Modeling information flows of the process of drilling wells and developing hydrocarbon deposits on the shelf

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Abstract. The article discusses the issues of modeling business processes and information flows of the process of drilling wells and developing hydrocarbon deposits on the shelf. It is shown that the IDEF0 notation is the most convenient for describing the tasks of the upper level of control and building a complex information model of the object under study. The resulting models make it possible not only to determine the functional interaction of individual independent technological problems, but also to justify the choice of methods and tools for their solution. This is of particular importance in the system of professional development of specialists. Information systems such as WellView (Peloton Company) or GeoView (TyumenNIIgiprogaz) are considered as examples.

1. Introduction
The last decades have been characterized by a significant increase in the volume of prospecting and exploration work on the continental shelf. In the Arctic and Far Eastern seas of the Russian Federation, oil and gas companies have drilled more than three dozen wells, a number of promising oil and gas fields have been discovered. Including an exploratory well at the Shtokman gas condensate field (GCF) in the Barents Sea, Kharasavey-Sea in the Kara Sea, etc. Large oil fields have been discovered in the Pechora Sea: Dolginskoye, Varandey-sea, Medynskoye-sea; gas: Sever-Kamennomysskoe, Kamennomysskoe-sea in the Ob Bay of the Kara Sea; the unique oil and gas condensate field Yuzhno-Kirinskoye on the shelf of Sakhalin Island. As a result of drilling, a large amount of valuable geological information was obtained. Collection, storage and processing of available geological and geophysical information in a limited amount is of particular importance when choosing the direction of geological exploration, identifying promising structures, assessing hydrocarbon reserves, etc.

Improving the quality of geological exploration work is possible due to the wider use of information and analytical systems for integrated data processing. Existing systems, such as WellView (Peloton) or GeoView (TyumenNIIgiprogaz), implement, first of all, an accounting function and allow storing and processing systematized geological and geophysical data of the drilling process and well data (Fig. 1, 2).

The presence of a large array of geological and geophysical data allows you to solve a fairly wide range of professional problems of managing wells and oil and gas fields (Fig. 3, 4). This fully applies both to the design and construction of new prospecting and exploration wells and to operating facilities at the stage of commercial operation. Special attention should be paid to the tasks of constructing geological models that take into account filtration processes [7, 8, 9, 10].
The presence of a large array of geological and geophysical data allows solving a fairly wide range of professional problems in managing wells and oil and gas fields:

- Preparation of a work plan
- Schedule creation
- Transfer of the plan to the rig
- Registration and reporting as work progresses
- Synchronization of "field" data with office
- Analysis of work efficiency
- Creation of documentation
- Analysis of data for similar wells and types of work

One of the most popular and significant tools for increasing the efficiency of exploration work is the implementation of a quality management system (QMS), which is a complex, multifactorial task with many restrictions and built on the principles of a systematic and process approach to management, decision-making based on facts, connectivity and synergy. In the conditions of a modern oil and gas enterprise, such a task is realized only on the basis of corporate information systems, including a module of advanced business intelligence. Priority tasks for geological exploration include:

- Assessment of filtration and storage properties and the nature of saturation of reservoirs of oil and gas fields;
- Calculation of hydrodynamic parameters of productive hydrocarbon (HC) deposits and fields in general;
- Assessment of maximum drawdowns during the secondary opening of hydrocarbon deposits.

The effective construction of prospecting and exploration wells and the solution of the priority tasks of geological exploration are largely determined by the methods and means of planning and managing the technical, technological and organizational resources of this project. The quality of the decisions made at each stage of the project implementation to a certain extent depends on the adequacy of the information model of the object (process) and the ability to objectively assess the quality of control actions.

It is possible to study the architecture of the control object, study the features of its functioning, highlight the "problem" areas and optimize them, relying on various notations for modeling business processes that underlie the construction of modern information-analytical and control systems: IDEF0, eEPC, DFD, BPMN, UML. To build models of business processes, the following tools are most often used: AllFusion Process Modeler (BPWin) [1], Business Studio (STU Group of Companies) [2], Aris [3]. As practice shows, for building models of top-level business processes, preference is given to the IDEF0 notation.

Omitting the construction of a conceptual diagram, the process of construction of an exploration well can be represented as a combination of the following main stages: deepening a well, performing coring operations, performing a well logging complex, casing a wellbore and some other types of
work. The dominant stage of construction is deepening of the well, since it is this that determines the condition for performing the remaining stages due to its primacy when constructing a well (Fig. 3) [4].

