DEVICES IN REMOTE MONITORING AND CONTROL SYSTEMS FOR COMMERCIAL MEASUREMENT OF NATURAL GAS

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ABSTRACT. Natural gas, electricity, water, heat are supplied through independent distribution networks. Measurement of the respective energy electricity, natural gas, water and heat is based on separate, independent measuring devices and their own processes for metering and control. The principle of systems for remote monitoring and control of commercial metering devices (STI) is combined in one or in all measuring devices and in one system in order to reduce costs and/or improve business processes. In addition, these systems are also suitable for the respective energy regulator in order to improve energy savings by providing more complete information on the energy consumption of the respective country.

Key words: natural gas, automated control, metering device, energy efficiency.

УСТРОЙСТВА В СИСТЕМИ ЗА ДИСТАНЦИОННО НАБЛЮДЕНИЕ И УПРАВЛЕНИЕ НА СРЕДСТВАТА ЗА ТЪРГОВСКО ИЗМЕРВАНЕ НА ПРИРОДЕН ГАЗ

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РЕЗЮМЕ. Природният газ, електроенергията, водата, топлоенергията се доставят с помощта на независими дистрибуторски мрежи. Измерването на съответния енергоносител електричество, природен газ вода и топлинна енергия се основава на отделни, независими измервателни устройства и техните собствени процеси за отчитане и управление. Принципът на системи за дистанционно наблюдение и управление на средства за търговско измерване (СТИ) се обединява в някой или всички измервателни устройства и в една система, за да се намалят разходите и/или да се подобрят бизнес процесите. Освен това, тези системи са подходящи и за съответния енергиен регулатор с цел подобряване на икономията на енергия, чрез предоставяне на по-пълна информация за потреблението на енергия на съответната страна.

Ключови думи: природен газ, автоматизирано управление, измервателно устройство, енергийна ефективност.

Introduction

In the theoretical achievements of the applied designed devices transformed for the means of remote monitoring and control of the "smart" flow meters, experiments will be performed on 24 researched points for development and validation of the design results, for confirmation of the correctness of the process and system studied, and a detailed analysis and conclusions of the experimental study will be conducted.

Uneven gas consumption in 24 studied development points creates preconditions for deviations in the accuracy of reading due to work at different operating points of the nonlinear curve of the individual flow meters. At the same time, the unevenness reinforces the random factor and the proper planning and pre-orders of gas. This is a serious disruption to gas distribution networks in general. This factor is considered in relation to the choice of flow meter for the remote monitoring and control system.

The results of the experiments performed at 24 points of study from the development of systems for remote monitoring and control of means for commercial measurement of natural gas are presented in tables and illustrated with graphical figures for each of the studied points. For most of the studied means, part of the gas distribution networks, prevailing values of this ratio between 30% and 40% are observed. Comparing the results, it can be concluded that for the smaller consumers of the points studied in the gas distribution networks, the average daily consumption is approximately half of the maximum registered daily consumption on an annual basis for 2019.

Gas consumption in the performed experiments at 24 studied points varies depending on the different conditions, as the seasonal factors and meteorological changes of the atmospheric temperature are the most influential factor of the results of the performed experiments. In the presented tables, those are illustrated in graphical figures. The approximate seasonal difference (January/July * 100 in %) in the consumption of the studied points (adjusted for the network segment) is shown in graphical figures.

The graphs and the corresponding initial data show a multiple increase in gas consumption in winter compared to the summer months. The data from the survey of consumers through the means of remote monitoring and control in the gas distribution networks are different for different regions of our

country, although averaged with other users of the gas distribution networks in the country part of the survey. The large seasonal differences in the uneven gas consumption of the different consumers in the studied points part of gas distribution networks creates preconditions for deviations in the accuracy of reading due to the operation of the nonlinear curve of the individual flow meters in different operating ranges. At the same time, the unevenness reinforces the random factor and the proper planning and pre-orders of gas. This is a serious disturbance for the gas distribution networks of our country as a whole. This factor is related to the choice of flow meter for intelligent measurement in the studied means for remote monitoring and control in the gas distribution networks.

In comparison, the studied points show the percentage of the average daily to the maximum daily gas consumption of the different surveyed consumers' part of the study.

