Heater parameters remote monitoring system

S M Nikitenko, M S Nikitenko, S V Remizov and S A Kizilov
Federal Research Center of Coal and Coal Chemistry, Siberian Branch of the Russian Academy of Sciences, 18 Sovetskiy pr., Kemerovo, 650000, Russia
E-mail: nsm.nis@mail.ru

Abstract. The article is devoted to the issues of mining enterprises heating equipment operation automation, to the parameters remote monitoring system development. The mine complex heater installation system managing structure and the heater installation monitoring system electronic control unit operation block diagram have been proposed.

1. Introduction
Heater installation is an integral element in a mining enterprise functioning system, ensuring shafts, lifting vessels and ropes freezing prevention, as well as comfortable working conditions creation.

Long-term observations show that mine heaters are practically not heat regulated, which leads to a significant waste of thermal energy. The lack of information from the dispatcher does not give the possibility of prompt intervention into the control in case of emergency situations, especially in the winter period [1, 2].

The main task at coal mine heating installation’s automation is to maintain the entering mine atmospheric air set temperature. For air heater installation automation the systems (AKU 3.1M, AKU 3.1.2M, AKU-63) are used, the main functions of which are to control the air temperature in the shaft by changing the folding door position and stabilizing the coolant temperature at the outlet from the heater by changing its amount passing through the air heater [3]. Industrial air heater installation parameters remote control system scheme development is initially the task of developing an automatic technological process control system (ATPCS), in this case the process of heating the ventilation air.

Design and development of ATPCS (automated process control systems) is a process aimed at increasing the productivity of mining enterprises, capable of providing a fundamentally new quality of work control, in this case, the inlet ventilation system, which is a life-support system and is included in MFSB (multi-functional safety system) list of controlled systems. The result of the control system design is a fully complete infrastructure, which is maximally adapted to the object.

2. Research objective
ATPCS progressive designing methods are based on regulatory document requirements compliance, which include the following principles: reliability; uninterrupted operation; functionality; convenience and ease of use.

The key principle – reliability – during the ATPCS design is ensured through the use of internal diagnostic subsystems, as well as through the use of monitoring and standardization systems. For achieving optimal results in automation projects implementation, you must use high-quality modern equipment.
A fundamental factor in improving the automated control systems’ quality and efficiency is the normative basis. The use of existing standards is widely applied at the design stage. Documents of the state standardization system (GOST) and documents containing, along with mandatory requirements, recommendatory, allowing possible solutions depending on specific conditions and related factors (SNiP, RD, MU) can be attributed to them. Such documents are widely used in the design process of automated control systems [4, 5, 6].

3. Methodology

The process of ATPCS creating is a set of activities arranged in time, interconnected, integrated into different work stages, the performance of which is necessary and sufficient to create a system that meets the specified requirements [6].

The main tasks solved in the process of ACS designing include the following:

- automation object analysis and technical requirements to the system formulation;
- automation rational level determination, automated process monitoring and control system structure determination;
- selection and justification of monitoring methods, technological processes regulating and controlling, forecasting and diagnosing;
- automation technical means complex choice;
- automation means optimal placement on the process equipment, in place;
- automated control systems and communication lines hardware installing methods effectiveness provision;
- technological and operational documentation preparation.

According to the requirements, during the underground mining operations, forced air circulation of a certain temperature (not lower than +50 C) inside the mine shafts should be provided. For this purpose heaters, consisting of a heat exchanger (heater), fan and air duct system are used. Considering the size of the mine complex, there may be a few of such installations, depending on the number and length of the mine shafts. In addition to the mine entering air heating function, the air heater plays an important role in the degassing process (removal of methane), which in turn ensures the safety of the mine as a whole.

The automated control system for the mine complex heaters must meet the following requirements:

- to carry out continuous ventilation of mine shafts;
- to maintain the required temperature of the supplied air regardless of climatic conditions;
- to maintain the necessary circulation, taking into account the work of several air heaters (complex);
- to be able to monitor remotely, to display the current state of technological processes on the screen of the operator’s console.

