

EFFECT OF ENVIRONMENTAL AND OPERATING CONDITIONS ON THE VERIFICATION INTERVAL FOR SMART ELECTRONIC ELECTRICITY METERS

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Abstract

According to metrological guidelines and specific legal requirements, every smart electronic electricity meter has to be constantly verified after pre-defined regular time intervals. The problem is that in most cases these pre-defined time intervals are based on some previous experience or empirical knowledge and rarely on scientifically sound data. Since the verification itself is a costly procedure it would be advantageous to put more effort into defining the required verification periods. Therefore, a fixed verification interval, recommended by various internal documents, standardised evaluation procedures and national legislation, could be technically and scientifically more justified and consequently more appropriate and trustworthy for the end user.

This paper describes an experiment to determine the effect of alternating temperature and humidity and constant high current on a smart electronic electricity meter's measurement accuracy. Based on an analysis of these effects it is proposed that the current fixed verification interval could be revised, taking into account also different climatic influence. The findings of this work could influence a new standardized procedure in respect of a meter's verification interval.

Keywords: smart meter, verification interval, measurement accuracy, measurement error, accelerated aging.

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1. Introduction

The widespread application of quality-management and business-excellence models has put increasing emphasis on the procedures for periodic instrument verification. In fact, it is recognized that, because of increased uncertainty and reduced accuracy being a consequence of aging, incorrect use of the instrument, as well as mechanical and thermal shocks, the risks associated with measurement-based decisions grow steadily over time and can be the cause of unforeseen management costs [1, 2]. Therefore, the management of the verification interval, as a technical specification of the measuring instrument, is metrologically and organizationally important.

1.1. Verification interval of smart electricity meter

The measurement accuracy of any instrument, including smart electricity meters, drifts over time. Therefore, determining verification intervals is the crucial problem. If the verification

interval is too long, the risk of exceeding the published measurement error tolerance of meters will increase; however, if the interval is too short, there will be a waste of resources and the normal use of an instrument will be affected [3]. The necessity of repeating the verification at appropriate time intervals is recognized in several international standards and recommendations, above all the ISO 10012 standard, considering the use of an instrument that is not well calibrated, one of the main causes of wrong measurement results [4, 5].

Different approaches to defining the optimal verification interval were analysed [2, 6] and clustered into two large groups: the techniques based on a mathematical model and those depending on the statistics of experimental tests. The first requires the collection and management of a large amount of data and the use of stochastic processes to build a reliability model that describes the behaviour of the class and consequently the error of meters under examination. The second group is based on the shortening and lengthening of verification intervals as a function of the results of current and previous verifications [6, 7].

1.2. Accelerated testing

The purpose of an accelerated test is to simulate the effect of a long period (e.g. 20 years) of normal use for a smart electricity meter in a short time (e.g. 21 days). In accelerated testing conditions, a smart meter is exposed to environmental conditions that are much more severe (e.g. temperature level is being changed from -40°C to $+80^{\circ}\text{C}$) than those experienced during its normal life, which enables to shorten the time-to-failure process for a smart meter without changing its failure characteristics [8–10]. Table 1 presents various types of accelerated tests. These tests can be divided into two groups: alternating environmental conditions, where temperature

Table 1. Common highly accelerated stress tests.

Name	No. (year of inception)	Description	Example test conditions		
			T [°C]	RH (%)	Duration [h]
IEC (International standard)	62059-32-1 (2012/5)	non-alternating env. conditions	70	50	1000
	62059-31-1 (2008/09)	alternating env. conditions	70	90	1000
			40	50	1000
60068-2-2 (2007/7)	non-alternating env. conditions	70	–	72	
Military Handbook	MIL STD 810F (2003/5)	alternating env. conditions	60	95	240
			30	95	240
JEDEC (US industrial standard)	22-A102-C (2008/6)	non-alternating env. conditions	121*	100	24
			130*	85	96
			110*	85	264
JIS (Japanese industrial standard)	C60068-2-66 (2001/11)	non-alternating env. conditions	110*	85	96
			120*	85	48
			130*	85	24
JEITA (Japanese domestic ind. standard)	ED-4701/100 Method 103 (2001/8)	non-alternating env. conditions	110*	85	192
			120*	85	96
			130*	85	48
proposed method	(2018/5)	alternating env. conditions	+80	10 < RH < 90	504
			–40		

(T , from 30 to 70°C) and relative humidity (RH , from 50 to 90%) of the climatic chamber are being altered during the test, and non-alternating environmental conditions, where T and RH are fixed during the test. The *Japanese Industrial Standard (JIS)*, *Joint Electron Device Engineering Council (JEDEC)* and *Japan Electronics and Information Technology Association (JEITA)* standards propose different T values, since this is limited by the product's environmental condition specification, which means that the applied T for the accelerated test has to be chosen from among the values in Table 1 marked with an asterisk (*). Our proposed method is shown in the last row and explained in detail in Subsection 2.1.

