Digital technologies in oil and gas production as a tool to ensure optimal energy efficiency and sustainability

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Abstract. Implementation of smart production technologies, digital technologies, and Industry 4.0 technologies in the oil production industry as a type of innovative management are indispensable tools for strengthening strategic, financial, and innovative sustainable development of enterprises operating in highly competitive domestic and foreign markets. Such technologies make it possible to adjust enterprise strategies promptly in real-time. All field digitalization solutions, operation of production units with any voltage and frequency level, heating, etc. are not workable without electric power. Electric motors of drilling rigs, downhole surfaces, and underground equipment use about 70 - 72% of all electricity consumed during oil and gas production. The authors give examples of energy-saving measures and the results of their implementation. Efficiency, energy conservation, and sustainable development are the challenges oil producers face today. The article considers strategic management in reality as a new trend in the sustainable development of oil production enterprises. Varying strategy in real time gives the oil-producing enterprises a general focus, individuality, daily simple actions, readiness to consider new ideas, and not being afraid to decide and take responsibility for them. The authors also analyzed the sustainable development strategies of the leading oil-producing companies in Russia. The article offers performance indicators for the sustainable development of oil and gas-producing companies.

1 Introduction

Russia, because of the current world situation, has become economically independent from Western countries with a stable position in the foreign market. Scientific, technological, design, research, and production relations have become more independent, holistic, import-substituting, and diversifiable, allowing Russian enterprises to compete by international standards with well-known global firms in any industry. The existing positive experience of technological projects shows the slowness of the receptivity of the economy, and production units of enterprises to innovation, especially in introducing digital technology, and also the export of high-tech products.

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Smart manufacturing technologies, digital technologies, and Industry 4.0 technologies at any stage of the production cycle in closed and semi-closed automatic modes are the most effective tools of scientific and technological development, performing information analysis and analysis with artificial intelligence, digital design and construction, simulation, digital twins, computer risk and hazard assessment, innovation cycle reduction, industrial internet of things, cognitive computing, virtual or augmented reality, smart workspace, and 4D printing.

Implementation of these technologies in the oil industry as a type of innovation management is an indispensable tool to strengthen the strategic, financial, and innovative stability of the development of enterprises operating in highly competitive domestic and foreign markets.

2 Research results

Each digital project, while having its characteristics, must also consider the future. Digitalization of fields at any stage of development uses the digital transformation of new technologies and solutions, software improvements, automation, network technologies, and wireless networks with high-speed data exchange Industrial 5G. Such technologies improve production efficiency, optimize processes, and monitor performance, including the security routers, and cloud-based enterprise solutions that provide flexibility, autonomy, reliability, security, versatility, efficiency, cost-effectiveness and competitiveness throughout the life cycle from data collection and control of exploration, drilling, well operation and maintenance, oil and gas pumping and treatment to logistics at the commercial metering hub. The location of wells across the company's fields has an extensive network of up to hundreds of thousands of kilometers of extended cable lines. Using two-wire lines with SHDSL and Radioline technologies, the creation of 4G/5G mesh network and transmission encryption technologies is one of the communication solutions of wireless mobile communication for operational drilling, production management, control, and diagnostics at long distances and decentralized access to the field equipment.

Digital technology software from foreign oil companies has an open Linux operating system with the Python programming language, which is ideal for artificial intelligence, machine learning, and system integration. Ethernet buses and Axioline modular input devices respond to changes in geological data or pumping equipment mode in 1 - 2 seconds.

The world's only science-intensive software of PJSC Rosneft's right holder, developer LLC RN-BashNIPIneft: RN-KIM hydrodynamic simulator for creating and analyzing three-dimensional digital field models, RN-SIGMA geo mechanical modeling and drilling risk management, RN-KIN oil and gas field development management, RN-ROSPUMP submersible equipment selection, and 9 more computer stimulators with a database. These software packages allow the creation in real-time numerical analogs of fields, to use of artificial intelligence algorithms for digital solutions of daily practical geological, and operational tasks in the drilling of vertical and directional wells, development of fields with hard-to-recover reserves, complex mining, and geological structure, specific features of Russian reserves structure, considering modern technologies of downhole oil and gas production. The software is based on the languages C++, and Python with the use of Qt5. Fast calculations in Python occur with the help of numpy, interactive 3D visualization of large data arrays occurs with the help of OpenGL 3+ and Qt5, and high-performance calculations consider the innovations of the standard C++ 17 [1].

All field digitalization solutions, operation of production plants at all voltage and frequency levels, heating, etc. are not workable without electrical power. Efficient grid expansion and retrofitting to maintain voltage, change the direction of power flow and consider the temperature ranges of electrical equipment, allow us to carry out demand-based

planning, and ensure safe, decentralized operation and maintenance. Good technical equipment, innovative technology, automation and cost-effectiveness ensure energy efficiency and reliable power supply.

