Innovative development technologies of oil and gas industries

O N Kiseleva, A V Kulbyakina and N A Ozerov
Yuri Gagarin State Technical University of Saratov, 77, Politechnicheskaya str., Saratov, 410054, Russian Federation

Abstract. Development of oil and gas industries on the base of innovative trends is indicator of sustainable development of the economy of any state. Advancement of innovative trends in the development of the Russian oil and gas industry is the only way to preserve and hold favorable positions on the home and international markets. The authors propose to apply an integrated approach to the design and implementation of innovative development projects at oil and gas enterprises. First, oil and gas enterprises should widely introduce a wide range of innovative technologies with a high potential for internal reserves. Implementation of innovative technologies by empowerment of the energy resources allows for significant economic benefits and upgrading the efficiency of an enterprise within a short term. Another aspect of the problem is related with supporting innovation technologies interconnected with managerial technologies or managerial innovations being the changes aimed at providing a favorable environment for the outcome of innovative technologies. Creation of a favorable management environment as the basis in innovative processes is one of the key factors for successful development. The proposed solution will contribute to innovative development of domestic enterprises and the Russian economy as a whole.

1. Introduction
The oil and gas industry is the most important strategic sector of the Russian economy, ensuring financial stability. At present, the statement that Russian enterprises must be involved into innovation development is unchallenged. It reflects the only possible way to improve the situation in the absence of market-oriented economy and prioritization of resource-based economy over technological advancement under the influence of geopolitical and economic factors. Within the given context, we should point out the attempts to create an innovative infrastructure, introduce tax privileges for innovative businesses, form the appropriate basis for laws and regulations required to promote the process of innovation development by oil and gas industry enterprises.

At present the domestic industry of processing raw hydrocarbons fails to keep pace with its global counterparts. Consequently, it is facing high competition and the companies are suffering from significant losses. This can be explained by such factors as tough environment conditions, significant amount of hard-to-reach oil fields, changes in the quality of raw materials, and remoteness of the oil fields from refinery facilities. Among negative trends affecting the industry we can highlight the outdated material and technical base of enterprises, ineffective methods of economic management of companies, high energy consumption, inefficient usage and heavy losses of energy resources. It is worth mentioning that the average share of energy resources in the product costs is about 50%. Meanwhile, the majority of hydrocarbon processing plants have considerable potential to improve their economic
and energy efficiency through introduction of cutting-edge approaches to the management of companies, modernization of outdated material and technical base, large-scale introduction of energy saving technologies, such as utilization of alternative fuels, and organization of autonomous power supply systems [1].

2. Innovative trends of oil and gas industry development

2.1. Technological approach to improving the efficiency of oil and gas sector enterprises

Current practices in the development of hydrocarbon processing enterprises, including their energy utilities, are based on the principles of introducing effective enterprise management models, increasing the depth of resource recovery in order to produce high quality products, upgrading the rational use of energy resources, introducing low-waste technologies, organizing a closed cycle technology of water supply/water removal with maximum utilization of secondary energy resources, including combustible wastes incinerated in the flare systems of enterprises [2].

The technological system of hydrocarbon processing enterprises is the basic structure of the whole enterprise and energy complex. The energy complex is indissolubly linked with the technological system and consists of fuel, electrotechnology and heat technology basic subsystems, has high potential for upgrading the efficiency, which allows for obtaining significant economic effect. Realization of this potential, formation of a rational structure used to determine optimal operation modes of energy facilities at hydrocarbon processing enterprises taking into account the real conditions of technological processes can be obtained at the following stages: structuring the business object, selecting and justifying the indicators and performance criteria, developing mathematical models and algorithms for structural and parametric optimization, synthesising the rational energy complex and developing alternative efficient energy systems of energy supply.

Designing the structure of the fuel conveying system for hydrocarbon processing enterprises is the first aspect in the analysis of effectiveness of individual components and the whole energy complex based on the decomposition-aggregation approach and block-hierarchy principle for analyzing complex systems. The main objective in the analysis of the fuel system structure is finding out its relationship with the technological, electrical and thermal systems of the energy complex, as well as external energy supply systems.

