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# Transformation of oil and gas fields based on information technologies

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Abstract. Currently, there is an opportunity to ensure digital transformation in the leading oil and gas companies in Russia. The main task of the transformation is to reduce capital and operating costs and increase production efficiency. The objects of transformation are processes, information, and people. Considering the existing technological and geological constraints for the Arctic fields, it is advisable to ensure the initial implementation of the principles of a digital intelligent field when creating control systems for wells and control production complexes. An important component is the development of an effective decision support system as a tool for calculating forecast tasks that provides strategic and tactical planning when modeling geological and technological processes online. The materials provide the structure of remote management of geographically distributed facilities of PJSC Gazprom, as well as solutions already implemented and confirmed the effectiveness of management for the Bovanenkovo oil and gas condensate field located in the Arctic on the Yamal Peninsula.

#### 1. Introduction

The digital economy is a key element of the competitiveness of the Russian fuel and energy complex. The transition from export-raw materials to resource-innovative development is the first stage in the implementation of the digital modernization strategy.

The oil and gas complex currently includes in the world a mineral resource base, a developed infrastructure, qualified personnel, significant innovative potential, including the implementation of digital technologies and business models for maintaining the leading positions of hydrocarbons in the long term [1]. These opportunities can be provided only through the introduction of information technologies based on the acquisition and processing of large data arrays, machine learning and digital twins to minimize uncertainty factors and assess risks, as well as to prevent possible emergency situations and minimize damage in case of violation of technological modes [2].

#### 2. Fundamentals of the digital oil and gas economy

Uncertainties can make it difficult to predict financial, social, logistic and other business conditions, and therefore long-term large projects may not be implemented. The created intelligent digital oil and gas economy is a new form of modern business based on innovative production management models in real time with minimal personnel participation in production, a demanded model of technological development, when the basis of efficiency is the ability to use all available production assets in real time at all stages the life cycle of the field. The transition to a new structure of the economy is associated



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with significant transformations in other areas: the development of the regulatory framework, the improvement of technological processes, the use of modern diagnostic methods and materials, the creation of a system of continuous retraining of personnel in accordance with modern requirements.

However, considering the limited financial capabilities, priority investments should not be made in the repair of capacities of the last century, but directed to the creation of modern highly profitable robotic industries.

The development of technologies and competencies in general will lead to the exclusion of a person from the control chains, their replacement with artificial intelligence, and will also ensure the creation of additional profit when organizing effective oil and gas processes covering the full technological cycle, including an underground technological complex (reservoir, well), aboveground infrastructure (preparation hydrocarbons to transport) and the integration of processes based on complex algorithms for the management and operation of assets based on the actual state and competencies. The objects of digital transformation in these processes are people, technology, and data.

- people are experts and bearers of knowledge, are responsible for creating and maintaining an innovative environment for an enterprise / project, an engineering culture. this can be achieved only through a development strategy, improvement of the structure and competencies of personnel.
- technologies ensure the transformation of existing, creation of new business processes based on machine learning algorithms for competencies and analysis using artificial intelligence.
- data allows you to analyse processes and trends, comprehend the business as a whole and form the value of assets.

## 3. Examples of innovative solutions for Arctic fields

A cluster of gas wells at the Bovanenkovo oil and gas condensate field (Yamal Peninsula) with thermal stabilization units is shown in Figure 1.



Figure 1. A cluster of gas wells with thermal stabilization units.

The operating experience convincingly shows that digital technologies in the fields provide an increase in the efficiency of not only individual wells, but also the field due to:

- introduction of optimal modes, ensuring efficient extraction of raw materials and well stock operation, high productivity of well equipment in conditions of technological and geological complications.
- reducing the impact of the human factor on the process, due to a decrease in the number persons involved in the conduct of the technological process and the transfer of part of the functions on robotic intelligent production control systems.

- application of technological algorithms (operations) and implementation at the facility decision support systems based on the construction of geological technological model of the field; functional expansion and modularity of solutions at all levels of well stock management.
- the possibility of minimizing reserve capacities and localizing emergency situations; ensuring a unified information interaction (space) between functional subsystems with the ability to transfer information to real time from the gas well to the simulation center field for the purpose of calculating forecasts, risks, as well as a single center dispatch management to ensure control and effective predictive management of pads and wells, fields, fields.
- the use of a single digital software and hardware platform with high-speed optical and satellite communication channels, wireless sensor networks, robotic processes, as well as widespread use in deposits of non-volatile, renewable energy sources (sun, wind, reservoir energy, etc.).
- widespread use in projects for the development of standard high-performance, cost-effective solutions for the arrangement of wells, gas well clusters, industries, and deposits in general.

