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THE CONCEPT OF A VIRTUAL POINT OF COMMERCIAL ACCOUNTING OF NATURAL GAS ENERGY AND THE ALGORITHM FOR ITS SOFTWARE IMPLEMENTATION

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Summary. *The issue of the quality of natural gas, including the development of tools and methods for measuring the energy of gas, is still relevant.*

The current «Rules for the supply of natural gas» regulate the procedure for paying consumers for natural gas, which must be carried out in cubic meters, reduced to standard conditions and expressed in energy units. According to the adopted regulatory documents, the 2021–2022 heating season should be the last one when the calculation for consumed natural gas should be made according to metric indicators. However, with the introduction of martial law in Ukraine, this period has been extended until May 1, following the date of termination or cancellation of martial law in Ukraine.

At present, the natural gas metering system is not ready for the introduction of energy measurement units, especially in the domestic sector. As of today, about 10 million household gas meters with mechanical reading devices have been installed in Ukraine, most of which do not even have natural gas temperature compensation devices. Therefore, it is technically impossible to upgrade these meters to convert them to gas metering in energy units. Along with this, today there are also no domestic means of accounting for natural gas in energy units.

The purpose of this work is to develop alternative approaches to the introduction of accounting for natural gas in energy units in Ukraine.

The concept of a virtual point of commercial metering of natural gas energy is proposed, implemented as a software application that is part of the information and communication system, which in turn contains databases on the daily values of the natural gas combustion heat in different regions of Ukraine, the value of the ambient air temperature and data. on the heights of settlements above sea level in which gas is accounted for. An algorithm for the software implementation of a virtual point of commercial metering of natural gas energy has been developed. The estimation of metrological characteristics of determination of energy of natural gas by the offered method is carried out.

Key words: *natural gas, energy, virtual point, custody transfer.*

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Statement of the problem. According to the law adopted on November 2, 2021 [1], the heating season of 2021–2022 should be the last one when the calculation for consumed natural gas should be made according to metric indicators [2]. But, with the introduction of martial law in Ukraine, this provision of the law [1], according to the amendments made to it, was postponed until May 1, following the date of termination or cancellation of martial law in Ukraine. Therefore, the procedure for settlement with consumers for natural gas in cubic meters, reduced to standard conditions and expressed in energy units, regulated in the Rules for the supply of natural gas [3], remains in force.

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De facto, the Ukrainian natural gas metering system was not ready for the introduction of energy measurement units, especially in the domestic sector. This is due to a large number of household gas meters with mechanical reading devices, which are installed at household consumers (according to [4], about 10 million are now installed in Ukraine). Most of them do not even have natural gas temperature compensation devices, which makes it impossible to bring the consumed gas volumes to the standard conditions regulated by the regulatory document [3]. Therefore, it is technically impossible to upgrade these meters to convert them to gas metering in energy units. Along with this, today there are also no domestic means of accounting for natural gas in energy units.

Analysis of recent researches. The law [1] establishes the following priority methods for determining the volume of natural gas in units of energy:

1) «by measuring the volume of natural gas in units of energy». From the point of view of measurement accuracy, this is the best way, but from the above it follows that now it is impossible to implement it, in particular in everyday life, due to the lack of household means for measuring the energy of natural gas.

2) «by converting the volume of natural gas in units of volume (cubic meters) into the volume of natural gas in units of energy (kilowatt-hours), determined along the relevant route in accordance with the code of the gas transmission system, the code of gas distribution systems». This method, in fact, is now implemented. But it is clear that any calculation method is always more subjective than the measurement one.

Law [1] establishes the following:

- «recalculation of the distribution of capacities at the points of entry into the gas transmission system and/or at the points of exit from the gas transmission system, ordered before May 1, following the date of termination or cancellation of martial law in Ukraine, defined in units of volume (cubic meters), into volumes defined in units of energy, is carried out according to a coefficient corresponding to the value of a higher calorific value and is equal to 10.64 kWh/m^3»;
- «recalculation of the volume of services for the storage (injection, withdrawal) of natural gas is carried out according to a coefficient corresponding to the value of a higher calorific value and is equal to 10.595 kWh/m^3»;
- «recalculation of the volumes of natural gas stored in gas storages is carried out according to a coefficient corresponding to the value of a higher calorific value and is equal to 10.595 kWh/m^3»;
- «recalculation of the volume of services for the distribution of natural gas ...by a coefficient corresponding to the value of a higher calorific value and is equal to 10.64 kWh/m^3»;
- «bring tariffs for services for transportation, storage (injection, withdrawal), distribution of natural gas… applying a coefficient corresponding to the value of a higher calorific value equal to 10.64 kWh/m^3».

