Journal of Chemical Technology and Metallurgy, 51, 4, 2016, 473-482

RESULTS OF DEVELOPMENT OPTIMIZED ADAPTIVE ACS ON NEURAL NETWORK FOR MINING

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Received 24 November 2015
Accepted 20 April 2016

ABSTRACT

The article deals with the problem for optimization of complex technological processes of mining and processing complexes of the Republic of Kazakhstan. Analyzed characteristics used control systems. The article has revealed and substantiated the necessity of the use of non-existing approaches to "fine" adjustment adaptive control systems. On the basis of the research proposed structure of an adaptive control system grinding process, built using artificial neural network of radial basis function. For the implementation of the experiments was developed a simulation model of the process. The absolute deviation of the simulated value - energy consumption is no more than 5.1 %. An analysis of the effectiveness of application of the developed system was conducted judging by the evaluation results of reducing energy consumption with the process model. It proved the possibility of reducing power consumption using the system for 6.9 %.

For a hardware implementation of the system the tendencies of development industrial automation were considered. Based on the analysis, a decision on the construction of the industrial controller Siemens (Simatic S7-300) was made. We developed algorithms of the system operation and implemented their programmecode.

Keywords: technological process optimization, resource saving, adaptive control system, artificial neural network, industrial controller.

INTRODUCTION

The innovative development of industrial enterprises at present is unthinkable without the formation of an effective management system. And the main focus at all levels of governance and management should be focused on the most efficient use of material, labor and financial resources, natural resources, elimination of unnecessary costs and losses. Despite the background of research in the field of construction of automatic control systems, these issues remain relevant at the moment.

The main constraints to solve these problems for processing plants on existing classical adaptive control system are the following:

- absence or lack of precision instrumentation;
- complication of the working conditions of processing equipment due to the depletion of mineral resources base and work on various ores;
- need for multi-parameter optimization and research for the presetting of the equipment;
- significant impact, if more precisely interaction, of technological processes and lines at each other;
- permanent "drift" of the zone of optimal performance due to the instability of the production intensity of the input and equipment wear [1].

At the same time, the development section of neural networks gives grounds to assume that such a control system can be designed and effective mainly on artificial neural networks (ANN), because the neural network focused on the processing of large volumes of information (including semistructured), capable of learning and adaptation. However, for today, for the use of artificial neural networks there are own unresolved issues.

This article presents the results of the development

of an adaptive optimal control system of technological process in iron ore grinding by a rod mill, built on the neural network. Development of automatic control system (ACS) and analysis of its effectiveness is made for the processes of crushing iron ore in rod mills under the largest plants of the Republic of Kazakhstan - JSC "Sokolov-Sarbai ore-dressing production association" (JSC "SSGPO") and LLP "Orken" [2 - 5].

The application of the results of this paper will enable the enterprises to reduce the cost of industrial product, partially solve the problems of optimization of technological processes.

Methods

Nowadays the industry has accumulated large amount of data "input-output" with the control apparatus of the process equipment. For example, for the factory of wet magnetic separation (WMS) of JSC "SSGPO" those data is presented in the form of protocols of the system work Contronic S[4].

Since the data of the protocol of the equipment correspond to different production plans we decided to bring the values of power consumption and productivity of final classes to specific energy consumption and performance.

Simulation of irregularly located data with respect to the grid is always more difficult, so the data protocols have been processed and presented in an uniform arrangement. Figs. 1a and 1b show nodal points corresponding to the processed data of the protocols.

The graph (Fig. 1a) of dependence of mill energy consumption of two ores ratio and water in the feeding was constructed in MATLAB package. For the approximation was used n-dimensional tabular interpolation. Fig. 1b shows the optimum percentage of water in the feeding mill for data of ores ratio. In the interpolated surface was found minimum energy consumption for each ore ratio. The values of the water content corresponding to these points are shown on the graph 1b. A significant influence on the grinding mills process has also the state of the mill - physical wear and tear of its components [6]. Since the data logging parameters are not taken into account, respectively, they are not reflected in the construction of dependency - it is partially explained by ripples on the graph.

