 62053 - 24** Electricity metering equipment (a.c.) - Particular requirements – Part 24: Static meters for apparent energy class 1 and 2;
- **EN 50470 -1** Electricity metering equipment (a.c.) – General requirements - Part 1: Tests and test conditions for metering equipment class A, B and C;

- **EN 50470 -2** Electricity metering equipment (a.c.) – Particular requirements – Part 2: Electromechanical meters for active energy class A and B;
- **EN 50470 -3** Electricity metering equipment (a.c.) – Particular requirements – Part 3: Static meters for active energy class A, B and C control;
- **EN 62058-21** Electricity metering equipment (a.c.) - Acceptance inspection - Part 21: Particular requirements for electromechanical meters for active energy (classes 0.5, 1 and 2 and class indexes A and B);
- **EN 62058-31** Electricity metering equipment (a.c.) - Acceptance inspection - Part 31: Particular requirements for static meters for active energy (classes 0,2 S, 0,5 S, 1 and 2);
- **OIML 46-1/-2** Active electrical energy meters. Part 1: Metrological and technical requirements Part 2: Metrological controls and performance tests;
- **ANSI C12.1** Electric Meters - Code For Electricity Metering.

There are also standards for equipment used for energy meter testing:
- **IEC 60736** Testing equipment for electrical energy meters;
- **IEC 62057-1** Test equipment, techniques and procedures for electrical energy meters-Part1: Stationary Meter Test Units;
- **EC 62057- 2** Test equipment, techniques and procedures for electrical energy meters-Part2: Portable test equipment and test procedure for electricity meters and electricity meter installations.

The standards describe methods of electricity meter testing and generally there are two types of tests:
- **type test** – a procedure according to which a series of tests is carried out on one meter or on a small number of meters of the same type having identical characteristics to verify that the respective type of meter complies with all the requirements of standard for the relevant class. Usually, mechanical, climatic, electrical, and safety properties are tested. Full testing is required to prove that this type of meter fits into standard requirements. During the manufacture of an approved type meter, the accuracy and safety of the meter are tested. Calmet's devices focus on accuracy tests.
- **acceptance (routine) test** - acceptance testing of directly connected or transformer operated electromechanical and static meters, newly manufactured or delivered to the customer, for active and reactive energy. The test is shorter than type tests.

During the testing procedure, the following should be verified:
- **no load (creepage)** – the powered electricity meter should not start counting energy in the register without the load connected;
- **starting current** – the lowest value of current specified by the manufacturer at which the meter should register electrical energy with unity power factor and, for polyphase meters, with balanced load;
- **accuracy** – accuracy dependence on load current, power factor and energy direction flow;
- **register or meter constant** – comparison of the registered energy portion by the meter under test and the reference meter (dial test) or comparison of the energy meter register increment with number of pulses or rotor revolutions;

## 3. No load test

The test should be performed with the meter connected to the nominal power supply $U_n$ or $U_n$ +15% and with no current in the current circuit. The Test consists of counting pulses (rotor revolutions) during the calculated time at least. Time ∆t in minutes can be calculated on the basis of the formulas in the table below. No more than one pulse (rotor revolution) can be counted in this time. The User doesn't want to pay for unused energy.

| ∆t ≥ [min] | Accuracy class | | | | |
|---|---|---|---|---|---|
| **Standard** | **0.2 (D)** | **0.5 (C)** | **1 (B)** | **2 (A)** | **3** |
| EN50470-3 | - | $\frac{240 \times 10^3}{C \times m \times U_n \times 1.15 \times I_{st}}$ | | | - |
| IEC62052-11 | - | $\frac{240 \times 10^3}{C \times m \times U_n \times 1.1 \times I_{st}}$ | | | - |
| IEC62053-21 | - | - | $\frac{600 \times 10^6}{C \times m \times U_n \times 1.15 \times I_{max}}$ | $\frac{480 \times 10^3}{C \times m \times U_n \times 1.15 \times I_{max}}$ | - |
| IEC62053-22 | 0.2S $\frac{900 \times 10^6}{C \times m \times U_n \times 1.15 \times I_{max}}$ | 0.5S $\frac{600 \times 10^6}{C \times m \times U_n \times 1.15 \times I_{max}}$ | - | - | - |
| IEC62053-23 | - | - | - | $\frac{480 \times 10^6}{C \times m \times U_n \times 1.15 \times I_{max}}$ | $\frac{300 \times 10^6}{C \times m \times U_n \times 1.15 \times I_{max}}$ |
| IEC62053-24 | - | $\frac{600 \times 10^6}{C \times m \times U_n \times 1.15 \times I_{max}}$ | | - | - |

where:
∆t [min] – minimum no load time testing;
C [imp/kWh] – meter constant;

m – number of measuring elements: 1 – for single-phase meter, 2 – for three-phase meter in Aaron circuit, 3 - for three-phase four-wire meter;
$U_n$ [V] – nominal voltage;
$I_{st}$ [A] – starting current in accordance with the table below;
$I_{max}$ [A] – maximum current in accordance with the table below;
$I_{min}$ [A] – minimum current in accordance with the table below;

The relationship between the starting current ($I_{st}$), minimum current ($I_{min}$) and maximum current ($I_{max}$) to the nominal ($I_n$) base current based on applicable standards is presented in the table below.

| **Connection** | **Direct** | | | **Transformer connected** | | |
|---|---|---|---|---|---|---|
| **Accuracy** | A | B | C | A | B | C |
| $I_{st}$ | 0.5% $I_n$ | 0.4% $I_n$ | 0.4% $I_n$ | 0.3% $I_n$ | 0.2% $I_n$ | 0.1% $I_n$ |
| $I_{min}$ | 5% $I_n$ | 5% $I_n$ | 3% $I_n$ | 2% $I_n$ | 1% $I_n$ | 1% $I_n$ |
| $I_{max}$ | 500% $I_n$ | 500% $I_n$ | 500% $I_n$ | 20% $I_n$ | 20% $I_n$ | 20% $I_n$ |

Example no load test time ∆t calculations for a few meter types are presented in the table below (values are rounded up to full minutes).

| **Meter Type** | **Class** | **m** | **$U_n$ [V]** | **$I_n$ [A]** | **$I_{st}$ [A]** | **$I_{max}$ [A]** | **C [imp/kWh]** | **∆t~[min]** |
|---|---|---|---|---|---|---|---|---|
| A52 Pafal | 2 | 1 | 230 | 10 | 0.05 | 40 | 375 | **121** |
| 12EA5 Pafal | 1 | 1 | 230 | 5 | 0.02 | 60 | 6400 | **6** |
| LEW323 Apator | B | 3 | 230 | 5 | 0.25 | 80 | 640 | **2** |
| MM20 DZG | 1 | 3 | 230 | 5 | 0.01 | 6 | 10000 | **13** |
| L&G550 Landis | B | 3 | 230 | 5 | 0.25 | 120 | 500 | **3** |

