Paweł WĘGIEREK, Michał KONARSKI

Lublin University of Technology, Faculty of Electrical Engineering and Computer Science, Lublin, Poland

doi:10.15199/48.2016.08.40

The temperature effect on measurement accuracy of the smart electricity meter

***Abstract**. The paper presents an analysis of ambient temperature influence on measurement accuracy of the smart electricity meter for different values of load current, voltage and frequency. The research scope was covered by the operating temperature range from -40°C to +70°C, which is consistent with the requirements of applicable standards and legal regulations. A meter used in the conducted tests was Iskra MT372 model, which is currently being installed at final customers.*

***Streszczenie.** W artykule przedstawiono analizę wpływu temperatury otoczenia na dokładność pomiarów inteligentnego licznika energii elektrycznej dla różnych wartości prądu obciążenia, napięcia i częstotliwości. Badania swoim zakresem objęły temperatury od -40ºC do +70ºC, co jest zgodne z wymaganiami stawianymi inteligentnym licznikom zarówno przez normy, jak i regulacje prawne. W badaniach wykorzystano obecnie instalowany u odbiorców licznik typu Iskra MT372. (**Wpływ temperatury na dokładność inteligentnego licznika energii elektrycznej**).*

Keywords: electricity measurement, measurement accuracy, smart metering, smart electricity meters.
Słowa kluczowe: pomiary energii elektrycznej, dokładność pomiarów, inteligentne systemy pomiarowe, inteligentne liczniki.

Introduction

The smart meters are the main parts of the smart metering system, which implementation to the power system is actually one of the most important challenges facing the Polish and the European electricity sector. This process is related to applicable legal regulations, such as the EU Directive 2009/72/EC [1], which requires Member States to equip in smart metering systems by 2020 at least 80% of customers. In the Polish case, this objective is planned to achieve in the year 2024 and it means the need to install approximately 15 million smart electricity meters, with the current implementation level of only 2,7% [2].

One of the most significant aspects of the smart metering implementation, both from the perspective of electricity consumers and suppliers, is to ensure the appropriate measurement accuracy. It is especially important at varying operating conditions, where, in the most unfavorable cases, may occur an extreme errors. A particularly important influence quantity is the ambient temperature. This fact is associated with the use of temperature-responsive electronic smart meters and their location in places directly exposed to the outdoor temperature and insolation. According to previous research, a temperature and its fluctuations have the greatest impact on stability and reliability of all electronic devices and modules [3].

Electricity Meter Accuracy

The main parameter determining the quality of the meter measurements is its accuracy class, specifying the maximum permissible error at reference conditions. This value is determined separately for active and reactive energy measuring. A meter percentage error δ for active energy A is calculated according to the formula (1) [4]. Similar formula applies to reactive energy B.

$$\delta = \frac{A_{counted} - A_{actual}}{A_{actual}} * 100\% \quad (1)$$

where: $A_{counted}$ – active energy counted by a meter, A_{actual} – actually consumed active energy

In smart meters the minimum class for an active energy measurement is B – corresponding to the 1% maximum permissible error. A reactive energy measurement must be realized in the accuracy class at least 3, with the 3% maximum permissible error. These requirements, as mentioned previously, apply only to the reference conditions. This means, that at changing external conditions or worse quality of the supplied power, the measuring quality may be decreased [5,6]. Influence quantities of the meter maximum permissible error are an ambient temperature, voltage and frequency changes, voltage unbalance, harmonics presence as well as magnetic induction and electromagnetic field effect [7].

The error introduced by the influence quantities is called the additional error and it affects the value of the maximum permissible error in other than the reference conditions. For example, the maximum permissible error of the class B meter, which is 1% in the reference conditions, in adverse conditions may rise to 4,5% and this will be a correct and class-consistent value [8]. A meter temperature additional percentage error δ_T for active energy A is calculated according to the formula (2) [8].

$$\delta_T = \frac{A_T - A_{To}}{A_{To}} * 100\% \quad (2)$$

where: A_T – energy counted at the temperature T' A_{To} – energy counted at the reference temperature T_o = 23ºC

Requirements for meters are distinctly defined in the law as well as in the Polish and the European standards. For various ambient temperature ranges, the additional temperature error of an electronic meter cannot exceed values specified in the table 1.

