

THE COMPARATIVE ANALYSIS OF AUTOMATIC CONTROL SYSTEMS FOR THE HEAT SUPPLY OF RESIDENTIAL BUILDINGS IN MONOTONOUS TRANSIENT PROCESSES AND IN PROCESSES RECOMMENDED BY REGULATOR MANUFACTURERS

V.L. Kodkin, kodkina2@mail.ru,

A.S. Anikin, anikinas@susu.ru,

A.A. Baldenkov, baloo@mail.ru

South Ural State University, Chelyabinsk, Russian Federation

Results of studies of the automatic regulation system of a residential complex along the street of Academician Sakharov in the city of Chelyabinsk are given in article. The analysis of actual indicators of volumes of consumed gas within several months 2015–2017 is carried out depending on average daily temperature of external air. It is shown that the adjustment of the controller by the factory method does not ensure the effective functioning of the heat supply system, especially at ambient temperatures close to 0 °C. The comparison was carried out in two ways: by the method of equivalent trends and by the average temperature and consumption of gas per month. The conducted analysis convincingly proves that the control system with monotonic processes is not only more effective from the point of view of the operation of the equipment, but also from the point of view of energy efficiency.

Keywords: optimization of heating system, energy efficiency of buildings, coolant temperature control, process optimization, coolant flow.

Introduction

For three years, studies were carried out to optimize the regulation of the heat supply of the residential complex by automatic means. In March 2016, in the system of automatic regulation of a residential complex along the street of Academician Sakharov in the city of Chelyabinsk. After the studies, parameters of the ECL Comfort 200 controller were installed, providing monotonic transients without oscillation. In May 2017, the volume of gas consumption was analyzed in the automated heating system of this residential complex. The results of optimization of the coolant temperature control processes are shown in the paper [1]. It is shown how the amplitude and the period of self-oscillations of the controlled temperature are significantly reduced from 10 °C for a period of 30 minutes to 1 °C for a period of 5 minutes (Fig. 1, 2).

Statement of the problem

At the same time, despite the obvious advantages of monotonous transient processes, due regard is not paid to their tuning, since fluctuations in the temperature of the coolant are not noticeable to the consumer, and direct saving of resources is not obvious at the same time. The latter is due to the fact that in the theory of automatic control of heat supply systems there is an idea of processes as processes in linear or close to them systems. So most often the object of heating is represented by a combination of links of lag and inertia [2]. In such a system, oscillation is not a sign of an increased consumption of resources. In addition, the documentation for regulators [3, 4] states that oscillatory processes are normal regulation. In the course of experiments with the control system conducted at the individual heat point of the house in February 2016, parameters were established to ensure practically monotonous control processes.

Methods and solutions

Figure 2 shows diagrams of gas consumption and outdoor temperatures for October, November and December 2015 and 2016, as well as for January, February and March 2015, 2016 and 2017. The con-

sumption data are recorded by the operation services [5], and the temperature is taken from the Internet resource [6], which provides the weather archive to the weather station. The comparison was conducted in two ways:

- Average temperature and gas consumption for a month;
- The method of equivalent trends (the comparable charts reveal similar temperature trends (not less than 5–6 days) and gas consumption and determine the efficiency of resource consumption – for the same temperature or low temperature for the same consumption).

Throughout these methods, efficiency with monotonic processes is higher.