## 4. Starting current test

The test should be performed with a meter connected to the nominal power supply $U_n$, applied $I_{st}$ current in the current circuit, unity power factor and balanced load. The test consists of counting pulses (rotor revolutions) that do not exceed the calculated time. Expected time between two pulses (revolutions) ∆t in seconds can be calculated on the basis of the formula below. At least two pulses (one full rotor revolution) must be counted in this time (because of the expected meter error, it is recommended to test in three times longer time). Utility wants to get paid for every energy usage.

$$\Delta t = \frac{3.6 \times 10^6}{m \times C \times U_n \times I_{st}}\ [s]$$

Example starting current test time ∆t calculations for a few meter types are presented in the table below.

| **Meter Type** | **Class** | **m** | **$U_n$ [V]** | **$I_n$ [A]** | **$I_{st}$ [A]** | **C [imp/kWh]** | **∆t ~[s]** |
|---|---|---|---|---|---|---|---|
| A52 Pafal | 2 | 1 | 230 | 10 | 0.05 | 375 | **834.8** |
| 12EA5 Pafal | 1 | 1 | 230 | 5 | 0.02 | 6400 | **122.3** |
| LEW323 Apator | B | 3 | 230 | 5 | 0.25 | 640 | **32.6** |
| MM20 DZG | 1 | 3 | 230 | 5 | 0.01 | 10000 | **2.1** |
| L&G550 Landis | B | 3 | 230 | 5 | 0.25 | 500 | **41.7** |

Conclusion: performing starting current test may take a lot of time.

## 5. Accuracy test

Checking the accuracy dependence of the load current value requires a decision on the type of test (type test, acceptance test), the type of electricity meter to be tested and the applicable standard. The set of load points depends on the meter connection (single-phase, three-phase, 4 – wires or 3 – wires, direct or transformer connected), meter design (static, electromechanical), meter class of accuracy limits and the standard according to which we want to test the meter. In the chapters below, the minimum number of points which should be checked and accuracy limits for each class of meter under test are presented. Each test point consists of the value of current, voltage, power factor value and characteristic (L – inductive, C – capacitive), the tested phase (L1, L2, L3 or L123 – all three phases), frequency and error limits.

### 5.1. Acceptance (Routine) Test load points and error limits for energy meters testing

5.1.1. Load points for direct and transformer connected **1-phase** energy meters (**electromechanical**) acc. to IEC 62058-21.

| ID | I | U | Load | Cosφ | f | Error limits for class | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | **2 (A)** | **1 (B)** | **0.5S (C)** |
| 1 | $I_{min}$ | $U_n$ | L1 | 1 | 50Hz | 2.5% | 1.5% | 1.0% |
| 2 | $I_n$ | | | 1 | | 2.0% | 1.0% | 0.5% |
| 3 | | | | 0.5L | | 2.0% | 1.0% | 0.8% |
| 4 | $I_{max}$ | | | 1 | | 2.0% | 1.0% | 0.5% |

$I_{min}$= 5% of $I_n$ for direct connected meters and 2% of $I_n$ for transformer connected meters

5.1.2. Load points for direct and transformer connected **1-phase** energy meters (**static**) acc. to IEC 62058-31.

| ID | I | U | Load | Cosφ | f | Error limits for class | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | **2 (A)** | **1 (B)** | **0.5S (C)** | **0.2S (D)** |
| 1 | $I_{min}$ | $U_n$ | L1 | 1 | 50Hz | 2.5% | 1.5% | 1.0% | 0.4% |
| 2 | $I_n$ | | | 1 | | 2.0% | 1.0% | 0.5% | 0.2% |
| 3 | | | | 0.5L | | 2.0% | 1.0% | 0.6% | 0.3% |
| 4 | $I_{max}$ | | | 1 | | 2.0% | 1.0% | 0.5% | 0.2% |

$I_{min}$= 5% of $I_n$ for direct connected meters and 2% of $I_n$ for transformer connected meters

5.1.3. Load points for direct and transformer connected **3-phase** energy meters (**electromechanical**) acc. to IEC 62058-21.

| ID | I | U | Load | Cosφ | f | Error limits for class | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | **2 (A)** | **1 (B)** | **0.5S (C)** |
| 1 | $I_{min}$ | $U_n$ | L123 | 1 | 50Hz | 2.5% | 1.5% | 1.0% |
| 2 | $I_n$ | | L123 | 1 | | 2.0% | 1.0% | 0.5% |
| 3 | | | L123 | 0.5L | | 2.0% | 1.0% | 0.8% |
| 4 | | | L1 | 1 | | 3.0% | 2.0% | 1.5% |
| 5 | | | L2 | 1 | | 3.0% | 2.0% | 1.5% |
| 6 | $I_{max}$ | | L123 | 1 | | 2.0% | 1.0% | 0.5% |

$I_{min}$= 5% of $I_n$ for direct connected meters and 2% of $I_n$ for transformer connected meters

5.1.4. Load points for direct and transformer connected **3-phase** energy meters (**static**) acc. to IEC 62058-21.

| ID | I | U | Load | Cosφ | f | Error limits for class | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | **2 (A)** | **1 (B)** | **0.5S (C)** | **0.2S (D)** |
| 1 | $I_{min}$ | $U_n$ | L123 | 1 | 50Hz | 2.5% | 1.5% | 1.0% | 0.4% |
| 2 | $I_n$ | | L123 | 1 | | 2.0% | 1.0% | 0.5% | 0.2% |
| 3 | | | L123 | 0.5L | | 2.0% | 1.0% | 0.6% | 0.3% |
| 4 | | | L1 | 1 | | 3.0% | 2.0% | 0.6% | 0.3% |
| 5 | | | L2 | 1 | | 3.0% | 2.0% | 0.6% | 0.3% |
| 6 | $I_{max}$ | | L123 | 1 | | 2.0% | 1.0% | 0.5% | 0.2% |

$I_{min}$= 5% of $I_n$ for direct connected meters and 2% of $I_n$ for transformer connected meters

### 5.2. Type Test load points and error limits for energy meters testing

5.2.1. Load points for direct connected **1-phase static** energy meters acc. to EN 50470-3.

| ID | I | U | Cosφ | f | Error limits for class | | |
|---|---|---|---|---|---|---|---|
| | | | | | **2 (A)** | **1 (B)** | **0.5 (C)** |
| 1 | $I_{min}$ | $U_n$ | 1 | 50Hz | 2.5% | 1.5% | 1.0% |
| 2 | ($I_n$/10) | | 1 | | 2.0% | 1.0% | 0.5% |
| 3 | | | 0.5L | | 2.0% | 1.0% | 0.5% |
| 4 | | | 0.8C | | 2.0% | 1.0% | 0.5% |
| 5 | $I_n$ | | 1 | | 2.0% | 1.0% | 0.5% |
| 6 | | | 0.5L | | 2.0% | 1.0% | 0.5% |
| 7 | | | 0.8C | | 2.0% | 1.0% | 0.5% |
| 8 | $I_{max}$ | | 1 | | 2.0% | 1.0% | 0.5% |
| 9 | | | 0.5L | | 2.0% | 1.0% | 0.5% |
| 10 | | | 0.8C | | 2.0% | 1.0% | 0.5% |