The energy complex and all of its subsystems are closely interlinked with the energy complex and external energy supply system in a continuous process of energy generation and consumption. Justification of directions for increasing the efficiency of the energy complex incorporated in the hydrocarbon processing enterprises, both designed or modernized, is based on the system of indicators of power efficiency of individual components, including devices, production facilities and systems.

Here are some of the indicators.

*The potential for improving efficiency* of fuel utilization is estimated by the difference between the annual actual consumption and demand ratio [3, 4].

\[
P_T = (\varphi_T + \varphi_o) \left[ \sum_{j=1}^{N} B_{jF} - \sum_{j=1}^{N} (V_j \cdot E_j + b_j \cdot \tau) \right]
\]

where \( P_T \) is the technically feasible potential of energy saving in the fuel supply system, t/year;

\( \varphi_T, \varphi_o \) - are the share of factors provided by changing the technology structure and improving the technical conditions, or modernizing the equipment and facilities;

\( \sum_{j=1}^{N} B_{jF} \) - is the actual consumption of fuel gas by the main and auxiliary enterprises of the technology system and energy complex of hydrocarbon processing plants, t/year;

\( V_j \) is the volume of the standardized process stream of corresponding rate (m3/year or t/year);
$E_s$ is the specific fuel gas consumption requirement (t) per unit in the corresponding process stream; $b_j, \tau$ are the standard fuel gas consumption rates (t/h), and operation time (h/year) of intermittent facilities.

A possibility for including low-grade fuel gases and wastes of the technological system from hydrocarbon processing plants into the fuel balance is estimated using the generalized power capacity rate value

$$E_s = \sum_{j=1}^{N} \left( E_j^C - \beta_j \cdot E_j^{SER} \right) \cdot V^{-1}$$

where $E_j^C$ is consumption of all types of fuel and energy complex of the main and auxiliary production facilities $j$, t;

$V$ is the amount of recycled hydrocarbons, thousand m$^3$ or thousand tonnes;

$\beta_j$ is utilization ratio of all types of secondary energy resources (including fuel wastes) in the energy complex of hydrocarbon processing plants;

$E_j^{SER}$ is the volume of secondary energy resources (t) disintegrated from the production facility $j$.

Efficiency indicators allowed developing scientifically substantiated directions for increasing the efficiency of oil and gas industry facilities.

2.2. Innovative management technologies for change projects at oil and gas companies

It can be argued that the goals relating the innovative development of Russian enterprises, defined on the state level, are not supported by the available resources and, above all, by the managerial resources. This problem is typical of the enterprises operating in the various sectors of economy, including oil and gas industry. We can assume that this factor might account for the fact that so far Russian enterprises have not achieved high rate in innovative development.

In our opinion, in spite of the twenty-year transition path to the market economy, the managerial system of the majority domestic enterprises has not advanced, and reminds the administrative structure of economy. As a result, the system does not adequately respond to the changes occurring under the influence of various factors. The current management system of the majority domestic enterprises is ineffective, tough, and is not responsive to the changes and public demands. The current management system of domestic enterprises dramatically needs new forms and technologies.

In the context of innovative development, the problem of effectiveness of the management system is aggravated by the need to solve complex managerial problems connected with implementation of innovative projects by enterprises. Introduction of new technologies for manufacturing new products requires advanced management technologies [5, 6].

The need for the changes in the existing management systems is confirmed by the conducted research, according to which at present up to 90% of the Russian enterprises can improve their performance by 20-25% by creating an adequate management model; developing effective patterns of financial and economic activities, and retraining the managerial staff in terms of new knowledge concerning the management system of enterprises [7].

Therefore, implementation of innovation development strategy in the domestic market should start with optimization of the present-day management systems in order to create the relevant management environment required to stimulate the innovation process. As indicated above, organization of innovation activities is one of key issues of the strategy [8, 9]. In other words, prior to starting a new production or technology, or creating an innovative product, it is important to learn new ways in order to handle the given process.

An important prerequisite for engagement in innovative activities is availability of organizational and managerial innovations targeted to improve effectiveness of the current management systems and their compliance with ongoing changes in the business environment. Creation and implementation of
organizational and managerial innovations by enterprises, provides conditions for innovations of other types and forms the basis for organization of innovative processes.