The measurement accuracy of a meter is one of the most relevant technical specifications and for that reason is crucial to its reliability. Since the main purpose of accelerated tests is to examine the meter's reliability, we decided to perform three different accelerated tests. According to the literature review the increased values of T and RH accelerate the aging process, while the oscillation of T and RH increases the probability of the device's failure [8–11]. Based on these findings the main goal is to observe the meter's measurement accuracy dependence on the alternating environmental T and RH in combination with the smart meter's I_{\max} (the current through the smart meter is 85 A). Therefore, the proposed method differs from other methods in terms of a combination of simultaneous alternating T , RH with a constant maximum current load of *meters under test (MUT)*.

2. Experiment

To test the hypothesis it was decided to use a mass-produced smart electronic electricity meter. The main goals of the experiment were the following:

- to examine the correlation between three different accelerated tests and the measurement accuracy;
- to verify if the currently fixed verification intervals are justified;
- to develop an innovative methodology for defining the verification intervals.

2.1. Experimental methodology

The guidelines for setting the environmental conditions (T and RH) during the accelerated test are based on IEC 62059-31 [12]. The temperature limits of the accelerated profiles, applied during the experiment, considered the typical smart meter's temperature span, which is limited from -40°C to $+70^{\circ}\text{C}$. Based on analysis of the accelerated methods, shown in Table 1, three different conclusions can be made: high T (recommended by 7 methods), high RH (recommended by 5 methods) and low RH (recommended by one method). For that reason it was decided to apply two accelerated tests with the following settings:

Test #1 constant $T = 80^{\circ}\text{C}$, $RH = 20\%$ and $I_{\max} = 85\text{ A}$,

Test #2 constant $T = 80^{\circ}\text{C}$, $RH = 90\%$ and $I_{\max} = 85\text{ A}$.

Smart meters are installed in various geolocations, where T and RH levels are alternating during the winter and summer periods. According to IEC 60721 [13] the geographical area of installation involves six different types of climate: cold, cold temperate, warm temperate, warm dry, mild warm dry and warm damp. According to IEC 62059-31 the profile of accelerated test should include: 10% of the cold climate, 70% of the warm damp climate and 10% of the mild warm dry climate. Based on this we decided to apply one additional test (test #3) with the following settings:

Test #3 T alternating between -40 and $+80^{\circ}\text{C}$, RH alternating between 10 and 90%, and $I_{\max} = 85\text{ A}$ (Fig. 1).

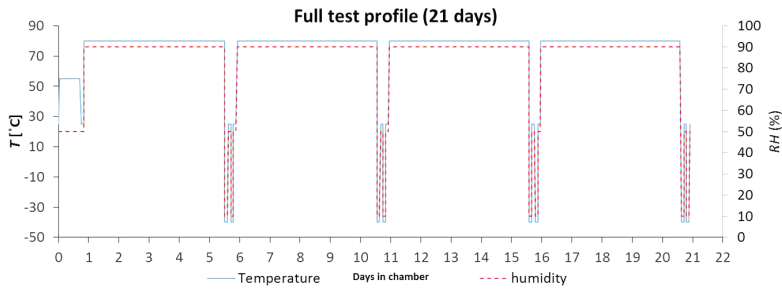


Fig. 1. Alternating T and RH , full 21-day cycle.

Based on the IEC 62052-21 guidelines [14] the duration of the accelerated tests was set to 21 days.

The full test lasted for 21 days (Fig. 1) and consisted of four sub-cycles (Fig. 2).

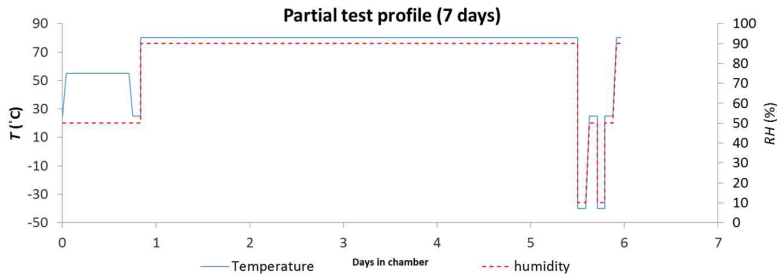


Fig. 2. Alternating T and RH , sub-cycle.