$I_{min}$= 5% of $I_n$ for direct connected meters and 2% of $I_n$ for transformer connected meters

5.2.2. Load points for direct connected **1-phase electromechanical** energy meters acc. to EN 50470-2.

| ID | I | U | Cosφ | f | Error limits for class | |
|---|---|---|---|---|---|---|
| | | | | | 2 (A) | 1 (B) |
| 1 | $I_{min}$ | $U_n$ | 1 | 50Hz | 2.5% | 1.5% |
| 2 | $I_n/10$ | | 1 | | 2.0% | 1.0% |
| 3 | | | 0.5L | | 2.0% | 1.0% |
| 4 | | | 0.8C | | 2.0% | 1.0% |
| 5 | $I_n$ | | 1 | | 2.0% | 1.0% |
| 6 | | | 0.5L | | 2.0% | 1.0% |
| 7 | | | 0.8C | | 2.0% | 1.0% |
| 8 | $I_{max}$ | | 1 | | 2.0% | 1.0% |
| 9 | | | 0.5L | | 2.0% | 1.0% |
| 10 | | | 0.8C | | 2.0% | 1.0% |

$I_{min}$= 5% of $I_n$ for direct connected meters and 2% of $I_n$ for transformer connected meters

5.2.3. Load points for direct connected **3-phase electromechanical** energy meters acc. to EN 50470-2.

| ID | I | U | Load | Cosφ | f | Error limits for class | |
|---|---|---|---|---|---|---|---|
| | | | | | | 2 (A) | 1 (B) |
| 1 | $I_{min}$ | $U_n$ | L123 | 1 | 50Hz | 2.5% | 1.5% |
| 2 | $I_n/10$ | | L123 | 1 | | 2.0% | 1.0% |
| 3 | | | L123 | 0.5L | | 2.0% | 1.0% |
| 4 | | | L123 | 0.8C | | 2.0% | 1.0% |
| 5 | $I_n/2$ | | L1 | 1 | | 3.0% | 2.0% |
| 6 | | | L2 | 1 | | 3.0% | 2.0% |
| 7 | | | L3 | 1 | | 3.0% | 2.0% |
| 8 | | | L1 | 0.5L | | 3.0% | 2.0% |
| 9 | | | L2 | 0.5L | | 3.0% | 2.0% |
| 10 | | | L3 | 0.5L | | 3.0% | 2.0% |
| 11 | $I_n$ | | L123 | 1 | | 2.0% | 1.0% |
| 12 | | | L123 | 0.5L | | 2.0% | 1.0% |
| 13 | | | L123 | 0.8C | | 2.0% | 1.0% |
| 14 | | | L1 | 1 | | 3.0% | 2.0% |
| 15 | | | L2 | 1 | | 3.0% | 2.0% |
| 16 | | | L3 | 1 | | 3.0% | 2.0% |
| 17 | | | L1 | 0.5L | | 3.0% | 2.0% |
| 18 | | | L2 | 0.5L | | 3.0% | 2.0% |
| 19 | | | L3 | 0.5L | | 3.0% | 2.0% |
| 20 | $I_{max}$ | | L123 | 1 | | 2.0% | 1.0% |
| 21 | | | L123 | 0.5L | | 2.0% | 1.0% |
| 22 | | | L123 | 0.8C | | 2.0% | 1.0% |
| 23 | | | L1 | 1 | | 3.0% | 2.0% |
| 24 | | | L2 | 1 | | 3.0% | 2.0% |
| 25 | | | L3 | 1 | | 3.0% | 2.0% |
| 26 | | | L1 | 0.5L | | 3.0% | 2.0% |
| 27 | | | L2 | 0.5L | | 3.0% | 2.0% |
| 28 | | | L3 | 0.5L | | 3.0% | 2.0% |

$I_{min}$= 5% of $I_n$ for direct connected meters and 2% of $I_n$ for transformer connected meters

5.2.4. Load points for direct connected **3-phase static** energy meters acc. to EN 50470-3.

| ID | I | U | Load | Cosφ | f | Error limits for class | |
|---|---|---|---|---|---|---|---|
| | | | | | | 2 (A) | 1 (B) |
| 1 | $I_{min}$ | $U_n$ | L123 | 1 | 50Hz | 2.5% | 1.5% |
| 2 | $I_n/10$ | | L123 | 1 | | 2.0% | 1.0% |
| 3 | | | L123 | 0.5L | | 2.0% | 1.0% |
| 4 | | | L123 | 0.8C | | 2.0% | 1.0% |
| 5 | $I_n$ | | L123 | 1 | | 2.0% | 1.0% |
| 6 | | | L123 | 0.5L | | 2.0% | 1.0% |
| 7 | | | L123 | 0.8C | | 2.0% | 1.0% |
| 8 | | | L1 | 1 | | 3.0% | 2.0% |
| 9 | | | L2 | 1 | | 3.0% | 2.0% |
| 10 | | | L3 | 1 | | 3.0% | 2.0% |
| 11 | | | L1 | 0.5L | | 3.0% | 2.0% |
| 12 | | | L2 | 0.5L | | 3.0% | 2.0% |
| 13 | | | L3 | 0.5L | | 3.0% | 2.0% |
| 14 | $I_{max}$ | | L123 | 1 | | 2.0% | 1.0% |
| 15 | | | L123 | 0.5L | | 2.0% | 1.0% |
| 16 | | | L123 | 0.8C | | 2.0% | 1.0% |
| 17 | | | L1 | 1 | | 3.0% | 2.0% |
| 18 | | | L2 | 1 | | 3.0% | 2.0% |
| 19 | | | L3 | 1 | | 3.0% | 2.0% |
| 20 | | | L1 | 0.5L | | 3.0% | 2.0% |
| 21 | | | L2 | 0.5L | | 3.0% | 2.0% |
| 22 | | | L3 | 0.5L | | 3.0% | 2.0% |

$I_{min}$= 5% of $I_n$ for direct connected meters and 2% of $I_n$ for transformer connected meters