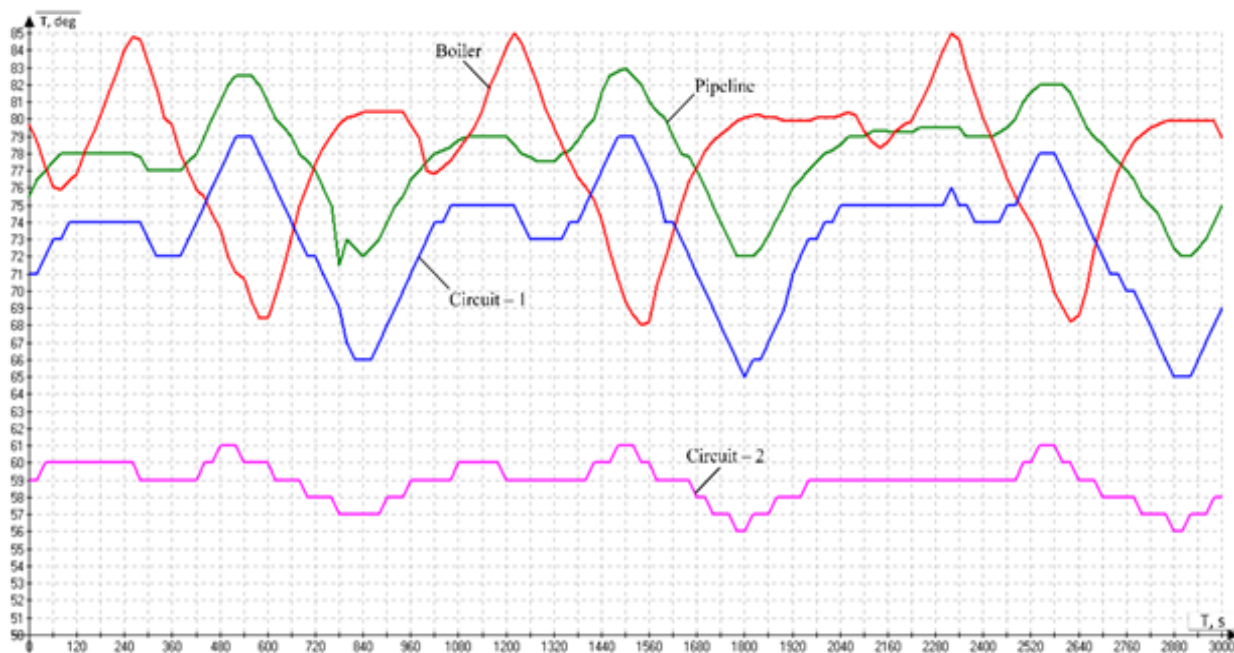


Fig. 1. Processes in the heating system with controller settings recommended by the instructions

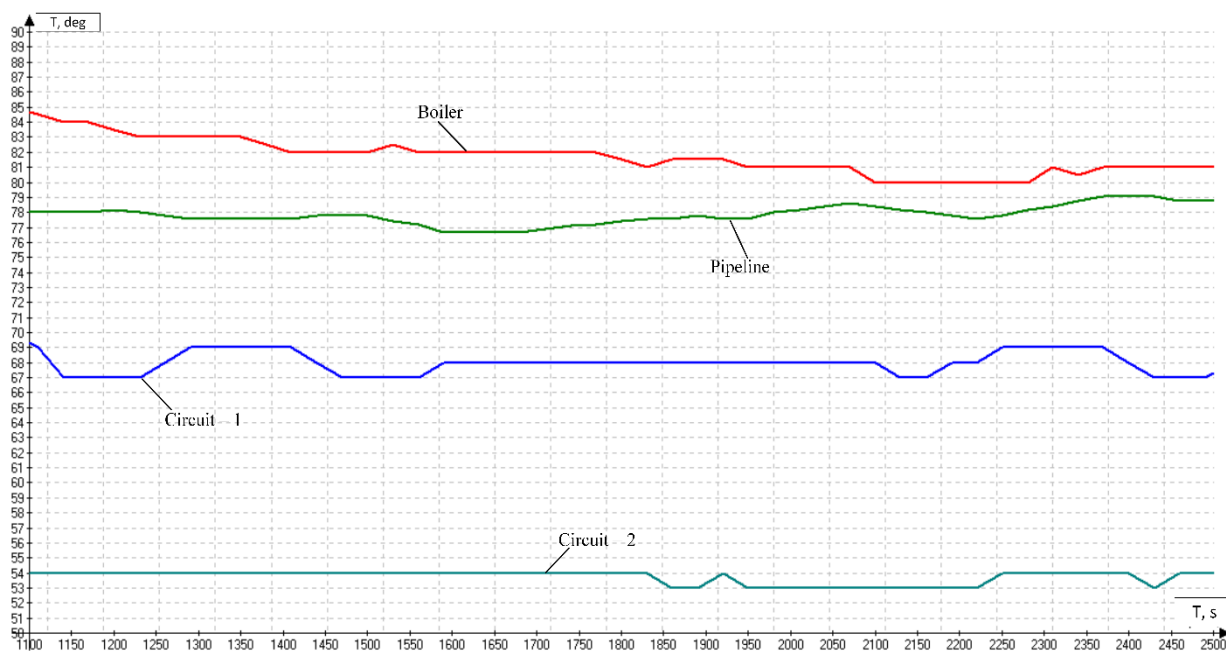


Fig. 2. Processes in the boiler room and heating circuits with the optimum settings of the controller

Краткие сообщения

I. By average values (according to the data in Tables 1–3)

Table 1

Summary table consumption of gas and average daily temperature of external air by months (2014–2015)

