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CREATION OF AUTOMATED CONTROL SYSTEM OF ENVIRONMENTAL SAFETY OF AN INDUSTRIAL COMPLEX

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ABSTRACT

This article presents the methodological approaches to the creation of modern automated control systems of environmental safety of an industrial complex, endowed with the property of rapid response in real time on the dynamics of the current environmental situation. These systems solve the complex tasks: environmental monitoring, an adequate prediction of the development of ecological situation with the variation of external conditions; operational formation of alternative management scenarios, their objective evaluation with a selection of the most efficient (from an environmental and economic point of view).

Keywords: automated control system, ecological situation, industrial complex territory, modeling, intellectualization.

INTRODUCTION

Social-economic and science and technology growth strategy of the modern state should be based on the fundamental principles of stable development, related to ensuring the high standards of living for the country's population and environmental safety of its territory. The level of material and social wellbeing of people is considerably defined by the country's industrial complex development, though it is precisely its objects functioning (at all stages of vital cycle) that is followed by the powerful negative impact on the environment. According to the data of Federal Service for Environmental, Technological and Nuclear Supervision environmental damage amount in the polluted atmospheric air caused by the industrial discharge (tens of millions tons of pollutants accompanying them annually) reaches over 2% of the gross domestic product. Polluted environment of the industrial regions exerts the negative impact on the health of more than 60 million inhabitants of the country. Besides, the formation of the certain environmental situation depends on the total impact of different industrial and transportation objects with a glance to their interrelation.

Effective problem solving of ensuring acceptable environmental quality (for the health and vital activity of the population) under anthropogenic objects influence can be reached by creating and implementation of the modern Automated Control Systems of Environment Safety (ACS ES).

Nowadays the industrial and transportation objects possess the properties of complex dynamic organizational and technical systems; their interactions with environmental components are also characterized by complexity and high dynamics. It defines several principal demands to the opportunities of environment safety control systems of the industrial complex: the necessity of collecting and processing the large contents of diverse information; searching and formalization of complex cause-effect relationship; forming objectively estimated alternative scripts of the situation development under changing environmental conditions and implementation of different control impacts; efficient reaction to the current changes both in the industrial objects and in the environment, the necessity of taking decisions and introduction of rational management decisions adequate to these changes. The implementation of such requirements today is essentially related to the usage of automation equipment, advanced information technologies, prospective methods of mathematical and computer modelling, that is creating the Automated Control System of Environment Safety of an Industrial Complex (ACS ES IC).

In the presence of the large number of scientific-research works and practical aids, performed in the sphere of environment safety control, nowadays there is no united theoretical and methodological approach to creating ACS ES of similar class, ensuring the adaptive control with a glance to the territory peculiarities and anthropogenic objects and environmental dynamics. The main direction of research in this sphere is connected with the development and using the technical control devices, data processing and transferring, increasing the number of stations and automatic sensors, active introduction of geo information technologies, developing models and programs to get information on the behavior and spreading of chemical and physical environmental pollutions, their dispersion modelling, projection the behavior, calculating ecological risks [1-6].

At the same time, it should be noted that currently functioning themselves monitoring and control systems at different stages occurs mainly at the base of stationary models. In the automated control systems there are no information flows, ensuring control, adaptive to the current changes in the natural and anthropogenic objects and environment, as well as to the territorial peculiarities. As a result there is the decrease of the objectivity of control process and substantial delay in the introduction of control influences.

The authors suggest methodological approaches for the development and organization of functioning of

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adaptive ACS ES IC at different hierarchy levels of administrative and territorial division, which will ensure not only the automated collection and information processing, but also

- The possibility of integral objective evaluation of the present ecological situation;
- High-precision predicting of its dynamics and the opportunities of ecological risks development;
- Dynamic forming of the alternative scripts of the situation development and control.

Object of scientific research conducted by the authors is a process of control of environmental safety of the industrial complex in modern conditions ensuring timely and effective decline (if possible, liquidation), as well as prevention of negative technogenic impacts on the environment. The subject of research is the models, methods and algorithms of creating and organizing the functioning of the ACS ES IC.

RESULTS AND DISCUSSIONS

The model of ACS ES IC

Figure-1 presents the generalized model of ACS ES IC, demonstrating the basic components, implementing the system functions, and information flows, reflecting their interactions between themselves and the environment.