In this case, it is allowed to implement the function by a programmable controller according to a given program without operator intervention in automatic mode.

Technically, this task can be solved by creating an industrial air-heating installation equipped with an automatic monitoring and control system. Structurally, this can be represented as shown in figure 1.

The air heater is equipped with sensor instruments, an electronic control unit (ECU) and a wired communication network (analogue connection) between the sensors and the ECU. The electronic units of all air heater installations are connected via digital communication (LAN) to the gateway (server or gateway), which, in turn, via wireless communication transmits information about each air heater installation to the control panel.

A standard heater unit contains the following structural elements: an independent source of heat supply, pipelines, a circulating pump, a heater, an air duct, a fan.
4. Results

To ensure the heater installation system operation remote monitoring, the sensor equipment installation is required in order to realize the ability to measure the key parameters. The list of sensors, their parameters and the range of operational measurements are presented in Table 1.

| Sensor name                    | Sensor model | Sensor range    | Measurement range |
|-------------------------------|--------------|-----------------|-------------------|
| Air temperature sensor       | TTM 2        | -20 to +50°C    | -2 to +50°C       |
| Air stream velocity sensor   |              | 0.1 to 30 m/s   | 0.1 to 30 m/s     |
| Heat carrier temperature sensor | Pt 500/1.3850 | 0 to +180°C    | 0 to +65°C        |
| Heat carrier pressure sensor | KRT9         | 0 to 0.6 MPa    | 0 to 0.6 MPa      |
| Heat carrier consumption     | ERSV -440L/25 | 0.085 to 17.69 m³/h | 0.085 to 17.69 m³/h |

Heater installation at the mining enterprises is a complex consisting of a number of heat exchangers (sections), which are located at the main pipe entrance of the supply ventilation duct. For a comprehensive parameter assessment the sensors must be distributed at certain distances. Sensor locations are schematically shown in figure 2.
Figure 2. Schematic diagram of the heater installation sensor location.
The list of measured parameters and their normal values in the heater installation normal operation mode is presented in Table 2.

| Measured parameter name                      | Measurement unit | Value range with normal system operation (per one heater) |
|----------------------------------------------|------------------|----------------------------------------------------------|
| Heat carrier consumption                     | m³/h             | fr 0.3 to 1.5                                            |
| Heat carrier at the inlet                    | °C               | fr +25 to +60                                             |
| Heat carrier at the outlet                   | °C               | fr +15 to +45                                             |
| Heat carrier pressure at the inlet           | MPa              | fr 0 to 0.6                                               |
| Heat carrier pressure at the outlet          | MPa              | fr 0 to 0.6                                               |
| Air velocity at the inlet                   | m/s              | fr 0 to 30                                                 |
| Air velocity at the outlet                   | m/s              | fr 1 to 30                                                 |
| Air temperature at the inlet                | °C               | fr -45 to +5                                              |
| Air temperature at the outlet                | °C               | fr +25 to +65                                             |
| Air temperature inside the section           | °C               | fr +5 to +60                                               |
| Air temperature inside the mine shaft        | °C               | fr +5 to +10                                               |

These parameters make it possible to assess the heater installation operation quality, to maintain the supplied air temperature depending on climatic conditions. The presence of temperature sensors inside the mine allows you to coordinate the work of other heater installations, to evaluate the entire mine complex ventilation system work.

The monitoring system will allow the dispatcher to be warned on time about the abnormal and emergency situations occurrence, which will make it possible to take timely measures to eliminate them and to avoid company losses.

An accident operator alert is performed by the system when the following parameters are registered:

- open circuit or short circuit of any sensor;
- air temperature drop inside the shaft below +5°C;
- air velocity drop to 0 m/s;
- pressure drop of the heat carrier to 0 MPa;
- the heat carrier temperature drop in the supply line is below 80°C.

The system operation algorithms will determine the amount of heat consumed, thermal efficiency and energy consumption. These indicators will be analyzed by the system and will optimize the costs associated with the heater operation. Heater installation monitoring system ECU operation block diagram is shown in Figure 3.

