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SMART system for the implementation of rational heat-supply regimes

Abstract: This article presents the current and future situation of heat consumption in the Republic of Kazakhstan. The predicted growth of thermal loads until 2030 is shown in the example of Karaganda city. Therefore, the task of creating and implementing automated heat points into the system of heat-supply complexes of cities of the Republic of Kazakhstan is relevant. The article considers the concept of measurement and processing of information in district heating supply systems based on variable cycles of the interrogation of parameters of heat supply at the heat points. As a result of the conducted research, a microcontroller SMART-system for the implementation of rational modes of heat supply used in the process of obtaining and processing information on heat-consumption parameters and making control decisions regarding variable cycles of heat-supply-parameter interrogation at heat points was developed and implemented. The results of the study have been successfully tested on the facilities equipped with automated heat points.

Keywords: urban heat supply, heat point, automation, measurement and processing, parameter interrogation

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Introduction

The Republic of Kazakhstan (RK) has ratified the United Nations Framework Convention on Climate Change (1992) and assumed certain commitments to reduce carbon dioxide emissions into the atmosphere and reduce the greenhouse effect. The way out of this situation is seen primarily as increasing energy efficiency, reducing heat losses at different stages of the process (from production to consumption) (Sorknæs et al. 2020), and the modernization of equipment and methods of heat generation, transportation and consumption (Agilbayeva and Kalinin 2019). The tariffs will be inevitably affected by this situation (Decree of the… 2014).

Consumer measures will help to reduce the negative impact on the population of inevitable increases in heat tariffs, which include replacing the existing standard heat payment system with an actual consumption payment system based on metering and improving the capacity of managing heat consumption and energy-saving measures for buildings and accommodations in general (Tomilova 2010). Currently, the lack of heat-load-regulation equipment at the consumer level leads to a situation in which some rooms are overheated while others are underheated (Rybakova et al. 2014). All consumers pay the same, which creates some social tension (Sagynganova et al. 2020). Heat-energy consumption according to the Agency for Strategic planning and reforms of the Republic of Kazakhstan Bureau of National Statistics (2021) and plans of the Government, will increase in large cities of Kazakhstan (Almaty, Nur-Sultan) by 30–40% (1700–2200 Gkal/h) by 2030, even including the demolition of dilapidated residential buildings and the release of the heat load (Decree of the… 2011; Design of thermal… 2018).

The study aims to project heat-load growth until 2030 using the city of Karaganda as an example.

1. Projected heat loads in the Karaganda district heating system until 2030

Karaganda continues to develop and build. Figures 1 and 2 show the dynamics of changes in the population of Karaganda. The projected increase in heat loads is shown in Table 1. A graphical representation of the change in the total heat demand of Karaganda is shown in Figure 3. The projected heat loads in the Karaganda district heating system until 2030 are presented in Table 2.

The 2011–2020 housing and utilities modernization program of the Republic of Kazakhstan aimed to provide comfortable living conditions for the population and improve the condition of the communal infrastructure. One of its tasks was the modernization of communal infrastructure. Heat point is one of the main elements of the system of the district heat supply of buildings,

