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APPLICATION OF AUTOMATION SYSTEMS FOR MONITORING AND ENERGY EFFICIENCY ACCOUNTING INDICATORS OF MINING ENTERPRISES COMPRESSOR FACILITY OPERATION

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The balance of electricity consumption a significant part is occupied by the production of compressed air at the mining enterprises. Many compressor stations of enterprises are equipped with automated parameter management systems that allow reliable, uninterrupted and safe operation of the compressor facilities. But the majority of automation systems at compressor stations do not perform the function of monitoring the energy efficiency indicators of the operation of a compressor station.

The article discusses the issue of including compressed air flow sensors (flow meters) in an automated control system of a compressor station, which allows you to control the production of compressed air and the consumption of electrical energy for its production. Monitoring and recording of these parameters makes it possible, using microprocessor technology, to control one of the main indicators of energy efficiency – the specific energy consumption for producing one cubic meter of compressed air, determine how efficiently the compressor station works, and take appropriate measures to reduce specific energy consumption in time. .

The use of additional functions of automated control and monitoring systems will allow the development and application of energy-saving measures aimed at improving the energy efficiency of the enterprise, which will lead to a reduction in the cost of finished products and increase their competitiveness

***Key words*:** automated control system; energy efficiency; energy efficiency indicators; specific energy consumption; compressor station; automated control system; microprocessor controller

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Introduction. Many industrial enterprises use different types of energy to operate electrical, mechanical, thermal and auxiliary equipment. In industry, widely used pneumatic energy, or the energy of compressed air.

Compressed air energy is one of the main types of energy at mining enterprises, since drilling, drilling, tunneling, mining, loading machines and mechanisms are used in mining and processing of rock mass. The energy of compressed air was also widely used for ventilation and drainage when pumping water and pulp [2-4, 6].

At the same time, the use of pneumatic energy has several serious drawbacks. In the production, distribution and consumption of pneumatic energy consumes a large amount of electrical energy.

Formulation of the problem. Pneumatic installations used in the mining industry are the most energy-intensive equipment. Their share in electricity consumption of mining enterprises with underground mining of minerals is high (Fig.1). For example, in the energy balance of the Severouralsky bauxite mine RUSAL (JSC SUBR) the share of electricity consumption for the production of compressed air is 20-40 % of the total electricity consumption of the enterprise.

The overall performance of the compressor unit and the compressor station as a whole depends on a number of external and internal factors that must be monitored during the operation of the entire compressor house of the enterprise.

One of the important indicators of energy efficiency of the compressor house of the enterprise is the specific consumption of electrical energy for the production of one cubic meter of compressed air.

$$W_{\text{p.u.}} = \frac{W_{\text{el}}}{Q_{\text{c}}},$$

where W_{el} – consumption of electric energy by the compressor unit for 1 h, kW; Q_{c} – the amount of compressed air produced during the same time interval, m^3.

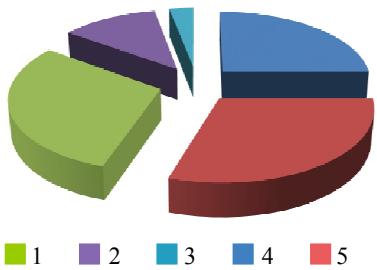

Fig.1. Power consumptionat the mining enterprise

1 – drainage; 2 - auxiliary production; 3 – domestic needs; 4 – ventilation; 5 – compressor facility

The rate of electrical energy consumption per cubic meter of compressed air can be calculated by the formula

$$W_{\text{p.u.}}^{\text{n}} = \frac{L_{\text{is}}}{3600 \cdot 102 \eta_{\text{is}} \eta_{\text{m}} \eta_{\text{g}}},$$

where L_{is} – isothermal operation of the compressor unit; η_{is} – isothermal efficiency of the compressor unit; η_{m} – efficiency of the electric motor of the compressor unit drive; η_{g} – gear efficiency.

Isometric operation of the compressor unit can be calculated by the formula

$$L_{\text{is}} = 2.3 p_0 V_0 \lg \frac{p_2}{p_0},$$

where V_0 – initial intake air volume equal to 1 m^3; p_2 – final compression pressure, MPa; p_0 – intake pressure, MPa.

To determine the efficiency of the compressor station by specific power consumption, it is need to be known the rate of consumption of electrical energy for the production of 1 m^3 of compressed air and compare it with the actual specific consumption of a compressor unit (see Table).

Normal specific electricity consumption for the production of compressed air in general-piston compressors, kWh/m^3

Compressors	Compressed air pressure, MPa	
	0.6	0.7
Vertical, two-stage capacity up to 20 m^3/min	0.115	0.12
Horizontal, angular capacity up to 100 m^3/min	0.095	0.105

When examining the compressor facilities of Ural mining enterprises, it was found that most of the compressor units operate with an increased specific consumption of electrical energy, therefore, the control of the specific consumption of electricity is one of the main tasks in the effective operation of the compressor economy of the enterprise..

Mostly, at the majority of compressor stations of enterprises accounting for the consumption of electrical energy is maintained, since it is technically simple and low-cost. Most of the compressor stations are equipped with visual or automated metering of electricity consumption (electric meters). However, a very small number of compressor stations have technical means to record the production of compressed air. These indicators are evaluated in aggregate (by indirect indicators) [1].