The need for digital transformation in the oil and gas industry is a consequence not only of the geographical location of unique and gigantic oil and gas fields in Western Siberia and the Arctic, but also involves the production of hard-to-recover oil and gas reserves under technological and geological constraints. The digital oil and gas economy is a new form of oil and gas business, which is based on innovative models of production management in real time [3].

The digital oil and gas economy is based on large geodata in digital form and a package of "end-toend" digital oil and gas technologies, which ensures a continuous production process controlled by personnel, technological and environmental safety based on criterion predictive control and processing cycles. Digital modernization of the oil and gas industry will increase the average efficiency in oil fields from 30 to 40% and in gas fields - from 75 to 80% of the initial state. The implementation of transformation technologies will ensure the required production volumes and significantly reduce the cost with the existing infrastructure.

Simplified, the architecture of a digital field includes underground and aboveground technological objects (wells and production infrastructure), a system for monitoring production operations in real time; integrated model of gas production; integrated management center; a fiber-optic system for collecting and transmitting large volumes of geological and field information based on non-volatile and wireless solutions; systems for intelligent control of wells and gas gathering networks using intelligent control of objects; bank of geological and field data [4].

Digitalization allows:

• optimal use of reservoir energy, which is especially important at the final stage of exploitation and declining production.

• organize the operation of gas wells in conditions of technological and geological constraints.

• provide comprehensive management and monitoring to reduce operating costs.

• in advance to identify hydro sand manifestations and carry out continuous measurement of bottomhole and wellhead characteristics of wells.

• achieve targets based on management criteria.

• provide analysis of the state of interfiled reservoirs and loops through the use of modern technologies for measuring temperature, pressure, acoustic parameters and noise, measurements of the composition and quality of products to monitor the quality of processes and ensure timely management and correction of production parameters.

The decision support system (DSS) is becoming a tool for calculating forecast tasks, providing strategic and tactical planning when modeling geological and technological processes online. Operating costs for digitalization of gas fields, according to calculations, will not exceed \$ 1-2 per 1000 m<sup>3</sup> gas, while it will be necessary to radically change the volumes of operational and calculated operational information on the management levels "well - field - field - enterprise - industry". Comparative characteristics of the amount of information in the automation of wells are shown in Table 1.

Parameter	Digital well with distributed sensors	Digital well with point sensors	Typical well
Number of sensors,pcs.	Up to 50,000	Up to 15	Up to 5
Placement	Along the wellbore from the mouth to the bottom	Mouth, bottomhole	Mouth
Information type	Digital	Digital	Analog
Information transfer type	Digital	Analog	Analog
The amount of information	Gb	Mb	Kb
Telemetry	Full control	Items	-
Artificial intelligence (AI) systems	AI, Intelligent control	Fuzzy logic	-
Support and decision- making system (SDMS)	Robotic and / intelligentcontrol, SDMS	Automated control system	Manual

Table 1. Formatting sections, subsections and subsubsections.

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Knowledge of the bottomhole zone allows to increase productivity in several wells in conditions of limitations by 30-40%. For new and reconstructed fields, it is possible to ensure operation in various modes: manual / remote / automatic, and in the future, a transition to the widespread use of intelligent control with the possibility of robotization of most processes and equipment.

The main goal of implementing a "digital field" is a trade-off between reducing costs and resources, used for this time and the role of the human factor. The most effective approach is achieved as competencies grow.

Considering the duration of transformation processes, there is currently no problem of a complete transition to digital control while ensuring 100% digitalization of production facilities, ensuring efficiency is achieved almost at the initial stage or partial digitalization like production technologies, where 80% of production volume is provided mainly by high-rate 10-20% of wells from the total stock available at the field. Digital transformation allows for increased intelligence based on all available information, i.e., both historically accumulated and predictive, and contextual, which is not initially contained in the system and is formed based on an analysis of various sources during operation.

Considering the complex geographically distributed structure of production, when using intelligent control, it is assumed that information resources and competencies are distributed by management levels, as well as short-term and medium-term and long-term forecasting of modes and development forecasts and prevention of emergency and emergency situations. Collecting and processing big data allows you to build a virtual system of connections and dependencies, which will later be required to simulate an object in real working conditions [5].

The required results can be obtained by changing the parameters of the built model, research and identifying various patterns, correlations between variables. Artificial intelligence (AI) has already found wide application in simplifying management decision-making procedures and involves the use of network tools and algorithms with a given accuracy and criteria for assessing the situation and is especially effective at the initial stage.