Collecting information on the volume of incoming ore was implemented by automated operational dispatch control system (AODMS) used by JSC "SSGPO". Information on the process of grinding in a rod mill was obtained according to the protocols of the system Contronic S. Measuring instruments were weighing conveyor VER-10, water meter PROMAG-30 (Fig. 2).

For information processing was used MATLAB ver.10 package and toolbox Simulink. A comparative analysis of the existing automated control system and the proposed adaptive system is implemented through computer simulation with the same input effects and evaluation of model operation of the investigated systems.

The software and hardware implementation of ACS is carried out on an industrial controller Siemens

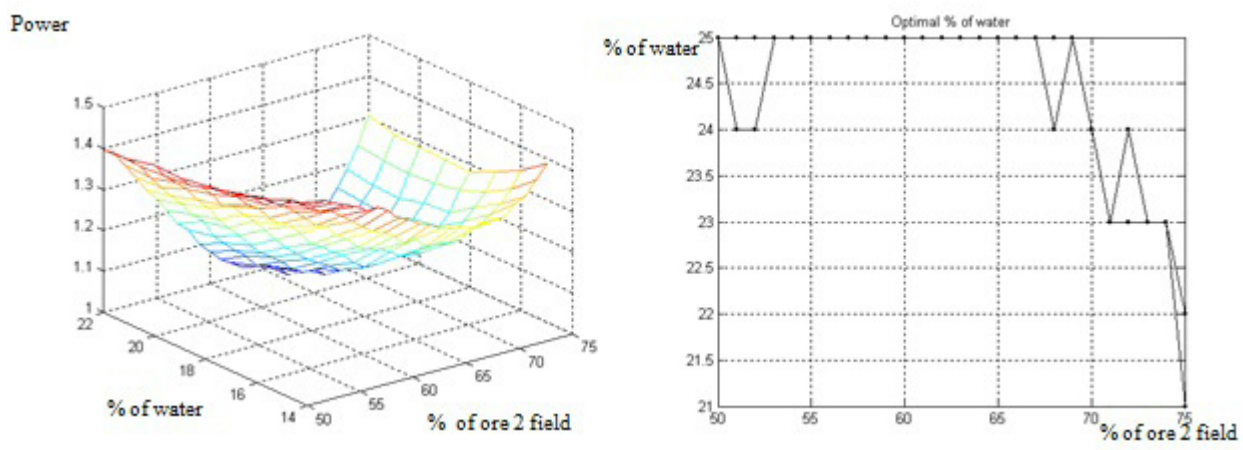

Fig. 1. The dependence of energy consumption of grinding process on the ratio "liquid-solid":
a) dependence of energy consumption on the ratio of the ore deposits and the ratio of «ore/water»;
b) optimal ratio of «ore/water» for various ratios of ore deposits.