The test procedure consists of:

- the initial evaluation of measurement accuracy (the method explained in Subsection 2.3.);
- operational conditioning at the:
 - I_{max} , T and RH level according to the specifications of applied accelerated test;
 - voltage, 110% of MUTs' nominal voltage = $1.1 \cdot 230 \text{ V} = 253 \text{ V}$, according to IEC 62059 [12];
 - power factor, $PF = 0.866$ inductive, according to IEC 62059 [12];
 - during the conditioning, intermediate energy registering differences between the reference standard metering device and MUT were taken according to IEC 62059 [12];
- the final evaluation of measurement accuracy.

Condensation during the change from high T and RH to low T was eliminated using a controlled climatic chamber. According to Olencki et al. the current value in such tests should be defined as being half of the meter's maximum current [15]. In our case the current source was adjusted to an even higher constant value of 85 A (smart meter's I_{max}), which is compliant with IEC 62059 [12]. The MUTs' measurement accuracy was monitored according to IEC 62059 [12] using a reference meter, which is the same type as the MUTs. In order to ensure a higher accuracy of the measurements, it was decided to include a reference standard metering device as well.

Intermediate measurements were carried out using the comparison method, while the *light emitting diode* (LED) pulses of the MUT were compared with the reference standard metering

device. The values of the MUT energy measurement error (the energy measurement differences between the MUTs and reference standard metering device) were taken every minute and recorded in a file. The energy registration, *i.e.*, a comparison of the meters' registers, was made between the registers of MUTs and the reference standard metering device. The energy, temperature and humidity levels were recorded every hour.

2.2. Measurement equipment

Thirty meters with accuracy class B (1% accuracy limit) were taken for the test and the initial evaluation of measurement accuracy was carried out. The MUTs were then sequentially connected to a three-phase power source and exposed to the same current (Fig. 3, left). The experimental setup consists of:

- the reference standard metering device;
- 6 meters (MUTs #1.1, 1.2, 2.1, 2.2, 3.1 and 3.2) always remained out of the climatic chamber for the measurement-accuracy reference purposes (the first half installed horizontally; the second half installed vertically);
- 12 meters (MUTs #1.3, 1.4, 1.5, 1.6, 2.3, 2.4, 2.5, 2.6, 3.3, 3.4, 3.5 and 3.6) were vertically installed inside the chamber;
- 12 meters (MUTs #1.7, 1.8, 1.9, 1.10, 2.7, 2.8, 2.9, 2.10, 3.7, 3.8, 3.9 and 3.10) were horizontally installed inside the chamber.

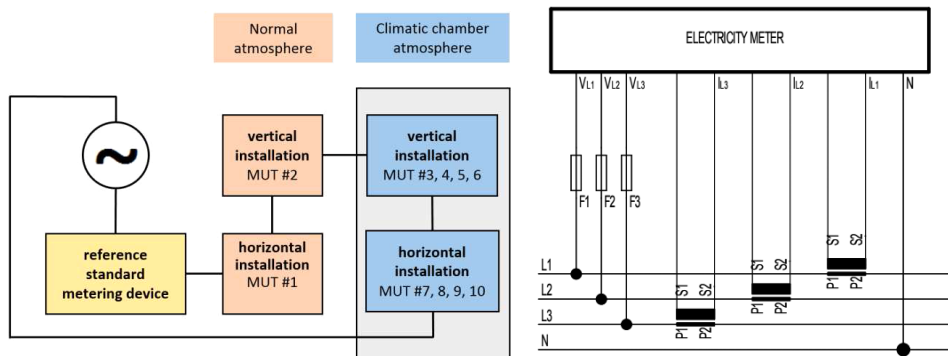


Fig. 3. The MUT installation during the accelerated test (left), the MUT wiring diagram (right).

The wiring diagram for the MUTs' voltage showing current connections to the power supply is presented in Fig. 3 (right). According to the experimental setup (Fig. 3, left), the following uncertainty contributions are considered in the uncertainty budget of instrumentation:

- $\pm 0.02\%$ for the reference standard metering device, which includes the uncertainty influences due to the variations of voltage, frequency and temperature;
- $\pm 0.08\%$ for the MUTs, which includes the uncertainty influences due to the variations of voltage, frequency and temperature;
- $\pm 0.07\%$ for the power source, which includes the uncertainty influences due to the variations of voltage, frequency and temperature.

The total uncertainty 0.11% is stated as the expanded uncertainty with the coverage factor $k = 2$, which for a normal distribution corresponds to a coverage probability of approx. 95%.

