Automated information and control complex of hydro-gas endogenous mine processes

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Abstract. The automated information and control complex designed to prevent accidents, related to aerological situation in the underground workings, accounting of the received and handed over individual devices, transmission and display of measurement data, and the formation of preemptive solutions is considered. Examples for the automated workplace of an airgas control operator by individual means are given. The statistical characteristics of field data characterizing the aerological situation in the mine are obtained. The conducted studies of statistical characteristics confirm the feasibility of creating a subsystem of controlled gas distribution with an adaptive arrangement of points for gas control. The adaptive (multivariant) algorithm for processing measuring information of continuous multidimensional quantities and influencing factors has been developed.

1. Introduction

From the point of view of the safety in mining operations, the airgas control (AGC) of the mine atmosphere is the most important issue. At present, it is regulated by the Provision on airgas control in coal mines [1], which establishes the procedure for organization of continuous automatic control over the parameters of mine atmosphere, dust content and air consumption in mine workings; detection of underground fires and the initial stages of their occurrence according to the parameters of the mine atmosphere; monitoring and control of the units and equipment operation to maintain a safe airgas regime.

In this issue, an important factor is the continuous monitoring of the concentration of three gases – methane, carbon monoxide and oxygen using individual portable gas analyzers that are handed over to miners before their going underground [2, 3]. The registration and processing of harmful gases measurements, time and place of measurement with the help of individual gas analyzers allows the following goals of ensuring safety during minerals extraction to be achieved:

- reduction of the explosion hazard of mine atmosphere (lowering of flammability and explosion hazard) in the mine workings when the methane concentration exceeds the allowed standards (or increases) and the alarm of gas analyzers belonging to three or more miners goes off;
- detection of underground fires and the initial stages of their occurrence according to the parameters of the mine atmosphere;
- provision of information for analysis and elimination of the causes of endogenous and exogenous fires;
- control of individual binding of the gas analyzer to each miner;

- provision of information on controlled parameters to specialists working at the mine who perform operational management of mining operations and ensure the mining operations safety;
- storage of information and possibility of its use for the development of comprehensive measures ensuring industrial safety at the mine for the purpose of current (operational) detection of natural and technogenic hazards that affect directly or indirectly the state of mine atmosphere;
- provision of remote control by indirect data.

2. Automated information and control complex

The developed automated system is designed to prevent emergencies, incidents and violations of safety rules associated with violations of aerological environment in the underground workings and leading to life and health risks of personnel. In addition, the tasks of integrated automation of handing over (receiving) and accounting of individual portable devices (cap lamps, radio stations, gas analyzers), as well as data transmission from gas analyzers and display of the controlled gases concentration in the mine atmosphere, were solved.

The typical structure of information means of the mine consists of underground and above-ground complexes separated by an intrinsic safety unit. In the example under consideration, the underground complex was implemented on the basis of mine information complex “Talnakh”, intended for construction of mining and underground radio communication systems and automation for various purposes in the underground part of mines [4, 5]. Current information from individual gas analyzers comes through “Talnakh” complex to the central server, where it is processed and stored on the database servers of the system under consideration.

The structure of the developed system includes the following subsystems:

- subsystem for accounting individual gas analyzers;
- subsystem for controlling the handed over and handed in individual portable devices (gas analyzers, radio stations, cap lamps);
- subsystem for displaying the content of oxygen, methane, carbon monoxide by individual means of continuous monitoring;
- subsystem for data exchange about mine workers.

With the help of the gas analyzer subsystem the user is able to keep a record of the gas analyzers of the organization. The following functions are realized: automated input of information about gas analyzers (sensor and radio tag) into the system; control over the number of gas analyzers (total, handed over, under repair); control over the timing of gas analyzers calibration.

The subsystem that controls the handed in and handed over individual portable devices is designed to record the facts of handing in and handing over the individual portable gas analyzers, radio stations and cap lamps using the device itself (equipped with automatic identification tools) and passes (contactless cards) of access control systems, automated verification and/or setting technological parameters, prohibition of device handing over, etc.

The subsystem for displaying the oxygen, methane, and carbon monoxide content by the individual continuous monitoring devices is designed to display the results of monitoring methane, carbon monoxide and oxygen by individual automatic portable gas analyzers, which every underground worker, when he is in the underground workings and hazardous aboveground facilities, should have. The subsystem provides automatic recording of threshold values for methane, oxygen, carbon monoxide in the database with time recording and indication of the location of the miner from the database “Gases”. Figure 1 shows the automated workplace of an air gas control operator.