The purpose of this work is to develop alternative approaches to the introduction of accounting for natural gas in energy units in Ukraine.

Formulation of the problem. The use of the calculation method proposed by law [1], in particular, only two values of the gross calorific value, will affect the reliability of determining the energy of natural gas in different regions of Ukraine and in different calendar months of the year, since the calorific value is a variable and depends on many factors. The paper [5] shows the range of changes in the maximum and minimum values of the calorific value above, as well as the average value of this value in all regions of Ukraine during the calendar year (Fig. 1).

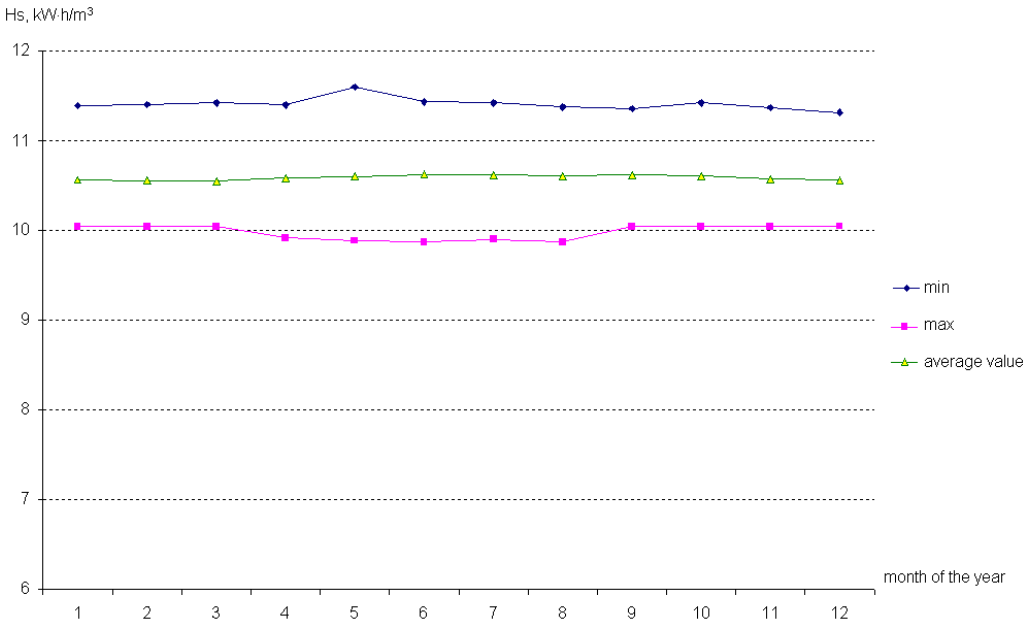

Figure 1. Calorific value higher than natural gas

As can be seen from fig. 1, the law [1] proposes to use the maximum and average value of the calorific value above when recalculating.

The relative deviation of the maximum and minimum values of the calorific value of natural gas from the average value is shown in fig. 2.

