Comprehensive methods to obtain and process information flows in centralized heat supply systems

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Abstract. The article discusses the principles of creating the structures of information and control systems for urban heat supply. The necessity to create and develop such systems is due to the significant energy intensity of the country’s GDP, which is twice as large as the majority of developed countries. Modern multi-level distributed control systems of the centralized heat supply system facilities, which are built according to the object rule, are described in the paper. The article analyses advantages and disadvantages of various options for information management systems. In the process of thermal automatics development based on software and hardware, including modern intelligent sensors and industrial controllers, modern thermal automation systems began to be intensively introduced. The use of standard techniques of cycling poll of all local objects included in the centralized heating systems, without taking into account the dynamic characteristics of the measured parameters, including the pipeline processing of this information, leads to a significant increase in the time of collection, processing, transmission of information and decision-making in a centralized heating systems. The concept of measuring and processing information in centralized heat supply systems is proposed, based on variable polling cycles of parameters of heat supply systems at heat points taking into account their dynamic characteristics with subsequent conveyor processing of information at the top level of automated centralized heating systems.

Keywords: urban heat supply, information and control systems, measurement and processing, parameter polling, variable cycles, pipeline processing of information

1. Introduction

The cold, sharply continental climate, low average temperature, the long heating period compared to European countries, as well as centralized heat supply, characterized by heavy heating networks, combined with low energy efficiency of production and transfer of thermal energy are a characteristic feature of thermal power systems in Kazakhstan.

Thermal energy consumption according to the Agency of Statistics of the Republic of Kazakhstan and the plans of the Government will increase by 15 thousand Gcal in 2010-2020 and reach 110 thousand Gcal [1].
Despite the existence of objective reasons for the high energy intensity of GDP of the Republic of Kazakhstan, there is a significant potential for improving energy efficiency and energy saving, since the energy intensity of GDP in Kazakhstan is twice as high as that of most developed countries [2].

Low energy efficiency is characterized by the production and transfer of thermal energy. According to expert data, fuel consumption for power generation is 10-15%, for heat supply - 15-20%. The cost of introducing energy savings is about 5 times lower than for new energy production [1]. The challenge is to determine the heat losses, to personalize which is some difficult due to the branching of the heat distribution networks, the number of boiler houses and pumping and transfer stations, and the irrational configuration of the house heating networks.

In this regard, the necessity to create and implement modern information and control systems for urban heat supply complexes in Kazakhstan is not in doubt.

It is known that the introduction and industrial operation of information management systems for heat supply will tentatively provide [3]:

- saving of heat generation and pumping capacity;
- decrease in accident rate in the megacity heat supply systems;
- reducing maintenance costs for electricity.

2. Research methodology

We now consider the main areas of research and technical solutions for the collection, transmission and processing of information at the base heating facility, i.e. thermal point.

Many researches and developments by V.K. Averyanova and S.I. Bykov [4, 5], B.N. Gromova [6], G.V. Monakhov [7, 8], N.I. Karasyova [9, 10], etc., had an important role in developing this direction. Their works decided to informatize the heat supply systems in megacities, which were considered as objects of control. Thus, the works [11, 12] are aimed at the system integration of information and mathematical models that form databases and knowledge for the decision support system to adjust heat supply systems in megacities. When calculating their thermal conditions, the problems of analyzing the steady-state hydraulic regimes of the heat-supplying system were solved, the mathematical model of the decision support system, which contains models of the motion of the heat carrier in technological elements of the heat-supplying system; models of steady-state hydraulic modes of heat supply systems in various regime situations, etc. was developed.

Figure 1 shows a generalized scheme of an automated process control system for the urban centralized heat supply.

The multi-level distributed system for controlling objects of the centralized heat supply system is built on the object principle.

The object of informatization is represented by the following aggregated technological installations: HS is the heat source represented by the technological structure of the TPP or DBH (district boiler house); CHP - central heat point (used to serve a group of consumers (buildings, industrial facilities); IHP - individual heat point of a consumer (used to serve one consumer (building or part thereof); PS - network pumping station on the supply or return pipelines in the main circuit; CS - controlled station for concentrating measuring and control information on the pipeline system.

Manufacturers of hardware and software solution/complex and devices. The ideology of Fieldbus Foundation, which ensures the transfer and implementation of measurement information processing algorithms (filtering, scaling, linearization, etc.), regulation (stabilization, tracking, cascade control, etc.), logic control (start, stop, blocking, etc.) to the lower control level is becoming one of future-oriented ideology of “intellectualizing” devices and I/O units. To implement this ideology, a new typical Fieldbus H1 field network that implements all the functions of HART protocol and also allows through communication with devices to program specific control and management algorithms implemented in devices using special technology languages [13] has been developed.
Figure 1. The generalized scheme of an automated process control system for the urban centralized heat supply

The lower control level of all technological installations combines separate controllers with remote I/O units, intelligent instruments and actuators (A - valve actuator, PO - throttling control elements, DT - temperature sensors, DD - pressure sensors, DP - energy consumption sensors, EP - electric drive of aggregates, HA - pumping units, IM - actuators with built-in controllers). Intelligent devices are connected to controllers through a standard digital field bus with a standard HART-protocol, which is supported by all. The ideology of such systems focused on the insufficient capabilities of thermal automation systems, as well as on mode calculations of systems taking into account various operational and seasonal factors. These are mostly not managing, but information systems.