AI technologies make it possible to achieve a high level of correspondence between the results of the operated object and its digital twin for all modes with the possibility of criterion control. The introduction of intelligent technologies based on the principles of remote monitoring and control ensures

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the receipt of additional volumes of oil and gas production through the introduction of a scalable instrumental basis, applied methodological foundations of model predictive control of digital production in real time, optimization of kinematics and dynamics of gas and oil flows in an integrated system digital oil and gas production and ensuring the required product quality. The booster compressor station of the gas field of the Bovanenkovo oil and gas condensate field is shown in Figure 2.



Figure 2. Booster compressor station of the Bovanenkovo oil and gas condensate field.

The advantage of intelligent control is the ability to switch to planned control without the participation of the field operator and, on the basis of neural models, effectively respond to emergency situations, simulate and intellectual enterprise for production within the Companies [6].

The development and mastering of more and more functional and cheap tools that collect, store and process big data, expands the possibilities of using AI, which increases business interest and contributes to the achievement of goals, among which the main ones can be distinguished:

- Reduced production costs. The creation and implementation process are costly and requires a lot of iterative calibration and testing, which is time consuming and expensive. Implementing this procedure in a virtual environment allows you to perform the above steps much better and faster, more cost-effectively and to ensure that the functions suitable for the given product are performed correctly.
- Reducing the time for product development into production and on the product market. Due to the possibility of creating a virtual prototype of a product and monitoring its functions using computer tools, the procedures for verifying and improving its model are easier, faster, and cheaper, which contributes to an earlier entry of development into production and mass application in processes.
- Predictable diagnostic service. With the help of innovative technologies, it becomes possible to collect all kinds of data from real objects using various sensors and predict possible breakdowns in a virtual environment and calculate the behavior of the system considering the actual state.

The synergy of technologies of full cycles of oil and gas business allows creating highly effective target business models for managing oil and gas production, providing an intensive increase in capital productivity and labor productivity [7].

PJSC Gazprom has implemented a unified structure for remote control of the main production facilities at the following levels: Central Production and Dispatch Service (CPDS) of PJSC Gazprom (Company) - Production and Dispatch Service (PDS) Gazprom Dobycha Region (base enterprise) - Gas production department (GPU) (support base of the base enterprise) - Gas production (GP, field) - clusters of gas wells (KGS, gas wells or remote technological facilities of the field). The control panel for the gas field of the Bovanenkovo oil and gas condensate field is shown in Figure 3.

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Figure 3. Control panel of the Bovanenkovo oil and gas condensate field.

Real-time monitoring and remote control of the main stock of gas production wells is provided using three main classes of automated systems: volatile, non-volatile, and based on local systems. This is ensured using broadband, wireless and satellite communication channels.

Digitalization allows to optimize the operation of autonomous wells and groups of wells; prevent the destruction of the bottomhole zone; provide well performance monitoring; to identify hydro-sand-manifestation; to measure bottomhole and wellhead parameters of wells; increase the flow rate of wells; provide monitoring and analysis of the state of interfiled reservoirs and loops in automatic mode.

The decision support system is becoming an important tool for calculating predictive tasks, providing strategic and tactical planning when simulating geological and technological processes of production and transport in real time. The final efficiency is objectively determined by the possibility of operational regulation between fields and withdrawals for specific clusters of gas wells and even individual wells in the fields, as well as the possibility of performing operational measurements to accurately implement production targets within the framework of the design indicators of the field infrastructure.

The main effect from the creation of an automated (intelligent) well (in the future "intelligent") can be obtained through the rational operation of the system "formation-bottom-hole-wellhead-interfiled reservoir" as a single technological complex, to allow the inflow of water and mechanical impurities to the bottom of the well and exclude the conditions of destruction and removal of rock particles to the surface [8].

In the future, based on intelligent wells and machine learning, the implementation of automatic control of the field and remote monitoring of the state of the field infrastructure takes place. The basic trend is becoming a repetitive correction cycle: figure - model - efficiency - economy, and the technological cycle of production process control is provided by the cycle: measurement - correction - control - forecast - impact.

#### 4. Control modes and transformation capabilities

Taking this into account, for new fields, it is envisaged to ensure the operation of fields and wells in manual / remote / automatic modes and, in the future, the implementation and widespread use of intelligent control.

The basis for managing digital gas production facilities ("digital fields") is the widespread use of information technologies, risk-oriented algorithms, and processes with minimal human participation in production. The task of creating artificial intelligence systems requires a significant change in existing practices and a serious formalization of the knowledge of experts and professionals in specific areas of

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not only mining, information technology, technological and environmental safety, but also the transition to the operation of production assets according to their actual state.

It should be noted that the interactive geological modeling used in this case should be based on hightech software systems based on operational data obtained from exploration and production wells throughout the life cycle of gas production.