The subsystem for exchange of data about mine workers imports from the organization’s access control system information about the mine employees and contractors performing underground works.

The developed system has ample opportunities for interaction with existing automated systems and databases at the enterprise, in particular, from the mine information complex “Talnakh”, access control system “KODOS” and the “Gases” database. Data streams during data import/export operations are schematically shown in figure 2.

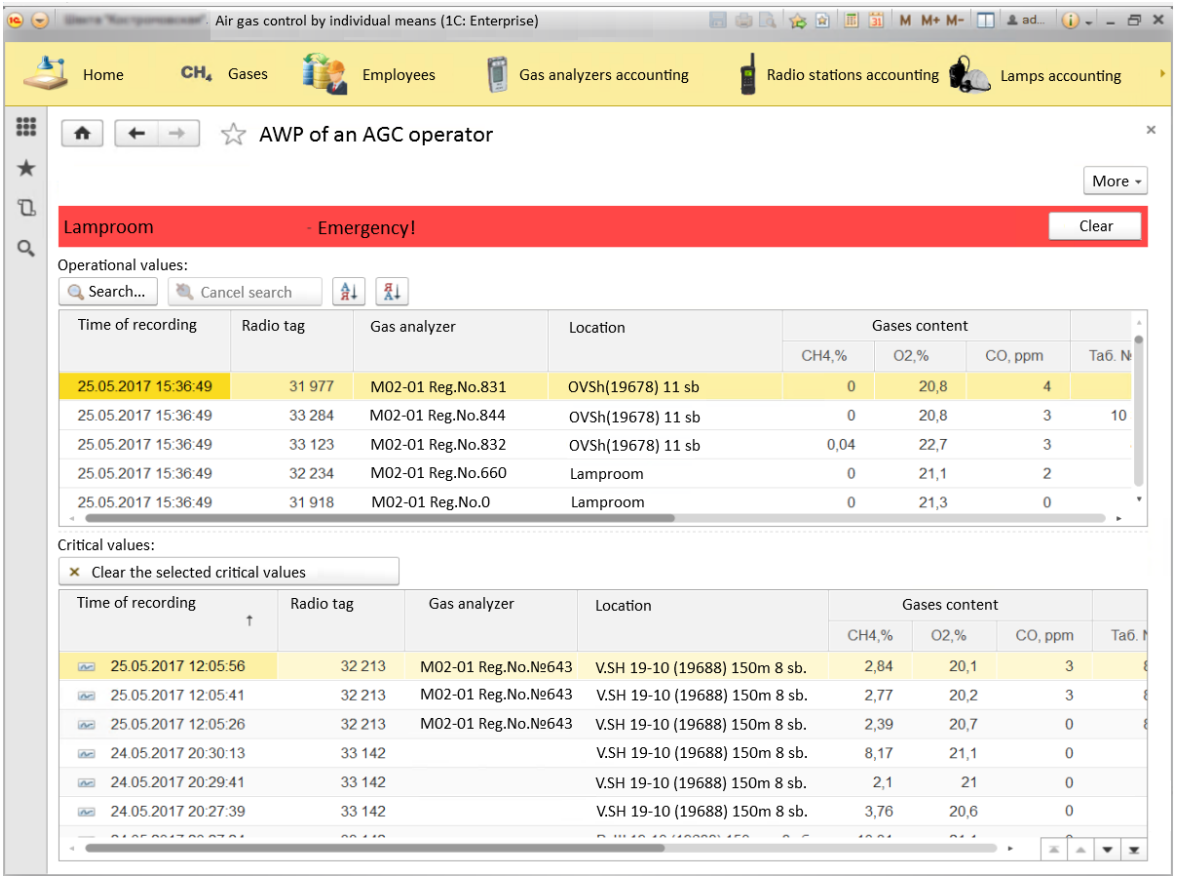

Figure 1. Automated work place of an operator of airgas control by individual means.

