Current state and approaches to automation of central heating stations at industrial enterprises

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Abstract. The paper examines the problems of forming technical requirements for the automation of central heating points of fuel and energy complex enterprises. The main technological schemes that are subject to automation are considered, the basic requirements for the installation of technical automation equipment are shown, the basic requirements are identified based on modern concepts for constructing automated control systems, and the main adjustable and controlled parameters of the central heating station for the main application in State Unitary Enterprise "Fuel and Energy Complex" are clarified.

1 Introduction

Most modern city boiler houses of the State Unitary Enterprise "Fuel and Energy Complex" (GUPTEK) are equipped with heating points. The task of improving the automation of central heating stations is to improve both the functional schemes of their automation and the use of more advanced controllers and technical automation equipment that can improve the quality of control and stabilize the quality indicators of hot water supply and heat.

The article analyzes the current state of central heating automation and proposes approaches to improving the quality of control and stabilizing parameters based on the use of modern automation tools.

2 Research methods and materials

Central heating units are used to supply heat to a group of buildings and structures. Central heating stations perform the function of providing consumers with hot water supply (HWS), cold water supply (CWS) and heat. Central heating stations can have both dependent and independent connection schemes to the heating network [1]. With a dependent connection scheme, the coolant at the heating point itself is divided into a heating system and a hot water

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supply system. In an independent connection scheme, the coolant is heated in the second circuit of the heating point by incoming water from the heating network.

The central heating station equipment includes the following elements:

- heaters (heat exchangers) - sectional, multi-pass, block type, plate - depending on the project, for hot water supply, maintaining the required temperature and water pressure at water points;
- circulation utility, fire-fighting, heating and backup pumps;
- mixing devices;
- thermal and water metering units;
- instrumentation and automation instruments;
- shut-off and control valves;
- expansion membrane tank.

Central heating stations are located at connection points between local heat supply networks and main heating networks and perform the following main functions:

- regulation of the supply of thermal energy for heating a group of buildings (usually a block);
- ensuring the circulation of the heating circuit coolant while maintaining the specified values of pressure and temperature in the forward pipeline and pressure in the return pipelines;
- ensuring the supply of hot water to consumers while maintaining the specified temperature and pressure in the forward pipeline and the specified temperature in the return pipeline;
- localization of emergency situations.

The technological scheme of the central heating station used at GUPTEK enterprises includes: control valve of the primary circuit of the heating network; hot water temperature control valve (mixture); control valve for heating network make-up; control valve for releasing water from the heating network; circulation control valve in the DHW network; pressure control valve in the DHW network [2].

The water temperature in the direct heating network is 150 ^{0}C. The water temperature in the heating system is 90 ^{0}C. The water temperature in the return heating system is 65 ^{0}C. The temperature of the direct DHW water is 65 ^{0}C, and the temperature of the return water from the DHW can vary within the range (35 ÷ 55) ^{0}C.

In accordance with the technological scheme of the central heating station, the following parameters are monitored:

- direct water flow by sensor;
- direct water temperature sensor;
- return water flow sensor;
- return water temperature sensor;
- heat meter;
- direct water pressure;
- return water pressure;
- pressure difference between forward and return water;
- outside air temperature;
- temperature of direct water into the heating system;
- return water temperature in the vehicle;
- flow rates of direct water from the vehicle and return water supplied by network pumps;
- make-up water consumption.

At the request of heat supply organizations, it is often necessary to install a flow meter on the supply and return pipelines simultaneously.

The heat meter calculates thermal energy consumption based on the measured flow rate by flow meters and the temperature difference from a pair of sensors.

The coolant temperature sensor is a resistance thermometer that provides a change in resistance proportional to the coolant temperature. This is achieved by using platinum conductors, in which this dependence is linear. Immersion sensors of the Pt 500 type are used. The sensor is inserted into a sleeve supplied upon request. Its upper part is located higher than the lower one. This is due to the fact that for better heat transfer to the sensor, the sleeve is filled with either heat-conducting paste or oil.

The differential pressure regulator protects the heating network from hydraulic misregulation. Protects the heating system from pressure fluctuations in the heating network. Maintains a constant pressure drop and constant external authority across the heat flow control valve, creating the best possible control conditions. Together with the maximum coolant flow rate at the subscriber, it also limits the mechanical performance of the valve electric drive, because maintains a constant pressure drop across the valve trim equal to the design conditions. If there is no regulator, pressure fluctuations in the heating network are transmitted to the regulator drive, impairing its performance.