Tab. 1. Maximum permissible values of temperature additional percentage error of electronic meters [8]

Temperature range	Power Factor	Maximum temperature additional error (in %) for meters of accuracy class:		
		A	B	C
5ºC to 30ºC	1	± 1,8	± 0,9	± 0,5
	$0{,}5_{ind}$ to $0{,}8_{cap}$	± 2,7	± 1,3	± 0,9
-10ºC to 5ºC	1	± 3,3	± 1,6	± 1,0
30ºC to 40ºC	$0{,}5_{ind}$ to $0{,}8_{cap}$	± 4,9	± 2,3	± 1,6
-25ºC to -10ºC	1	± 4,8	± 2,4	± 1,4
40ºC to 55ºC	$0{,}5_{ind}$ to $0{,}8_{cap}$	± 7,2	± 3,4	± 2,4
-40ºC to -25ºC	1	± 6,3	± 3,1	± 1,9
55ºC to 70ºC	$0{,}5_{ind}$ to $0{,}8_{cap}$	± 9,4	± 4,4	± 3,1

Research methods

The research on temperature effect on smart meter measurement accuracy was carried out by using a specialized climatic chamber, which allows conducting tests in constant, user-specified temperatures. The university-owned chamber is Discovery DY600C, produced by Angelantoni Industrie, with a useful capacity of 559 liters. The chamber enables conducting experiments at the temperature range from -75°C to +180°C. The use of advanced adjusting methods provides exceptional stability of internal climate conditions, with the possible temperature fluctuation of only ±0,1°C to ±0,3°C. Due to equip the chamber with the hermetic portholes it is possible to input and output electrical wiring without affecting the internal temperature stability. The research scope was covered by the operating temperature range from -40°C to +70°C, which is consistent with the requirements of applicable standards [4] and legal regulations [6].

A smart meter used in the conducted tests was electronic three-phase Iskra MT372 meter of accuracy class B. The examined meter enables [9]:

- two-way active energy measurement and registration in the accuracy class B,
- two-way reactive energy measurement and registration in the accuracy class 2,
- load profile registration at any time interval,
- operating temperature range -40°C / +70°C,
- two-way GSM communication with a power system operator,
- optical communication for local meter programming and data downloading,
- electricity supply monitoring,
- remote reading of measurement data.

Energy counted by the tested meter is determined on the basis of measurements of phase voltages and currents. Three voltage and three current metering elements are built in the meter. The current sensor is the Rogowski coil (a current transformer with an air core), while a voltage sensor is a resistive voltage divider. Signals of currents and voltages are fed to the A/D converters, and then they are digitally multiplied so that instantaneous power is calculated. The instantaneous powers are integrated and summed in a microcontroller, and then the energy consumed in a predefined registration period is determined [8]. A simplified structure of a single-phase metering system is shown in figure 1.

In order to ensure stable supply voltage parameters, in the research stand was used KIKUSUI PCR4000M regulated AC power supply, which enables exact voltage and frequency setting.

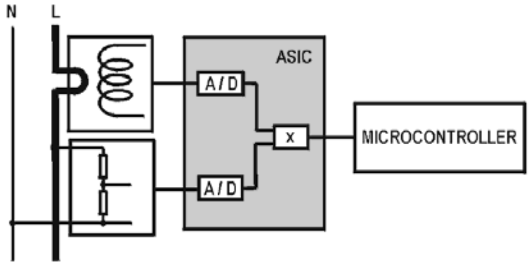

Fig. 2. Metering system of Iskra MT372 [9]

For precise adjustment of meter load current, in the measurement system was used an auto-transformer. For all examined cases, as the reference energy value was taken energy counted in the reference temperature of 23ºC. In order to minimize the impact of a meter rounding error (resulting from meter registration accuracy of 1 Wh), a registration period for each temperature lasted 30 minutes. To ensure thermal stability during measurement, between each measuring points was allocated a 30 minute break to change and stabilize the chamber internal temperature. Measurement data from the meter was collected by using a optical interface and the PC with dedicated software. On the basis of obtained results, the temperature percentage additional error δ_T was calculated according to the formula (2). A simplified structure of measuring stand for temperature examining of electricity meters is shown in figure 2.

Results

Each measuring series included energy measurements at the following temperatures: -40°C, -25°C, -10°C, 5°C, 23°C, 30°C, 40°C, 55°C and 70°C. Those temperatures are compatible with the limit values from table 1. The first measurement series, which was a reference for subsequent measurements, was carried out at the meter rated operating parameters – supply voltage of 230 V, supply voltage frequency of 50 Hz and load current of 5 A. On each of the graphs presented in the paper, this series is marked in green (green series in fig. 3, fig. 4 and fig. 5). In this case, the maximum temperature additional error occurred at 70°C and it amounted to approx. 0,85%.