5.2.5. Load points for direct connected **1-phase electromechanical** energy meters acc. to EN62053-11.

| ID | I | U | Cosφ | f | Error limits for class | | |
|---|---|---|---|---|---|---|---|
| | | | | | 2 (A) | 1 (B) | 0.5 (C) |
| 1 | $0.05I_n$ | $U_n$ | 1 | 50Hz | 2.5% | 1.5% | 1.0% |
| 2 | $0.1I_n$ | | 1 | | 2.0% | 1.0% | 0.5% |
| 3 | | | 0.5L | | 2.5% | 1.5% | 1.3% |
| 4 | | | 0.8C | | - | 1.5% | 1.3% |
| 5 | $0.5I_n$ | | 1 | | 2.0% | 1.0% | 0.5% |
| 6 | | | 0.5L | | 2.0% | 1.0% | 0.8% |
| 7 | | | 0.5C | | - | 1.0% | 0.8% |
| 8 | $I_n$ | | 1 | | 2.0% | 1.0% | 0.5% |
| 9 | | | 0.5L | | 2.0% | 1.0% | 0.8% |
| 10 | | | 0.8C | | - | 1.0% | 0.8% |
| 11 | $I_{max}$ | | 1 | | 2.0% | 1.0% | 0.5% |
| 12 | | | 0.5L | | 2.0% | 1.0% | 0.8% |
| 13 | | | 0.8C | | - | 1.0% | 0.8% |

5.2.6. Load points for direct connected **1-phase static** energy meters acc. to EN62053-22

| ID | I | U | Cosφ | f | Error limits for class | |
|---|---|---|---|---|---|---|
| | | | | | 0,5S | 0,2S |
| 1 | $0.02I_n$ | $U_n$ | 1 | 50Hz | 1.0% | 0.4% |
| 2 | | | 0.5L | | 1.0% | 0.5% |
| 3 | | | 0.8C | | 1.0% | 0.5% |
| 4 | $0.1I_n$ | | 1 | | 0.5% | 0.2% |
| 5 | | | 0.5L | | 0.6% | 0.3% |
| 6 | | | 0.8C | | 0.6% | 0.3% |
| 7 | $I_n$ | | 1 | | 0.5% | 0.2% |
| 8 | | | 0.5L | | 0.6% | 0.3% |
| 9 | | | 0.8C | | 0.6% | 0.3% |
| 10 | $I_{max}$ | | 1 | | 0.5% | 0.2% |
| 11 | | | 0.5L | | 1.0% | 0.5% |
| 12 | | | 0.8C | | 1.0% | 0.5% |

5.2.7. Load points for direct connected **3-phase electromechanical** energy meters acc. to EN62053-11

| ID | I | U | Load | Cosφ | f | Error limits for class | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | **2 (A)** | **1 (B)** | **0.5 (C)** |
| 1 | $0.05I_n$ | $U_n$ | L123 | 1 | 50Hz | 2.5% | 1.5% | 1.0% |
| 2 | $0.1I_n$ | | L123 | 1 | | 2.0% | 1.0% | 0.5% |
| 3 | | | L123 | 0.5L | | 2.5% | 1.5% | 1.3% |
| 4 | | | L123 | 0.8C | | - | 1.5% | 1.3% |
| 5 | $0.5I_n$ | | L123 | 1 | | 2.0% | 1.0% | 0.5% |
| 6 | | | L123 | 0.5L | | 2.0% | 1.0% | 0.8% |
| 7 | | | L123 | 0.8C | | - | 1.0% | 0.8% |
| 8 | | | L1 | 0.5L | | - | 2.0% | 1.5% |
| 9 | | | L2 | 0.5L | | - | 2.0% | 1.5% |
| 10 | | | L3 | 0.5L | | - | 2.0% | 1.5% |
| 11 | $I_n$ | | L123 | 1 | | 2.0% | 1.0% | 0.5% |
| 12 | | | L123 | 0.5L | | 2.0% | 1.0% | 0.8% |
| 13 | | | L123 | 0.8C | | - | 1.0% | 0.8% |
| 14 | | | L1 | 0.5L | | 3.0% | 2.0% | 1.5% |
| 15 | | | L2 | 0.5L | | 3.0% | 2.0% | 1.5% |
| 16 | | | L3 | 0.5L | | 3.0% | 2.0% | 1.5% |
| 17 | $I_{max}$ | | L123 | 1 | | 2.0% | 1.0% | 0.5% |
| 18 | | | L123 | 0.5L | | 2.0% | 1.0% | 0.8% |
| 19 | | | L123 | 0.8C | | - | 1.0% | 0.8% |
| 20 | | | L1 | 1 | | 4.0% | - | - |
| 21 | | | L2 | 1 | | 4.0% | - | - |
| 22 | | | L3 | 1 | | 4.0% | - | - |

5.2.8. Load points for direct connected **3-phase static** energy meters acc. to EN62053-22

| ID | I | U | Load | Cosφ | f | Error limits for class | |
|---|---|---|---|---|---|---|---|
| | | | | | | **0,5S** | **0,2S** |
| 1 | $0.02I_n$ | $U_n$ | L123 | 1 | 50Hz | 1.0% | 0.4% |
| 2 | | | L123 | 0.5L | | 1.0% | 0.5% |
| 3 | | | L123 | 0.8C | | 1.0% | 0.5% |
| 4 | $0.1I_n$ | | L123 | 1 | | 0.5% | 0.2% |
| 5 | | | L123 | 0.5L | | 0.6% | 0.3% |
| 6 | | | L123 | 0.8C | | 0.6% | 0.3% |
| 7 | $0.5I_n$ | | L1 | 1 | | 0.6% | 0.3% |
| 8 | | | L2 | 1 | | 0.6% | 0.3% |
| 9 | | | L3 | 1 | | 0.6% | 0.3% |
| 10 | | | L1 | 0.5L | | 1.0% | 0.4% |
| 11 | | | L2 | 0.5L | | 1.0% | 0.4% |
| 12 | | | L3 | 0.5L | | 1.0% | 0.4% |
| 13 | $I_n$ | | L123 | 1 | | 0.5% | 0.2% |
| 14 | | | L123 | 0.5L | | 1.0% | 0.5% |
| 15 | | | L123 | 0.8C | | 1.0% | 0.5% |
| 16 | | | L1 | 0.5L | | 1.0% | 0.4% |
| 17 | | | L2 | 0.5L | | 1.0% | 0.4% |
| 18 | | | L3 | 0.5L | | 1.0% | 0.4% |
| 19 | $I_{max}$ | | L123 | 1 | | 0.5% | 0.2% |
| 20 | | | L123 | 0.5L | | 1.0% | 0.5% |
| 21 | | | L123 | 0.8C | | 1.0% | 0.5% |
| 22 | | | L1 | 1 | | 0.6% | 0.3% |
| 23 | | | L2 | 1 | | 0.6% | 0.3% |
| 24 | | | L3 | 1 | | 0.6% | 0.3% |