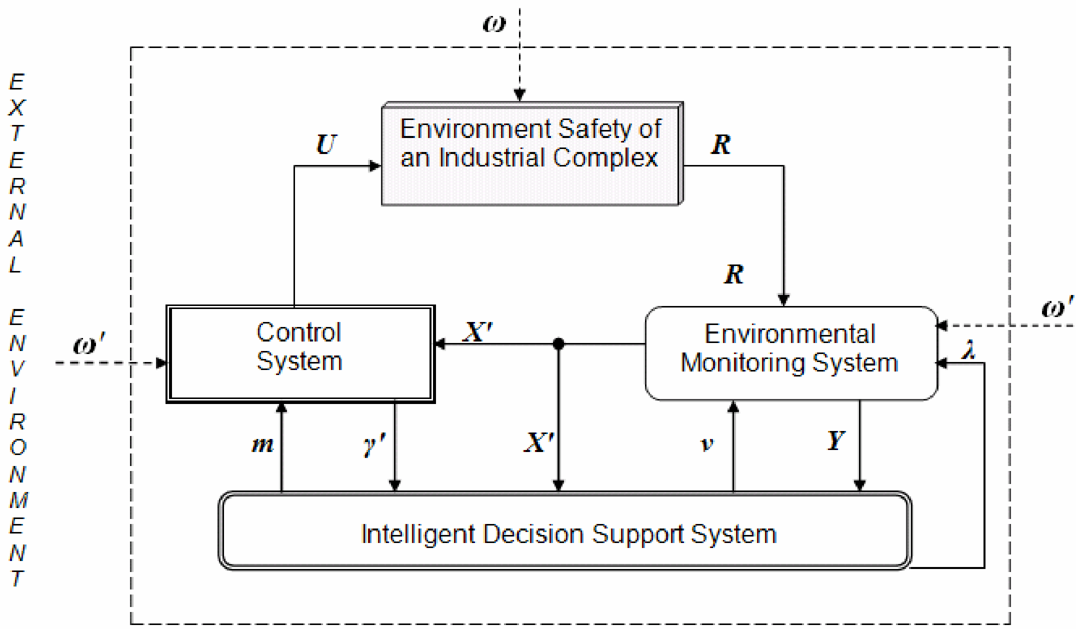

Figure-1. Generalized model of ACS ES IC.

The distinctive feature of the presented model is the introduction of inner control contours, ensuring the system's adaptivity, its self-regulation under the changing conditions of environmental and parameters of the object under control.

ACS ES IC under study consists of the following main subsystems: control object (Environment Safety of an Industrial Complex), Control System (subject of control), Environmental Monitoring System, Intelligent Decision Support System (IDSS). The scheme presents: R - the set of parameters describing the state of the control object; U - the control actions; Y - the set of measured parameters, X' - the set of evaluation results of environment safety of the territory in the monitoring system; m - the set of alternative scripts of control decisions; λ - the control signals for the regulation of controlling and measuring subsystem work in the monitoring system (the set of specially created models), v - the control signals for the subsystem making the evaluation and spatio-temporal analysis of the current state of ecological safety of the industrial complex in the monitoring system (the set of specially created models); ω, ω', ω'' - the set of environmental influence on the ACS ES IC subsystems; γ' - feedback signals (the choice results for the practical implementation of the particular control scripts).

In the inner control contours the IDSS is the subject under control; and the Monitoring System/Control System is the object of control. In case, when Control System is the object of control, the sets ω' and X' characterize the external influence on it, m presents the control signal, and γ' - the feedback signal; the IDSS realizes the mapping f: $X' \times \gamma' \rightarrow m$. In case, when control object is the Monitoring System, the sets λ and v - are the components of the control signal from the IDSS, X' and Y - are the components of the feedback signal, and the sets R

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and ω'' define the external impacts on the monitoring subsystem; the IDSS realizes the mappings: f': $Y \times X' \rightarrow v$ and f'': $Y \times X' \rightarrow \lambda$.