The use of this approach allows you to create real 3D-models of the productive formations of the field, to determine and timely adjust the main development indicators, to reduce the risks in assessing reserves and the technological mode of operation. The developed 3D models of productive formations are used as part of the geological modeling subsystem of the automated control system for field development and are used to solve the following tasks:

- automated calculation of current hydrocarbon reserves in productive formations and forecasts of field development at the current production level.
- calculation of optimal field development indicators using a 3D model.

• automated calculation of the current and projected material balance, as well as the number of inhibitors for the field.

• calculation and transfer of corrective settings to the decision support system (DSS) of the field and the higher to DSS IASU TP of gas fields and fields at the level of the mined enterprise.

Considering modern technologies and scientific developments, investments in promising technologies increase once; it is necessary to create specialized centers for the development and implementation of design models (digital twins) of software and hardware systems; it is necessary to develop Concepts for the Development of Enterprises to ensure a unified technical policy in the short and long term; adoption of standard design approaches, with the possibility of widespread replication.

At the same time, automation of technological processes is the basis and is carried out in accordance with the requirements for the composition of controlled parameters and risk assessment of operating modes, operational monitoring of the current technical condition of production facilities, scenarios and algorithms for automatic control and response, as well as other necessary operational information characterizing technological processes and scenario risks of development of regular and emergency situations. To ensure the evolutionary transition of all transformation objects (data, processes, personnel) in the development process, it is necessary to provide an evolutionary cycle: standardizationautomation-informatization-intellectualization-robotization.

#### 5. Applied elements of digital transformation

Taking into account the world's best practices and competencies, a number of key technologies are used as elements for solving practical problems of the digital oil and gas production complex:

- Artificial intelligence using neural networks, machine learning and other methods to develop forecasting scenarios, modeling and the possibility of optimal management of production facilities and technological processes.
- "Digital twins" for building information models of facilities and infrastructure, optimizing production processes, modeling production and operational, engineering, and economic problems, the state of technological complexes.
- Corporate data storages with the possibility of territorial and organizational distribution of information capacities and volumes of storage of information about the work, the state of production facilities, the geological and technological state of oil and gas fields at all stages of the life cycle, coming directly from the fields and facilities as development, aging and state change.
- "Big Data" structures for processing and configuring arrays of structured and unstructured online data obtained during construction and operation, for use by control and monitoring systems, by various departments in real time.
- A single information resource for enterprises to provide elements of the organizational target architecture involved in the management and operation of technological and production processes

(including dispatch control) for solving problems of document flow automation, budget and resource planning, logistics of regulations and work, information exchange and task formation.

• Industrial Internet, elements of virtual and augmented reality for organizing effective data collection from technological facilities; the use of unmanned aerial vehicles, robotic systems and mobile workers to work in hazardous industrial and hard-to-reach areas, as well as diagnostics of the state of facilities and technologies.

A global challenge requiring a solution in the field of digital technologies is the creation of an interdisciplinary design and research environment, i.e., the integration and interaction of fundamental and applied sciences, students and teachers, industrial workers, and researchers to solve specific industry problems. The ongoing transformation processes should significantly change the traditional and rather conservative relationships in the industry on the key issues of creating an innovative environment and engineering culture in several key production areas, namely personnel, technology, and information [9].

Implementation of digital technologies allows rational use of reservoir pressure; optimize equipment operation and well operation; reduce production costs and increase the level of technological and environmental safety. The concept of digitalization of oil and gas production is shown in Figure 4. The complexity of developing adequate methodologies, models, and techniques to achieve the level of acceptable risks is due to many factors, including interdisciplinary problems, historical conservatism, and caution in the use of new technologies at hazardous production facilities, the complexity and hierarchy of processes, the presence of cause-effect relationships and restrictions for all areas of activity. A significant limitation is the insufficient number of specialists with modern competencies, transformation mechanisms and knowledge in the oil and gas field, with practical experience in development, design, and operation. Difficult to implement is also many mathematical, graphic and means for solving the problem of transitioning to a management model with minimal human participation in production processes.



Figure 4. Oil and gas production implementation concept.

# 6. Conclusion

The successful implementation of intelligent technologies and artificial intelligence in the oil and gas industry provides additional volumes of oil and gas production through the implementation of a scalable instrumental basis, applied methodological foundations of model predictive control of digital production in real time, optimization of kinematics and dynamics of gas flows in an integrated digital system. oil and gas production and ensuring the required product quality. The transition to a new economic structure is associated with significant transformations in other areas: the development of a regulatory framework, improvement of technological processes, the use of modern diagnostic methods and materials, the creation of a system of continuous retraining of personnel in accordance with modern requirements. The creation of a digital oil and gas industry in Russia will allow solving not only the most important problems of the industry, but also creating a foundation for the future effective development of applied industries and technologies in the Russian Federation.

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