The results of all successfully passed research work are given in tables and illustrated with graphical figures. For most consumers, part of the study of the means for remote monitoring and control of gas distribution networks, prevailing values of this ratio between 30% and 40% are observed. Comparing the results, it can be concluded that for the smaller consumers in the study, the average daily consumption is approximately half of the maximum registered daily consumption on an annual basis for 2019.

The large seasonal differences in gas consumption (on average up to about 600%) show an uneven load on the studied points. This suggests that it makes sense to analyse the gas distribution processes and to develop strategies and procedures for automated redistribution of available gas quantities when working outside the normal operating mode (in case of gas shortage).

In the analysis of the existing condition of the gas distribution networks and for the needs of designing the system for remote measurement of the gas consumption, the technical information for the user at the studied point is important.

The studied points are part of different gas distribution networks, all of them live in highly urbanised areas (central urban areas, buildings and blocks). Therefore, the majority of gas consumers in the study live in highly urbanised areas. In this sense, in the construction of the entire system for remote measurement of gas consumption the focus is on methods and relevant technical means for generalised collection and remote transmission of data from individual flow meters. It is economically advantageous to use means that allow the collection of flowmeter data in a tree-like or hierarchical structure and the subsequent processing and aggregation of a centralised data collection system. The structure and the technical solution for each separate segment/region of the system is determined by the density of distribution of the users, the respective distances, and additional factors such as the availability of power supply and suitable locations for installations of technological equipment.

Depending on the technical possibilities on site, the type of connection (wired or wireless) and the type of communication are assessed for each specific user of natural gas. The assessment is related to the specific topology and spatial distribution of the user.

The distance between the individual switchboards is relatively small (less than 100 m) and has been suitable for the construction of an internal cable network through which to collect data from individual flow meters in a suitable concentrator to act as an archiver and buffer between gas flow meters and a centralised data collection system in the event that power is provided for the hub in question and, accordingly, the flow meters are also supplied via two-wire data wiring (wired M-Bus). Moreover, through the local displays of the flow meters in the building, it is possible to show the costs for the individual consumers. The percentage (2% to 3%) of residential buildings is mainly observed at the stage of new construction in urban areas in which the flow meters are located on landings in passable niches specially made by the builder from the first to the last floor, where the same solution was used.

A considerable part of the cases with the intelligent flow meters are located outside the building in a special gas distribution board. This solution has been suitable for building a local system with a data concentrator and a modem for transmitting information over a wired or wireless line (e.g. GPRS) to a central server.

In the majority of cases (≈ 95%), the smart flow meters are located in gas distribution boards, installed on the property border or outside this border. Thus, they do not create difficulties in the service because there is no restriction to the access to the smart means of commercial metering.

Only in 2% ÷ 5%, the intelligent means of commercial metering are located in a gas distribution panel on the territory of the user, which restricts the access to the service of the facility in hard-to-reach places.

One of the main advantages of intelligent commercial metering is the way data is collected and transmitted and invoiced to the central operating system.

A parameter that influences and determines the type of intelligent commercial metering devices for consumers (such that would integrate an automatic remote shut-off valve) is the number of procedures for stopping and restoring gas supply to a consumer. The summarised data from all gas distribution networks on the territory of the country show that on average monthly gas supply to many consumers is interrupted for various reasons (accident, non-payment of bills, refusal to consume gas, etc.).

Main characteristics of the considered experimental systems for remote monitoring and control of commercial measuring instruments (JTI) for the period № 1.1, such as the frequency of the received data, operating modes, seasonal factors, and meteorological changes of the atmospheric temperature

Characteristic №1 that can be noted is that the need to integrate an external shut-off valve for remote interruption of gas supply to the flow meter is not necessarily urgent and is rather a matter of economic assessment, taking into account the necessary maintenance and periodic maintenance measures especially for the valve. The presence of a built-in valve in the flow meter would be important in the event of an emergency need to disconnect a subscriber or section of the gas distribution network, which is currently done manually at the end user or centrally for the segment.

There are a large number of detected attempts to manipulate the meters for natural gas consumption; in recent years there has been a tendency to increase the detected attempts. Assuming that there are also unregistered cases, which is difficult to prove in the absence of automated real-time registration systems and gas balance. Due to attempts to manipulate the readings of flow meters, it was appropriate to seek a simple technical solution to inform the gas distribution

company of violations in commercial metering devices. The operation can be coordinated with the schedule for prevention, repair, service adjustment, etc., as the information about the condition of the device is suppressed until the completion of the planned activities.

