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Creating a Structural-Functional Schematic of Environmental-Economic System Management Software for Oil-and-Gas Industry Enterprises

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Abstract

This paper considers the concept of environmental-economic systems in the context of oil-producing regions. A basic control circuit has been developed for environmental-economic systems of oil-and-gas industry involved in intensive technogenic alteration of natural objects; principal components of the circle have been analyzed. A goal and objectives have been formulated for optimal management of environmental-economic equilibrium. Peculiarities of environmental-economic systems have been studied with the aim of reflecting them in computer modeling aimed at development of optimal environmental protection programs to attain sustainable nature management. Multi-level computer modeling environment was used to create a structural and functional diagram of environmental-economic process management in order to facilitate its automation.

Keywords*: Environmental-economic system; Sustainable nature management; Oil industry enterprises; Environmental protection programs; Information and control system.*

1. Introduction

Here, the authors understand environmental-economic systems (EES) as "a complex of interrelated economic, technical, social and natural factors in human environment" [1], "integration of economics and nature, consisting in interrelated and interdependent functioning of production and natural processes". EESs of oil-and-gas industrial facilities, formed by an oil-and-gas producer (OGP) and natural environmental objects (NEOs) in the process facilities' vicinity, pertain to the class of systems characterized by exceptionally high responsibility of managerial decisions.

Modern OGPs shall demonstrate high responsibility in resolving the tasks of environmental friendliness and efficient use of natural resources and systematic increase of environmental industrial safety. Provision of environmental and industrial safety is a high-priority area of activities of such enterprises, on par with their main activity–development of deposits and production of natural resources. As a rule, environmental management systems are created and developed through a number of years. They are effective in all business and support units and bring together effort of environmental scientists, lab specialists and employees of various branches aimed at prevention and elimination of accidents and mitigation of their consequences. The scale of activities of such enterprises is vast, so there are large numbers of monitoring points and multiple observed environmental and economic indicators in territorial information systems.

In order to regulate operations of managerial bodies and minimize costs of environmental programs–sets of environmental protection measures, in this project they are based on MARS modeling environment [2]–there is a system of management for environmental and economic systems of oil-and-gas industry enterprises. It shall allow for automation of studying the dynamics of environmental characteristics when they are influenced by operating facility, or by facilities involved in environmental protection measures (EPM) under environmental protection

programs. So, its activities are directed towards an automated synthesis of economically effective environmental protection programs with considerations for available technical means and qualification of personnel.

2. Basic control circuit of environmental economic systems of oil-and-gas industry enterprises

Basic control circuit of environmental economic systems of oil-and-gas industry enterprises (Fig. 1) includes four types of components: 1) control; 2) oil-and-gas producer (OGP); 3) environmental system; 4) external environment.
Limits of the system are defined by territory of the enterprise' activities

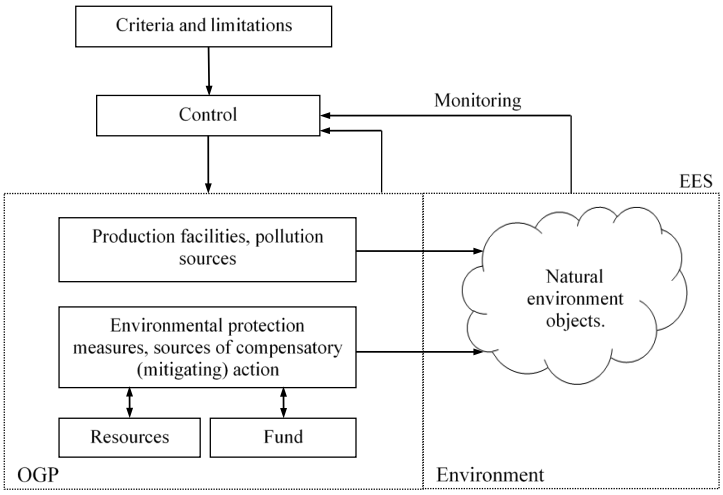

Fig. 1. Basic control circuit of environmental economic system

Description of EES control circuit:
1. Monitoring of production facilities and natural environment objects (NEO) is implemented at production fields, in accordance with legislative regulations of the Russian Federation [3-4];
2. The monitoring results are used to evaluate pollution of NEOs (soils, ground waters, air, water bodies);