	March 2014	February 2015	March 2015	October 2015	November 2015	December 2015
Gas consumption per month, $m^3 \cdot 10^3$	628,2	694	636	491	715,5	767
Average daily temperature for the month, °C (information from the site)	-1,5	-8,5	-3,4	+1,8	-6,8	-7,2
Heating coefficient (room temperature 18 °C)	32,22	26,2	29,7	30,3	28,85	30,56

The tables show calculated “Heating coefficients”, as the ratio of the volume of gas consumed per month to the average temperature on which the room was warmed – from the average outside air temperature to the average “comfortable” temperature – 18 °C. As can be seen from the above results, this coefficient depends on the external air temperature. If the outside temperature is about 0°C, the coefficient is higher. This is explained by the fact that with the intensive operation of the control system, its efficiency decreases, and at low temperatures, when the operation of the heating system is required to its full capacity, its efficiency increases. There are no costs for regulating the supplied heat. This circumstance once again confirms the important role of the quality of automatic control processes in the operation of heating systems. In support of this provision, we will review the data on heat costs for 2015 and early 2016. In these months, the regulators worked with the manufacturer's recommended settings, i.e. with oscillatory processes (Fig. 1). At an air temperature of - 2 to + 2 °C, the coefficient is 32 and above, and at a temperature of -10 °C and below it is about 27. This shows the prospects in saving resources due to the quality of regulation of more than 20%. After setting the parameters of the regulators that ensure a minimum oscillation of the processes, these coefficients decrease, although the trend persists: at high ambient temperatures the coefficients are 25–26, and at low 29–30. The heating factor improved by 7–10%. This confirms the hypothesis of the energy efficiency of a regulatory system with monotonic processes, shows that the effect of improving regulatory systems can be even more significant, for which it is required to continue theoretical analysis and research.

Table 2

Summary table consumption of gas and average daily temperature of external air by months (2016)

	October 2016	November 2016	December 2016	January 2016	February 2016	March 2016
Gas consumption per month, $m^3 \cdot 10^3$	502,5	694,4	857,4	954,8	684,6	667,3
Average daily temperature for the month, °C (information from the site)	+1,4	-9,5	-15,5	-16,4	-6,22	-3,84
Heating coefficient (room temperature 18 °C)	30,272	25,25	25,6	27,8	25,6	30,55

Table 3

Summary table consumption of gas and average daily temperature of external air by months (2017)

	January 2016	February 2016	March 2016
Gas consumption per month, $m^3 \cdot 10^3$	809,12	726,2845	603,5045
Average daily temperature for the month, °C (information from the site)	-13,36	-12,61	-4,081
Heating coefficient (room temperature 18°C)	25,801	23,727	27,331

II. By trends (according to the graphs in Fig. 3)

All the graphs below were analyzed for the presence of close-in-temperature outdoor air or gas consumed time periods. There were quite a few such intervals. It is:

1. October 2015, 2016 (Fig. 3a):

– according to the gas consumption: from 6 to 9 October, from 14 to 19 October and from 26 to 29 October. In all cases of the same gas consumption, the outside temperature with “monotone regulators” was lower;

– according to the outdoor temperature: from 23 to 28 October 2016 gas consumption is lower.