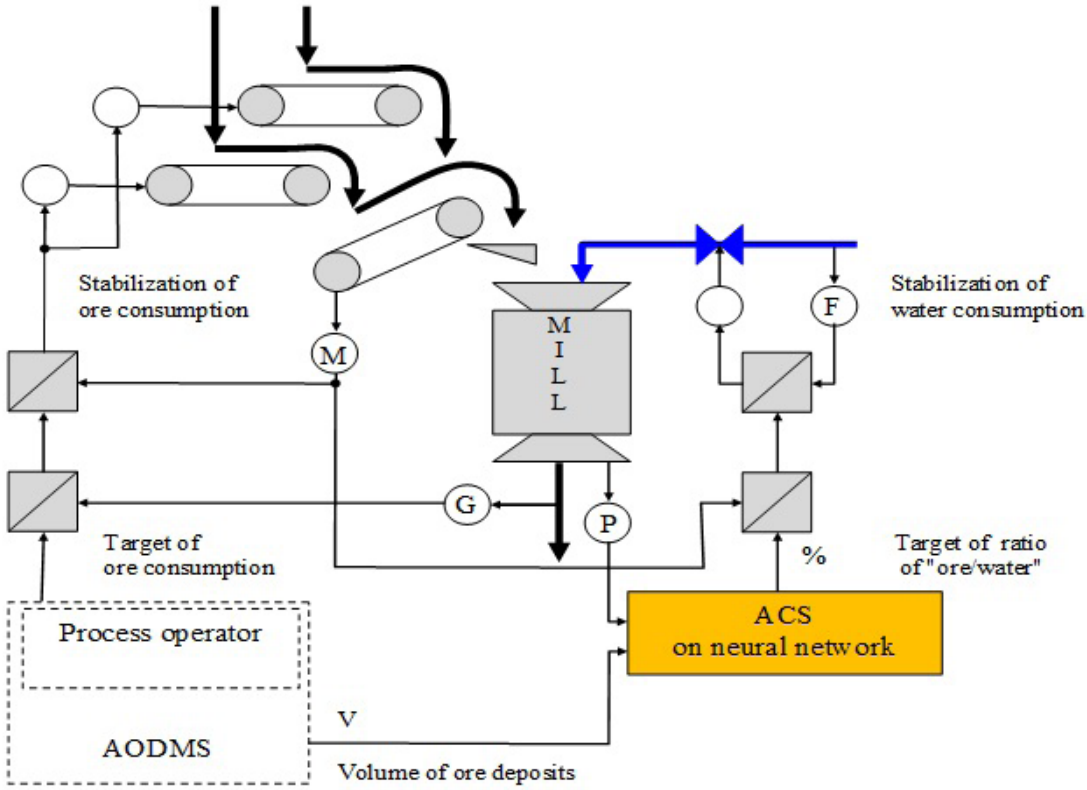

Fig. 2. The tecnological process (V (V_1, V_2, …) - input parameters (volume of ore deposits); P - optimization parameters (power of mill); % - control parameter (ration «ore/water»); M - weighing conveyor VER-10; F - water meter PROMAG-30; G - granulometry).

(Simatic S7-300). For encoding a structured control language SCL was used.

Literature Review

Issues dedicated to the optimization of mining processing plants are reflected in many works [6 -10].

Modern tasks of automation are affected by many factors, and in description and modeling are usually chosen several major, most significant factors in the case of construction complex control systems on the technological control object (CO). Other factors are not taken into account, and therefore a situation of uncertainty is created a priori, attributed to the errors in regulation as random and deterministic and systematic.

For an analytical description of complex nonlinear dynamical CO most authors consider the use of the most common equations of state apparatus, which is unique, rigorous and valid [11].

For more accurate facility for optimum operation is proposed an usage of neural networks. It is proposed to improve the existing automatic control system through introduction of add-ons in the form of a neural network. Neural network should be adjusted in a small range without disturbing the overall operation of the main control system, the amount of control task [11].

The proposed approach on the one hand, allows fine-tuning process that can yield significant economic benefits, on the other hand, a limitation on the value of the corrective task of neural network influences, even in violation of its work will not lead to significant losses, since the main control system will continue operate within the acceptable range.

RESULTS AND DISCUSSION

The purpose and objectives of the research presented in the article is to develop an effective system of control using processing equipment in mining and processing on the basis of adaptive automatic control systems using artificial neural networks.

Accordingly, the following objectives are implemented:

- analysis of the state of automation processes of crushing iron ore and their application;

- development of a model of adaptive control system based on ANN for the grinding process;

- analysis of the effectiveness of its application as compared with the existing scheme of control;

- software and hardware implementation of ACS controller Siemens Simatic S7-300.

When analyzing the state of the automation systems, we found that the equipment on the processing complex of Kazakhstan is presented mostly by equipment manufactured in the 60 - 80 years of the last century [3, 5, 6]. The same applies to the majority of automation systems. The analysis of the state of the automation process has shown that it is presented by well-functioning control systems at the lower level - ACS TP. On the second level the automation systems are shown mostly by automated control systems, although widely used until now is the manual control system. Higher-level systems consist principally of dispatching control and act as process optimization and does not function as process optimization.

For investigation and optimization we have selected the grinding process in a rod mill as the most energy-intensive in the mining and processing of iron ore production [6].