## 5.3. Load point test time evaluation

The test time for each load point consists of an integer number of time periods between pulses or full rotor revolutions. The time between pulses (t) depends on the power applied to the meter and the meter constant according to the following equation:

$$t = \frac{3600 \times 10^3}{m \times U_n \times I \times cos\varphi \times C} \, [s]$$

where:
t [s] – time between pulses;
m – number of measuring elements;
$U_n$ - [V] – nominal voltage;
I [A] – load current;
cosφ – power factor;
C [imp/kWh] – meter constant

Example times between pulses for loads $I_{min}$, $I_n$ and $I_{max}$ for a few meters at cosφ=1 (and assumption that the meter error is equal zero) are presented in table below:

| **Meter Type** | **C [imp/kWh]** | **$U_n$ [V]** | **$I_{min}$ [A]** | **$P_{min}$ [kW]** | **$t_{min}$ [s]** | **$I_n$ [A]** | **$P_n$ [kW]** | **$t_n$ [s]** | **$I_{max}$ [A]** | **$P_{max}$ [kW]** | **$t_{max}$ [s]** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A52 | 375 | 230 | 0.5 | 0.115 | **83.48** | 10 | 2.3 | **4.17** | 40 | 9.2 | **1.04** |
| 12EA5 | 6400 | 230 | 0.25 | 0.0575 | **9.78** | 5 | 1.15 | **0.49** | 60 | 13.8 | **0.04** |
| LEW323 | 640 | 230 | 0.25 | 0.1725 | **32.61** | 5 | 3.45 | **1.63** | 80 | 55.2 | **0.10** |
| MM20 | 10000 | 230 | 0.1 | 0.069 | **5.22** | 5 | 3.45 | **0.10** | 6 | 4.14 | **0.09** |
| L&G550 | 500 | 230 | 0.25 | 0.1725 | **41.74** | 5 | 3.45 | **2.09** | 120 | 82.8 | **0.09** |

The time between pulses for low loads, especially for power factor cosφ<1 is long. Usually the test requires to count at least 2 pulses for low loads and more for high loads, but in a time less than 10…20s. The typical functionality of the test bench station allows two methods of test setting: by counting pulses, which requires calculating this number for each load point or by setting a constant test time, e.g. 10s. In this method, pulses are collected during the 10s, but it is necessary to get at least 2 pulses, so the time will be automatically extended. Measurements at load points should be performed at least 3 times (3 cycles) in order to receive a better uncertainty of measurements and standard deviation calculation.

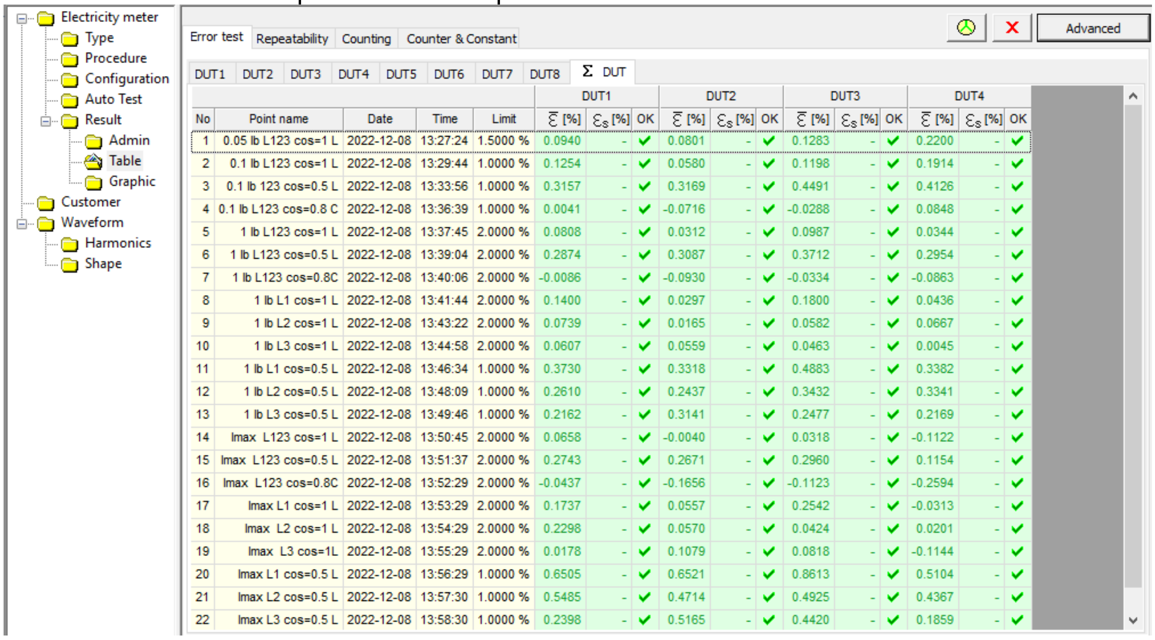
Example test time evaluation for energy meter L&G E550 ($U_n$=230V, $I_n$=5A, $I_{st}$=0.25A, class B, C=500imp/kWh) according to the EN50470-3 standard is presented in the table below. Load points (U, I, cosφ, connection), accuracy class, and the calculated time between 2 pulses are mentioned. Then it is assumed that at least two pulses are required for the test. However, the start of the test is not synchronized with the pulses, so the time of “0.5” pulse on average is added. If the minimum test time is set to 10s, the test will take 2.5 pulses for low loads, but for higher loads there will be more pulses in 10s.