The visualisation of the current indications for individual consumption of each consumer in the gas distribution networks in the country at the moment is reduced to monitoring the pulse counter of the flow meter itself. Consumers are divided into three groups depending on the annual gas consumption:

• large industrial consumers with a consumption of over 200 thousand m^3;

• medium-sized consumers with a consumption between 200 thousand m^3 and 10 thousand m^3;

• industrial consumers with a consumption of less than 10 thousand m^3.

The dynamics and the coefficient of uncertainty in the gas distribution networks are determined by:

• Seasonal change in consumption;

• Stopping the gas supply due to repairs, accidents and incorrectness of the customer;

• Connecting new subscribers;

• Detected attempts to manipulate data and readings;

• Defective and replaced flow meters;

• Unplanned and uncoordinated construction and installation works in the easement of the network, which led to the interruption of gas pipelines, etc.

The graphs of the surveyed intelligent commercial metering devices show a serious seasonal (winter/summer) change in the consumption of consumers included in the survey. For example, the change data provided by some surveyed points show 1000% change. In some of the surveyed users, the seasonal change is between 250% and 400%

Characteristic № 2: such a large seasonal change in consumption poses serious problems to the gas distribution network. Highly uneven flow is a problem when choosing the connection size of the flow meter. At the same time this calls into question the linearity in the readings of the device. It is also difficult to stabilise the pressure in the network. The pulsations in the consumption are also related to problems with readjustment of the parameters of the intelligent means of commercial measurement and determine an admissible period for readjustment.

The need to change the calorific value of the gas, which in current practice is set once during the initial installation of the device, is also important. At the same time, *Bulgartransgaz* issues a certificate for the composition of the gas every day.

Characteristic № 3: the daily change of the calorific value of the gas under the current conditions of network management ("manual") is physically impossible. On this basis, it should be considered that the introduction of intelligent metering systems for remote tuning and modification would significantly increase the accuracy of grid metering and consumer confidence.

Some of the problems of the gas distribution networks are related to the elimination of damages and accidents due to:

• construction work;

• performing activities in the easement of the networks by other companies;

• leaks from threaded connections and seals and regulators;

• unsecured stable power supply of AGRS and hence problems with gas heating;

• change of pressure outside the norms;

• hit facilities and damaged integrity of the timing belt, as a result of excavation activities;

• actuation of timing cutters;

• malicious actions of persons outside the system and the company.

A considerable amount of work is related to the collection, processing and input of information on:

• the state of the network;

• the number and status of the subscribers;

• the amount of gas consumed.

For the condition of the network, monthly patrols are made to check natural gas leaks, failure of the route, the condition of the cast iron gaskets and shafts, shut-off valves, the presence of construction and installation work near the network, as well as for checking the operation of odorising stations, measuring the parameters of EHR, verification of the protective potential, etc. The results of the survey are summarised in statements of findings, which are submitted in writing. On-site checks are made on the amount of gas consumed. In the general case, the data are recorded on paper and balances are made. All these operations will be automated with the intelligent systems.

Characteristic № 4: the opinion on the gas distribution networks is that the automated intelligent systems for remote collection of information from the various devices on the network will automatically deliver data on the measured values and parameters of the cathode and odour stations, on the condition that the crane units will significantly improve maintenance and management of the gas distribution network and would facilitate their overall operation.

Main characteristics of the considered experimental "Point № 1" for the period № 1.1, such as the frequency of the received data, operating modes, seasonal factors, and meteorological changes of the atmospheric temperature

In Table 1, the data obtained for four days from systems for remote monitoring and control of means for commercial measurement of natural gas and their use for balancing are considered. It clearly visualises how the consumption of natural gas can be related to the ambient temperature and to predict the future consumption of a given consumer or gas distribution network.

