Evaluation of the effectiveness of innovative solutions in the construction of oil and gas wells

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Abstract. This article contains an assessment of the effectiveness of innovative solutions in the construction of oil and gas wells. Despite the fact that the oil and gas industry is not knowledge-intensive, quite conservative in the implementation of innovations and gives a large share to the federal budget, it is designed to increase competitiveness and ensure sustainable development of the country's economy. The introduction of innovative solutions is designed to increase the company's revenues, reduce the cost of production, reduce operating costs, and increase the company's competitiveness and image. They help to maintain existing market positions and conquer new market segments. Among the most promising technologies that are actively used in the construction of oil and gas wells, a special place is occupied by the use of "digital twins", which are modern digital models of objects. Such a model most accurately reflects the real condition and performance of its physical prototype. No matter how precise, detailed and elaborate the actions will be at the design, modeling and production preparation stages, during operation, as a rule, the processes proceed a little differently, and the digital twin is able to be the main access tool to the necessary information about the actual operation of the facility.

1. Introduction

The Our country has world's leading storage of hydrocarbon reserves. Its share is almost 32% of the world's gas reserves (first place) [1] and more than 10% of the world's proven natural oil reserves, which is 7th in the world (reserves that, according to geological, technical and economic indicators, can be extracted from the subsoil). [2]

Despite such significant reserves, we note the difference in two main indicators. These are the seventh place in terms of the amount of natural oil reserves (in the first places are Venezuela, Saudi Arabia and Canada) and the second place in terms of oil production among the producing countries in the world economy, such as the USA, Saudi Arabia and Iraq. In the future, the current trend and its continuation will lead to a decrease in natural resources. In the short term, this will most likely lead to the impossibility of keeping production figures at the current level. However, due to the fact that the oil and gas industry occupies a dominant position in the Russian economy (the share of oil and gas revenues was slightly less than 41% in the total revenues of the federal budget [3]), the importance of oil and gas companies is very great for the country's development.
According to [4], one of the most significant long-term goals of our country is to increase the share of the innovative component in economic growth in order to minimize emerging risks in an unstable economy and gain advantages over other countries.

This strategy of our country poses such serious tasks as:
- economic growth;
- expanding and increasing positions in the world markets of advanced high technologies;
- activity growth of Russian companies in the innovation field.

At the moment, the Russian oil and gas complex considers one of the most important tasks not only to introduce innovations, but also to find the necessary capital and management sources, to ensure payback in the future and to have test sites for the implementation of various innovative solutions. Under the influence of a combination of internal and external factors, oil and gas enterprises have the problem of an increasingly unstable situation in the field of production and sale in the processing sector. The indicated problems can be solved to a greater extent by the emergence of innovative technological tools. At the same time, due to the importance of the formulated tasks, we are talking about an innovation "boom" through the rapid overcoming of missed opportunities, which can enhance the economic development of the country.

At the same time, we note that contradictions are being formed in the oil and gas industry. The value of the oil produced is rising, and easily accessible reserves are being depleted. At the same time, the search for new deposits and oil production require a large amount of resources. Therefore, the task of scientific and technological development of the oil and gas industry is paramount. Its main directions of development are presented in table 1.

Table 1. Problems of industry development and ways to solve them.

| Decision | Method | Investments |
|----------|--------|-------------|
| Growth in the number of hard-to-recover reserves | - horizontal drilling along the stratum profile; - hydrodynamic methods of impact on the enclosing rocks (hydraulic fracturing); - mechanical methods of fluid displacement with displacement (injection of water, carbon dioxide, etc.); - thermal effects on fluid properties (injection of superheated water, hot gases, etc.); - physicochemical effects on fluid properties (injection of aqueous solutions, including those with surfactants and polymers). | - this requires serious investments in the purchase of materials and equipment that are necessary to implement the technology |
| Working with outdated technologies using outdated equipment | - technical re-equipment of the oil and gas sector - R&D | - it takes a lot of time and investment in research and development |
| High cost of oil recovery | - reducing the cost of well construction with existing technologies and equipment through the introduction of digital technologies | - it requires little investment; - implementation is fast enough |
Analysis of the table shows that solving the main problems in the industry requires the introduction of innovative technologies and equipment upgrades, which will entail significant investments and take time.