We developed a model of the investigation object - the grinding process of iron ore. Analysis of the model was held by the method proposed by O. Balci [12, 13]. The analysis of this model, by the accuracy parameter showed that the absolute deviation of the simulated power consumption of the real values is 0.0612 MW or 5.1 %.

In developing the structure of the system it is suggested that the system of control relation "ore/water" of grinding process should be a combination of self-learning systems, and a search system. Therefore, its structure must have the following elements:

- search module for adapting and finding the optimal

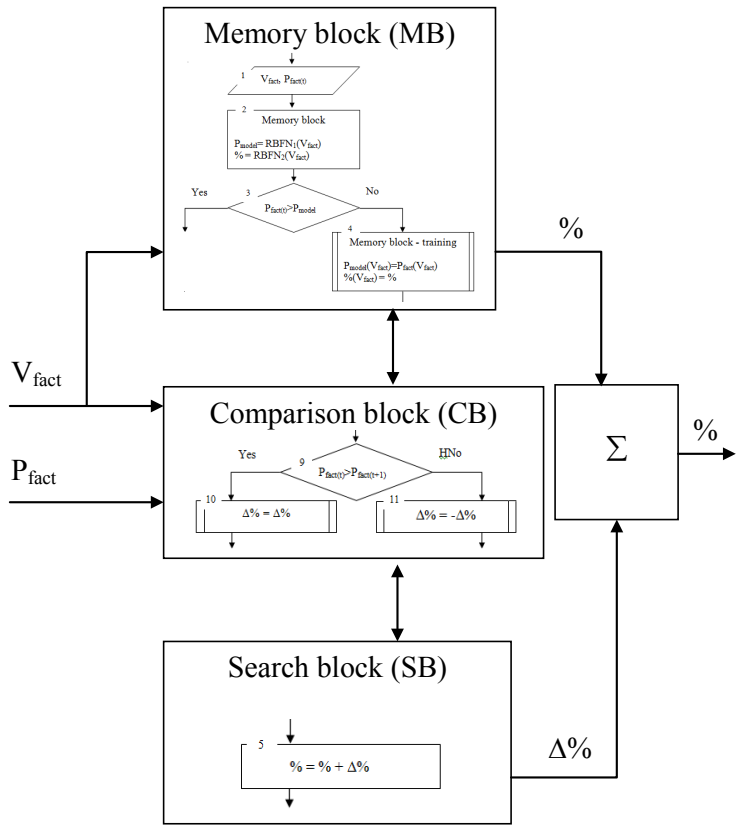

Fig. 3. The structure of the ACS with self- and training (Vfact - input parameters (Actual volume of ore deposits); Pfact(t) - optimization parameters (Actual volume of mill's power at the time t); Pfact(t+1) - optimization parameters (Actual volume of mill's power at the time t+1); Pmodel - optimization parameters (Simulated power of mill); % - control parameter (ration «ore/water»).

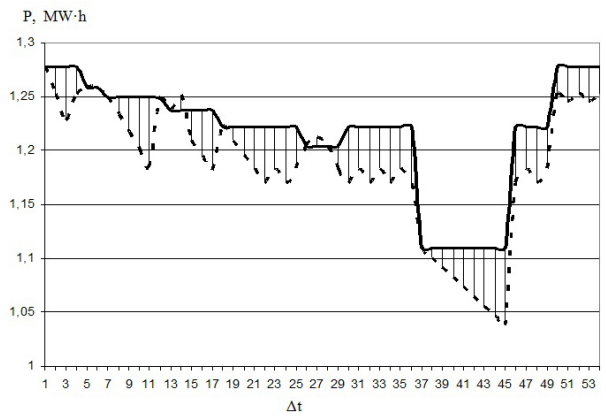

Fig. 4. Graph of energy consumption.