The first quantity, which impact on the temperature error was investigated, was the load current. A measurements series was carried out for unchanged power supply parameters (230 V, 50 Hz) and for the load current of 10 A (Fig. 4, red series). In this case, the maximum temperature additional error also occurred at 70°C and it amounted to approx. 0,5%.

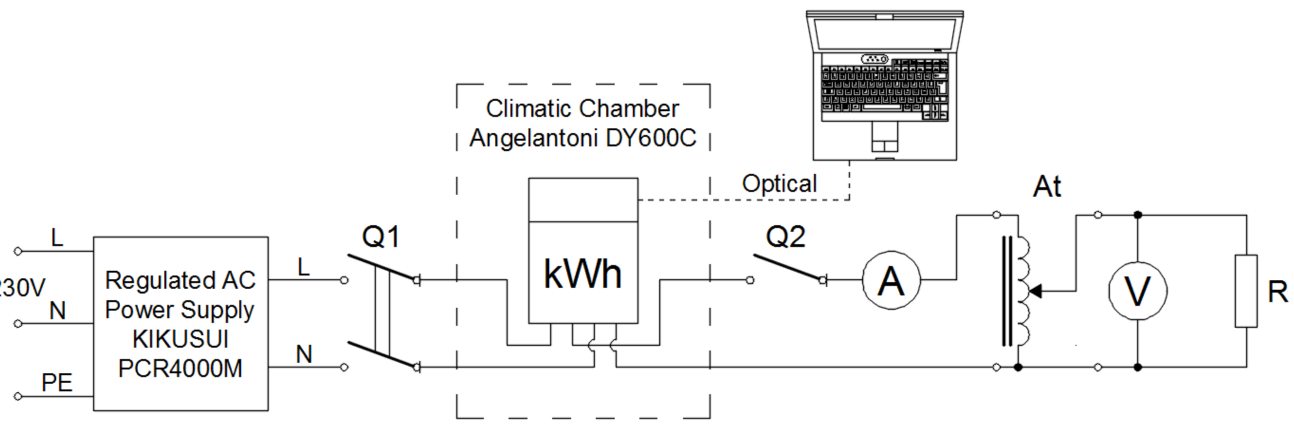

Fig. 2. Measuring stand for temperature examining of electricity meters

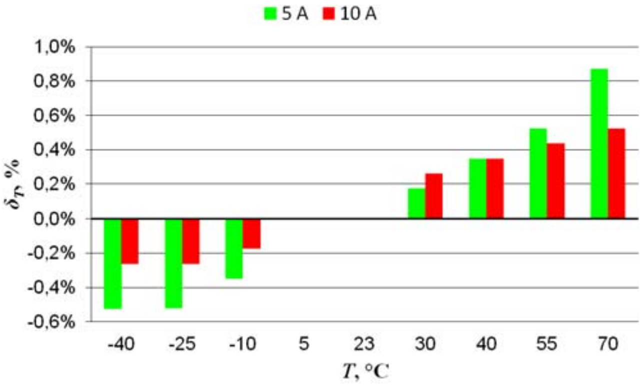

Fig. 3. Temperature additional error vs. ambient temperature for different load currents

Another tested influence quantity was the supply voltage. Measurements were carried out for rated load current (5 A) and frequency (50 Hz). Measurement series were made for voltages different from the rated value of ± 10% – 207 V (Fig. 5, blue series) and 253 V (Fig. 5, red series). For both voltages, the maximum temperature additional error occurred at 70°C and it amounted to approx. 0,6% for 207 V and approx. 0,8% for 253 V.

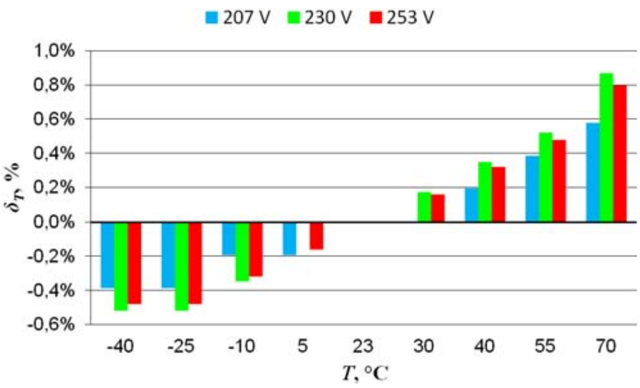

Fig. 4. Temperature additional error vs. ambient temperature for different supply voltages

Last tested influence quantity was the supply voltage frequency. Measurements were carried out for rated load current (5 A) and supply voltage (230 Hz). Measurement series were made for frequencies different from the rated frequency of ± 2% – 49,5 Hz V (Fig. 6, blue series) and 50,5 Hz (Fig. 6, red series). For both frequencies, the maximum temperature additional error occurred at 70°C and it amounted to the same value of approx. 0,85%.