The uncertainty of the climatic chamber is $\pm 1.2^\circ\text{C}$ and $\pm 2.7\%$ RH, which includes the uncertainty influences of air T and RH spatial distribution and temporal stability, the uncertainties

associated with the working standard used for the calibration, the radiation effect associated with the emissivity of the temperature sensor and sensor dimension, caused by different temperatures of the walls of the chamber and air in the chamber, time-dependent T differences between air, measuring probes and load in chamber, the influence of the loading of the chamber on the spatial distribution and temporal stability of air T and RH , the influence of ambient conditions and resolution of indicators [17].

2.3. Stability test of metrological characteristics

In order to ensure that all three accelerated tests are comparable, a set of new meters of the identical type was always installed. According to IEC 62053 [16] the measurement accuracy of each meter was observed at 38 measuring points, where points 1–19 are defined for the received active energy and points 20–38 are defined for the transmitted active energy.

3. Experimental results and their interpretation

3.1. Accelerated test #1

The measurement errors of MUTs that had not been exposed to the accelerated test inside the climatic chamber, but had remained outside of it for 504 hours and exposed to constant I_{\max} (85 A), indicate a slight change (Fig. 4): the blue line represents the error of the horizontally installed MUT (#1.1) and shows a change of -0.03% (the initial value of 0.33% and the final value of 0.30% , after the test was concluded), the orange line represents the error of the vertically installed MUT (#1.2) and shows a change of -0.02% (the initial value of 0.27% and the final value of 0.25% , after the test was concluded). The result is in line with the expectations since the MUTs had not been exposed to any harsh climatic conditions.

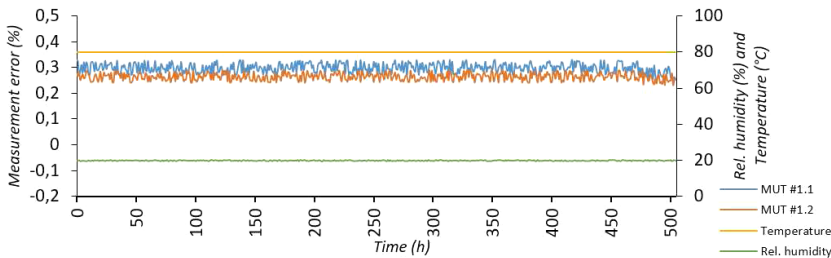


Fig. 4. Measurement errors of MUTs outside the chamber – MUT #1.1 and #1.2.

MUTs #3 to #10 had been exposed to high temperature ($T = 80^\circ\text{C}$), low humidity ($RH = 20\%$) and I_{\max} (85 A) for 504 hours. Interpretation of the results (Fig. 5) indicates the following decline of the measurement error, which represents the energy measurement differences between the MUTs and the reference standard metering devices: the green line represents the average error of all the vertically installed MUTs (#1.3, 1.4, 1.5 and 1.6) and shows a change of approx. -0.22% (the initial value of 0.30% and the final value of 0.08% , after the test was concluded), the black line represents the average error of all the horizontally installed MUTs (#1.7, 1.8, 1.9 and 1.10) and shows a change of approx. -0.25% (the initial value of 0.34% and the final value of 0.09% , after the test was concluded). Since the MUTs had been exposed to increased environmental T ,

the change within the limits of the measurement error, defined in the MUT datasheet, is expected (the longer the exposure, the higher the deterioration) and proven.

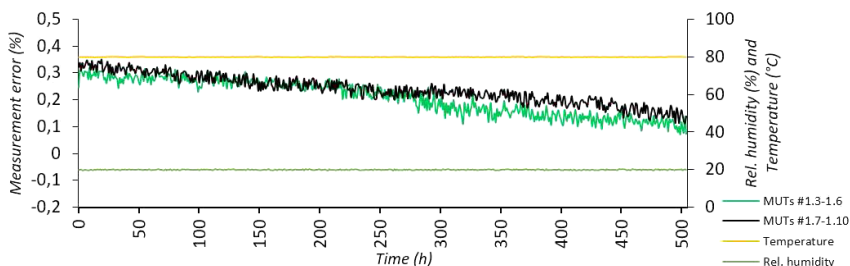


Fig. 5. Measurement errors – MUTs #1.3–1.6 and MUTs #1.7–1.10.