A. Reduction of NEO pollution to maximum permissible values is attained by means of environmental protection measures, which may be performed simultaneously or sequentially within the framework of an environmental protection program (EPP);
B. EPP execution consumes material resources, uses technical means and spends enterprise's finances. Consumption of resources and funding of a program depend on the level of environment pollution.
C. EPP is planned in accordance with applicable standards, regulations and guidelines. It is a foundational document for management of environment protection activities of an OGP. Environmental protection program is a set of environmental protection measures, e.g., processes aimed at reducing negative effect that production exerts onto components of the natural environment. At the planning stage, the following optimal parameters shall be defined for each EPM:

- parameters and consumption rates of resources, in units/hour;
- costs of EPM, in rubles;
- effectiveness of the measure, in components of the environment;
- prevented environmental damage, in thousand rubles;
- duration of implementation.

Generalized criterion for optimality of EPM implementation: Compensatory effect of an EPM shall provide reduction in pollution of a NEO to maximum permissible value with minimal consumption of resources (material, technical, etc.) and funds (financial resources).

EES control objective is sustainable development of the enterprise' territory. Sustainable development of a territory assumes attaining economical growth while preserving (or recovering) environmental balance [4]. Environmental economic balance is understood as regulation of social production structure, its rate of development and natural potential utilization capacity with the aim of providing expanded reproduction and preservation of the environment [5].

Objective of territorial management authorities is selection of such conditions for enterprise activities (regulatory framework, fines, privileges) that encourage the latter to selecting activities the results of which are the most advantageous for the management authorities.

Priority objective of management at enterprise level consists in provision of environmental and industrial safety during deposit development and production of natural resources [6-9]. The objective consists in selection of such environmental protection programs that provide monitoring (collection, evaluation and transmission of data) and consistent improvement of environmental and economical characteristics of economic activity of the enterprise in accordance with the legislative and regulatory requirements. Under modern market conditions, the winner is the one with more efficient production, lower costs of not only raw materials and equipment, but of prevention and mitigation of environmental consequences of the production as well [5]. Innovation-aware management is one of the most important factors of sustainable development.

3. Specifics and objectives of modeling environmental economic systems for sustainable environmental management

Specifics of EES management in OGP is that:

1. Results of activities of managed subjects have several aspects (there are at least two levels, economic and environmental) [10].
2. Presence of identified management environments, contribution from components from various subsystems (humans, machines, natural environment, investment) [11], presence of multi-component vector streams in links (material, informational, financial, organizational, technical. etc.) [12] and relations with external environment characterize EES as a large system.
3. EES management is based on analysis of vast arrays of information obtained through monitoring of managed facilities and their natural environment. Validity of the information, promptness and timeliness of its processing and analysis influence management and decision-making efficiency [13-14].
4. Currently, the main factor of sustainable development is investment [15-16].
5. Systems pertaining to the same class as EES cannot protect their interests, their reaction is characterized with inertness and happens with delay [17].
6. Environmental economic systems have a "high degree of openness, reflected, in particular in a large number of linear control inputs". For example, "investment, treatment of industrial effluents, forest plantation, innovation, training, healthcare" [18].
7. Interests of various managing bodies may conflict not only with the interests of the enterprise, but also with each other.
8. Expenses on environmental monitoring, including collection, evaluation and transmission of information are reduced by introduction of automated information systems [19-20].
9. Regulatory framework imposes significant constraints on activities [3-4]
10. Responsibility in management and decision-making in this class of systems is immense, while true-life experiment is impossible in a number of cases due to serious consequences for territories and their inhabitants.

EES management supposes targeted management of the system structure and parameters of industrial and environmental processes, rates and volumes of consumption of natural and technical-economic potential with the aim of preserving (or recovering) environmental balance of the territories with considerations for external inputs.

NEO, which together with OGP facilities form an ESS of the oil-and-gas-producing territory, in any given moment may be in one of the following states:

a) stationary (background, initial) state;
b) stationary state with process-related deviations;
c) emergency state with process-related deviations;
d) stationary state with environmental deviations;
e) emergency state with environmental deviations;
f) combined state with deviations and emergencies in process equipment and natural environment;

Pollution of natural environment is determined by introduction or appearance of new, previously untypical streams of physical, chemical or biological agents, or exceeding the natural long-run annual average concentration of the same reagents during the period in question. Pollution is divided into several types:

– natural pollution caused by natural causes;
– anthropogenic pollution caused by human activity.