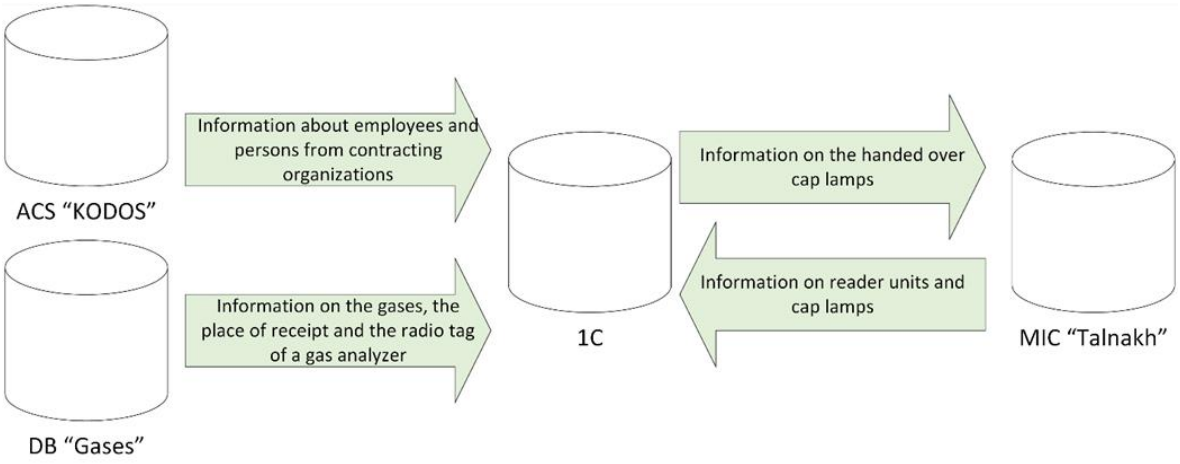

Figure 2. Data streams.

The system has been successfully implemented at several mines in Kemerovo region, but the work continues on improving the current information control system, in terms of processing the information received from gas analyzers. A lot of works are devoted to the problem of improving airgas control methods, for example [6 - 9]. Nevertheless, in real conditions of distribution and non-stationarity of the

airgas parameters of mine processes, sudden increases in local gas concentrations and, as a consequence, exceedance of the maximum permissible concentrations of explosive gas mixtures (in particular, methane), as well as various disturbances in the flows of air, causes an additional danger of explosions and fires.

Therefore, it is especially urgent to ensure the safety and reliability of the mines by creating a modern automated technology for obtaining measurement information about a number of air gas parameters of the mine atmosphere and the ventilation regime, its joint processing, in order to determine timely the characteristic changes in the informational parameters of the state of controlled objects.

An adaptive automated information and control complex is designed to prevent emergencies, incidents and violations of safety rules related to aerological situation in the underground workings, as well as to transmit and display measurement data and take preemptive actions. A distinctive feature of this complex is the integration into the basic stationary system of a mobile information system based on the indications of individual gas analyzers handed over to miners. And also a distinctive feature is the diagnostic subsystem built into the existing production control and regulation system based on the operational multi-variant joint processing of the measuring information and development of advanced solutions. The simplified functional structure of the proposed complex is shown in figure 3.

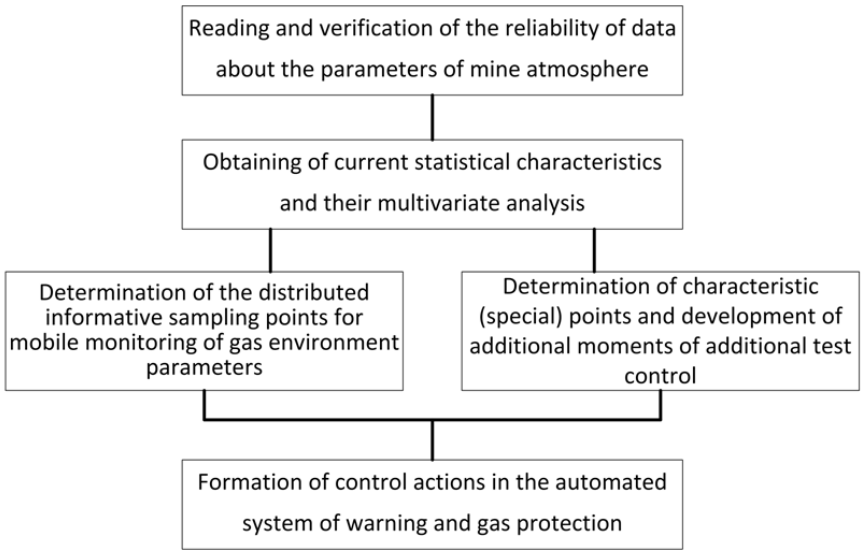

Figure 3. Functional structure of the complex.