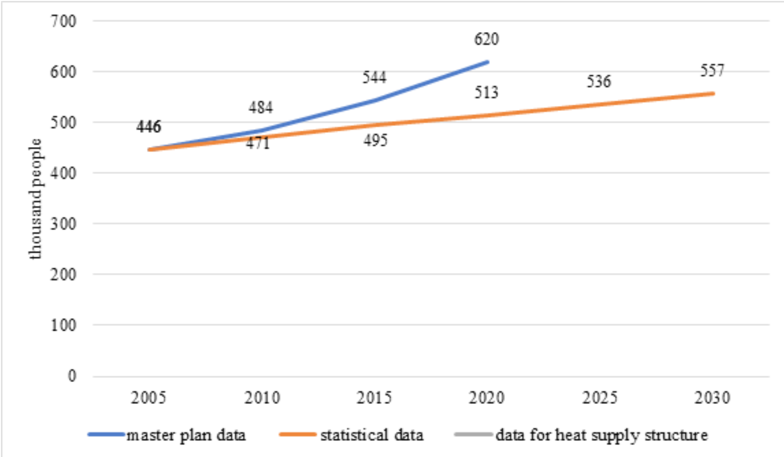

Fig. 1. Dynamics of population change in Karaganda

Rys. 1. Dynamika zmian ludności w Karagandzie

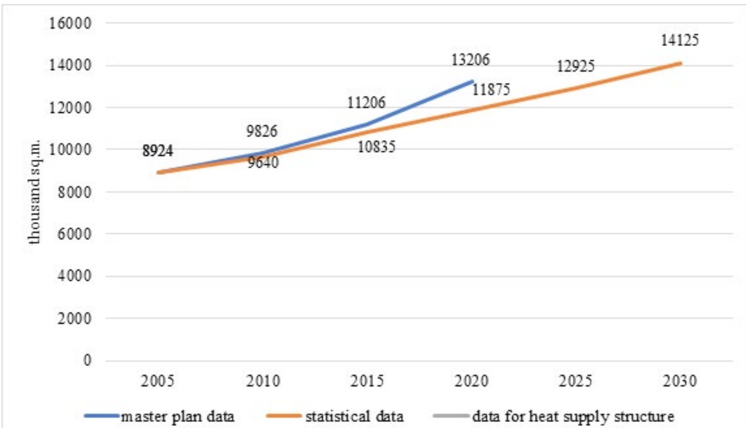

Fig. 2. Evolution of change in residential-development areas in Karaganda

Rys. 2. Ewolucja zmian na obszarze zabudowy mieszkaniowej w Karagandzie

Table 1. Projected increase of heat load given for Karaganda [Gcal/h]

Tabela 1. Prognozowany wzrost obciążenia cieplnego podany dla Karagandy [Gcal/h]

Name	Growth 2015–2020	Growth 2021–2025	Growth 2026–2030	Total 2015–2030
Low-rise buildings	37	33	38	108
Multi-story buildings	46	57	47	150
Public buildings	32	45	32	109
Industrial enterprises	13	23	21	57

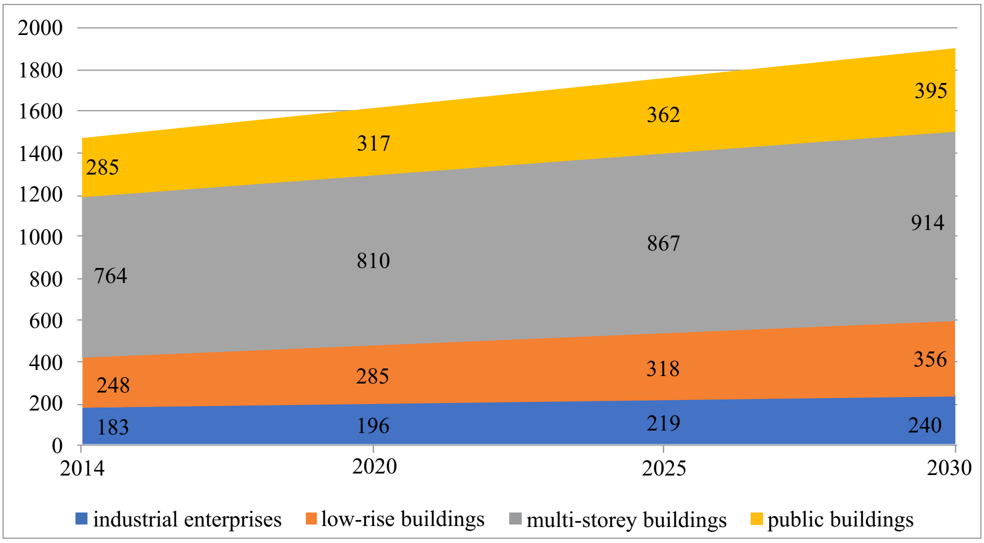

Fig. 3. Heat-load change dynamics in Karaganda city in the period until 2030

Rys. 3. Dynamika zmian obciążenia cieplnego w mieście Karaganda w okresie do roku 2030

TABLE 2. Projected heat loads in the Karaganda district heating system [Gcal/h]

TABELA 2. Prognozowane obciążenia cieplne w sieci ciepłowniczej Karaganda [Gcal/h]

Name	2014	2020	2025	2030
Low-rise buildings	248	285	318	356
Multi-story buildings	764	810	867	914
Public buildings	285	317	362	394
Heat load of industrial enterprises	183	196	219	240
Heat load total for the city	1,480	1,608	1,766	1,904
Increase in heat loads for the city as a whole:				
between 2015 and 2020		+128		
between 2021 and 2025			+158	
between 2026 and 2030				+138

Automation of heat points.

performing the functions of the heat-carrier reception, transformation of its parameters (if necessary), distribution among the consumers of heat energy and the metering of its consumption. The automation of the HP for the metering and control of transferred/received heat energy can be performed according to the structure shown in Figure 4.