Rising energy prices and increased energy consumption are the most acute problems of the electric power industry. Electric motors of drilling rigs, downhole surface, and underground equipment consume about 70 - 72% of all electricity in oil and gas production. Old electric motors are replaced with ones of higher energy efficiency class in the order of their failure. On average, one higher energy efficiency class replaced about 50 - 53% of electric motors and 28 - 30% by two energy efficiency classes; only 25 - 28% of the fields were completely modernized. Table 1 shows examples of energy-saving measures and results from their implementation in Russia.

The most pressing issue on land, water, and air is sustainability. Efficiency, energy saving and sustainable development are challenging tasks that oil production companies face today. The economic, social, environmental, production, technological, and digital elements of sustainable development interrelate and remain inseparable from one another.

Digitalization of field reserves, creation of digital twin fields, virtual geo mechanical support of drilling in real-time with optimization of trajectory and well designs, modeling of maximum oil and gas production level with an energy-efficient selection of producing surface and underground equipment, etc. allow the creation the concept of asset management strategy of oil producing enterprise in conditions of uncertainty. The development of an asset management strategy for oil and gas companies will allow us to react instantly, and quickly make technological or organizational decisions when drilling, managing equipment, well stock, and technological modes at different depths of any field.

Table 1. Areas of energy conservation and energy efficiency in oil production in Russia.

Energy saving measures	**Technological results from the implementation**	**Economic results from the implementation**	**% completed**
- Managing the stock of production and injection wells; - Limiting water injection into the reservoir; - Influence on bottom-hole zone; - Carrying out repair and insulation works in the wells; - Reducing associated water production and re-injection; - Stopping unprofitable well stock; - Carrying out geological and technical measures	- Reducing the amount of fluid withdrawn, increasing oil production, reducing variable costs that depend on the volume of fluid produced; - Monitoring of operating parameters of each well in real-time; - Implementation of an automated process parameter control system (APCS)	- Reduction of the variable part of the costs of the following items: electric power for lifting fluid from the reservoir, oil collection and transportation, equipment maintenance, and operation; - Opportunity to save capital investments; - Reduction of payment for electric power consumption	Up to 40%
- Application of modern energy-saving nano coated units with electric centrifugal pump and increased efficiency coefficient; - Introduction of intelligent control stations for sucker-rod pump units; - Conversion of marginal well stock to operation with screw pumps; - Cascade control with parallel installation of pumps; - Speed control of pumps with unchanged network parameters	- Increase of overhaul period of well operation; - Completion of control stations with individual certified electricity meters for each well	- Reduction of energy consumption and energy costs; Creation of an organizational structure at the enterprise that has the authority to solve the tasks of reducing energy consumption effectively.	20%

Continuation of Table 1.

- Replacement of power transformers from higher to lower capacity; - Use of a submerged cable with a larger cross-section; - Heating of cable line; - Replacement of asynchronous motors; - Replacement of pumps of higher power with lower power; - Replacement of power plants with diesel engines with more economical gas turbines; - Operation of submersible equipment in intermittent operation modes; - Selection of optimal size and replacement of pump units; - Installation of variable speed drives for pumping equipment; - Reduction of losses in electrical networks	- Saving heat and reducing the cost of paying for heat; - More productive equipment for oil and gas production; - Ability to track process parameters over time: current, voltage, pump inlet pressure, submersible motor temperature, dynamic level, power consumption, etc. for each well	- Reducing the payment of the electricity component; - Reduction of energy costs; - Increased profits by reducing operating costs; - Getting a certificate for conducting internal audits of the energy management system under the international standard ISO 50001	12 - 15 %
Improving the energy efficiency class of electric motors IE2 high, IE3 premium, IE4 super-premium	- Material replacement or coating of coils, windings, insulation, cable lines, magnets, stator, rotor, motor housing, bearings to Improving mechanical, electrical strength, vibration resistance, and chemical resistance; - Fine-tuning of equipment; - Use of low-noise cooling fans, modern frequency converters - Coefficient of performance 96 - 98%; - Increasing the load factor cos φ	As the energy efficiency class increases, the cost of the motor increases; IE2 high: savings up to 7% of generated electricity, payback period 2.5 - 3.2 years IE3 premium: 15 - 20% less motor losses, up to 15% less overheating, 30 - 40% longer service life IE4 super-premium increases the service life of electric motors by 80%, energy saving by 70 - 80%	IE2 High to 53% IE4 Super-premium up to 28%

Strategic management in reality is a new trend in the development of enterprise sustainability strategy with the help of digital technologies, a transformation of rethinking the situation. The real-time strategy gives the company an overall focus, personality, daily simple actions, willingness to consider new ideas, and not being afraid to decide and take responsibility for them.

Rosneft's Board of Directors approved the sustainable development strategy "Rosneft-2030: Reliable Energy and Global Energy Transition" at the end of 2021. The key priorities are carbon footprint reduction, operational leadership, and efficiency increase. The Company's strategy contributes to the achievement of the goals of the Strategy for Socio-Economic Development of the Russian Federation for Low Greenhouse Gas Emissions up to 2050, the Paris Agreement on Climate Change, as well as 17 UN Sustainable Development Goals. Carbon neutrality is the basis for Rosneft's strategic vision: to remain a reliable producer with minimal impact on the climate and the environment. The Rosneft-2022 strategy fully meets the modern challenges of the energy industry. Sustainable development envisages an increase in business profitability and returns on core assets through the intensification of their development, implementation of key projects, and changes in the

management model. This will enable sped up replication of new technologies and move the company to a qualitatively new level in the face of the challenges of the digital era [2].