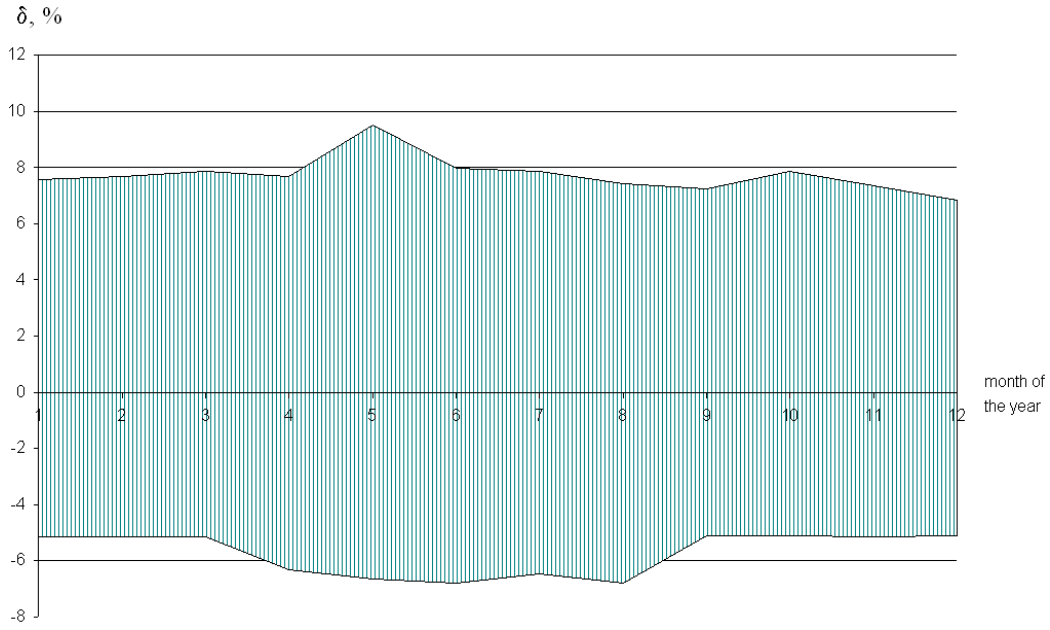

Figure 2. Relative deviation of the maximum and minimum values of the calorific value of natural gas from the average value

Based on the data given in fig. 2, the error of the calculation method, in the case of using the average value of a higher calorific value (10.595 kWh/m^3), will be approximately 10% to minus 7%; in the case of using the maximum value of a higher calorific value (10.64 kWh/m^3) – up to minus 17%.

The way out of this situation, taking into account natural gas in energy units, in particular in everyday life, is the introduction of virtual means of commercial accounting. Moreover, the training of specialists in the design of such tools is carried out in accordance with the standard of higher education in the specialty «Metrology and Information and Measurement Technology» [6], which defines as one of the special professional competencies: «The ability to demonstrate knowledge and understanding of mathematical principles and methods, necessary for the creation of virtual measuring instruments and information-measuring equipment».

Methods of research. The law [1] declares: «The state encourages the introduction of the latest systems, including natural gas metering hardware, including those that provide the possibility of remote transmission of commercial metering data and enable the consumer to actively manage their own consumption».

So far, virtual measuring instruments have not been used in the field of natural gas accounting. However, their use in the field of accounting for another energy carrier – electricity – is regulated by a regulatory document [7].

According to the Code of commercial metering of electric energy [7], «physical and virtual points of commercial metering are used in the electric energy market». Moreover, a virtual metering point, like a physical one, is used for settlements between participants in the electric energy market and/or for reporting [7].

Virtual electricity metering points solve similar problems inherent in natural gas metering: «virtual commercial metering points are created for the purpose of functioning of the electric energy market if it is necessary to generate commercial metering data based on calculations, in particular on the basis of measurement results from one or more measurement points» [7].

Based on the above, the concept of a virtual point of commercial accounting of natural gas energy has been developed, which is as follows:

- virtual point of commercial accounting of natural gas energy (VPCA) is a virtual means of measuring natural gas energy, which has its own identification code related to the data of commercial accounting of natural gas energy used for settlements between participants in the natural gas market and/or reporting;
- VPCA is used together with a natural gas meter, which is installed at the consumer or is already used by the consumer to measure the volume of natural gas;
- physically, VPCA is a software application that is part of the information and communication system, which in turn contains databases of daily values of the calorific value of natural gas H_s in different regions of Ukraine, the value of ambient air temperature $T_{\text{нс}}$ and data on the heights of settlements above sea level h where gas is accounted for. Natural gas energy E this application is calculated by the formula given in [8], developed on the basis of the methodology given in [9]:

$$E = \frac{T_b}{T_{\text{нс}}} \cdot \left(1{,}0321 - 1{,}13812 \cdot 10^{-4} h\right) \cdot H_s \cdot V, \qquad (1)$$

where T_b – standard (basic) value of natural gas temperature given in [1]. The maximum allowable error in determining the energy of natural gas, according to [8], will be: in the case of using VPCA and a gas meter of class A – ± 1,0 %, class B – ± 2,0 %, class C – ± 2,5 %.

- VPCA in the form of a software application can be placed in the mobile phone of a natural gas consumer, a representative of a gas supplier who reads readings from a gas meter, as well as in a personal account of a natural gas consumer on the website of the supplier of this energy carrier;

- the VPCA application may contain an interface for scanning gas meter readings using a mobile phone camera and automatically recognizing them and entering them into the information and communication system database.

Results of the research. Algorithm for software implementation of a virtual point of commercial accounting of natural gas energy:

The first step: reading the gas meter and recognizing it.