2. November 2015, 2016 (Fig. 3b):

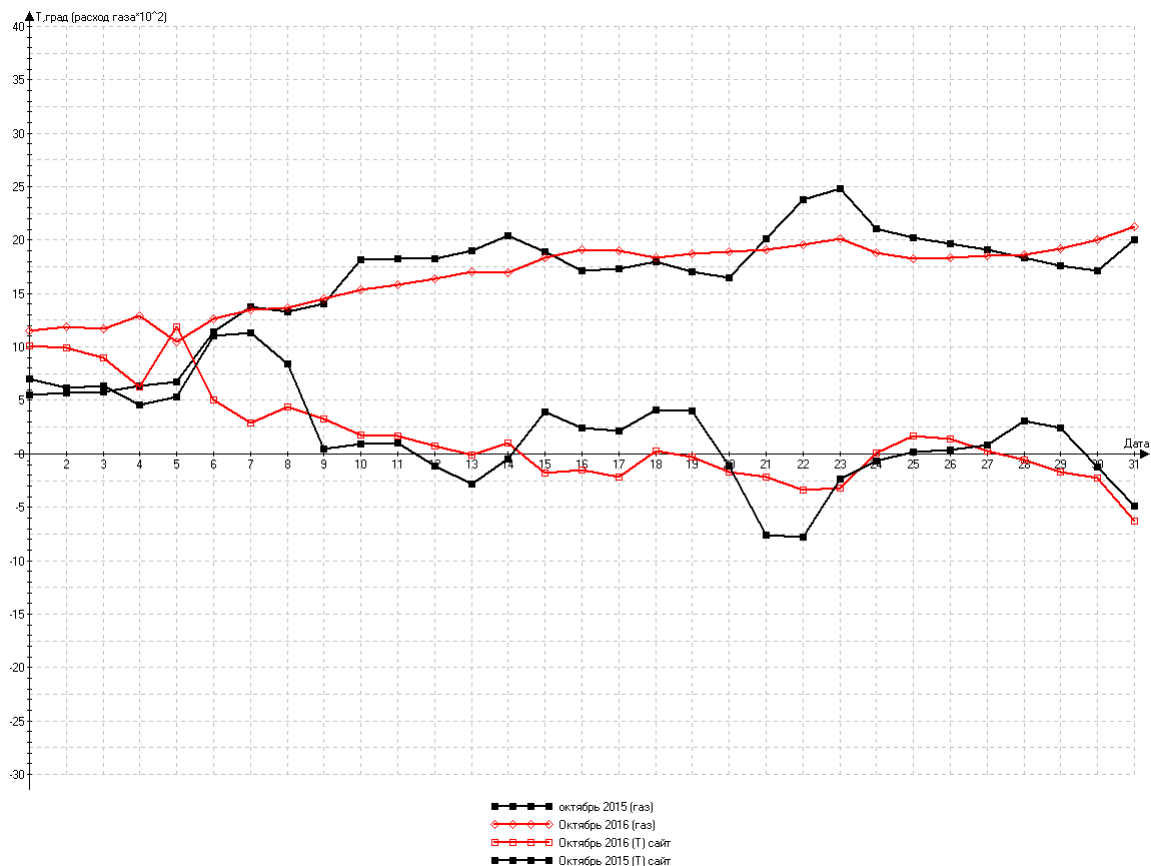
– according to the gas consumption: all days from 1 to 20 November, special from 12 to 20 November. With the same gas consumption, the outdoor air temperature in November 2016 with “monotonic regulators” is lower.

3. January 2015, 2016 and 2017 (Fig. 3d):

– according to the gas consumption: On the graphs of gas consumption are close areas from 4 to 10 January 2015 and 2017, but the temperature in 2017 is lower;

– according to the outdoor temperature: coincides with the interval from 7 to 13 February 2015 and 2017, but gas consumption in 2017 is lower.

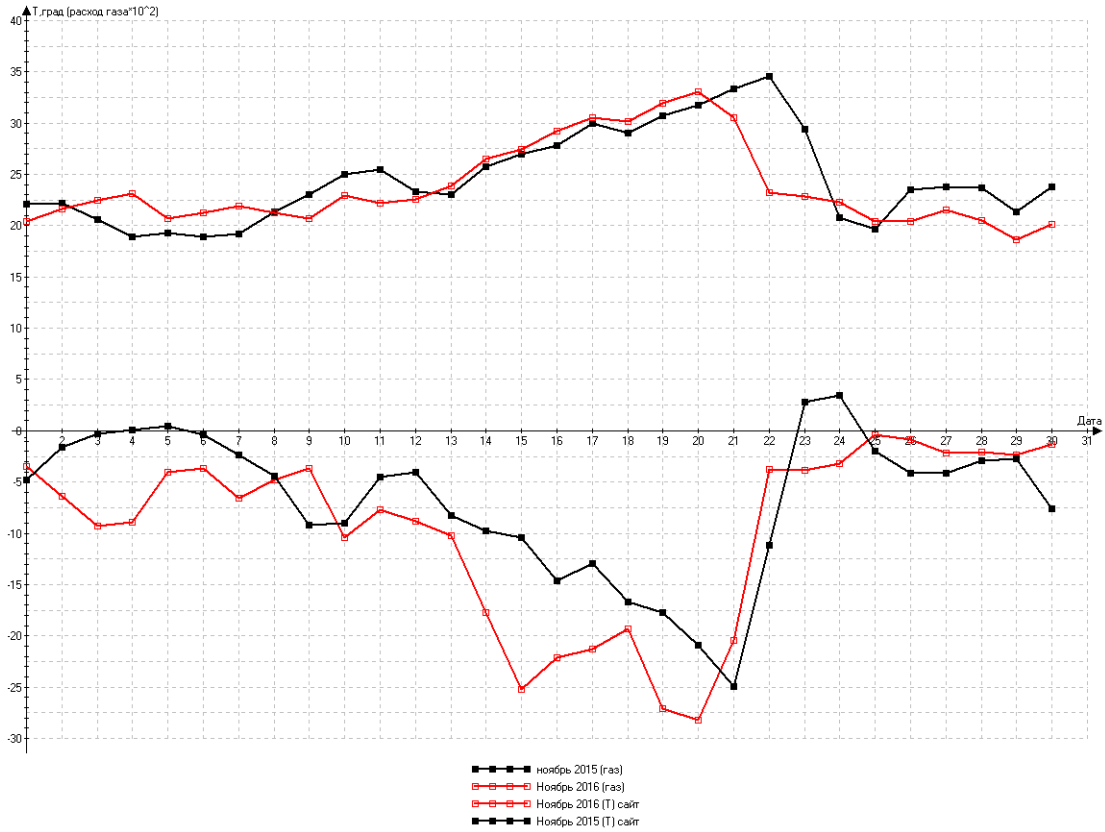
There is no trend with “opposite” trends on the charts. One should pay attention to the diurnal delay between the temperature peaks and consumption under oscillatory tuning, which is not present in monotonic processes. So in Fig. 3a the peak of the decrease in the outside air temperature falls on 9.10.2015, but the gas consumption continues to increase on October 9 and 10. The next minimum temperature was on 13.10.2015, but the increase in gas consumption continued until 14.10.2015. Such delays can be observed on other dates. After the introduction of monotonic regulators, there are no such examples.