Many compressor stations of mining enterprises have an automated control system for compressor units. As a rule, these systems are designed to control and control the production of compressed air. The pressure of compressed air in the manifold of the pneumatic network is controlled, which allows controlling the performance of the compressor station. These automatic control systems do not provide for monitoring and accounting for the production of compressed air, as the cost of the compressed air flow sensor, its installation and operation is high.

Therefore, accounting and control of the production of compressed air is an important task for the modernization of existing and design of newly commissioned compressor stations.

Methods for solving the problem. To account for the flow of compressed air and the possibility of further automation of compressor stations, it is proposed to install a flow sensor (flow meter) of compressed air (Fig.2) [1, 5, 7, 8].

Modern compressed air flow meters can be used as part of automated control, monitoring and energy accounting systems using a frequency-pulse and digital signal. The installation of this sensor

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allows you to monitor in real time the indicators of compressed air consumption and control the operation of the compressor station [8-10]

Automated systems used at compressor stations of mining enterprises are mainly designed to ensure uninterrupted operation of the enterprise's pneumatic facilities. Automated systems monitor the pressure in the pneumatic network and, depending on the readings of the pressure sensors, regulate the performance of the compressor units. In this case, automated systems can record and control the flow of compressed air, but, as a rule, it is not used [11, 14].

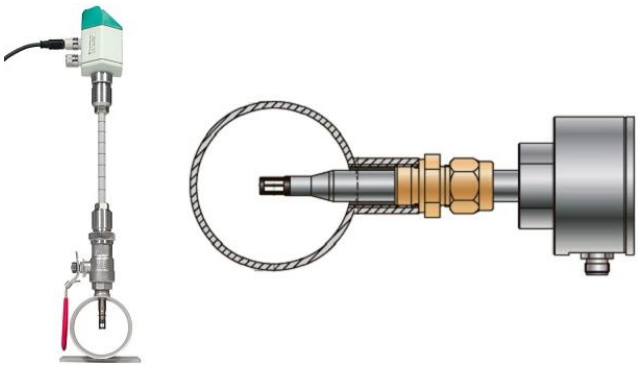

Fig.2. Connection scheme of the compressed air flow sensor to the pneumatic network

When using automated control systems for compressor facilities of enterprises, the main element for controlling the production of compressed air is the flow sensor, which is connected to the microprocessor control panel. Measuring information is fed to the dispatcher's automated workstation (AWP) server [12]. When using specialized software products, this information can be archived and transmitted to the energy services of the enterprise. At the same time, the dispatcher in real time can control not only the operation of the compressor station, but also the energy efficiency indicators.

To automate the process of control of compressor installations, special microprocessor controllers are used, which have a programmable control algorithm and allow for the full automation of the operation of a compressor station or a group of compressor installations and the reduction of energy consumption [13].

When using automated control systems for compressor stations, several solutions are possible. Consider the controllers of the Belgian company METACENTRE, specially designed to control the compressor stations (Fig.3).

METACENTRE controllers allow you to solve a number of functional tasks:

– control simultaneously up to 24 groups of compressor units;

– reduce the average amplitude fluctuation of the working pressure;

– use adaptive regulation (controls the number of shutdowns and the transition of compressor units to idle, calculates the optimization and coordinates the work);

– apply up to six different configurations of the presented parameters of the operating modes;

– perform in real-time conditions the complete shutdown of the compressor unit or the reduction of pressure during the lunch or inter-shift breaks;

– to control pressure in three different zones of the pneumatic network;

– manage the additional and auxiliary equipment of the compressor station;

– transmit information to the operator, dispatcher or top-level AWPs.

Fig.3. Automated compressor station control system on a METACENTRE microprocessor controller

Approbation of work results. In the «Artinsky Zavod» Jsc. (Sverdlovsk Region), the existing automated system for monitoring and accounting of energy resources was upgraded to control and further analyze the specific energy consumption for the production of 1 m^3 of compressed air. To do this, compressed air flow sensors were introduced into the existing system (electricity meters in the system have already been used). Using the top-level program of the compressor station manager and the METACENTRE microprocessor controller, which received a signal from the compressed air flow sensor, we set the control of the specific energy consumption. As a result of the obtained data, a significant excess of the specific energy consumption for the production of 1 m^3 of compressed air (0.17 kWh/m^3 at a rate of 0.115 kWh/m^3) was revealed. On the basis of the obtained data, the reasons for the deterioration of the energy efficiency of the compressor station operation were analyzed. Prompt decisions on current repair and replacement of equipment at the compressor station made it possible to reduce the specific energy consumption to the optimum value.

Conclusion. The automated system is capable of supplying consumers with the required amount of compressed air at the lowest possible energy cost, which saves up to 25 % of electric energy in comparison with traditional tactile control systems of compressor stations.

Using the functions of controlling the generation of compressed air and monitoring the specific consumption of electrical energy to produce 1 m^3 of compressed air allows the analysis of the efficiency of the compressor unit and the compressor farm as a whole.

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