To create the upper level of heat-supply-system control in the city, the "Information and graphic software complex TGID-07", created by a team of developers production cooperati-

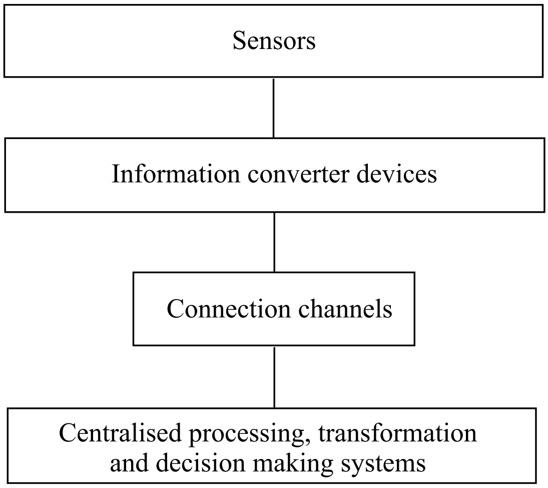

Fig. 4. Typical structure for receiving and processing information from the HP

Rys. 4. Typowa struktura odbierania i przetwarzania informacji z HP

ve firm "Sirius" (2021) (Karaganda, RK), has proved to be a good solution. The purpose of TGID-07 is modelling and spatial and the technological analysis of established thermal-hydraulic modes of district heat supply systems, controlling operation modes and the comprehensive development of complex heat supply systems, with the possibility of controlling the calculated and measured parameters of system operation (Karasev et al. 2004). It includes a "Designer" module for creating and adjusting heat-supply schemes of heat-supply points with the possibility of reading real data (Fig. 5).

The functionality of the "Designer" module:

- creating and editing the heat-supply point scheme;
- saving the heat-supply point scheme in the related library;
- displaying indicators of the heat-metering device on the value scheme;
- coding of heat-metering devices on saving schemes with the creation of a database of metering devices for integration with a third-party software shell;
- working as an independent application to study options for heat-supply point schemes.

However, the increase in the number of tasks performed by the local automation systems at the heat points leads to the multiplication of measured and processed information. A complete interrogation cycle for all district heating points in a metropolis can take several hours (Hryshchenko 2020). The triggering of protections and the detection of abnormal situations require an even faster response time (Huo et al. 2020). Interrogation of technological parameters of heat-supply point-operation can be carried out during different periods (Abid et al. 2021). Groups of parameters with different dynamic characteristics are distinguished in the heat point (Yong et al. 2021):

- value of the heating water temperature in the supply line [°C];
- value of the heating water temperature in the return pipe [°C];

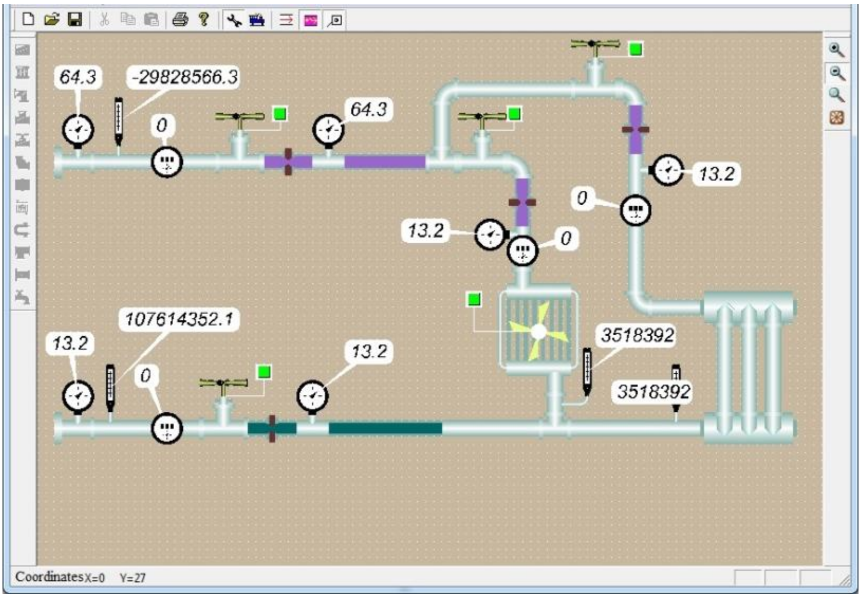

Fig. 5. The scheme of a heat point in the "Designer" software

Rys. 5. Schemat węzła cieplnego w programie „Designer"

- circulation temperature value [°C];
- flow rate of heating water in the supply pipeline [tonnes/hour];
- flow rate in the return pipe [tonnes/hour];
- value of the heating water pressure in the supply line [kgf/sm];
- value of the heating water pressure in the return pipe [kgf/cm];
- indoor temperature value [°C];
- amount of the released heat [Gcal].

Also recorded in real-time:

- the current date and time of the connection;
- communication parameters;
- connection response time – for the debug mode.

The program algorithm for interrogating the process parameters of the heating point is demonstrated in Figure 6.