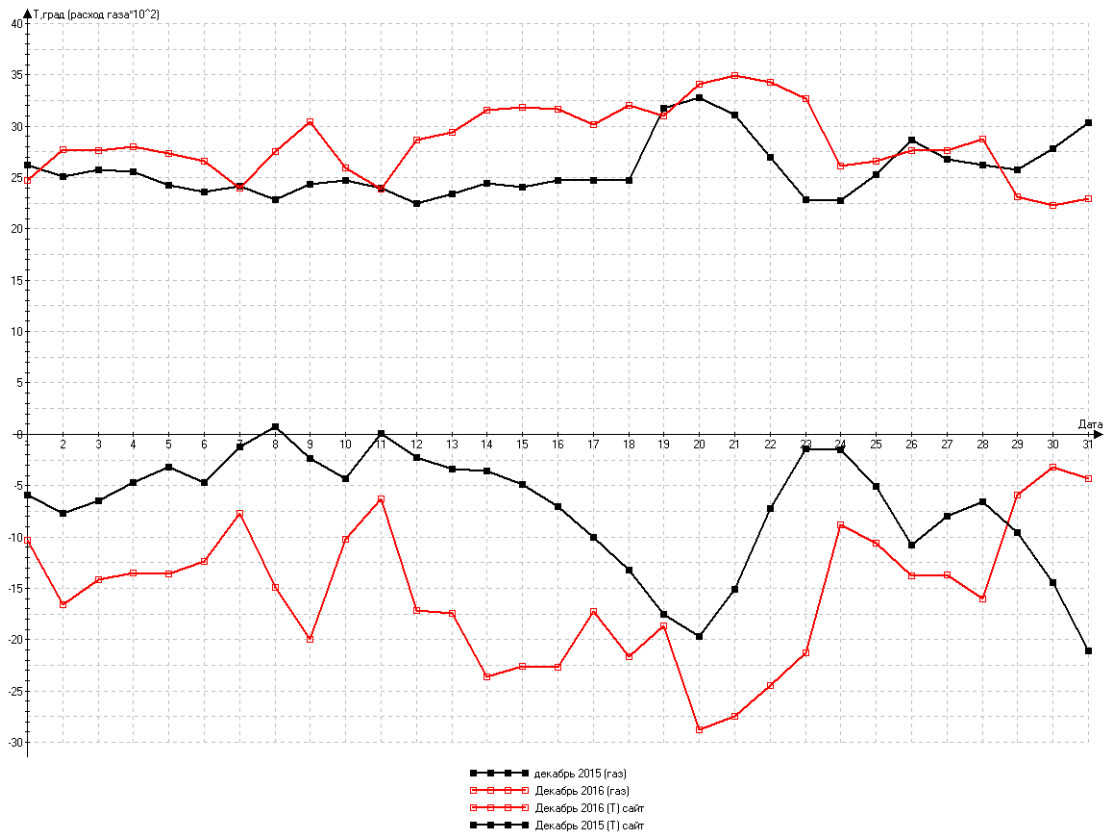
a) October (2015, 2016)

Fig. 3. Graphs of gas consumption and outdoor air temperature by months
(see also pp. 160–162)