3.2. Accelerated test #2

The measurement errors of the MUTs that had not been exposed to the accelerated test inside the climatic chamber, but had remained outside it for 504 hours and exposed to I_{\max} (85 A), indicates a slight change (Fig. 6): the blue line represents the error of the horizontally installed MUT (#2.1) and shows a change of -0.02% (the initial value of 0.32% and the final value of 0.30% , after the test was concluded), the orange line represents the error of the vertically installed MUT (#2.2) and shows a change of -0.04% (the initial value of 0.27% and the final value of 0.23% , after the test was concluded). The result is in line with the expectations since the MUTs had not been exposed to harsh climatic conditions.

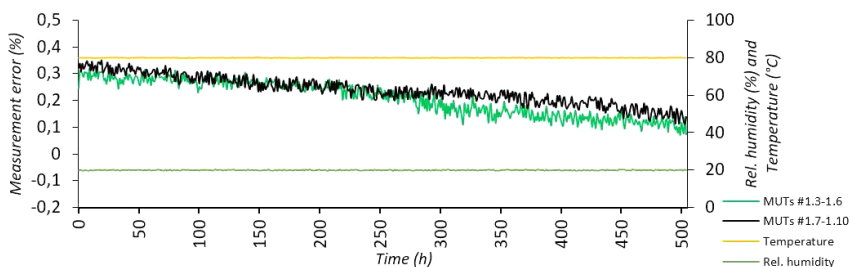


Fig. 6. Measurement errors of MUTs outside the chamber – MUT #2.1 and MUT #2.2.

MUTs #3 to #10 had been exposed to harsh climatic conditions inside the chamber (increased $T = 80^{\circ}\text{C}$, high $RH = 90\%$) and I_{\max} (85 A) for 504 hours. Interpretation of the results (Fig. 7) indicates the following change of measurement error: the green line represents the average error of all the vertically installed MUTs (#2.3, 2.4, 2.5 and 2.6) and shows a change of approx. -0.30% (the initial value of 0.34% and the final value of 0.04% , after the test was concluded), the black line represents the average error of all the horizontally installed MUTs (#2.7, 2.8, 2.9 and 2.10) and shows a change of approx. -0.32% (the initial value of 0.28% and the final value of -0.04% , after the test was concluded). Since the MUTs had been exposed to increased environmental T and RH , the deterioration within the limits of the measurement error, defined in the MUT datasheet, is expected (the longer the exposure, the higher the deterioration) and proven.

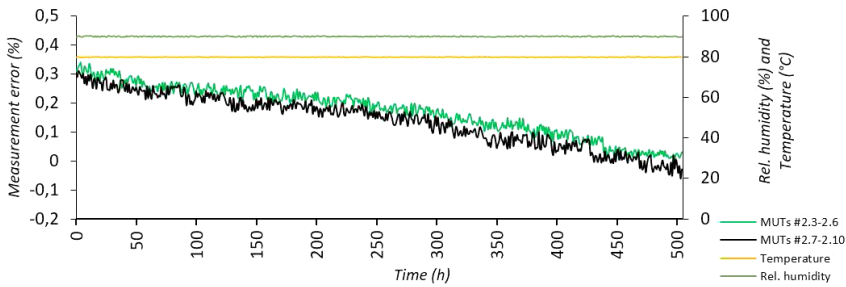


Fig. 7. Measurement errors – MUTs #2.3–2.6 and MUTs #2.7–2.10.

3.3. Accelerated test #3

The measurement error of the MUTs that had not been exposed to an accelerated test inside the climatic chamber, but had remained outside it for 504 hours and exposed to I_{max} (85 A), indicates a slight change (Fig. 8): the blue line represents the error of the horizontally installed MUT (#3.1) and shows a change of -0.03% (the initial value of 0.31% and the final value of 0.28% , after the test was concluded), the orange line represents the error of the vertically installed MUT (#3.2) and shows a change of -0.01% (the initial value of 0.21% and the final value of 0.20% , after the test was concluded). The result is in line with the expectations since the MUTs had not been exposed to harsh climatic conditions.

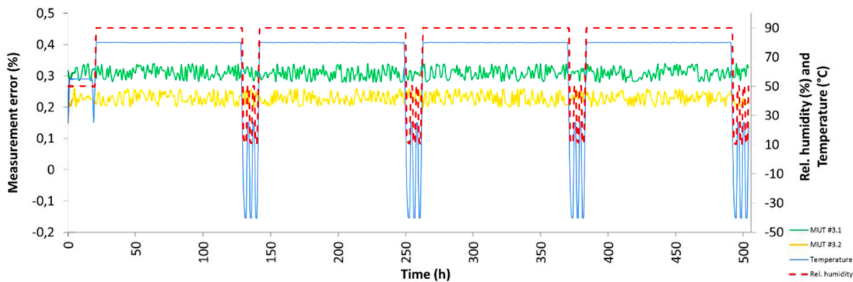


Fig. 8. Measurement errors of MUTs outside the chamber – MUT #3.1 and #3.2.