The relevance of commitment to organizational and managerial innovations is defined by the fact that realization of new engineering initiatives is associated, firstly, with the need for substantial funding, and secondly, with time span. In other words, development and implementation of technological innovations require the relevant material resources and timing budget, which presently are unavailable for practically all business entities to improve their competitive capacity. Under present conditions, building competitive advantages through effectiveness of the management system based on organizational and managerial innovations has a number of benefits. First, forming and implementation of organizational and managerial innovations is not always connected with substantial costs, which might easier the problem with additional sources of funding the modernization plans. Moreover, the positive effect from implementing organizational and managerial innovations may be achieved in terms of sources of funding product innovations. Secondly, optimization of the management system is the basis for creating conditions to introduce technological innovations, having additional positive effect on competitiveness of enterprises.

3. Results and discussions

3.1. Performance indicators of innovative energy supply schemes for oil and gas enterprises

The undertaken multiple factor analysis of the energy complex at hydrocarbon processing enterprises, using the developed performance indicators, allowed for working out the ways for increasing the efficiency of an object, as well as finding complex technical solutions.

Using the methods of system analysis and synthesis of intricate energy technology engineering systems, the variants of energy supply schemes have been designed [10], which might be integrated into a hybrid oil refining unit. Figure 1 presents a block diagram to a variant of the in-house energy supply source including disposal of spent fuel and waste; on the figure 1 A, B - energy recovery units: A – combined-cycle plant (CCP); I – gas turbine unit (GTU); II – heat-recovery boiler; III – steam turbine unit (STU); IV – integrated heat exchangers; V – heat consumer; VI – waste steam condensation unit; VII – water conditioning; B – disposal of spent fuel and waste: VIII – neutralizer of industrial wastes; 1-17 – process streams: 1 – power gas; 2 – air; 3 – recycled gas fuel; 4 – industrial wastes; 5 – high temperature flue gases; 6 – flue gases for drying; 7 – 9, 17 – steam (7 – turbine intake, 8 – turbine offtake, 9 – for condensation, 17 – for technological needs); 10 – condensed water; 11 – chemically purified water; 12 – electric power; 14, 15 – heating load and gas-air mixture; 16 – dried flue gas; 17 – dry waste.

![Figure 1](image-url)
Sales gas and partially dry gas produced in-house during the feedstock processing (stream 17 in figure 1), are used as fuel gas in the gas turbine (I). Sales gas and partially dry gas (stream 17 in figure 1), as well as processed hydrocarbon (streams 7 and 15 in figure 1), serve as fuel to neutralize industrial wastes (VIII). Efficient combusting of hydrocarbon gases generated by mixing is provided due to the special features of the designed burner [11].

Design characteristics of the proposed scheme are determined by specific technological topology of the target for hydrocarbon processing, as well as required parameters for the generated energy carriers. In the case of the hybrid unit GK-3, the given technological parameters include the required amount of heat (342 GJ/year) and electric (61.02 GWh/year) energy needed for oil processing.

Introduction of the in-house source of energy supply along with the disposal unit for waste fuel and effluents into the GK-3 structure allows for increasing the system efficiency due to the following technological, schematic and design solutions:

generation of heat and electric energy in the in-house source by replacement of the given type of energy resources coming from external systems;
beneficial usage of heat from waste flue gases (from the neutralizing tank and gas turbine unit;
usage of combustible waste and effluents as fuel for cogeneration of heat and electric energy in the disposal unit by reducing the fuel gas consumption ratio coming from the network of an enterprise;
thermal decontamination of waste fuel and effluents, drainage, and wash water, which increases environmental safety of the whole facility and prevents contamination of the lithosphere and hydrosphere;
beneficial usage of steam condensation allows for reducing the overall costs for water supply and providing the closed cycles of water supply and removal;
the block-modular principle allows introduction of the proposed system used to supply the designed facility with energy and water, and additionally, incorporate this facility into existing technological systems.

Effectiveness of power supply for the hybrid unit GK-3, excluding the waste fuel and effluents in the fuel balance, is characterized by the indicators given in the table 1.