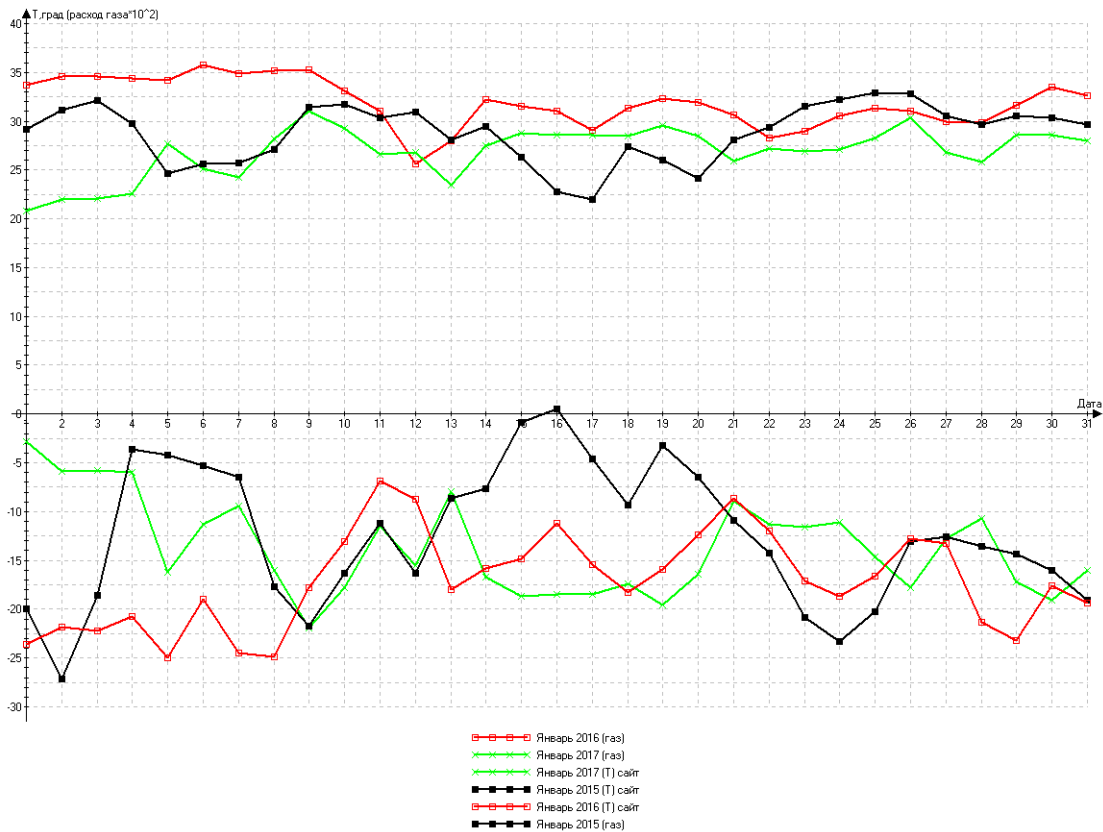
Краткие сообщения



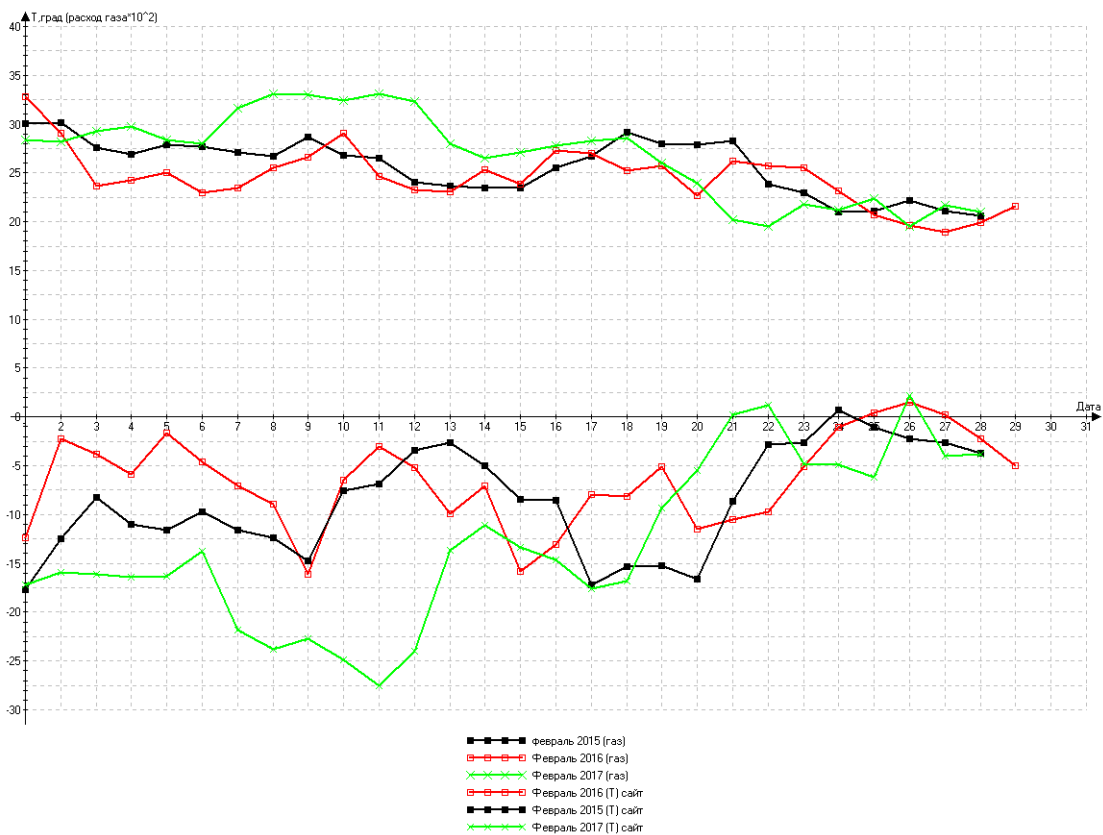
b) November (2015, 2016)