In connection with the set tasks, there are increased requirements to the mathematical apparatus and, accordingly, to the algorithmic support of the described complex.

3. Multivariate algorithm for processing the measurement information

An adaptive (multivariant) algorithm for processing the measurement information of continuous multidimensional quantities and influencing factors is developed. Its multivariant algorithmic structure is presented in figure 4.

The synthesis of these algorithms is based on the procedures of a robust smoothing of non-stationary series of primary and calculated data. The need for a robust estimation of structural and statistical characteristics of airgas control, for example, in the form of a polynomial description for a slowly varying vector component of correlation moments measurement of quantities coupling in it, conditioned by the presence of coarse control interferences and sharp individual changes in the course of operation in the workings.

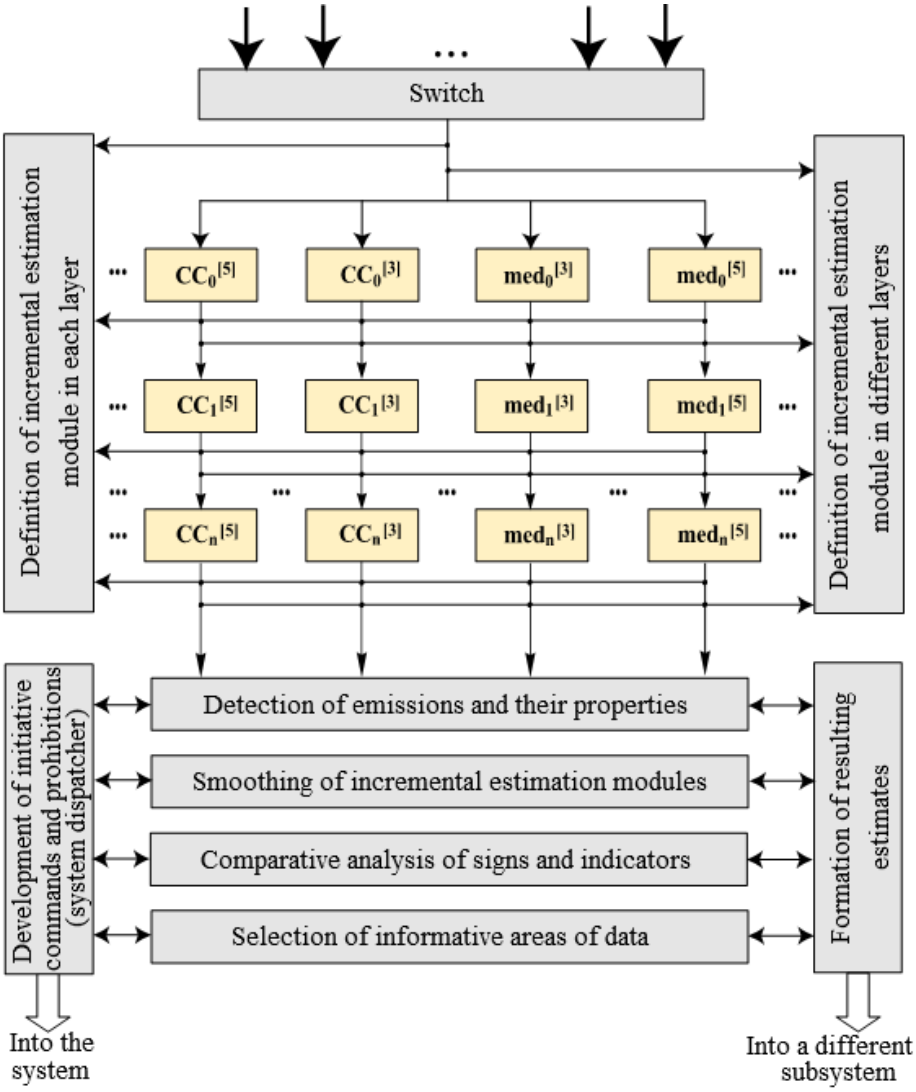

Figure 4. Multivariant algorithmic structure.

Data processing based on conventional averaging results leads in such conditions to the overestimated range of estimations variation compared to significant deviations in the real object itself, which is confirmed by numerous results of histograms and correlation moment matrices plotted with the use of the recorded data on gas distribution and other parameters of endogenous mine processes (figure 5).