MUTs #3.3–3.10 had been exposed to harsh climatic conditions inside the chamber (alternating T from -40°C to $+80^{\circ}\text{C}$, alternating RH from 10% to 90%) and I_{max} (85 A) for 504 hours. Interpretation of the results (Fig. 9) indicates the following change of the measurement error: the green line represents the average error of all the vertically installed MUTs (#3.3, 3.4, 3.5 and 3.6) and shows a change of approx. -0.36% (the initial value of 0.27% and the final value of -0.06% , after the test was concluded), the black line represents the average error of all the horizontally installed MUTs (#3.7, 3.8, 3.9 and 3.10) and shows a change of approx. -0.40% (the initial value of 0.37% and the final value of -0.03% , after the test was concluded). Since the MUTs had been exposed to alternating environmental T and RH , the change within the limits of the measurement error, defined in the MUT datasheet, is expected (the longer the exposure, the higher the deterioration) and proven.

During the conditioning, intermediate energy registering differences between the reference standard metering device and MUT were taken according to IEC 62059 [12]. This process was made before, during and after the accelerated test. Table 2 shows the registration error of all the

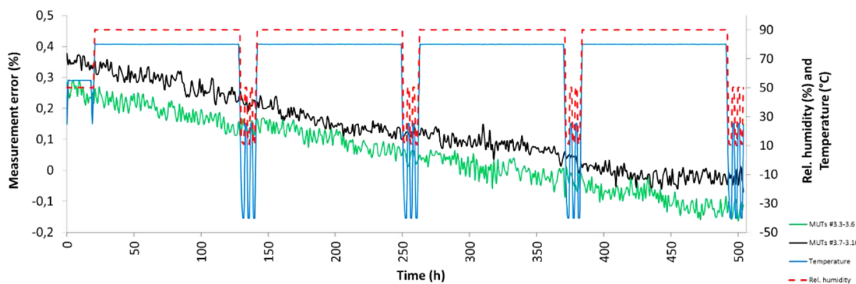


Fig. 9. Measurement errors – MUTs #3.3–3.6 and MUTs #3.7–3.10.

MUTs, where the 2nd column shows the average errors of all horizontally installed MUTs outside the chamber, the 3rd column shows the average errors of all vertically installed MUTs outside the chamber; the 4th column shows the average error of all vertically installed MUTs inside the chamber (with a standard deviation of 0.31%) and the 5th column shows the average error of all horizontally installed MUTs inside the chamber (with a standard deviation of 0.42%). The 7th line in the table indicates that the registration error of all 30 MUTs did not exceed the e_{\max} level.

Table 2. Errors of the MUTs.

Register address	MUTs #1.1, #2.1, #3.1 (%)	MUTs #2.2, #2.2, #3.2 (%)	MUTs #1.3–1.6, #2.3–2.6, #3.3–3.6 (%)	MUTs #1.7–1.10, #2.7–2.10, #3.7–3.10 (%)
1	0.38	-0.46	0.61	-0.37
2	-0.25	0.12	-0.52	-0.26
3	0.42	0.22	-0.31	0.46
4	-0.55	-0.19	0.11	0.12
5	0.20	-0.49	-0.36	-0.19
6	-0.65	0.24	-0.28	-0.22
pass	OK	OK	OK	OK

3.4. Interpretation of experimental results

3.4.1. Measurement error deterioration of the reference MUT

The reference MUTs, which had not been exposed to accelerated tests (#1.1, 1.2, 2.1, 2.2, 3.1, 3.2), are marked with the orange and red colours in Fig. 10. As those MUTs had been exposed to the same current for the same time period as the MUTs inside the climatic chamber, the measurement error changed only from -0.01% to -0.04% .

3.4.2. Correlation between increased RH and the measurement error

The influence of increased RH is detected through the measurement error change during accelerated test #2. The humidity difference between accelerated test #1 and #2 results in a change of the measurement error of the vertically installed MUTs by -0.08% (the difference in

the error between the left grey column and the centre grey column in Fig. 10) and -0.07% for the horizontally installed MUTs (the difference in the error between the left yellow column and the centre yellow column in Fig. 10).

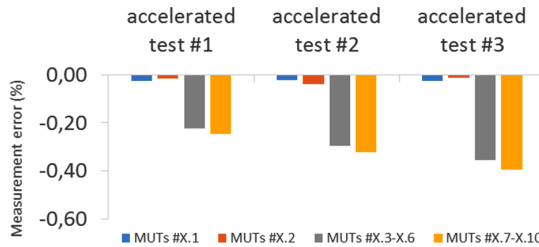


Fig. 10. Comparison of measurement errors for the accelerated tests.