c) December (2015, 2016)

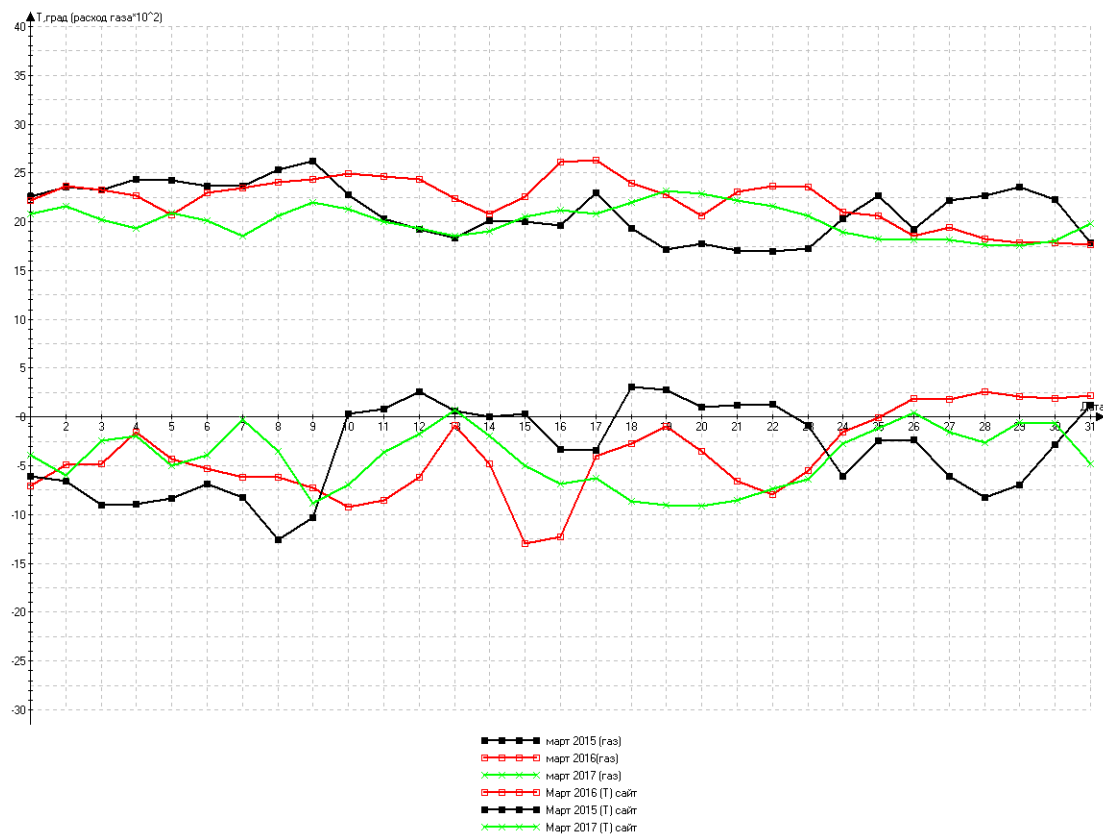


d) January (2015, 2016 & 2017)



e) February (2015, 2016 & 2017)

Fig. 3. Continuation



f) Mach (2015, 2016 & 2017)

Fig. 3. Ending

Conclusions

Thus, the conducted analysis convincingly proves that the control system with monotonic processes is not only more effective from the point of view of the operation of the equipment, but also from the point of view of energy efficiency.