A pipeline data is effective for processing a significant amount of information [14-16]. This method with regard to the urban centralized heat supply systems are described in [17].

However, the centralized approach, in which the object of control and management for the information management system is the heat supply complex of a large city, requires the organization of two-way functional and redundant information from heat points to servers and from servers to heat points. Cyclic polling of information on the objects of control of each heat station takes large intervals of time, which significantly increases the response time to events and reduces the efficiency of
managing heat point objects. The whole system becomes inoperative in case of any failure at the top level.

The use of standard technologies for cyclic polling of all local objects included in the centralized heating system, without taking into account the dynamic characteristics of the measured parameters, including conveyor processing of this information, leads to a significant increase in the time of collecting, processing, transmitting information and making decisions in the centralized heating system.

Recently, systems aimed at solving local automation tasks at the level of heat points have been intensively introduced in thermal automation based on software and hardware, including modern intelligent sensors and industrial controllers [18]. The heat point (HP) is one of the main elements in the centralized heat supply systems of buildings that performs functions of receiving the heat carrier, converting (if necessary) its parameters, distribution among consumers of thermal energy and accounting for its costs. Depending on the purpose, conditions of connection of consumers to the heating network, customer requirements and other HPs can be composed of a number of individual functional units.

To simplify the process of designing, assembling and installing, the HP can be manufactured in the factory and delivered to the construction site in the form of ready blocks - a block heat point (BHP). BHP is a separate functional units assembled on a frame into a general structure, as a rule, complete with instruments and devices for control, automatic regulation and management The Danfoss Company offers standard automated block heat points of full factory readiness for use in Kazakhstan that intended for connection to the heat network of various heat consumption systems and executed according to standard technological schemes using water heaters based on soldered or collapsible plate heat exchangers of its own production. The use of Danfoss automated BHPs contributes to solving the most important task in the field of heat supply - raising its quality level, which is to provide comfortable climatic conditions in buildings, the temperatures and hot water consumption required by sanitary standards with the minimum energy consumption [19].

The uniformity of modern technical solutions of BHP and their streamlined production at modern Danfoss plants allow us to: simplify the process of completing a heat supply station with equipment and materials as compared to delivering them to the construction site in bulk, ensure the highest quality of BHP manufacturing, eliminate preparatory and serious installation and commissioning works on site, reducing them to installing the unit in the premises of heat point and connecting it to the building pipelines and power supply networks [19].

In such decentralized systems with their large numbers, and in cities with a significant number of heat points, in the process of work conflict regimes arise when local systems fail to cope with the management of modes, the centralized redistribution of energy flows is necessary.

But an increase in the number of tasks solved by local automation systems at heat points leads to a multiple increase in the measured and processed information. Tens of parameters are subject to measurement with several branch lines at each heat point. A full cycle of polling all urban heat points can take several hours.

At the same time, parameters such as temperature change slowly, and flow rates and pressure have a higher response rate. The protection operation, the identification of emergency situations require even higher speed.

There is proposed the concept of measuring and processing information in centralized heat supply systems, based on variable polling cycles of parameters of heat supply systems at heat points taking into account their dynamic characteristics with subsequent pipelining of information at the top level of automated central heating systems.

There are three groups of parameters to be monitored at the heat point:

- Control of protection operation.
- Control of pressure, flow and power consumption.
- Temperature control.
Polling of parameters of a heat point can be carried out in different periods. Groups of parameters with different dynamic characteristics are distinguished in a heat point.

The heat point receives the setting actions for the drives of pumping stations.

Information on the coolant temperature, averaged pressure and flow data for the heating mains and electricity consumption is periodically transmitted to the central control centers. Information about protection operation is promptly transmitted.

Information processing at central control centers is carried out by pipelined (conveyor) methods.

The solution of such tasks can be provided by a hierarchical structure in which the information necessary for control and management of the entire heat supply system is transmitted to the upper level, and the tasks of managing and controlling each object of the heat supply system are transferred to local subsystems that define variable polling cycles depending on the dynamic characteristics of technological parameters (temperature of heat carriers, pressure, flow, etc.).

The proposed concept combining variable polling cycles at each level of the heat supply system with pipelining of information at central control centers will reduce the load on information transmission channels, significantly reduce traffic when transmitting information from local heat points to central control centers through cellular communication, increase speed, and reduce the time to take solutions in centralized power supply systems.

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