At the same time, increasing the efficiency of the development of already operating fields with the help of innovative solutions will reduce costs without significant investment. Almost always, this is more economically feasible than the development of new fields with difficult production conditions that require huge investments, a lot of time and heavy calculations with special equipment. According to experts [5], drilling and field development account for about 70% of all costs of oil and gas production. In turn, the operating fields already have an established infrastructure and require less investment. The funds saved from the implementation of digital solutions can be used to implement a solution to the problem associated with the extraction of hard-to-extract resources, as well as the problem associated with the outdated technical equipment of the industry.

Thus, the global economic situation in the oil market, low prices for hydrocarbons and an increase in the cost of oil extraction make companies look for new opportunities to reduce capital investments in the implementation of oil and gas projects. Well construction ranges from 40% to 98% of all project costs. In such conditions, it is necessary to introduce innovative solutions that would significantly reduce costs in this area.

To improve the efficiency of the development of existing fields, oil companies are starting to implement projects of "digital twins" [15].

A digital twin is a virtual copy of real objects that reflects all technological processes and the operation of mechanisms. [6] The digital twin provides a wide range of opportunities for analyzing the current state of the facility, planning events and maintenance, finding potential problems and their solutions.

2. Methods
Creation of a digital model of the process of construction of oil and gas wells allows oil companies to construct wells more efficiently by analyzing data obtained using a digital model of the process.

Many digital twins can be divided into 3 categories presented in Table 2.

| Form            | Name                        | Abbreviation | Entity                                                                 |
|-----------------|-----------------------------|--------------|------------------------------------------------------------------------|
| Prototype       | Digital Twin Prototype, DTP | A virtual analogue of a real physical object. It contains all product data, information about the design and production stages, for example, product requirements, a three-dimensional model of an object, a description of technological processes, disposal conditions, etc. |
| Aggregated twin | Digital Twin Aggregate, DTA | A system that integrates all digital twins and their real prototypes and allows to collect the data and exchange in real time. |
| Instance        | Digital Twin Instance, DTI  | Data that describes a physical object. For example, an annotated 3D model, information about materials and components of a product, information about work processes, test results, records of repairs performed, operational data from sensors, monitoring parameters. |

Thus, the digital twin can be viewed as a virtual prototype of a real object or process, which contains all the data about it, history and information about the current state. Interactive analysis of this data using Big Data technologies allows you to effectively perform the following important management functions:
- to get accurate information about system performance;
- to predict future states using predictive analytics ML models;
- remote control of the object in real time. [7]

This work contains an attempt to assess the effectiveness of an innovative project aimed at creating and working with a digital twin instance of an oil well (Digital Twin Instance, DTI), which contains data on the description of a physical object.

Most often, such models contain an annotated three-dimensional model, materials data that is used in the past and present, components, information about the processes performed in all time periods, test results, records of repairs performed, operational data obtained from sensors and monitoring parameters.

The digitalization of the well construction process is carried out using sensors that record all technological and technical processes in time. The information from these sensors enters a single system for receiving, storing and transmitting data. Thus, the company receives a digital twin, which can be further analyzed for each component of the process that takes place on the rig. A deeper analysis of the modes and consequences of failures, which contains statistical methods of data processing, is done on the basis of the created digital instance model.

The digital model makes it possible to process information in order to obtain clear engineering and management decisions that can significantly reduce costs.

The operation of the field forces the company to build several standard wells, step by step noting patterns and flaws in the construction process. In the future, the noted "bottlenecks" of the process expand and the enterprise receives a comprehensive system of improving measures for the construction of a typical well, the construction time of which will be the shortest even with the use of the existing technical equipment (Fig. 1).

![Figure 1. Decision tree based on a digital model.](image)

As you know, well construction, like any complex technological process, is divided into several technological stages. At the same time, the digital model allows comparing these stages and the adopted improvements from well to well. The best solutions that gave each stage a minimum implementation time are recorded and implemented at all subsequent wells. Thus, the company receives a process that does not have many costs.

A well that is constructed in this way will be called a "medium well". Then the model of the already changed process goes through several more cycles of analysis. This allows the company to develop and adopt such management and technological decisions that will first significantly reduce non-productive time
(thus it will be possible to achieve the "best composite well") and then completely eliminate it. As a result, the enterprise will be able to reach the most "practically achievable" well (Fig. 2).

The construction of a “almost achievable” well will take the least amount of time. However, this does not mean that the analysis of the digital model can be completed and satisfied with the results. The next stage of optimization is the introduction of innovations. At this stage, the digital model will be especially useful, because it will accumulate a large amount of useful information, which will be very important to use for testing various innovative equipment, technology or materials. After implementing an innovative solution, the enterprise will be able to improve the process to the extent of the shortest time (Fig. 2). Thus, an oil company that has built only one well during a month will be able to build from 1.5 to 2 wells during the same period. This will accelerate the achievement of the goal of increasing and reducing the cost of oil or gas production.