LUKOIL Group's strategic benchmarks for sustainable development include 11 UN sustainable development goals and 15 objectives. LUKOIL Group aims to improve industrial safety, reduce injuries and ensure accident-free operation of its production facilities, and also to reduce its environmental footprint continuously. The company has identified investment in upstream projects in Russia, high investment discipline, conservative financial policy, cost control, improvement of operational efficiency, and commitment to the principles of sustainable development [3].

The strategy of RussNeft's sustainable development envisages active investment activities aimed at increasing the volume of production drilling, commissioning new fields in promising areas, creating new and upgrading the existing infrastructure, and achieving stable growth in the medium term. The fundamental goals of the company's sustainable development are to provide stable growth of hydrocarbon production and increase of reserves by production programs with an optimal system of development and production management and decrease of operating costs. The RussNeft-2022 sustainable development strategy covers all areas of the company's activity, including ecological, social and economic (including corporate) areas. The company has a goal of environmentally friendly production, minimizing the impact on the environment and preserving it for future generations [4].

The key aim in Gazprom Neft's 2030 Sustainable Development Strategy is to build a new-generation company and become a benchmark for other companies in the global oil industry in terms of efficiency, technology and safety. To achieve these goals, Gazprom Neft seeks to maximize the cost-effective extraction of reserves in its current resource base by disseminating practices for optimizing development, reducing the cost of technology, and attracting and implementing new technologies [5].

Knowledge of organization of production process of oil production, the satisfaction of needs of main production, reduction of production cost of oil, high level of investments in servicing of wells, introducing innovations in equipment, new technologies in development, operation of wells and drilling of fields, technological mutual support, full capacity utilization, improvement of information support, application of digital technologies - are only part of a global system of sustainable development of oil producing enterprises, which allows us responding quickly, promptly to the slightest changes in the external environment during oil production. Change in business conditions allows the enterprise to reduce the risks of technological and organizational activities, and to accumulate funds for specific investment or reorient capital in a particular field, technology of production management, reducing the unit capital and operating costs [6].

The primary goal of sustainable development for any oil producer is to achieve consistent profitability, increasing production volumes and reserves. This is possible, for example, through better management of the field at all stages of the life cycle, well operations, improved automation, 24/7 digital monitoring and improved production and exploration technology, and using innovative approaches to recruit and keep talented prospective employees. Deep integration of oil production technology and real-time control allows us to manage tangible assets and personnel, make real-time decisions, and link financial results with asset management flexibility and financial performance achievement.

Indicators of efficiency of sustainable development of oil-producing enterprises are:

- return on investment and sales, cost reduction ratio, return on equity, debt ratio, return on shareholders, reduction in the cost of 1 ton of oil, the volume of oil production, growth of oil reserves;
- in geophysical research - the number of R&D works, the volume of geophysical research of wells of geo-information systems in operating, drilling, drilled wells, cost of geophysical services, reduction of unit costs of geo-information systems;

- during drilling - annual drilling footage in production and exploration drilling, reduction of unit costs per meter of penetration, number of commissioned wells, success in prospecting and exploration drilling;
- in equipment repair - reduction of unit costs for oilfield equipment repair;
- for capital construction - reduction of unit costs for capital construction;
- resource-saving and environmental friendliness - industrial injury rate, the value of preventing environmental damage, etc.

The offered indicators of efficiency allow us to estimate the value of the oil company as an indicator of sustainable development [7]. The more the enterprise directs infestations on the development of the company, the higher the growth rates of efficiency indicators, growth of assets, and growth rates of the value of the company, and the more it has stable development.

3 Conclusion

Implementation of smart production technology, digital technologies, and Industry 4.0 technologies in the oil production industry as a type of innovative management is an indispensable tool for strengthening strategic, financial, and innovative sustainable development of enterprises operating in highly competitive domestic and foreign markets. In all field digitalization solutions, the operation of production units with any voltage and frequency level is not workable without electric power. Electric motors of drilling rigs, downhole surfaces, and underground equipment use about 70 - 72% of all electric power consumed during oil and gas production. Examples of energy-saving measures in Russian fields allow us to evaluate the results of their implementation. Efficiency, energy saving, and sustainable development are challenging tasks that oil production companies face today. Strategic management in real-time is a new trend in the development of a sustainable development strategy for an oil production enterprise using digital technologies, a transformation of rethinking and expecting the situation. The real-time strategy gives the company an overall focus, personality, daily simple actions, willingness to consider new ideas, and not being afraid to decide and take responsibility for them. We have analyzed the strategies for the sustainable development of the leading oil companies in Russia. The proposed and forecasted performance indicators allow us to estimate the value of an oil company as an indicator of sustainable development. The more the company directs the amount of net profit to the development of the company, the higher the growth rate of efficiency indicators, assets, and company value, and the more sustainable development it has.

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