The HP parameter interrogation module was written using the Golang language (Go). Go is a compiled, open-source programming language developed by Google in 2009. It has provided an alternative to Java and C++ for application developers, offering easy-to-read code and clear documentation as well as access to many features (Moallemi et al. 2019). Parallel programming in many environments struggles to properly implement access to shared values (Yang et al. 2020). Go language supports a different approach in which shared values are passed through channels and are never actively distributed across executable streams (Guzzini et al. 2020;

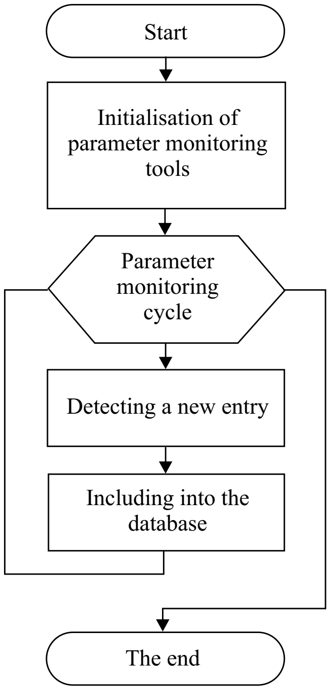

Fig. 6. Algorithm of the program

Rys. 6. Algorytm programu

Wirtz et al. 2020). Only one go-routine has access to a shared value at any time. Go-routines are distributed to multiple operating-system streams, and if one gets blocked, due to I/O pending, the others will continue to run (Figures 7 and 8).

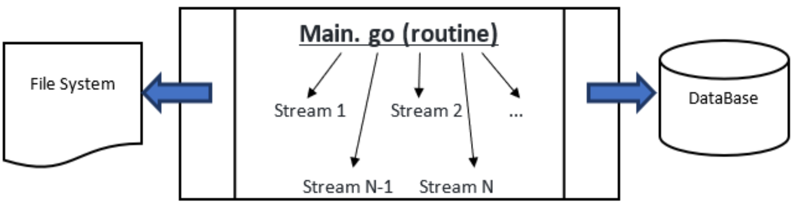

Fig. 7. The relationships between the program elements scheme

Rys. 7. Schemat zależności między elementami programu

As a result, the metering devices installed in the automated heat point (AHP), according to the interrogation cycles for the system control center (SCC), transmit information on the heat-carrier temperature, pressure, and electricity consumption. Information on protection activation is also promptly transmitted.

```
//main block of the program
func main() {
// initialise a new Watcher class object to monitor a directory with a parameter file
watcher, err := fsnotify.NewWatcher()
defer watcher.Close()
done := make(chan bool)
// start monitoring the directory with the parameter file go func() {
// condition if file record event occurs if event. Op& fsnotify. Write == fsnotify.
Write {log.Println("Data came from AHP:", event.Name)
```

Fig. 8. Fragment of Go code for reading data from the automated heating point devices

Rys. 8. Fragment kodu Go do odczytu danych z automatycznych urządzeń punktu grzewczego

Conclusions

The installation and adjustment of equipment in AHP to test the performance and speed of the proposed algorithms of operation was carried out by the "MV Engineering" (Karaganda) company, which provides complex engineering solutions for heat- and water-supply systems. Due to the division of information processing into levels (the controller level in HP and the upper smart level in TGID-07) and also due to use of the created "Designer" software, in which the idea of pipeline data processing has been carried out, the speed of the receiving-processing of information both at AHP and SCC has increased by 5–15%.

As a result, a microcontroller SMART system was developed and implemented for the implementation of rational regimes of heat supply, using the information on heat-consumption parameters and management decisions in the process of receiving and processing, variable cycles of heat-supply interrogation parameters at thermal points. The application of the developed SMART systems and principles enabled the increase of reliability, and efficiency of both heat points and the heat-supply system as a whole.

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System SMART do realizacji racjonalnych reżimów zaopatrzenia w ciepło

Streszczenie

W artykule przedstawiono aktualną i przyszłą sytuację zużycia ciepła w Republice Kazachstanu. Przewidywany wzrost obciążeń termicznych do 2030 roku pokazuje przykład miasta Karaganda. Dlatego istotne jest stworzenie i wdrożenie zautomatyzowanych punktów ciepłowniczych w system kompleksów ciepłowniczych miast Republiki Kazachstanu. W artykule rozważono koncepcję pomiaru i przetwarzania informacji w sieciach ciepłowniczych w oparciu o zmienne cykle badania parametrów zaopatrzenia w ciepło w punktach cieplnych. W wyniku przeprowadzonych badań opracowano i wdrożono mikrokontroler SMART-system do realizacji racjonalnych trybów zaopatrzenia w ciepło, który jest wykorzystywany w procesie pozyskiwania i przetwarzania informacji o parametrach zużycia ciepła oraz służy do podejmowania decyzji sterujących dla zmiennych parametrów zaopatrzenia w ciepło w punktach cieplnych. Wyniki badań zostały pomyślnie przetestowane na obiektach wyposażonych w zautomatyzowane punkty grzewcze.

Słowa kluczowe: ciepłownictwo miejskie, punkt cieplny, automatyka, pomiary i przetwarzanie, badanie parametrów