Comparison of the robust and conventional procedures allows the former to be preferred, because they lead to more reproducible statistical characteristics at different time intervals of mine operation, including using simple median and relay-exponential smoothing algorithms. At the same time, there are cases of insufficient speed performance of both conventional and the described robust procedures in the operative tracking of significant changes in the trends of endogenous processes. Therefore, additional developments were made to develop adaptive robust algorithms of smoothing multidimensional data series with a joint analysis of deviations of actual and smoothed values for all interrelated variables.

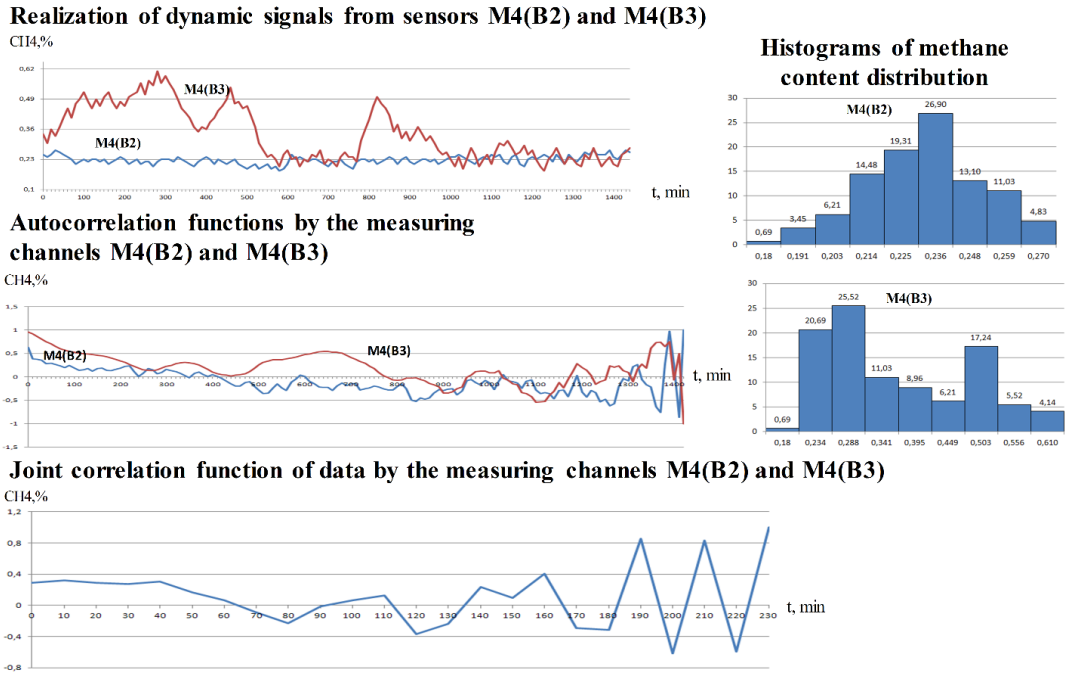

Figure 5. Statistical characteristics.

A multidimensional version of the algorithm, implemented in [10] and presented in a simplified form in figure 4, can be considered as one of the most adapted algorithms for a wide application in automated information systems. Such analysis is carried out in order to timely identify significant changes that are consistent in the changes in most primary taken into account and calculated data.

The obtained results of the trend estimation (non-stationary mathematical expectation), auto- and intercorrelation moments in the joint processing of data for all monitored gas control points proves the satisfactory reliability and speed performance of the proposed procedures.

4. Conclusions

The dynamic estimates of the correlation coefficients between the methane measurement values in the fixed points, found with the help of a multidimensional multivariant algorithm, have a pronounced non-stationarity. At different time intervals there is a “drifting” dispersion of information, which confirms the expediency of creating a subsystem of controlled gas distribution monitoring with an adaptive arrangement of gas control points. The version of a control action is developed, according to which the distance between adjacent points is subsequently adjusted depending on the difference between the current cross-correlation coefficients and their average value over all pairs of control points. Together with this, the increments of smoothed variables in the adjacent time intervals of the real object should be used. In case of exceedance of the established threshold values by the instability indicators, the control solutions are developed, including special test control measurements of the gas concentration.

The command control of gas distribution contributes to a more timely and reliable assessment of the actual state of endogenous mine processes, increasing the representativeness and speed in collecting and analyzing multidimensional measurement information, as well as expanding the functional potential of human-machine system for development of effective solutions and eliminating emergency situations in operation of the mine complex.

Acknowledgements

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