![Figure 3. Decomposition of the module "Perform well deepening".](image)

From the point of view of the business process "Deepen the well" it means "Carry out the destruction of the rock" and "Flush the well" in order to release its bottom. Both processes occur (are performed) simultaneously, because only in this case it is possible to perform productively the function "Construction of a well". This is also indicated by the corresponding connections in the diagram: the output of the block "Carry out rock destruction" - "cuttings" is simultaneously the input of the block "Flush the well", while the output of the latter - "free bottomhole" - is the input arrow (arc) block "Carry out the destruction of rocks." From the point of view of the SADT methodology, the function “Carry out rock destruction” is controlled by changing the technological parameters: bit type, changing the axial load on the bit and its rotation frequency. This takes into account the physical and mechanical properties of the rock, which in this case act as restrictions, i.e. regulations for the implementation of these control actions. Control of the "Flush the well" process is ensured by changing the flushing mode parameters and flushing fluid parameters, which affects its specific gravity and binding properties.

The combination of the last two functional models (Fig. 4) reflects the physical essence of the technological process of deepening the well (destruction of rocks and flushing the well) and allows to justify the structure of the mathematical model of this physical phenomenon due to the fact that the structural functional model of this level of decomposition reflects the relationship between physical parameters of both components.

![Figure 4. Combined decomposition of the "Deepen wells" module.](image)
A complex mathematical model of the well deepening process, consisting of three independent but interrelated processes, can be represented as a system of nonlinear equations, for example, [5, 6]:

- mathematical model of rock destruction

$$v_0 = k \omega^a G^\beta$$ - initial ROP, where \(a, n, k, \alpha, \beta\) - adaptation empirical coefficients;

- mathematical model of the well flushing process

$$P = f(L, F_{Kin}, \gamma, Q, \lambda);$$

$$\gamma = f(\tau, \eta);$$

$$U = f(G, G_0, n, \gamma_{Kin}, \gamma, D, dc, dn);$$

The presence of such models makes it possible to check models of business processes in an environment, for example, AllFusion Data Model Validator (Erwin Examiner), and to study mathematical models using software and hardware methods (MathLab, MatCAD, Maple, Delphi, C #, VB) or simulation (Simulink, GPSS, AnyLogic) modeling.

Formalization of the business process allows you to move from a modeled system through the study of its functional model to the creation of information and control systems. Formalized presentation of design (for new wells) and production (technological, operational) tasks of geological exploration contributes to a better understanding of the peculiarities of the system's functioning, including in the process of obtaining special (specialized) technical education and advanced training of specialists in the oil and gas industry.

An example of a scheme for attracting information and analytical systems and industry (Oil and Gaz, electronic field) solutions of SAP to retraining specialists for the oil and gas industry within the framework of the SAP University Alliance and the Russian State University of Oil and Gas named after I.M. Gubkin is shown in Fig. 5.

![Figure 5. Scheme of interaction between SAP and the Russian State University of Oil and Gas named after I.M. Gubkin.](image)

Using similar approaches and methodologies, such technological problems as the choice of the best type of bit (equipment) were formulated and solved; optimization of drilling modes (load on the bit and its rotation speed) under approximately the same drilling conditions in the area for newly constructed wells; operational control of the drilling mode based on adaptive models and algorithms.
2. References

[1] Dubeykovsky V.I. Practicing functional modeling with AllFusion Process Modeler 4.1. Where? What for? How? - M.: DIALOG, 2004. - 464 p.

[2] Maklakov S.V. Creation of information systems with AllFusion Modeling Suite. - M.: DIALOG, 2003. - 432 p.

[3] Kamennova M., Gromov A., Feraontov M., Shmatalyuk A. Business Modeling. ARIS methodology. M.: Publishing house "Silver threads", 2001. - 327 p.

[4] Sidorov V.V. Formalized display of the process of construction of prospecting and exploration wells at sea in the form of a structural functional model // Construction of oil and gas wells on land and at sea, No. 9, 2006. - M.: VNIIIOENG, p. 31-35.

[5] Leonov E.G. A new model for optimizing rotary drilling modes. Choosing the best bit type // Construction of oil and gas wells onshore and offshore, No. 5, 2005.

[6] Leonov E.N., Isakiev V.I. Hydroaero-mechanics in drilling. - M.: Nedra, 1987. - 304 p.

[7] Yankova N., Kadochnikova L. Geological modeling with filtration processes. Oil & Gas Journal, Russia, No. 8 [118] 2017, p.28-34.

[8] At the interface of disciplines. An interview with Andrey Bochkov, Deputy General Director for Exploration and Development of the Resource Base at the Gazpromneft STC. Oil & Gas journal, Russia, No. 8 [118] 2017, p.36-42.

[9] Zubkov S.A. Information and technological support for shelf development. Business magazine Neftegaz.ru, No. 1 [85] 2019. p. 28-34.

[10] Krivosheya K.V., Lygin I.V., Sokolova T.B., Shirokova T.P. Solving problems of oil and gas geology. Possibilities of modern gravity and magnetic prospecting. Business magazine Neftegaz.ru, No. 1 [85] 2019. p. 66-72.