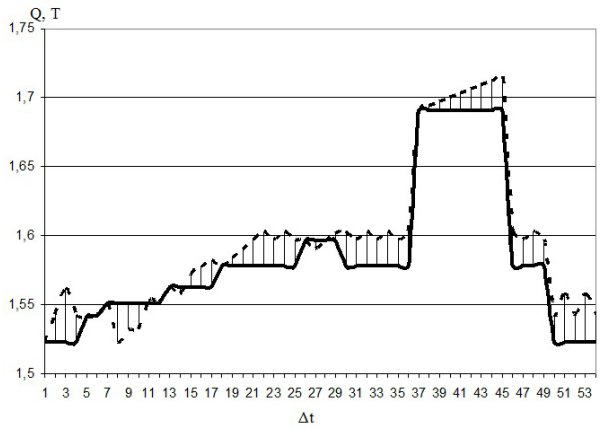

Fig. 5. Graph of productivity.

value in the changing the external influences on the control object and the system itself;

- unit or the memory unit for storing the previous experience of optimization and optimal settings available;

- comparison module for training opportunities and improve the stored values. The structure of the system can be represented by the diagram in Fig. 3.

The presented scheme of ACS is efficient in those cases where the transition processes in the control facility and ACS will be much less than the significant change of the input parameters. Since the value of the ratio of ores in the industrial product supplied to grinding, significantly changes (5 - 6 times a day), and the transient time in the mill is minute, so it is possible to neglect resulting from transient error. This regulation served as a justification for non-implementation mechanism of the account history of control object state (CO).

For use in the memory module, the possibility of using both classical approaches (polynomial and spline interpolation), and through the application of neural networks (networks with reverse distribution errors, networks of radial basis functions (RBFN) et al.) is investigated [12 - 15]. RBFN showed the best and sufficiently high accuracy compared with other types of neural networks and approximation algorithms. This has also justified the decision on its application in the memory [16].

For technical systems of commercial use, the basic indicator of the effectiveness of implementation of a particular scheme of automation is reduction of the cost of production. The introduction of an adaptive automatic control system in grinding process is to reduce production costs. The main parameter that affects the cost is the power consumption of the mill. Also an important parameter is the change of productivity of the mill by final class.

Graphs of energy consumption and productivity of the mill by final class when compared to the work of a core model of the mill with automatic adaptive and automated control for 1 hour are shown in Figs. 4 and 5.

On the graph the continuous line shows the power consumption and the productivity of the mill at the automated control, a dotted line - the adaptive automatic control. The stepped nature of the graphs is due to the use of the mechanism of promotion model time Δ t. Individual sections of the excess power consumption and performance degradation is caused by work in the search block away from the optimum value of the ratio "ore/water".

The total power consumption of a model mill using the ACS study, compared with standard is less than 76 kW·h. The error simulation is 61.2 kW·h. Based on the worst case (error modeling applied to energy savings) is the fact that significant energy savings are in the amount of 15.8 kW·h. Thus, the saved energy of the mill in one month is

$$Э_{e/c(month)} = Э_{e/nc(hour)} \cdot T \cdot K = 15,8 \quad kW \cdot h \quad \cdot$$
$$24 \quad hours \quad \cdot 30 \quad days \quad = 11,376 \quad MW \cdot \text{h}$$

The productivity of the mill with final class also tends to increase, which characterizes the improvement of the quality of the control process.

For software and hardware implementation of the adaptive system an analysis of trends in the development of hardware database of control systems was made. It

was found that the construction of the proposed structure to the typical solution is possible on the basis of neurochips, specialized modules and standard industrial controllers.

The development of ACS in specialized module requires professionals with a very wide range of knowledge in the field of application, hardware and software. Upgrading these systems is complicated due to lack of unification of approaches for developing and poor documentation. The change of hardware often leads to profound modernization of all software. Support and development of ACS on specialized modules, as a rule, may only be directed to the developers of the system.

In the hardware implementation of neurochips, in recent years, is seen a significant dynamics: there are available commercial solutions, capacity and performance of neurochips growing. However, in the field of neuroprocessor technology there are a number of problems, for example, a small productivity of neuroprocessor devices due to the low frequency of neurochips (30 - 150 MHz). There are obstacles to the creation of multimicroprocessor structures based onneuroprocessors:

- neural are yet expensive and piece goods, and not every organization can acquire them in an appropriate amount;

- design and analysis of specialized multiprocessor-based systems are very labor-intensive neurochips and complex process.