Model of the process of determining gas meter displays in the form of a sequence of transformations of the meter display image, given in [10].

$$\begin{cases} M = M_k \xrightarrow{S_1} M_{ms} \xrightarrow{S_2} M_s \xrightarrow{S_3} M_f \xrightarrow{S_4} M_b \xrightarrow{S_5} \\ \rightarrow M_z \xrightarrow{S_6} M_c \xrightarrow{S_7} M_v \xrightarrow{S_8} M_e \xrightarrow{S_9} M_u \xrightarrow{S_{10}} M_w \end{cases}, \quad (2)$$

where M_k – color image model containing gas meter displays; M_{ms} – scalable image model; M_s – grayscale image model; M_f – image background model; M_b – image model without background; M_z – anti-aliased image model; M_c – closed loop model; M_v – model for determining a circle in an image; M_e – model of the process of determining the rectangle on the image; M_u – model of the process of determining the image of the counter display; M_w – gas meter display board image model; $S_1,...,S_{10}$ – model conversion functions.

Second step: identification of the route by which natural gas is delivered to the physical gas metering point, by the recognized gas meter number.

The third step is to send a request and get the natural gas calorific value from the corresponding database for the identified route.

The fourth step: sending a request and receiving a numerical value of the ambient air temperature at the time of reading the gas meter readings for the settlement where the physical metering point is located from the corresponding database.

Fifth step: sending a request and obtaining a numerical value of the geographical height of the settlement above sea level, where the physical metering point is located, from the corresponding database.

Sixth step: calculation of the energy of the consumed gas according to the formula (1).

Seventh step: transfer of data on the consumed volume and energy of natural gas from VPCA to the appropriate database.

Eighth step: displaying natural gas energy consumption data in a software application on a device from which VPCA is accessed.

Conclusions. The concept of a virtual point of commercial metering of natural gas energy is proposed, implemented as a software application that is part of the information and communication system, which in turn contains databases on the daily values of the calorific value of natural gas in different regions of Ukraine, the value of the ambient air temperature and data on heights of settlements above sea level in which gas is accounted for. An algorithm for the software implementation of a virtual point of commercial metering of natural gas energy has been developed. The estimation of metrological characteristics of determination of energy of natural gas by the offered method is carried out.

The subject of further scientific research will be the development of a specification of requirements and a software application for the implementation of a virtual point of commercial metering of natural gas energy, as well as an experimental study of the metrological characteristics of a gas metering system.

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КОНЦЕПЦІЯ ВІРТУАЛЬНОЇ ТОЧКИ КОМЕРЦІЙНОГО ОБЛІКУ ЕНЕРГІЇ ПРИРОДНОГО ГАЗУ ТА АЛГОРИТМ ЇЇ ПРОГРАМНОЇ РЕАЛІЗАЦІЇ

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Резюме. *Питання якості природного газу, в тому числі розроблення засобів і методів вимірювання енергії газу залишається й досі актуальним.*

Чинні «Правила постачання природного газу» регламентують процедуру розрахунку зі споживачами за природний газ, який повинен здійснюватися в метрах кубічних, приведених до стандартних умов і виражених в енергетичних одиницях. Відповідно до прийнятих нормативно-правових документів, опалювальний сезон 2021–2022 років мав бути останнім, коли розрахунок за спожитий природний газ мав здійснюватися за метричними показниками. Однак із запровадженням в Україні воєнного стану цей термін продовжено до 1 травня, що настає за датою припинення або скасування воєнного стану в Україні.

Зараз приладова система обліку природного газу не готова до запровадження енергетичних одиниць вимірювань, особливо в комунально-побутовій сфері. Станом на сьогодні в Україні встановлено приблизно 10 млн. побутових лічильників газу з механічними відліковими пристроями, у більшості з яких відсутні навіть пристрої компенсації температури природного газу. Тому технічно неможливою є модернізація цих лічильників для переобладнання їх на здійснення обліку газу в енергетичних одиницях. Поряд з цим, на сьогодні відсутні також побутові засоби обліку природного газу в одиницях енергії.

Метою даної роботи є розроблення альтернативних підходів до запровадження в Україні обліку природного газу в енергетичних одиницях.

Запропоновано концепцію віртуальної точки комерційного обліку енергії природного газу, реалізованої як програмний додаток, який входить до складу інформаційно-комунікаційної системи, що, в свою чергу, містить бази даних про щоденні значення теплоти згоряння природного газу в різних регіонах України, значення температури повітря навколишнього середовища та дані про висоти населених пунктів над рівнем моря, в яких здійснюється облік газу. Розроблено алгоритм програмної реалізації віртуальної точки комерційного обліку енергії природного газу. Здійснено оцінювання метрологічних характеристик визначення енергії природного газу запропонованим методом.

Ключові слова: *природний газ, енергія, віртуальна точка, комерційний облік.*

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