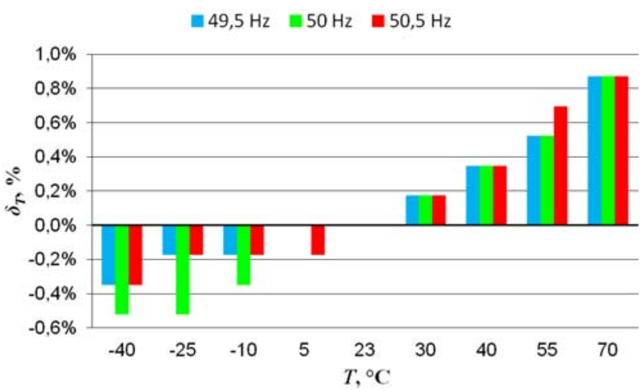

Fig. 5. Temperature additional error vs. ambient temperature for different supply voltage frequencies

Conclusions

- The temperature additional error increases with moving away from the reference temperature for each analyzed case.
- For temperatures above the reference temperature, the additional error is positive, and below the reference temperature, its value is negative.
- The maximum positive error in the highest operating temperature is greater than maximum negative error in the lowest operating temperature.
- For all examined cases, the additional error did not exceed permissible values specified for the meter class in the standard PN-EN 50470-3:2009.
- The temperature effect on measurement accuracy decreases with increasing meter load current.
- The temperature additional error values are comparable for different voltages, but the error is always slightly lower for the lowest tested voltage.
- The frequency impact occurs in negative temperatures, where moving away from the reference frequency results in the error reduction.

***Authors**: dr hab. inż. Paweł Węgierek, prof. PL, mgr inż. Michał Konarski, Lublin University of Technology, Department of Electrical Devices and High Voltages Technologies, Nadbystrzycka 38A, 20-618 Lublin, Poland, E-mail: p.wegierek@pollub.pl, konarski.michal@pollub.edu.pl.*

REFERENCES

[1] European Parliament and of the Council, Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC, *Official Journal of the European Union*, vol. L 211, 55-93, 2009

[2] Minister Gospodarki, Projekt założeń projektu ustawy o zmianie ustawy – Prawo energetyczne oraz ustawy o zasadach pokrywania kosztów powstałych u wytwórców w związku z przedterminowym rozwiązaniem umów długoterminowych sprzedaży mocy i energii elektrycznej. Draft legislation of May 4, 2015, version 1.21

[3] Ćwirko J., Ćwirko R., Temperature testing of electronic modules, *Biuletyn WAT*, vol. LVII, no. 2, 133-142, 2008

[4] Polski Komitet Normalizacyjny, PN-EN 50470-1:2008 – Urządzenia do pomiarów energii elektrycznej (prądu przemiennego) – Część 1: Wymagania ogólne, badania i warunki badań – Urządzenia do pomiarów (klas A, B i C), 2008

[5] Urząd Regulacji Energetyki, Wzorcowa Specyfikacja Techniczna dla postępowań przetargowych na dostawę infrastruktury licznikowej dla systemów AMI, Warszawa, Poland, 2014

[6] Minister Gospodarki, Rozporządzenie Ministra Gospodarki z dnia 7 stycznia 2008 r. w sprawie wymagań, którym powinny odpowiadać liczniki energii elektrycznej czynnej prądu przemiennego, oraz szczegółowego zakresu sprawdzeń wykonywanych podczas prawnej kontroli metrologicznej tych przyrządów pomiarowych, *Dziennik Ustaw 2008*, nr 11, poz. 63, Warszawa, Poland, 2008

[7] Polski Komitet Normalizacyjny, PN-EN 62053-21:2006 – Urządzenia do pomiarów energii elektrycznej (prądu przemiennego) – Wymagania szczegółowe – Część 21: Liczniki statyczne energii czynnej (klas 1 i 2), 2006

[8] Polski Komitet Normalizacyjny, PN-EN 50470-3:2009 – Urządzenia do pomiarów energii elektrycznej (prądu przemiennego) – Część 3: Wymagania szczegółowe – Liczniki statyczne energii czynnej (klas A, B i C), 2009

[9] Iskrameco, Iskra Mx37y Technical Desripction, 2008