Table 1. *Point № 1 for the period № 1.1*

Tempera-ture in Celsius °C	*t°*	*t°*	*t°*	*t°*
	2	*3*	*4*	*5*
	01.10.20	02.10.20	03.10.20	04.10.20
8:00	14,2	1,3	1,6	5,9
9:00	13,9	1,6	4,8	8,8
10:00	15,7	2,3	8,0	12,9
11:00	19,3	3,4	10,2	16,8
12:00	19,5	4,4	12,3	19,1
13:00	18,6	4,8	13,7	20,6
14:00	18,9	5,0	15,2	21,8
15:00	19,6	4,8	16,0	22,6
16:00	19,1	4,8	16,9	23,0
17:00	17,4	5,3	17,1	23,2
18:00	15,3	5,6	16,7	22,7

19:00	13,9	4,9	15,5	21,5
20:00	12,5	3,6	12,4	17,7
21:00	11,1	2,6	9,7	15,0
22:00	10,3	1,4	8,5	12,5
23:00	8,7	1,2	7,3	11,1
0:00	3,5	1,2	7,0	15,5
1:00	5,2	0,7	6,9	12,8
2:00	4,6	0,7	6,1	11,9
3:00	3,9	0,6	6,0	11,6
4:00	3,1	0,4	5,9	11,4
5:00	2,1	0,1	5,9	10,9
6:00	1,6	-0,4	5,4	10,9
7:00	1,1	-0,5	5,2	10,1
MAX t°	***20***	***6***	***17***	***23***
MIN t°	***1***	***-1***	***2***	***6***
Average t°	***11***	***2***	***10***	***15***
sum t°	***308***	***71***	***268***	***421***
Total m3	***135 340***	***186 624***	***138 869***	***105 392***
Representative caloric	**10,517**	**10,517**	**10,517**	**10,517**
	Nm3	**Nm3**	**Nm3**	**Nm3**
	2	***3***	***4***	***5***
Consump-tion in Nm3	**14.04.20**	**15.04.20**	**16.04.20**	**17.04.20**
8:00	6 194	8 710	9 187	6 411
9:00	6 354	9 802	9 032	6 140
10:00	6 752	9 402	8 486	5 836
11:00	5 375	8 878	7 654	5 680
12:00	5 178	8 428	6 803	5 382
13:00	4 654	8 546	6 623	5 111
14:00	4 510	8 414	6 088	4 571
15:00	4 249	8 172	5 385	4 150
16:00	3 983	7 753	5 083	3 864
17:00	4 903	7 301	4 531	3 720
18:00	5 746	7 578	4 802	3 430
19:00	6 614	7 985	4 776	4 097
20:00	6 885	8 261	5 587	4 245
21:00	6 514	8 553	6 055	4 791
22:00	6 653	8 598	5 975	4 843
23:00	6 533	7 694	5 720	4 457
0:00	5 743	7 149	5 042	4 061
1:00	5 329	6 492	4 762	3 681
2:00	4 905	5 943	4 213	3 395
3:00	4 892	5 921	4 096	2 982
4:00	4 905	5 916	4 190	3 103
5:00	5 156	6 048	4 340	3 359
6:00	5 965	6 717	5 014	3 629
7:00	7 348	8 363	5 425	4 454
Тотал	**135 340**	**186 624**	**138 869**	**105 392**
16:00	**34 507**	**53 766**	**47 785**	**34 560**
%	**25,50%**	**28,81%**	**34,41%**	**32,79%**
23:00	**91 097**	**134 075**	**101 787**	**76 728**
%	67,31%	71,84%	73,30%	72,80%

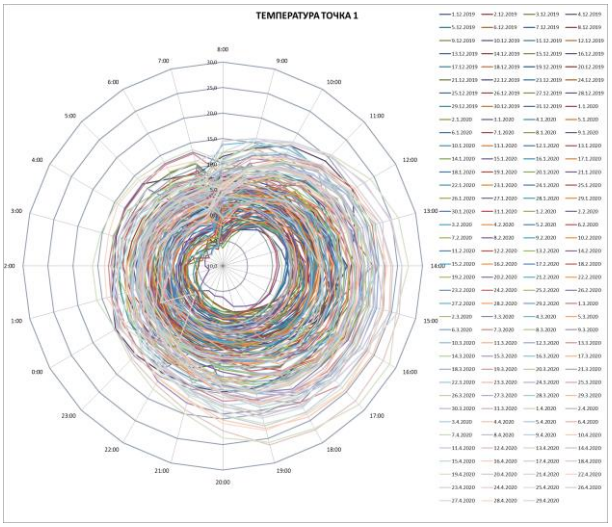

Fig. 1 shows the radar temperature at "Point 1"; the study of this point was conducted on an hourly basis in the course of 151 gas days. During the research conducted, the ambient temperature was measured and the hourly development of the temperature was clearly visualised.