To ensure the effective functioning of the inner contours of control in the IDSS the dynamic forming and storing of the necessary mathematical and computer models is carried out. Most of them are related to the implementation of the cause-effect relationship between the parameters, characterizing the state of the control object components of the ACS ES under study: parameters, responsible for the conditions of the industrial complex objects and at the same time defining the level of the negative impact on the environment components; parameters, characterizing these components quality. The former, for example, include technical and technological characteristics, production volumes and services, their quality, and the second include the concentration of pollutants in different surroundings, the levels of physical impact, polluted waste water volumes, etc.

Modelling and support of expert-information system function

The model of the Intelligent Decision Support System has been built. Its structure is defined by the following functions: data processing and storage; model forming and storage; scientific prognostication of the present ecological situation; evaluation and forecasting environmental quality indexes considering the existing and supposed anthropogenic load, and managing results; integral evaluation of the safety and environmental condition of the industrial complex; parametric estimation of its objects, ensuring the demanded condition of environmental components; visualization of monitoring data and results of the imitation experiments; forming alternative control scripts; substantiation of rational instrument arrangement and spatial structure of observation network on the territory.

Figure-2 presents the scheme of the IDSS, including the following main subsystems:

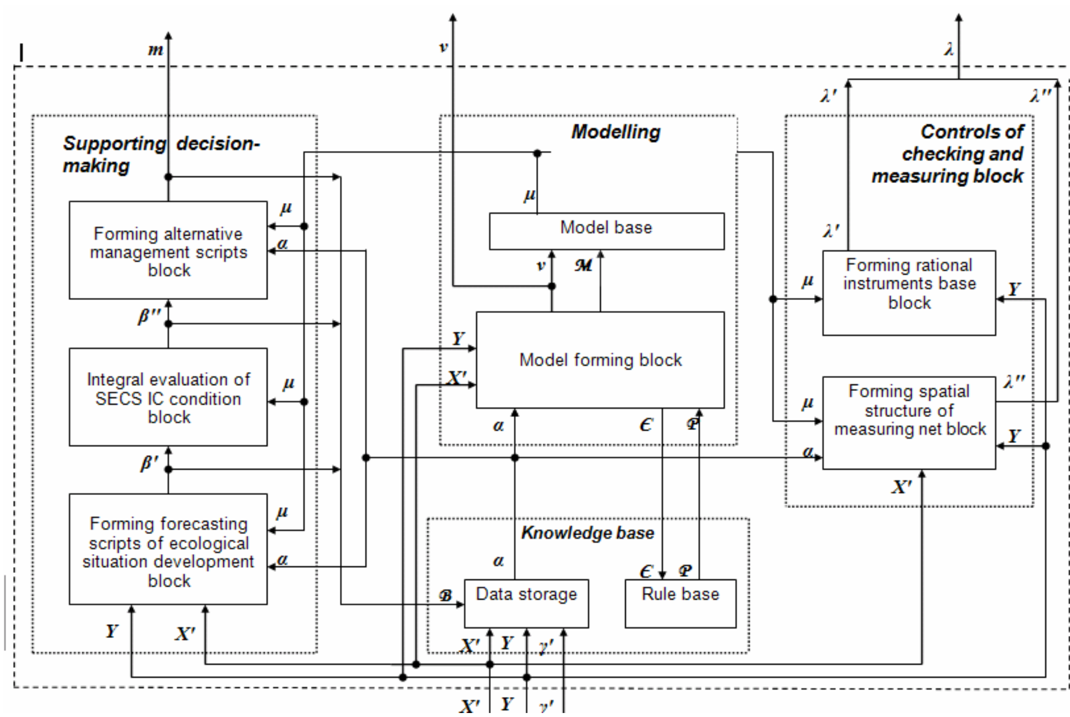

Figure-2. IDSS model.

Knowledge base, Modelling, Supporting decision-making, Controls of checking and measuring block. Knowledge base consists of *Data storage* and *Rule base.* The first includes data bases, necessary for carrying out the spatial and time analysis, modelling, imitation experiments and incoming as components α to the other system blocks.

The Rule base contains rules P, necessary for the models forming. Modelling subsystem consists of the *Models forming block* and M*odels base*. Different models are generated at the first block level, which are used both inside the system (M) itself, and in the monitoring system (v). Therein new rules ($Є$) are formulated while revealing new cause-effect relationship.

The built models go into models base; on demand of the other subsystems the set of models μ are formed, necessary for the functioning of ACS ES at the present moment of time.