Any modern system of automatic monitoring and control involves the procedure of calibration, adjustment and diagnostics. The calibration procedure is assumed at the system’s stage of installation and start-up. At this stage, it is necessary to make oneself sure in the normal functioning of the system, check the sensor equipment readings’ accuracy. To fulfill the routine maintenance work, and to repair the system, a diagnostic procedure is carried out. Modern monitoring systems are based on microprocessor technology. Control units based on processors allow you to convert sensor readings.
into digital signals, perform logical operations, transmit information via digital bus, and interact with other digital devices.

Figure 3. Heater installation monitoring system ECU operation block diagram.

5. Discussion
When describing the air heater installation remote control system, an important question was raised about the staff permanent control limited ability of the air heater installation. Based on this, the next step is the development of an industrial automated air heater installation with remote control. The new generation of air heater installations should have a number of distinctive features, along with a simple remote control.

The following distinctive parameters can be outlined:
1. The parameters’ advanced control possibility.
2. The choice of the optimal control parameters for a number of specific standard and emergency situations.
3. The ability to partially self-healing.
4. Ability to use low-speed channels for transmitting information to the operator console.

The following describes each of these parameters in more detail.

Under the heater installation advanced parameters regulation, you should understand the ability of the control system which is based on input parameters change monitoring to predict in the dynamics the further development of the situation. It is worth considering this parameter through an example. The control system receives data from various sensors. From air temperature sensors at the heater inlet and at the heater outlet, heat carrier temperature sensors at different points of the system, from pressure and flow sensors. When the weather changes, the temperature of the incoming air begins to decrease. The temperature does not fall sharply, by 1-2 degrees per hour. The control system records this drop in temperature. Such a drop will have practically no effect in 1-2 hours on the output parameters of the air from the heater, even if it is not controlled. But with a prolonged decrease in temperature, the temperature of the heat carrier at the inlet to the heater will also begin to decrease. Accordingly, the control system can conclude that the incoming air temperature can be further lowered. The control system introduces a corrective action, for example – will increase the heat
transfer of the heaters until the moment when the air temperature sensor at the outlet changes its readings. Advanced regulation will significantly reduce the heat carrier flow during operation of the heater in climate conditions with frequent temperature changes.

It is important to understand that the forecast of the change in system parameters and the correct response to the forecast are two different things. If we consider a heater installation, then there are two main groups of parameters affecting the output parameters of the heated air – the parameters of the outside air (temperature, velocity) and the parameters of the heat carrier – water (temperature, flow rate, pressure). Since the heater installation is part of the mining enterprise life-support system, the air parameters must be constant and precisely comply with the normative. Accordingly, only with one of them – the heat carrier, we can operate to change the output parameters. To achieve maximum economic indicators, it is necessary to determine very precisely what actions with the heat carrier in the air heater installation need to be made at the moment. This is especially relevant when the system of advanced regulation is in operation. The complexity of the problem lies in the fact that it is impossible to put into the program all the options for changing the weather, the temperature and pressure of the heat carrier, the state of the heaters. Consequently, it is necessary to calculate in real time what will happen with the system if one performs the basic control algorithm with the available input parameters. Compare the result with the reference and make corrections to the algorithm. Check again and repeat until the reference reading is reached. Thus, it becomes necessary to use a mathematical simulation digital model of the heater separately and a scalable installation model of several heaters. The possibility of applying a forecast mathematical model in the control system of a heater installation arises for the following reasons:

- the processes occurring in the heater installation are stretched in time and in most cases do not require an immediate response from the control system;
- changes in parameters that require the use of modeling do not occur all the time, but occasionally.

Consider what each of the points gives us. The processes stretched in time - all the transient processes in the heater installation do not occur instantaneously or even in a minute. Such time indicators give time to calculate the optimal mode in the forecast mathematical model. If there is no need for instantly complex calculations, then accordingly in the control system there is no need to use an expensive and super-powerful computer, which will have a positive effect on the cost of such a control system. The load on a computer with a mathematical model decreases even more when it becomes possible to use it occasionally. In practice, there is no need to adjust the parameters of the heater installation when there is a small change in the input data. Part of their time of work, the heater installation operates at relatively constant inlet air temperature, and conventionally constant heat carrier pressure and temperature. At this point, there is no need to use a forecast mathematical model of states. Such moments can reduce the load on the central computer.