The worst case scenario is that the pressure in the pipeline exceeds the drive force. If the drive does not have shutdown protection at this moment, it will either burn out or be destroyed. If there is a power outage, the drive closes to prevent destruction of the heating system from excess coolant temperature in accordance with [3]. If there is no such threat, then valves with a normally open shutter or an intermediate shutter arrangement in the event of a power failure are used.

The heat flow regulator valve changes the supply of coolant from the heating network to be mixed with cooled coolant from the return pipeline, ensuring the required temperature of the coolant at the entrance to the heating system.

The electronic regulator controls the temperature of the coolant at the entrance to the heating system using a temperature sensor. Regulation is carried out according to a programmed temperature schedule by comparing it with the outside air temperature readings from the outside air temperature sensor, as well as according to a programmed energy-saving mode - nightly reduction of energy consumption by the heating system, reduction of energy consumption on weekends.

The control is adjusted based on the temperature of the coolant in the return pipeline according to the readings of the temperature sensor. In this case, regulation according to the specified sensor has priority. In addition to regulating the system during the heating period, the electronic regulator prevents sticking of the heat flow regulator valve stem and the pump shaft during the non-heating period, periodically turning them on for a short period of time (once every three days for one minute).

These functions are additional options and are implemented if necessary by programming the electronic controller. For example, it is recommended to turn on the pump occasionally in any heating system. The heat flow regulator is also switched on sporadically. In this case, additional coolant flow is minimized by asynchronizing the activation of the pump and valve.

The coolant temperature sensor is similar to the sensor. The sensor must be installed in a small circulation ring. This allows you to perceive the temperature of the coolant at the entrance to the heating system in all modes of its operation. Additional sensors enable faster and more accurate control.

By installing these two sensors, it becomes possible to use the temperature method for adjusting the heating system without any additional measuring instruments, because the temperature of the coolant in the pipelines is displayed on the display of the electronic regulator. The temperature method most reliably shows the correspondence of the power of the heating system to the heat loss of the building.

Submersible and surface-mounted sensors are used. Clip-on sensors are used on small diameter pipelines. Such sensors are the cheapest and least inertial. However, they perceive the temperature of the pipe surface, while regulation should be carried out according to the temperature of the coolant. In addition, they are susceptible to destruction of the heat-receiving surface if handled improperly - the attached sensor moves out of place due to rotation around the pipe, or is pulled along the pipe. Therefore, even with small diameters, it is recommended to find the possibility of installing submersible sensors, for example, on a pipeline bend, which allows the sleeve to be welded over its entire length.

The heating system control valve is designed for setting up a heating system with manual balancing valves on risers or on instrument branches. In systems with automatic differential pressure regulators (two-pipe systems with variable hydraulic mode), or automatic flow regulators on risers or on instrument branches (two-pipe or one-pipe systems with constant hydraulic mode), this valve is not installed. Its functions are performed by the specified automatic regulators [4].

A safety valve is installed on a branch of the heating network, which is designed to protect the heating system from possible excess pressure exceeding the operating pressure if the automatic valves do not operate. The preferred location of the valve is on the return pipeline from the side of the heating system to the shut-off valve. At the same time, if the coolant is discharged, then it is cooled. It is recommended to discharge into special storage containers. As a last resort - into the sewer.

The shut-off valve for the heating system is designed to turn off the heating system and prevent contaminated coolant from entering the heating unit equipment when flushing the system. Drainage valves are designed to empty the heating system. They are also used to connect compressors when flushing the heating system, and in small systems - for hydraulic testing.

The bypass valve ensures the circulation of coolant through a small circulation ring (through itself) when the thermostats of a two-pipe heating system with variable hydraulic mode are closed. At this moment, the heat flow regulator valve closes because the temperature in the small circulation ring will be constant and equal to the required value. In addition, this valve stabilizes the coolant pressure, partially improving the operation of thermostats (only when they are closed). They are used when using automatically uncontrolled pumps that are unable to operate at zero flow. They are not installed in one-pipe and two-pipe heating systems with constant hydraulic mode.

The pump group circulates the coolant in the heating system.

The coolant pressure in the return line is 0.3 MPa, which does not exceed the operating pressure in the heating system elements. If there is an excess, it should be eliminated by the pressure developed by the pump.

The check valve prevents the coolant from flowing from the supply pipeline of the heating network into the return pipeline.

Heat exchangers are designed to transfer thermal energy from network water to the coolant of the heating system.

Buildings connected to district heating networks must be equipped with commercial metering devices for consumed thermal energy installed at customer inputs [3]. Commercial accounting of heat consumption is carried out to determine the cost of thermal energy consumed by the subscriber. This cost is calculated based on the readings of the metering device (heat meter). The heat meter determines the amount of energy consumed over a set period of time based on the mass flow rate and the difference in enthalpies of the coolant in the supply and return pipelines.