Thus, the industrial development in the ACS on neural controllers faced with the same set of problems, which have become typical and specialized modules.

Based on the mentioned above approaches to the construction of the adaptive automatic control system with neural network based on specialized modules, and, paradoxically, on the basis of neurochips and neural controllers currently unpromising for industrial performance and replication. Construction of the developed system can effectively use modern types of controllers (PLC), built on a modular integrated architecture, clocked, and preferably provides a mechanism sections.

The analysis of available characteristics on PLC allows to formulate criteria for selection of the industrial controller to implement adaptive ACS for grinding process: controller type in the number of I/Os - medium to large, on the location of modules - modular, on the application - universal general-purpose, according to the method of programming - programmable using a personal computer programming languages - the languages of IEC 61131-3.

After comparing the above-described characteristics of the PLC, for implementation of ACS was selected controller Siemens Simatic S7-300. This controller meets the required criteria for the system being developed, as this equipment is already in use in the investigated companies (JSC "SSGPO" and LLP "Orken"), which is an important criterion for future implementation.

For operation of the system proposed in Fig. 2, the following algorithm was developed:

1. If the Y value at the current X, stored in the memory, is the best obtained from the control object and decreases the absolute value of the difference, the more accurate direction of optimum value is preserved. The comparator does not produce any signal. The unit stores the direction of the sign Δ X. The values of the memory block are not changed.

2. If the Y value at the current X, stored in the memory, is the best obtained from the object control and increases the absolute value of the difference, it is necessary to change the direction of refinement of the optimal value. Since the comparator signal is applied to the flow direction. Block direction changes sign Δ X. The values of the memory block are not changed.

3. If the Y value at the current X, stored in the memory unit, is worse than received from CO, a more accurate optimum value is obtained. The comparator sends to the memory a value of the pair of X and Y. The unit stores the direction sign Δ X. The values of the memory block are changed.

At any given time, the input control signal X in ACS consists of geometric signal sum X, as a function of the input value, and the increment signal search Δ X, issued by the BN.

For the operation of S7-300 controller an algorithm of the basic program was developed (Fig. 6).

The memory unit, mounting installation in accordance to any input value of the output signal of the neural network is built on a radial basis function (RBFN).

To train the network to radial basis function a variety of methods are used:

- basic EM algorithm;
- media modifications EM algorithm;
- stochastic EM algorithm;
- classification EM algorithm and others [17].