Figure 2. Stages of well construction optimization.

Considering that for the successful application of the digital model, it is necessary to digitize and analyze many wells similar in technique, geology and technology, it can be concluded that this innovative solution will be especially useful for operating fields that have the construction of a large number of typical production wells [14].

The creation of a digital model that allows the company to make such significant positive changes in the well construction process has the following scheme.

The process begins with the recording of technologically important drilling parameters using measuring sensors mounted on the rig. Then the information from the sensors enters a single unit for storing and transmitting information. At the moment, to create a digital model from a technical point of view, enterprises use measuring complexes, for example, "IVE-50", which is widely known for its reliability and accuracy. They are designed to measure, register, visualize and remotely transmit the parameters of technological operations during geological exploration, all types of drilling operations, repairing wells in the oil and gas industry, provide secure storage of the collected data and are used as a part of complex solutions for remote control of the work process. The central module of the measuring complex performs the functions of controlling the process of measurement, registration, indication, secure data storage, as well as communication between the components of the measuring complex and the upper-level software. It is used for all types of drilling operations. It provides the ability to integrate with the rig’s ICS. Figure 3 shows a way to interact with it.
After the information enters into a single unit for receiving and transmitting, the information is encoded and visualized in a special program for analytics. Its interface displays the change in the parameters of the well construction process over time. Operators then process this information. They mark typical stages of the process and record when a particular operation exceeds the norms of performance. Then managers and engineers analyze the model and look for technical, technological and organizational errors. The product of this analysis is charts and reports that explain the reasons why the time limits are exceeded (total time saved for the wells) and provide recommendations for their elimination [13].

However, companies' ambition to reduce costs forces them to develop innovative solutions that can eliminate “unnecessary” costs. The costs of this process are the leasing of the measuring complex and the salary of the personnel who service it.

**Figure 3.** Diagram of the digital model of the process (option 1).
It should be noted that measuring well construction parameters is a key stage in creating a digital model and cannot be avoided. Drilling rigs are initially equipped with all the necessary measuring equipment, respectively, it is necessary to develop software that performs the functions of the used measuring complex. This will require development costs, but will avoid unnecessary costs in the future. Further, the saved funds can be used to create an automated information processing and analytics system. Successful creation of such a system will make it possible to reduce costs at the stages of information processing by the operator and analysis of information by the contractor's engineering group (Fig. 4).

**Figure 4.** Proposed scheme for creating a digital model (option 2).

3. Results
If the proposed scheme for creating a digital model is implemented, the fixed and variable project costs will change, which is reflected in Figures 5 and 6. The introduction of innovative solutions for the construction of oil and gas wells can reduce fixed costs for the project by 40% and variable costs by 130%.
Evaluation of the efficiency of investments aimed at the development of software that can replace the leasing of the measuring complex was done according to the standard method [8], taking into account the industry characteristics [9]. The first stage structured and determined the main costs of implementing the technology, then calculations were made to assess the effectiveness of the costs incurred. During the study, the following results were obtained.

### Table 3. Cost-effectiveness of implementing an innovative solution.

| Index       | Value               |
|-------------|---------------------|
| Investments, rub | 8 950 000,0       |
| NPV, rub.       | 13 306 992,0       |
| PI            | 1,48                |
| PP            | 5 months            |
| IRR, %        | 60                  |

The analysis of the table shows that NPV is positive, the return on investment exceeds the threshold value (1). It follows that it is effective to invest in the implementation of an innovative solution in the construction of oil and gas wells.

### 4. Conclusion

The use of digital twin technology in the construction of oil and gas wells will make it possible to describe in detail each process that takes place on a drilling rig. This precise description provides the engineer with
opportunities to help determine the root causes of the problem areas in the process. In turn, this will form
the basis for developing an optimal strategy for the construction of future wells.

The principle of operation of the model, which is described in this article, assumes both the direct
participation of a specialist in data analysis (option 1) and the development of software that can minimize
his participation (option 2). However, future technology prospects could seriously diminish this
participation. In addition to introducing an integrated approach to creating digital twins, there is another
significant trend in this area. This is the desire of technology companies to teach the virtual production
model not only to reflect the physical analogue in the smallest detail, but also to "think" and also to act
autonomously. That is why the development of artificial intelligence capabilities is so important for the
digitalization of production. In the coming years, work will be very active in this direction.

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