3 Modern approaches to creating automated control systems for central heating points

Currently, the requirements of operating organizations for the automation of central heating stations are increasing. First of all, these are requirements to increase the number of controlled parameters, to include heat and hot water supply metering devices, fire and security alarm systems in the system, the possibility of long-term storage and display of information about process parameters and switching, transfer of information to remote control centers and etc. These requirements are explained by the desire to optimize the technological process, save energy resources and the prospect of a gradual transfer of central heating stations to work without the constant presence of service personnel with a high level of automation and, in the future, intellectualization of processes and automation of central heating stations [5].

Optimization of the supply of thermal energy to consumers involves a transition from local automated control systems for technological equipment to an automated control system for the central heating unit as a whole (ACS central heating unit), which controls both groups of pumping units and control valves and other equipment.

These circumstances served as the reason for revising and improving technical solutions for central heating automation systems.

The general approach involves the construction of a decentralized two-level control system, with the lower level being local automatic control systems (ACS), metering devices, etc., and the upper level being a system for collecting, storing and displaying information on the facility as a whole [6].

This design principle ensures higher reliability of the implementation of control functions. The failure of one local system does not disrupt the operation of the rest of the equipment, and in the event of a failure at the upper level, the local systems remain fully operational. In this case, control of the functioning of local systems and management is carried out using local control posts.

Thus, the creation of an automated control system for central heating centers contributes to resource conservation, while increasing the economic and environmental indicators of central heating centers [7].

4 Requirements for automated process control systems

Modern approaches to automation of central heating centers involve the widespread use of modern microcontrollers and technical automation equipment. The main indicator of the efficiency of the central heating station is the stabilization of the temperature of water for heating and hot water supplied to the consumer. The purpose of the central heating control system is to maintain the temperature of the hot water supply within the specified limits (65 ± 1) ^{0}C and the temperature in the heating system (90 ± 1) ^{0}C to ensure the required technical and economic indicators of the central heating station [8].

The developed automated control systems for central heating points must meet the following modern requirements [9, 10]:

- accuracy of maintaining the regulated parameter - water temperature in the hot water system within specified limits according to the regime map (65 ± 1) ^{0}C, temperature in the heating system (90 ± 1) ^{0}C;
- ensure control and regulation of central heating station parameters;
- ability to work in manual and automatic mode;
- the presence of a temperature and water flow alarm circuit for the heating system and hot water supply;

- the presence of modern smart sensors with a built-in microprocessor, allowing one device to measure several quantities;
- the ability to change settings and set parameters;
- the ability to register, visualize and store parameters;
- use of technical automation equipment with unified signals;
- creation of a reliable system (mean time between failures of equipment 40,000-50,000 hours);
- average recovery time is no more than 1.5 hours.

5 Conclusion

Based on the requirements for automated process control systems and analysis of modern automation equipment, an updated list of technical requirements for the controlled and adjustable parameters of the automated process control system for central heating systems for GUPTEK enterprises, typical for work in St. Petersburg, was formed, Table 1.

Table 1. Parameters of the central heating control system Controlled and adjustable parameters.

Controlled and adjustable pa	Value	Control accuracy
Water temperature from the direct branch of the vehicle to the heat exchanger	150 ^{0}C	±1 ^{0}C
Return water temperature	65 ^{0}C	
Heating water temperature	90 ^{0}C	
Water flow from the direct branch of the heating network to the heat exchanger	28 m^3/h	± 0.5 m^3/h
Water consumption in the return heating network	27.5 m^3/h	
Water consumption for heating	28 m^3/h	
Water consumption for hot water supply	28 m^3/h	
Water pressure from the direct branch of the heating network to the heat exchanger	0.4 MPa	± 0.05 MPa
Water pressure in the return heating network	0.3 MPa	
Pressure drop between the forward and return branches on the heating network	0.1 MPa	
Maximum heat flow for heating	50 kW	± 0.05 kW
Maximum heat flow to DHW	30 kW	

Built taking into account the listed requirements, the central heating control system will be resource-saving, which will reduce current costs, increase productivity, and thereby obtain additional economic benefits.

Analysis of the current state of automation of central heating stations and comparison with modern scientific and technical achievements allows us to create reasonable technical specifications for the design and creation of automated control systems for central heating stations, develop automation systems that can increase the level of stabilization of water parameters of central heating stations for heating and hot water supply by increasing the volume and quality of information processing, and technological personnel - to make timely and optimal decisions in emergency situations, to increase the reliability and performance of the system as a whole.

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