References

1. Kodkin V.L., Anikin A.S., Baldenkov A.A., Kachalin A.Yu., Nemkov V.L. [Optimization of Energy Consumption in Thermal Systems by Methods of the Theory of Automatic Control]. *Science of South Ural State University. Proc. of the 67th Scientific Conference. Section of Technical Sciences*, 2015, pp. 1058–1062. (in Russ.)
2. Kodkin V.L., Anikin A.S., Baldenkov A.A., Kachalin A.Yu. [Identification of Heat Supply Regulators by Dynamic Links with Variable Characteristics]. *Science of South Ural State University. Proc. of the 67th Scientific Conference. Section of Technical Sciences*, 2015, pp. 1049–1054. (in Russ.)
3. Rotach V.Ya. *Teoriya avtomaticheskogo upravleniya teploenergeticheskimi protsessami: uchebnik dlya vuzov* [Theory of Automatic Control of Heat-and-power Processes: Textbook for High Schools]. Moscow, Energoatomizdat Publ., 1985. 296 p.
4. Tsyppin Ya.Z. *Osnovy teorii avtomaticheskikh sistem* [Fundamentals of the Theory of Automatic Systems]. Moscow, Nauka Publ., 1977. 560 p.
5. ECL Comfort 200. User's Manual. Available at: http://www.danfoss-rus.ru/catalog/sections_files/VI7BC550_P30.pdf.

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СРАВНИТЕЛЬНЫЙ АНАЛИЗ СИСТЕМ АВТОМАТИЧЕСКОГО УПРАВЛЕНИЯ ДЛЯ ТЕПЛОСНАБЖЕНИЯ ЖИЛЫХ ЗДАНИЙ В МОНОТОННЫХ ПЕРЕХОДНЫХ ПРОЦЕССАХ И В ПРОЦЕССАХ, РЕКОМЕНДОВАННЫХ ПРОИЗВОДИТЕЛЯМИ РЕГУЛЯТОРОВ

В.Л. Кодкин, А.С. Аникин, А.А. Балденков

Южно-Уральский государственный университет, г. Челябинск, Россия

Приведены результаты исследований системы автоматического регулирования жилого комплекса по ул. Академика Сахарова в городе Челябинске. Анализ фактических показателей объемов потребляемого газа в течение нескольких месяцев 2015–2017 гг. осуществлялся в зависимости от среднесуточной температуры наружного воздуха. Показано, что регулировка контроллера по рекомендации завода изготовителя не обеспечивает эффективного функционирования системы теплоснабжения, особенно при температуре окружающей среды, близкой к 0 °С. Сравнение проводилось двумя способами: методом эквивалентных тенденций и средней температурой и потреблением газа в месяц. Проведенный анализ убедительно доказывает, что система управления с монотонными процессами не только более эффективна с точки зрения работы оборудования, но и с точки зрения энергоэффективности.

Ключевые слова: оптимизация системы отопления, энергоэффективность зданий, контроль температуры жидкости, оптимизация процессов, поток жидкости.

Литература

1. Оптимизация энергопотребления в тепловых системах методами ТАУ / В.Л. Кодкин, А.С. Аникин, А.А. Балденков и др. // Наука ЮУрГУ. Материалы 67-й научной конференции. Секции технических наук. – 2015. – С. 1058–1062.

2. Идентификация регуляторов теплоснабжения динамическим звеньями с переменными характеристиками / В.Л. Кодкин, А.С. Аникин, А.А. Балденков, А.Ю. Качалин // Наука ЮУрГУ. Материалы 67-й научной конференции. Секции технических наук. – 2015. – С. 1049–1054.

3. Ротач В.Я. Теория автоматического управления теплоэнергетическими процессами: учеб. для вузов. – М.: Энергоатомиздат, 1985. – 296 с.

4. Цыпкин, Я.З. Основы теории автоматических систем / Я.З. Цыпкин. – М.: Наука, 1977 – 560 с.

5. ECL Comfort 200. Руководство пользователя. – http://www.danfoss-rus.ru/catalog/sections_files/V17BC550_P30.pdf.

Кодкин Владимир Львович, д-р техн. наук, профессор кафедры автоматизированного электропривода, Южно-Уральский государственный университет, г. Челябинск; kodkina2@mail.ru.

Аникин Александр Сергеевич, доцент кафедры теоретических основ электротехники, Южно-Уральский государственный университет, г. Челябинск; anikinas@susu.ru.

Балденков Александр Александрович, аспирант кафедры автоматизированного электропривода, Южно-Уральский государственный университет, г. Челябинск; baloo@mail.ru.

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