3.4.3. Correlation between alternating T , RH and the measurement error

The influence of alternating T and RH levels on the measurement error change is represented in Fig. 10 with grey and yellow columns (in the centre and the right-hand side). On the vertically installed MUTs the change results in a value of -0.06% , while on the horizontally installed MUTs it results in a value of -0.08% .

3.4.4. Correlation between the MUT installation method and the measurement error

The greatest influence of the MUT installation method on the measurement error change is proven by accelerated test #3, shown on the right-hand side of Fig. 10. The difference between the grey and yellow columns represents a change of -0.04% .

4. Discussion

The above-described experiment proves the correlation between the T , RH and measurement accuracy of the MUTs. The experiment had lasted for 21 days (504 hours) and the change had a negative/falling trend, shown in Figs. 5, 7 and 9. Since the accelerated tests cannot run for ever, an extrapolation could be done based on following assumptions:

- During the accelerated tests no MUT will fail.
An MUT's failure would be detected by a sudden change of its measurement accuracy deterioration, which is according to experimental setup constantly monitored. However, despite the fact that no such deviation was found during the experiment, there are no guarantees that some MUTs would not fail if the accelerated test would be continued further.
- During the accelerated test no climatic chamber failure will occur.
A failure of the climatic chamber would be recognized by independent measurements of T and RH , measured by the stand-alone equipment, which is not part of the climatic chamber equipment. Since those measurements had not produced any deviation in comparison with chamber settings during the experiment, it could be assumed that no failures of the climatic chamber would occur if the accelerated test would be continued further.
- MUT's measurement accuracy change will remain linear.
As seen in Figs. 5, 7 and 9, the deterioration trends of accelerated tests #1, 2 and 3 are quite

linear, therefore it could be assumed that the deterioration trend would remain linear if the accelerated test would be continued further.

Based on the above mentioned assumptions, the extrapolation of the MUTs' measurement error is done and presented in Fig. 11. It indicates that if the accelerated tests were not stopped after 21 days, but were allowed to continue further, the falling deterioration trend would eventually hit the measurement error limit of 1%, defined by the smart electronic electricity meter manufacturer. At that point a specific MUT would have to be verified as its measurement error would be out of the permitted tolerances. The simulation result, shown in Fig. 11, can be interpreted as showing that MUTs subjected to:

- accelerated test #1, would hit the error limit of 1% within 146 days;
- accelerated test #2, would hit the error limit of 1% within 112 days;
- accelerated test #3, would hit the error limit of 1% within 70 days.

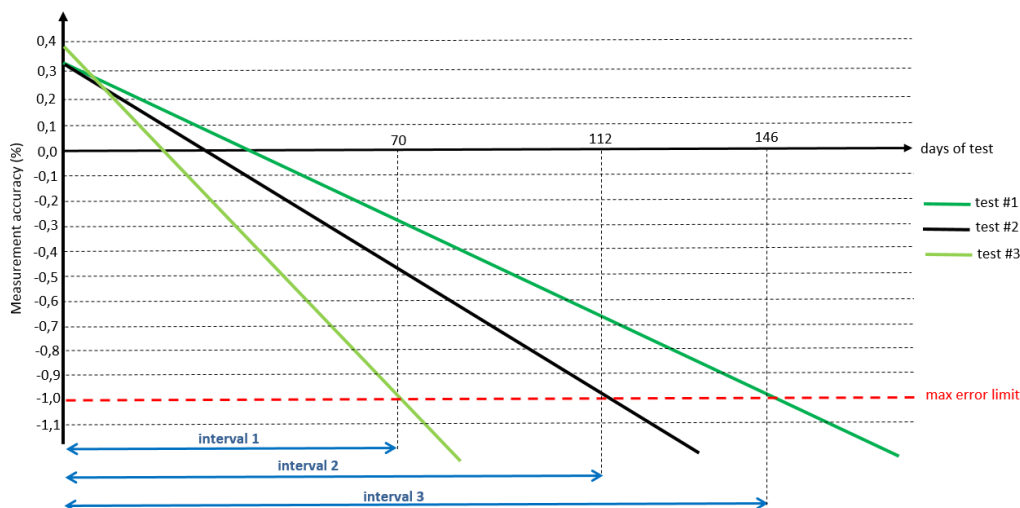


Fig. 11. Correlation between the environmental conditions and the measurement-accuracy deterioration.