| ID | I | U | Load | cosφ | f | Class | Time between 2 pulses | Real, expected number of pulses | Time of test | Setting time | Time for **1 cycle** | Time for **3 cycles** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1 (B) | [s] | | [s] | [s] | [s] | [s] |
| 1 | 0,05In (0,25A) | Un | L123 | 1L | 50Hz | 1.5% | 41,74 | 2,5 | 104,35 | 10 | 114,35 | 323,05 |
| 2 | 0,1In (0,5A) | Un | L123 | 1L | 50Hz | 1.0% | 20,87 | 2,5 | 52,18 | 10 | 62,18 | 166,53 |
| 3 | | Un | L123 | 0,5L | 50Hz | 1.0% | 41,74 | 2,5 | 104,35 | 10 | 114,35 | 323,05 |
| 4 | | Un | L123 | 0,8C | 50Hz | 1.0% | 26,09 | 2,5 | 65,23 | 10 | 75,23 | 205,68 |
| 5 | In (5A) | Un | L123 | 1L | 50Hz | 1.0% | 2,09 | 5 | 10,45 | 10 | 20,45 | 41,35 |
| 6 | | Un | L123 | 0,5L | 50Hz | 1.0% | 4,18 | 3 | 12,54 | 10 | 22,54 | 47,62 |
| 7 | | Un | L123 | 0,8C | 50Hz | 1.0% | 2,61 | 4 | 10,44 | 10 | 20,44 | 41,32 |
| 8 | | Un | L1 | 1L | 50Hz | 2% | 6,27 | 2 | 12,54 | 10 | 22,54 | 47,62 |
| 9 | | Un | L2 | 1L | 50Hz | 2% | 6,27 | 2 | 12,54 | 10 | 22,54 | 47,62 |
| 10 | | Un | L3 | 1L | 50Hz | 2% | 6,27 | 2 | 12,54 | 10 | 22,54 | 47,62 |
| 11 | | Un | L1 | 0,5L | 50Hz | 2% | 12,54 | 2,5 | 31,35 | 10 | 41,35 | 104,05 |
| 12 | | Un | L2 | 0,5L | 50Hz | 2% | 12,54 | 2,5 | 31,35 | 10 | 41,35 | 104,05 |
| 13 | | Un | L3 | 0,5L | 50Hz | 2% | 12,54 | 2,5 | 31,35 | 10 | 41,35 | 104,05 |
| 14 | Imax (120A) | Un | L123 | 1L | 50Hz | 1.0% | 0,09 | 112 | 10,08 | 10 | 20,08 | 40,24 |
| 15 | | Un | L123 | 0,5L | 50Hz | 1.0% | 0,18 | 56 | 10,08 | 10 | 20,08 | 40,24 |
| 16 | | Un | L123 | 0,8C | 50Hz | 1.0% | 0,11 | 91 | 10,01 | 10 | 20,01 | 40,03 |
| 17 | | Un | L1 | 1L | 50Hz | 2% | 0,27 | 38 | 10,26 | 10 | 20,26 | 40,78 |
| 18 | | Un | L2 | 1L | 50Hz | 2% | 0,27 | 38 | 10,26 | 10 | 20,26 | 40,78 |
| 19 | | Un | L3 | 1L | 50Hz | 2% | 0,27 | 38 | 10,26 | 10 | 20,26 | 40,78 |
| 20 | | Un | L1 | 0,5L | 50Hz | 2% | 0,54 | 19 | 10,26 | 10 | 20,26 | 40,78 |
| 21 | | Un | L2 | 0,5L | 50Hz | 2% | 0,54 | 19 | 10,26 | 10 | 20,26 | 40,78 |
| 22 | | Un | L3 | 0,5L | 50Hz | 2% | 0,54 | 19 | 10,26 | 10 | 20,26 | 40,78 |
| | | | | | | | | | | | **802,93** | **1968,79** |
| | | | | | | | | | **Time in hh:mm:ss** | | **00:13:23** | **00:32:49** |
| 23 | Ist = (0,25A) | Un | L123 | 1L | 50Hz | | | - | 41,74 | 10 | 51,74 | |
| 24 | 0 | Un | L123 | 1L | 50Hz | | | - | 145,18 | 10 | 155,18 | |
| | | | | | | | | | | | **206,92** | |
| | | | | | | | | **Time in hh:mm:ss** | | | **00:03:27** | |
| | | | | | | | | | **Total testing time hh:mm:ss** | | | **00:36:16** |

The calculated time of the accuracy test is 32 minutes and 49 seconds. The time of the start-up test and no load test is 3 minutes, 27 seconds. The total time of those tests is 36 minutes and 16 seconds.

### 5.4. Example tests of energy meters accuracy and time of testing

The calculated time was tested in practice for the energy meter L&G E550 ($U_n$=230V, $I_n$=5A, $I_{st}$=0.25A, class B, C=500imp/kWh) according to the EN50470-3 standard by means of the four-position Test Bench Station TB41. The results of the test are presented in the picture below.




| | | | | | DUT1 | | | DUT2 | | | DUT3 | | | DUT4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No | Point name | Date | Time | Limit | $\bar{\varepsilon}$ [%] | $\varepsilon_s$ [%] | OK | $\bar{\varepsilon}$ [%] | $\varepsilon_s$ [%] | OK | $\bar{\varepsilon}$ [%] | $\varepsilon_s$ [%] | OK | $\bar{\varepsilon}$ [%] | $\varepsilon_s$ [%] | OK |
| 1 | 0.05 Ib L123 cos=1 L | 2022-12-08 | 13:27:24 | 1.5000 % | 0.0940 | - | ✔ | 0.0801 | - | ✔ | 0.1283 | - | ✔ | 0.2200 | - | ✔ |
| 2 | 0.1 Ib L123 cos=1 L | 2022-12-08 | 13:29:44 | 1.0000 % | 0.1254 | - | ✔ | 0.0580 | - | ✔ | 0.1198 | - | ✔ | 0.1914 | - | ✔ |
| 3 | 0.1 Ib 123 cos=0.5 L | 2022-12-08 | 13:33:56 | 1.0000 % | 0.3157 | - | ✔ | 0.3169 | - | ✔ | 0.4491 | - | ✔ | 0.4126 | - | ✔ |
| 4 | 0.1 Ib L123 cos=0.8 C | 2022-12-08 | 13:36:39 | 1.0000 % | 0.0041 | - | ✔ | -0.0716 | - | ✔ | -0.0288 | - | ✔ | 0.0848 | - | ✔ |
| 5 | 1 Ib L123 cos=1 L | 2022-12-08 | 13:37:45 | 2.0000 % | 0.0808 | - | ✔ | 0.0312 | - | ✔ | 0.0987 | - | ✔ | 0.0344 | - | ✔ |
| 6 | 1 Ib L123 cos=0.5 L | 2022-12-08 | 13:39:04 | 2.0000 % | 0.2874 | - | ✔ | 0.3087 | - | ✔ | 0.3712 | - | ✔ | 0.2954 | - | ✔ |
| 7 | 1 Ib L123 cos=0.8C | 2022-12-08 | 13:40:06 | 2.0000 % | -0.0086 | - | ✔ | -0.0930 | - | ✔ | -0.0334 | - | ✔ | -0.0863 | - | ✔ |
| 8 | 1 Ib L1 cos=1 L | 2022-12-08 | 13:41:44 | 2.0000 % | 0.1400 | - | ✔ | 0.0297 | - | ✔ | 0.1800 | - | ✔ | 0.0436 | - | ✔ |
| 9 | 1 Ib L2 cos=1 L | 2022-12-08 | 13:43:22 | 2.0000 % | 0.0739 | - | ✔ | 0.0165 | - | ✔ | 0.0582 | - | ✔ | 0.0667 | - | ✔ |
| 10 | 1 Ib L3 cos=1 L | 2022-12-08 | 13:44:58 | 2.0000 % | 0.0607 | - | ✔ | 0.0559 | - | ✔ | 0.0463 | - | ✔ | 0.0045 | - | ✔ |
| 11 | 1 Ib L1 cos=0.5 L | 2022-12-08 | 13:46:34 | 1.0000 % | 0.3730 | - | ✔ | 0.3318 | - | ✔ | 0.4883 | - | ✔ | 0.3382 | - | ✔ |
| 12 | 1 Ib L2 cos=0.5 L | 2022-12-08 | 13:48:09 | 1.0000 % | 0.2610 | - | ✔ | 0.2437 | - | ✔ | 0.3432 | - | ✔ | 0.3341 | - | ✔ |
| 13 | 1 Ib L3 cos=0.5 L | 2022-12-08 | 13:49:46 | 1.0000 % | 0.2162 | - | ✔ | 0.3141 | - | ✔ | 0.2477 | - | ✔ | 0.2169 | - | ✔ |
| 14 | Imax L123 cos=1 L | 2022-12-08 | 13:50:45 | 2.0000 % | 0.0658 | - | ✔ | -0.0040 | - | ✔ | 0.0318 | - | ✔ | -0.1122 | - | ✔ |
| 15 | Imax L123 cos=0.5 L | 2022-12-08 | 13:51:37 | 2.0000 % | 0.2743 | - | ✔ | 0.2671 | - | ✔ | 0.2960 | - | ✔ | 0.1154 | - | ✔ |
| 16 | Imax L123 cos=0.8C | 2022-12-08 | 13:52:29 | 2.0000 % | -0.0437 | - | ✔ | -0.1656 | - | ✔ | -0.1123 | - | ✔ | -0.2594 | - | ✔ |
| 17 | Imax L1 cos=1 L | 2022-12-08 | 13:53:29 | 2.0000 % | 0.1737 | - | ✔ | 0.0557 | - | ✔ | 0.2542 | - | ✔ | -0.0313 | - | ✔ |
| 18 | Imax L2 cos=1 L | 2022-12-08 | 13:54:29 | 2.0000 % | 0.2298 | - | ✔ | 0.0570 | - | ✔ | 0.0424 | - | ✔ | 0.0201 | - | ✔ |
| 19 | Imax L3 cos=1L | 2022-12-08 | 13:55:29 | 2.0000 % | 0.0178 | - | ✔ | 0.1079 | - | ✔ | 0.0818 | - | ✔ | -0.1144 | - | ✔ |
| 20 | Imax L1 cos=0.5 L | 2022-12-08 | 13:56:29 | 1.0000 % | 0.6505 | - | ✔ | 0.6521 | - | ✔ | 0.8613 | - | ✔ | 0.5104 | - | ✔ |
| 21 | Imax L2 cos=0.5 L | 2022-12-08 | 13:57:30 | 1.0000 % | 0.5485 | - | ✔ | 0.4714 | - | ✔ | 0.4925 | - | ✔ | 0.4367 | - | ✔ |
| 22 | Imax L3 cos=0.5 L | 2022-12-08 | 13:58:30 | 1.0000 % | 0.2398 | - | ✔ | 0.5165 | - | ✔ | 0.4420 | - | ✔ | 0.1859 | - | ✔ |