The paper proposes to use a modification of the net-

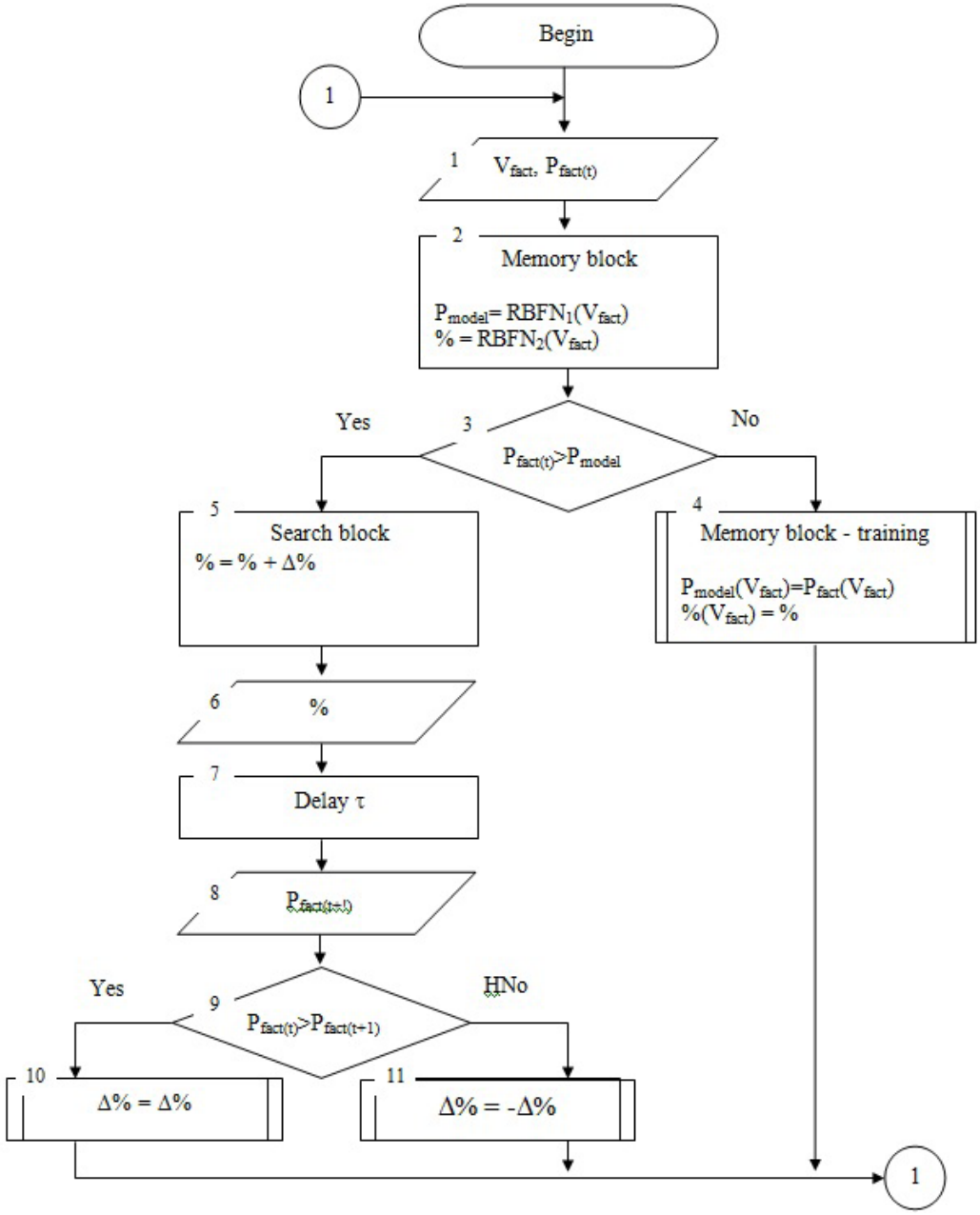

Fig. 6. The flowchart of the adaptive system.

work learning algorithm based on the gradient algorithm based on the minimization of the objective function of network errors that was proposed by Tomsk scientists VN Vichugov (Fig. 7) [18]. This algorithm allowsto use for RBFN property of plasticity and migration only in specified locations.

To implement the automatic control system a structured control language SCL was used.

Nowadays the design of the system and of security documents is continuing.

CONCLUSIONS

The article presents the results of investigation on development adaptive automatic control system of technological processes in mining and processing complex.

To be able to investigate the behavior of adaptive ACS, we developed a model of the grinding process and