Table 1. Effectiveness of the power supply system.

| Indicators                                      | Value     |
|------------------------------------------------|-----------|
| 1 Electric power capacity, MW:                 | 9.2       |
| 2 Thermal power capacity, MW:                  | 14.2      |
| 3 Fuel consumption, t/h                        | 2.844     |
| 4 Profitability index, rub/rub                  | 1.963     |
| 5 Integrated effect (within 10 years), mln rub | 990       |
| 6 Payback period, years                        | no more then 5 |

Thus, implementation of the presented innovative technology of energy supply is one of the solutions to the existing problems relating the innovation development of the oil and gas complex. Focused on enhancing effective usage of internal reserves, the presented method allows for upgrading the performance efficiency within the shortest time, and does not entail substantial costs.

However, as has been mentioned, intensification of innovation development at domestic enterprises is determined not only by advancements in the oil and gas complex as the key drivers of innovation. Significantly, introducing the change-oriented management system is of prior importance in the process of innovative development.

3.2. Innovative approach to the formation of the management system of oil and gas enterprises

Organizational and managerial innovations in the management system are an essential component of innovative potential of enterprises, as they determine motivation for the changes interconnected with
innovative activities. In practice, preliminary work for organizational and managerial innovations lays the ground for the changes in the system, which makes the transition less radical and painful for all the participants of the given process. It is implementation of organizational and managerial innovations, and bringing the management system in conformity with the requirements, as well as providing the necessary conditions for further development and introduction of product innovations, form the basis for choosing development strategies. Hence, organizational and managerial innovations should be given the priority in innovation development of enterprises. Moreover, adherence to continuity and complexity principles regarding their implementation on all the management stages is of prior importance.

At present we must introduce a new approach to forming a management system based on organizational and managerial innovations, which can ensure both an increase in the efficiency of innovation activities of domestic enterprises, and improve the management practices. The concept of innovative management approach is based on assertion that the enterprise’s management system must be based on continuous development and implementation of organizational and managerial innovations, which can ensure advancement of a business entity in terms of environmental needs. Thus, continuous management system renewal is the key parameter of the given system. The key principle of the new approach is the innovation principle, which determines the demand for continuous innovations in the management system, which in their turn guarantee the continuous development of a business entity. The characteristic of the proposed approach is presented in table 2.

| Table 2. Characteristics of innovative approach to forming the management system based on organizational and managerial innovations. |
|---------------------------------------------------------------|
| **Main characteristic** | **Environmental characteristic** | **Key factor** | **The management system aims and objectives of** | **Role of innovation in enterprise performance** |
| Based on the key role assigning of innovations in various spheres of activity | Great impact of external factors, rapid changes, severe competition | Innovation | Providing conditions for the development of a business entity by continuous development and implementation of organizational and managerial innovations | Technological and other forms of innovation are equally important, and complement each other |

One of the tools for practical implementation of the given approach is working out the concept of the management system, which defines a uniform understanding of the mainstream, aims and objectives of the transition by all the participants of the management process. Formulation of this concept will facilitate the so-called formalization of the management processes based on organizational and managerial innovations, help in working out procedures needed for enterprises to introduce innovations on a regular basis.

### 4. Conclusion

Summarizing the results of our research, it is important to highlight the following aspects:

- initiatives aimed at dynamic growth of innovation development of the Russian economy should primarily refer the industries having the necessary innovative potential and state support. One of these industries is the oil and gas complex;
- the basis for implementation of innovation trends within the oil and gas complex should be the projects targeted to improve the efficiency of technologies utilized and focused on enhancement of internal resources, that will ensure the benefits of all the participants involved in the transition process, and at the same time ensure implementation of other sophisticated and long-term projects related with exploration and development of new oil and gas fields;
the key factor which determines successful implementation of innovation strategy targeted at the development of oil and gas enterprises concerns the reforms of their current management systems in order to help them accommodate to the management system based on the development and implementation of organizational and managerial innovations.

We assume that implementation of the given directions will contribute to the solution of the current problems and promote successful innovative development of Russian oil and gas enterprises and the economy on the whole.

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