The real time result of the test, including the accuracy test, start-up current test and no load test, is 35 minutes and 37 seconds, which is very close to the evaluation of the test time.

## 6. Register or meter constant test

The Register test, especially for electromechanical meters, confirms compliance of the rotor disc revolutions with the energy meter register. The test consists of applying a known portion of energy to the meter so that the least significant position of the register would make a full revolution (or increased ten times in case of a static meter). The minimum portion of energy depends on the register resolution R [Wh] and it is equal to 10 x R. For typical energy meters, it is 100Wh for a register with 2 digits after decimal point, 1000Wh for 1 digit and 10000Wh for a register without decimal point. Examples of energy flow $E_{min}$ and flow time for a few types of meters at nominal and maximum power are presented below:

| Meter Type | Resolution R [kWh] | $E_{min}$ [kWh] | $U_n$ [V] | $I_n$ [A] | $P_n$ [kW] | $t_{@In}$ [min:s] | $I_{max}$ [A] | $P_{max}$ [kW] | $t_{@Imax}$ [min:s] |
|---|---|---|---|---|---|---|---|---|---|
| A52 | 0.1 | **1** | 230 | 10 | 2.3 | **26:05** | 40 | 9.2 | **6:31** |
| 12EA5 | 0.1 | **1** | 230 | 5 | 1.15 | **52:10** | 60 | 13.8 | **4:21** |
| LEW323 | 0.1 | **1** | 230 | 5 | 3.45 | **17:23** | 80 | 55.2 | **1:05** |
| MM20 | 0.01 | **0.1** | 230 | 5 | 3.45 | **1:44** | 6 | 4.14 | **1:27** |
| L&G550 | 0.01 | **0.1** | 230 | 5 | 3.45 | **1:44** | 120 | 82.8 | **0:05** |

The result is correct if the digit next to left position changes value by 1. In practice, the test is performed by recording the register value before the test $E_{start}$, applying a known energy portion $E_{reference}$ >> $E_{min}$ (or power delivery for a specified period of time) and recording the register value after the test $E_{stop}$. The error ε can be calculated as:

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

The meter constant test verifies the difference between energy flow represented by the number of pulses (rotor revolutions) divided by the meter constant and the energy recorded in the meter register does not exceed 1/10 of the accuracy class at the tested load point. The load point can be selected arbitrarily in the range between $I_n$/10 ($I_n$/20 for transformer connected meters) and $I_{max}$. It is recommended to use high load current in order to shorten the test and increase its accuracy. The duration of the test depends on the meter under test register resolution to get the required accuracy. The minimum energy flow is given by formula below:

$$E_{min} = \frac{1000 \times R}{b} \; [Wh]$$

where:

R – resolution of the energy meter register expressed in Wh;

b – the accuracy class of the meter under test expressed in %.

The energy flow requires the meter to be supplied with appropriate power for a certain period of time.

Example energy flow $E_{min}$ and flow time for a few types of meters at nominal and maximum power are presented below:

| Meter Type | Class b [%] | Resolution R [kWh] | $E_{min}$ [kWh] | $U_n$ [V] | $I_n$ [A] | $P_n$ [kW] | $t_n$ [h:min] | $I_{max}$ [A] | $P_{max}$ [kW] | $t_{max}$ [h:min] |
|---|---|---|---|---|---|---|---|---|---|---|
| A52 | 2 | 0.1 | **50** | 230 | 10 | 2.3 | **21:45** | 40 | 9.2 | **5:26** |
| 12EA5 | 1 | 0.1 | **100** | 230 | 5 | 1.15 | **20:00** | 60 | 13.8 | **7:15** |
| LEW323 | B (1) | 0.1 | **100** | 230 | 5 | 3.45 | **28:59** | 80 | 55.2 | **1:49** |
| MM20 | 1 | 0.01 | **10** | 230 | 5 | 3.45 | **2:54** | 6 | 4.14 | **2:25** |
| L&G550 | B (1) | 0.01 | **10** | 230 | 5 | 3.45 | **2:54** | 120 | 82.8 | **0:08** |

Conclusion: this test takes a lot of time and can be shorted by readout the state of internal meter registers by means of infrared communication head (or any other communication method). Usually internal registers have higher resolution (R) than meter display. Time of test also depends on standard used to set load points. Acceptance tests are shorter than type tests.