External factors may cause deviations of EES from a normal stationary state.

Control inputs, applied onto EES with the aim of improving or preserving its state shall correct operation of the system with consideration for various factors and in accordance with set criteria and limitations, compensating them, preventing their action or mitigating environmental risks.

Tasks performed during EES management may be classified in the following way:

1. Collection and storage of EES monitoring results is observation of dynamics of environmental indicators of regional NEOs while attempting to predict behavior of the environmental system. Taking into account the diversity of indicators of the environmental state of the region, the most significant indicators shall be selected for monitoring; among them are values of pollutant concentration on the surface and in the soils, population of the most valuable species of plants per unit area, animal populations, human population within the territory and other factors. Currently, geoinformation systems (GIS) are used to automate tasks of environmental monitoring; they are connected to enterprise data bases that perform the function of collection, storage and processing of information on environmental state in the territory of the enterprise.
2. Assessment of pre-emergency and emergency situations of organizational and process environment with capabilities for modeling consequences for EES territory with considerations for social factors allows automating planning and virtual evaluation of measures aimed at prevention and mitigation of process deviations and emergency situations.
3. Prognosis of situation development for pollution of NEOs under the influence of constant and temporary polluting factors is performed at the enterprise in a manual mode, basing on experience of specialists in analysis and prediction of regional environmental state. Currently, various mathematical and simulation models as well as several analytic methods are being developed in order to automate this task. Its partial automation is attained by means of various systems of automated calculation and simulation modeling. However, they are not capable of automatic interaction with GIS and databases storing historical and current information on NEOs of the territory. This factor impedes or prevents prediction of situational development in environment pollution, as use of incomplete set of parameters and factors makes the model inadequate to the real situation.
4. Modeling of possible pre-emergency and emergency situations on OGP allows assessing possible environmental consequences for the territory and its population, as well as planning preemptive measures aimed at prevention of such situations. To that end, developed mathematical and simulation models of EES are supplemented with models of various factors in the form of additional terms of existing equations or new equations that allow modeling various deviations of environmental development characteristics of the territory caused by adverse effects. Modeling of pre-emergency and emergency situations often requires global reworking of the EES model in question due to its analytic transformation,

calculation of new parameter values and coefficients, as well as analysis of the mathematical model on a certain time interval. Synthesis of economically optimal environmental protection programs providing sustainable development of the territory is usually performed at the enterprise in manual mode, as a result of implementing environmental protection measures aimed at improvement of characteristics of environmental state of the oil-and-gas production region, as well as taking into consideration existing organizational, technical and financial resources. Composition of an environmental protection program shall take into account many environmental, economic and technical factors and characteristics.

5. The task of planning an enterprise-level environment protection investment strategy with considerations for influencing factors may be analyzed as a task of simulation modeling of the enterprise's financial streams, part of which may be invested into environmental protection activities. In practice, this task is divided into a number of subtasks, each of them subsequently taken by different services. For example, budgeting of the enterprise and allocation of financial resources to implementation of an EPP is done by economic planning departments, while formation of EPPs from provided means is performed by environmental services of the enterprise. Inefficiency of such functional division often results in EPPs produced in such way either not allowing for attaining necessary environmental indicators employing the resources available to the enterprise, or the EPPs are economically inviable. Use of EES computer modeling will make it possible to justify investment in EPPs and determine optimal values of such investments.

4. Synthesis of a structural-functional scheme of environmental-economical process control system for oil-and-gas industry enterprises

A structural-functional scheme of environmental-economical process control system for oil-and-gas industry enterprises has been suggested and developed (Fig. 2).