The apparatus of artificial neuron nets and fuzzy logic has been chosen for the creating the necessary mathematical and computer models. The implementation effectiveness of intellectual modeling technologies in the

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sphere of environment safety control is confirmed by many researchers, for example [1-4].

Particularly, to implement the evaluation and prospecting of the atmospheric pollution during the summer and winter periods (the concentration of CO, NO_x, SO_2), the level of waste water pollution (suspended substances and oil products), the level of the noise impact on the acoustic environment, as well as to define the possible control influences the complex of Artificial Neuron Nets (ANN) has been developed. These models are necessary for the filling the sets *m* and *v* and the support of functioning of the inner control contours of ACS ES.

The definite architecture of every ANN has been defined by making and checking its adequacy and prospecting abilities of the great numbers of different ANN. The quality of obtained models was defined with the help of calculating the standard error of mean, minimized in the process of teaching ANN; determination index; average approximation error in teaching and testing selection. The series of field testing experiments has been carried out. The analysis has demonstrated the high quality of teaching and good prospecting opportunities for all created ANN:

$mse = 7{,}40 \cdot 10^{-8} \div 1{,}870 \cdot 10^{-4}$, $\overline{A}_{об.} = 0{,}005 \div 1{,}470$ %; $\overline{A}_{ïðîã.} = 0{,}310 \div 5{,}060$ %.

Environmental situation in the industrial complex territory is characterized by the combined quality of various components in the environment that have an impact on the health and livelihoods of the population. The authors use the concept of a linguistic variable (for formation of characteristics) and fuzzy logic (for the synthesis of knowledge about the state of the individual components of the environment) while constructing this model. We introduced a linguistic variable such as

$ES = \langle S, T, B, G, H \rangle$

where S is the ecological situation in the industrial complex territory, T means term variable of S, whose domain is the set of numbers in B; G means syntactic rules that generate the name of the term; H shows semantics. $T = \{T_1, T_2, T_3, T_4, T_5\}$:

- T_1 "normal" indicates the quality of all components in the environment meeting the standards in this area,
- T_2 "relatively dangerous" shows the pollution of the individual components in the environment exceeding acceptable level, but deviations from the rules are not stable (in space and time),
- T_3 "dangerous" presents contamination of the components in the environment exceeding the permissible level, but without the formation of stable environmentally hazardous locations, or only certain components of contamination exceeding acceptable level, but deviation from the norm is significant and contributes to the formation of stable ecologically hazardous area,
- T_4 "very dangerous" characterizes the quality of all components in the environment not meeting the standards, and the deviations for some of them are significant and contribute to the formation of stable, environmentally hazardous area,
- T_5 "critical " shows the pollution of all components in the environment which is much higher than the permissible level to form stable environmentally hazardous areas.

Terms T_2, T_3, T_4, T_5 are connected with a poor environmental situation. It is advisable to use a composite linguistic variable such as $ES=(S_1, S_2,\ldots, S_J)$, where S_j means «the level of air pollution", "water pollution", "waste collection", etc. and j = 1, ...J. Classification process of the environmental situation in this case is the analysis of interaction of different parts that are included in the *ES*, and the result is synthesized. For its implementation, a set of conventional rules should be made.

Software implementation of the constructed models is done on the platform of computer mathematics MATLAB. The program "Assessing and predicting the level of ecological situation in the industrial complex territory" is created for the following computer experiments: assessment and prediction of CO, NO_2, SO_2 in the atmosphere and the equivalent noise levels on the territories adjacent to the industrial complex, integrated assessment of the environmental situation, choice of effective control actions.

CONCLUSIONS

The authors suggested theoretical methodological instrument for the practical aims of ACS ES IC building for the territories of different administrative territorial division hierarchy, including the local territories, subject to the negative impact of the certain industrial objects.

Complex ecological monitoring of the definite densely populated territory has been carried out with the scientific analysis of its results. The ACS ES IS model has been developed, as well as mathematical and program complexes, for the functioning support of the inner control contours, ensuring the adaptiveness of the system under study.

Investigations carried out for the making and organizing of functioning ACS ES IC in the densely populated urban areas confirmed adequacy of models, methods, and algorithms, making the developed theoretical basis and methodology based on it. ACS ES IC and its elements adoption in the Central Federal Region of RF and different enterprises and organizations of Orel and Moscow regions demonstrated both social and economic effects.

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