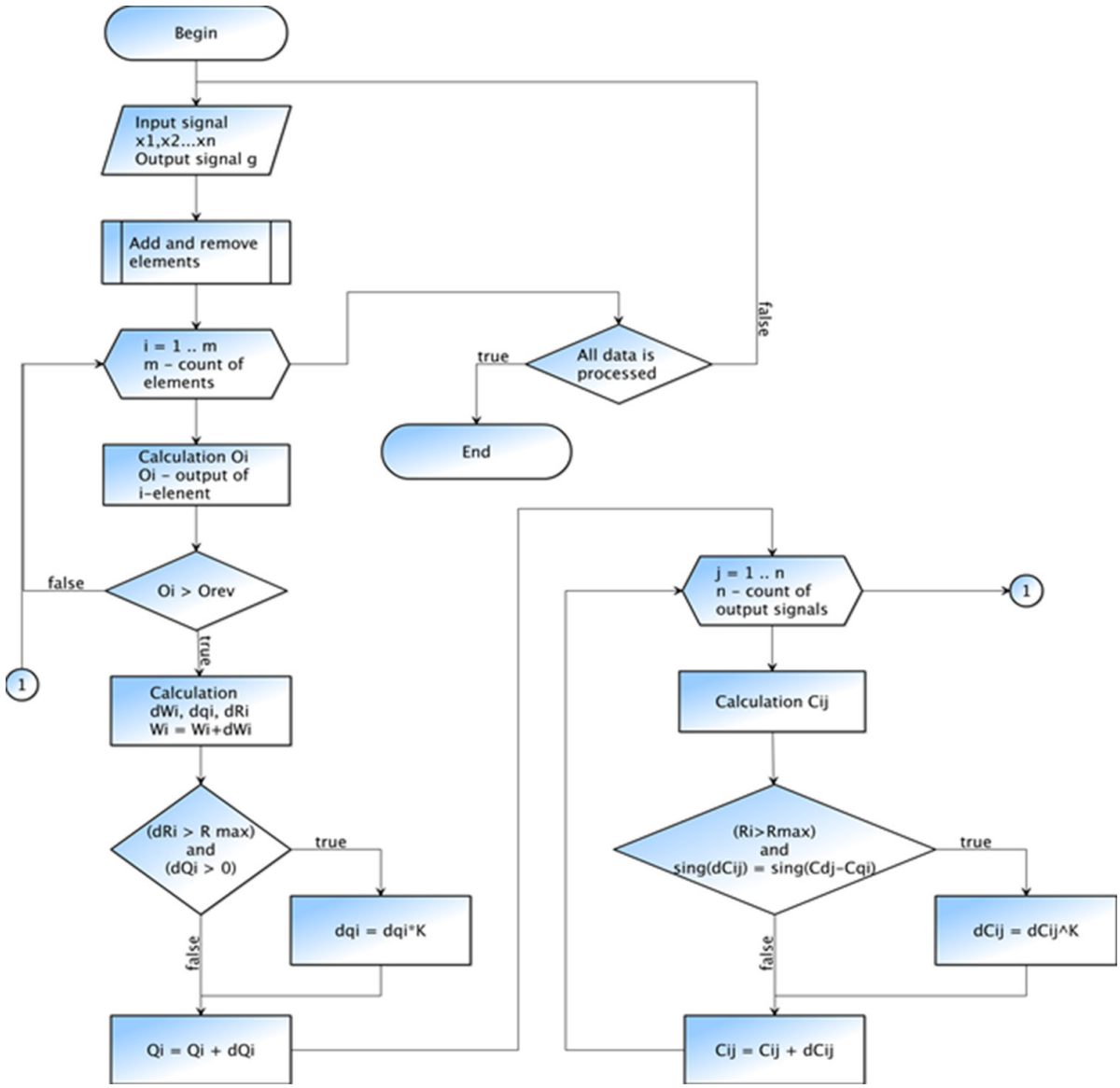

Fig. 7. Block diagram of a modified algorithm for learning network RBF, proposed by Vichugov V.N.

prove its adequacy to the real system. The error model was 5.1 %.

To construct adaptive optimized ACS a structure of the system was proposed. For its implementation in the memory block the applicability of various methods was investigated. Here was proposed to use networks of radial basis functions.

During investigation an analysis of the effectiveness of developed ACS was conducted compared to the current control circuit. Analysis of the data produced in the model experiment is performed. As a result, it is proved a reduction of energy consumption in the mills up to 15.8 kWh. This proves the effectiveness of the proposed approach for solving problems of production.

As a result of analysis of the methods of constructing control systems modern trends in the hardware implementation of control systems are found. It was revealed that approaches designed to build self-propelled ACS on specialized modules, and, paradoxically, onneural controllers currently are unpromising for industrial performance and replication. For building the system developed, at the moment the most effective is the use of modern standard industrial controllers. The controller for implementation of ACS selected is Siemens Simatic S7-300.

In developing the program code the following was made:

- detailed algorithms of the system operation;
- informed choice of control language SCL for programming the controller;
- code of the programme.

The developed system is currently going through a debugging and documentation.

Acknowledgements

The work was performed as part of the Republic of Kazakhstan state grant 0113RK00617 on "Developing self-learning adaptive automatic control system of mining and processing equipment to optimize production processes in the conditions of instability input parameters".

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