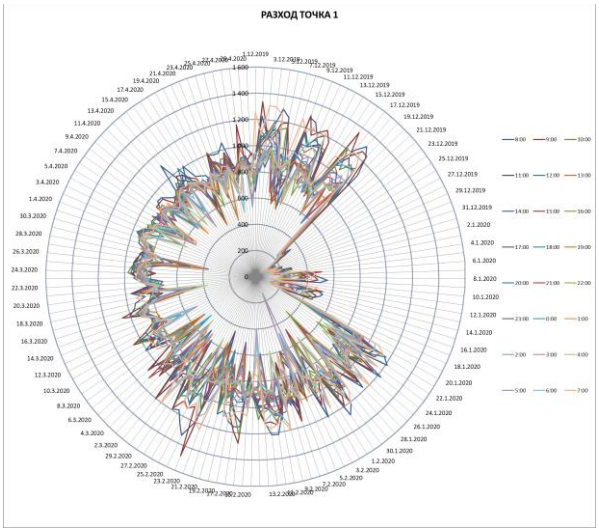

Fig. 2. Consumption of natural gas at "Point 1" of the attached designed device of the systems for remote monitoring and control of means for commercial metering of natural gas

Conclusions from the analysis of the situation in systems for remote monitoring and control of means for commercial measurement of natural gas in the gas distribution networks in the country

The large seasonal change in consumption, as well as the uneven consumption of gas poses serious problems for the gas distribution network. The highly uneven flow is a problem when choosing the connection size of the flow meter and at the same time calls into question the linearity in the readings of the device. It is also difficult to stabilise the pressure in the network. The pulsations in the consumption are also related to problems with readjustment of the parameters of the correctors and determine the admissible period for readjustment. At the same time, the unevenness reinforces the random factor and the

proper planning and determination of pre-orders for gas. This is a serious disruption to the gas distribution network as a whole.

It is physically impossible to change the daily calorific value of the gas under the current network management conditions ("manual"). This gives us reason to believe that the introduction of remote tuning/change (for example by introducing a SCADA system) would significantly increase the accuracy of reporting the energy performance of the network and consumer confidence.

The large number of different flow meters and correctors, supplied by different manufacturers and installed in the gas distribution networks is impressive. This implies a greater stock of spare parts and devices and a wider qualification of the service personnel responsible for their maintenance. In this sense, as much typification as possible could be considered, at least with regard to device manufacturers. Of course, this is a difficult task, because its solution is related to the connection sizes of the devices, as well as to tender procedures and delivery periods.

At present, diaphragm, rotary and turbine flow meters are used in the gas distribution networks, i.e. of a mechanical type.

There are also difficulties in maintenance and the need for periodic rehabilitation due to wear of moving parts and deformations in these flow meters. Despite the lack of standards and norms in Bulgaria at the moment, it is advisable to consider the introduction of "smart" gas flow meters, to move to those that are based on more modern methods of measuring gas consumption, such as ultrasonic, laser, based on microthermal technology with C-mos sensor, etc., with longer service life and remote monitoring (after technical and economic analysis).

Due to attempts to manipulate the readings of the flow meters for household needs, it is advisable to look for a simple technical solution (eg. installation of a tamper), through which to inform the service center about improper opening of the device cover. The operation of the tamper (open/closed) can be coordinated with the schedule for maintenance, repair, service adjustment, etc., as the information about the condition of the tamper is suppressed until the end of the work.

For household subscribers in the gas distribution network, it can be assumed that the need to integrate an external shut-off valve for remote interruption of gas supply with the flow meter is not necessarily urgent and is rather a matter of economic assessment, taking into account the necessary maintenance and periodic maintenance measures especially for the valve. Such a function can be sought when replacing obsolete flow meters with new ones, following the logic that the company would gradually switch to a system for "Smart metering". In the case of still usable flow meters, the status quo may be maintained.

Conclusions that can be made regarding the workload and responsibilities of the employees of the gas distribution networks:

As has been established, the relative length of the network, which should be serviced by one employee in the individual gas distribution networks, the work with different number of household and business subscribers, is very different. In this sense, it can be argued that the workload (responsibility) of employees in the individual gas distribution networks is too unevenly distributed. The service personnel of the gas distribution networks are seriously overloaded. This conclusion determines the need for the introduction of a system for automated remote data collection from peripheral devices, which will formally reduce the workload of employees of gas distribution networks with a larger volume of work.

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