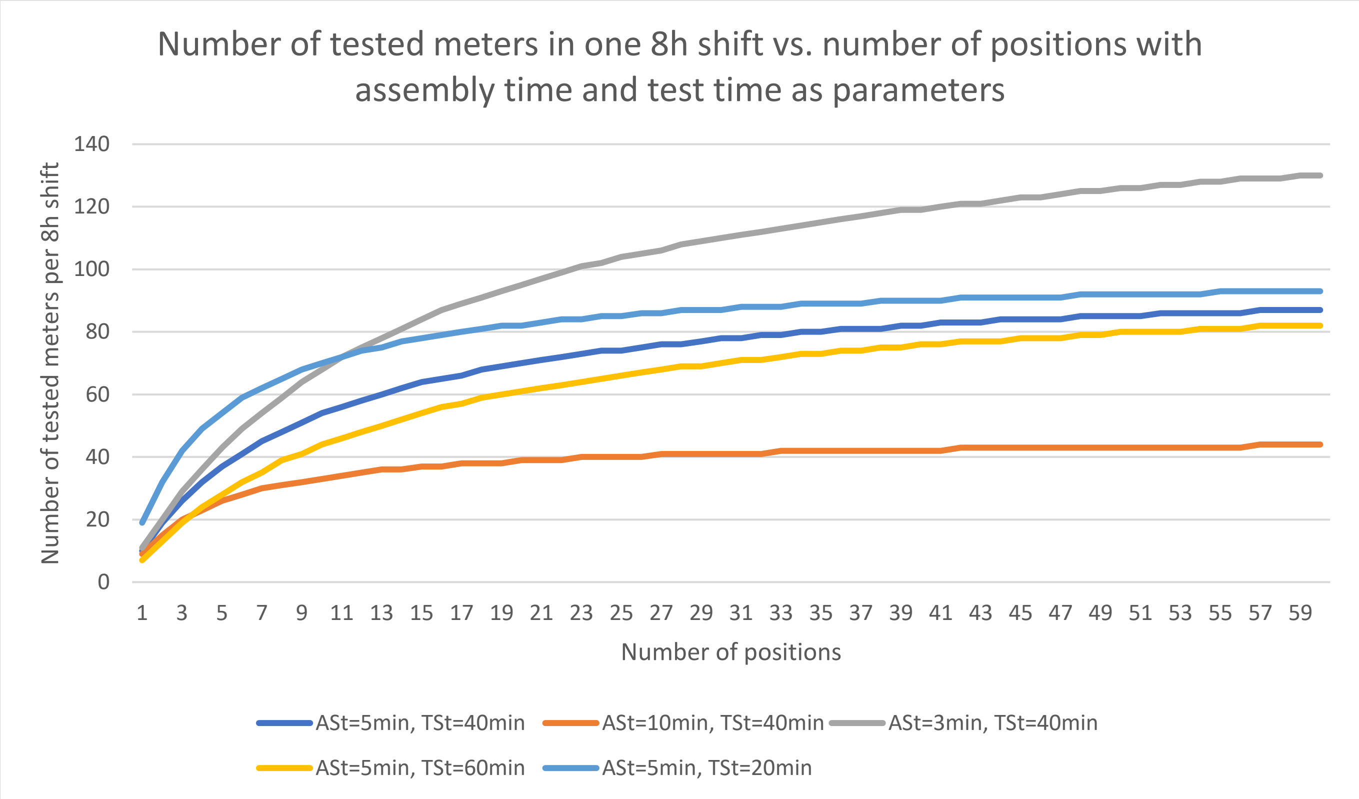
## 7. Number of meters tested in one 8-hour shift

The number of meters tested by Energy Meter Test Bench depends on the number of positions in the station, the time of meter assembly to the test station position and scanning head tuning and testing, then testing the time of accuracy, start-up, no load, and register tests.

Total testing times for sample meters are shown in table below.

| Meter Type | C [imp/kWh] | $U_n$ [V] | $I_n$ [A] | Test time [hh:mm:ss] | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Accuracy | Start-up | No Load | ← Sum | Register | Total |
| A52 | 375 | 230 | 10 | 00:42:16 | 00:14:05 | 02:01:10 | 02:57:31 | 00:06:31 | **03:04:02** |
| 12EA5 | 6400 | 230 | 5 | 00:06:45 | 00:02:12 | 00:06:10 | 00:15:07 | 00:04:21 | **00:19:28** |
| LEW323 | 640 | 230 | 5 | 00:28:36 | 00:00:43 | 00:02:10 | 00:31:29 | 00:01:05 | **00:32:34** |
| MM20 | 10000 | 230 | 5 | 00:15:19 | 00:00:12 | 00:13:10 | 00:13:22 | 00:01:27 | **00:14:49** |
| L&G550 | 500 | 230 | 5 | 00:32:49 | 00:00:52 | 00:02:35 | 00:36:16 | 00:00:05 | **00:36:21** |

In general, the dependence of the number of tested meters on the number of positions of the calibration test bench station with the time of assembly and connection of the meter and the time of testing depending on the selected standard as parameters can be evaluated in the form of a diagram.




Where:

- assumed time of shift is 8 hours;
- ASt – time of meter assembly to its position on the station and tunning the scanning head;
- TSt – time of accuracy, start-up, no load, and register tests according to the selected standard.

It can be seen that the curves are saturated and the optimal number of positions in terms of efficiency, with the meter connection and test times set, is between 3 and 15 positions.

## 8. Conclusions

The presented testing time evaluation calculations are close to the results obtained in the real test by means of bench station. Tests were performed on four positions of the TB41 test bench station. Assuming the average test time of about 40 minutes and 5 minutes for each meter assembly in the quick connector and setting scanning head, we get 60 minutes for a 4 meters test (40min + 4x5min). This allows us to test up to 32 meters per an 8h shift and up to 160 meters per week.

The testing time depends on the number of test points (and the standard against which the test is performed), meter parameters - especially the meter constant. Typically, the no load and start-up current tests take the longest.

It seems that the more important factor in selecting a Test Bench Station is the number of meters we need to test rather than the number of positions available on the test bench station. We need to optimize the number of positions and the volume of meters we want to test. This allows us to take advantage of small calibration stations and does not require special, large rooms and does not consume a lot of electricity. Single-phase power is sufficient.