Another parameter that distinguishes the heater system of the new generation from those used is the ability to partially self-healing. In the cold season, such air heaters operate 24/7, right up to the time of routine maintenance. But any mechanical damage to the heaters that caused the leak requires stopping the entire system and bringing it in for repair. Damage to heaters can occur for various reasons, local overheating and burning, freezing, physical external effects. According to engineering mining enterprises data, today, up to 30% of a heating installation elements fail in one year. This means every time the transition to the reserve – stop – repair – start. In the heater system of the new generation, constructive solutions are provided to exclude most of the situations leading to such repair stops [7-9].

In addition, to improve the safety and uninterrupted operation of the installation, the control system monitors using the sensors of heat carrier appearance from each heater that is included in the heater installation. Each element is equipped with individual controlled valves on the input and output. This design allows you to turn off remotely each air heater module. In automatic mode, the control system determines the fact of heat carrier leakage. With the help of leak sensors, design of the heater section and special algorithms, a specific problem heater is determined. Without stopping the entire installation, the control system disconnects the damaged element from the supply of heat carrier. The
built-in simulation system chooses the best option to compensate for the heat transfer of the lost element. Such a self-healing system can significantly reduce the heater installation number of stops for repairs. In the scheme of things, stopping a heater installation with a similar design for repair will be necessary only in the event of force majeure damage to the heater elements or damage to the main communications.

A distinctive parameter in relation to a new-generation heater installation is the ability to transmit telemetry and receive control commands from an operator through low-speed data transmission channels. Often, a heater installation is a facility that is remote from the main control room of a mining enterprise. Laying a multi-kilometer high-speed communication line is an expensive and complex undertaking. But there is a telephone line to almost all heater installation sites, often of not the best quality, which rules out the possibility of using high-speed modems. Even more difficult, when the heater installation is located at a remote facility, where there is no wired and cellular communications, it is possible to use only satellite communications here. Satellite communications are expensive and often work at very low data rates. From this it follows that the system of remote monitoring and control should be built in such a way as to receive only the changing parameters in digital form from the heater installation. Decoding of the received data and visualization should be made already on the operator’s side. And the control action must also be transmitted in compressed form and decoded by the control system of the heater.

6. Conclusion
The staff of the mine does not have the ability to be near the air heaters constantly, and it is important to receive prompt information about their work mode and the nature of the problems that occur in the system. Air heater parameters remote control system is capable of monitoring the mine entering air basic parameters, also capable of giving a contact control signal to the actuators to stabilize them, ensure safety, and to eliminate any abnormal situation occurrence.

References
[1] Tsyba A M 2012 Herald of Kuzbass State Technical University 4 14-16
[2] Nikitenko S M, Nikitenko M S and Kiselev Yu Ye 2017 Proc. of Int. Scientific-Practical Conf. pp 29–34
[3] Pazukha A V and Skorobogatova I V 2017 Analysis of the Mine Heater Installation as an Automation Object (Donetsk: GOUVPO Donetsk National Technical University)
[4] GOST 34.003-90 Information Technology. Set of Standards for Automated Systems. Automated Systems. Terms and Definitions
[5] GOST 34.201-89 IT Complex of Standards for Automated Systems. Types, Completeness and Indication of Documents when Creating Automated Systems
[6] GOST 34.601-90 Automated Systems. Stages of Creation
[7] Zubkov N N, Nikitenko S M, Nikitenko M S 2017 IOP Conference Series: Materials Science and Engineering 253 012021
[8] Kiselev Yu E, Getzman A E and Nikitenko M S Patent RUS 2341732 09.09.2006
[9] Kiselev Yu E, Nikitenko M S and Getzman A E Patent RUS 2567884 25.11.2014