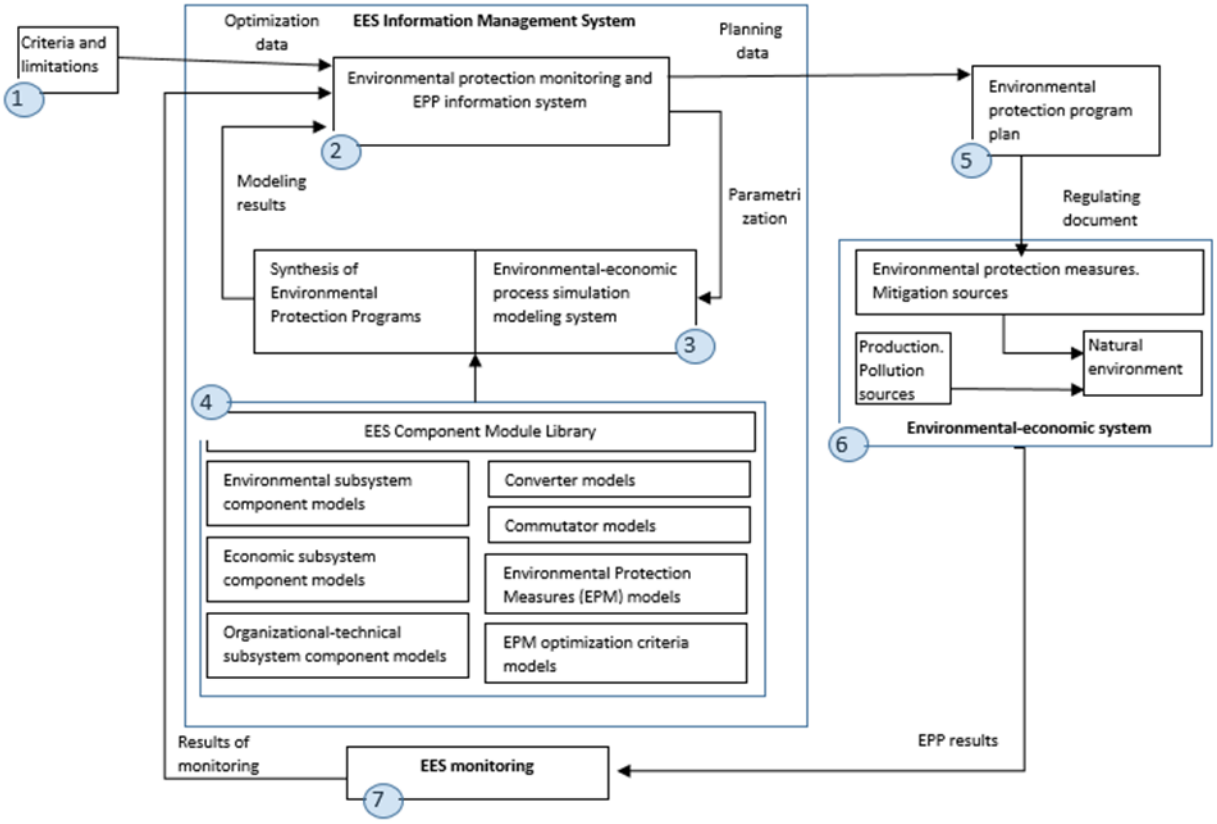

Fig. 2. Structural-functional scheme of environmental-economical process control system for oil-and-gas industry enterprises

In the Figure 2, block 1 characterized the processes of setting criteria and limitations on EES state, which are used in solving the problems in optimization of environmental protection measures parameter. Block *2* is a software for collection and automated processing of data concerning environmental monitoring and programs of environmental protection measures, a means for dynamic formation of summary analytic reports, while block *3* represents a tool for modeling of environmental-economical processes and systems, synthesis of EPPs. Modeling results are transmitted to information subsystem. block *4* contains geometric and functional models of components, supporting processes of formation and solution of simulation models of the environmental economic system.

The set of components forms an EES component library, including components of environmental, economic, organization-technical subsystems, components for integration of models from various subsystems into a common EES (Converters), components for EPP synthesis (Commutators), models of environmental protection measure optimization criteria. Block *5* represents a plan of environmental protection program composed on the basis of modeling results and optimization of parameters of environmental protection measures. Block *6* – is a real-live EES, which represents a set of interrelated production facilities and natural environment, functioning on the basis of environmental program, aimed at preservation or recovery of environmental-economical balance. Block 7 is a system of environmental-economical metrology. From results of monitoring, the states of NEOs and production facilities are evaluated, as are efficiency of environmental protection measures with subsequent correction of the environmental protection program. Monitoring results are transmitted to information subsystem. At this stage, control circuit of environmental-economical processes and system is closed.

5. Conclusion

Step-by-step implementation of the scheme presented in Fig. 2 will allow organizing and maintaining an automated information system for management of environmental-economic processes at oil-and-gas industry enterprises, cutting time and production expenses for formation of environmental protection programs aimed at sustainable development of oil-and-gas producing regions.

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