The correlation between the climatic parameters and the measurement accuracy, shown in Fig. 11, suggests that the duration of the verification interval is correlated with the measurement accuracy as well. The levels of T and RH , to which the smart electronic electricity meters are exposed, are therefore influencing the duration of verification interval. The verification intervals are defined by national metrology legislation. As seen in Table 3, the intervals are different.

Since the T and RH values of each individual accelerated test could reflect different climatic areas, the main usefulness is that the climatic conditions are decisive when it comes to their influencing the duration of the calibration interval. Depending on the climatic conditions the same type of smart electronic electricity meter could have different verification interval.

It is proposed that the definition of verification interval takes into consideration the climatic conditions specific for the geo-location of the meter installation.

The proposed methodology for the interval duration definition consists of the following steps:

1. provide ten new meters of the identical type and specifications as the ones, which are used in a certain geo-location;
2. provide meteorology statistics of the geo-location, where the meters are to be installed;

Table 3. Durations of the verification intervals applied world-wide.

Country	Verification interval	Source, date of issue
Austria, EU	8 years	Gesamte Rechtsvorschrift für Maß- und Eichgesetz (MEG), 30.12.2014
Germany, EU	8 years	Mess- und Eichverordnung (MessEV), 11.12.2014
Switzerland	10 years	Verordnung des EJPD über Messmittel für elektrische Energie und Leistung (EMmV), 01.01.2018
Slovenia, EU	6 years	Pravilnik o overitvah merilnikov el. energije, 01.01.2017
ZAE	10 years	Customer metering regulations, ED/R01/005, 01.07.2005
Canada	10 years	Reverification periods for electricity meters and metering installations (E-26, rev. 5), 22.11.2010
Taiwan	8 years	Technical specification for verification and inspection of electricity meters (CNMV 46, 5th edition), 18.08.2016

3. define the profile of accelerated test, which will take into consideration the local specific climatic conditions (T and RH);
4. execute the accelerated test in compliance with the steps mentioned in Subsection 2.2.;
5. define the measurement deterioration curve by applying the same approach as described in Section 3;
6. extrapolate the deterioration curve and include it into the graph, where the meters' measurement error is placed on Y axis while the duration is placed on X axis;
7. the duration of verification interval is defined with the cross-section of the extrapolation curve (see black or green line in Fig. 11) and the value of meter's limited tolerance (see dotted red line in Fig. 11).

The costs of the above described methodology should be covered by the manufacturer of smart meters which in turn would represent a benefit for the end-user (*i.e.* the meters' user).

5. Conclusion

Smart electronic electricity meters are used all over the world and are subject to different climatic conditions. In this study we carried out an experiment to identify the effects of alternating temperature and humidity on the measurement accuracy of a smart electronic electricity meter. Thirty meters had been exposed to three different accelerated tests (with different T and RH settings and maximum current) for 21 days. The expanded uncertainty of the measurement system is 0.11%. Interpretation of the final results indicates the correlation between the environmental conditions and the measurement-accuracy deterioration of a smart electronic electricity meter.

The first goal of this research was to confirm that the alternating temperature and humidity lead to a higher measurement-accuracy deterioration than just a combination of increased temperature and humidity. Based on the performed experiment we proved that a combination of alternating T , RH and I_{\max} causes a deterioration of 0.36% (for the vertically installed meters) and 0.40% (for the horizontally installed meters).

If the accelerated tests were not stopped after 21 days, but were allowed to be continued further, the falling deterioration trend would eventually hit the measurement accuracy limit of 1%, defined by the smart electronic electricity meter manufacturer. At that point the specific smart meter would have to be verified as its measurement accuracy would be outside the permitted limits.

Based on this finding it is proposed, as a second goal of this research, that the currently valid fixed verification interval should be revised, taking into account the influence of different climatic conditions. This finding could influence the new standardized procedure in respect of the smart meters' verification interval.

The third goal of the research was to develop an innovative methodology for the definition of the verification interval duration. Based on the meteorology statistics of a geo-location, where the meters are to be installed, the profile of accelerated test is defined and then applied in the climatic chamber, where the smart meters are exposed to the previously mentioned climatic parameters, which are specific for that geo-location. The outcome of the accelerated test is an extrapolated curve, which shows the meters' measurement accuracy deterioration. The duration of geo-specific verification interval is represented by the cross-section of the deterioration curve and the meters' measurement error limit, as shown in Fig. 11. Based on the results of our experiment we can define a flexible scheme for prescribing the verification periods, reflecting real operating conditions as opposed to rigid rules that are not optimal for all applications.

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