Management of development and conservation of oil and gas fields

Viktor R. Chupin[1] and *Denis I.* Maisel[2]

[1]Irkutsk National Research Technical University, 664074, Lermontov str. 83, Irkutsk, Russia
[2] early. department of JSC "Verkhnechonskneftegaz", Bolshoy Liteiny prospect, 3, Irkutsk, Russia

Abstract. The purpose of the work is to develop a methodology for managing the development and conservation of fields of field gas-oil pipelines. The analysis showed that the solution of this problem is not paid attention, both on the part of designers and specialists in the automation of design solutions. Although this is one of the most important design problems, on the solution of which the rationality of capital investments depends, the optimality of subsequent periods of operation. Traditionally, this operation is performed manually. The designer, using his experience and intuition, outlines several alternative options, which are then evaluated automatically, including for reliability, hydraulic stability and operational controllability (for example, using the OLGA software package). Methods. For optimal control of these processes, a methodology for indicative and adaptive management of the development and conservation of the field is proposed, which allows taking into account the uncertainties that arise in the future stages of the field operation. At each stage of this technique, it is proposed to carry out a comprehensive optimization of the main field pipelines and use the technique of redundant design schemes with the solution of circuit-structural and circuit-parametric optimization problems, including the stages of conservation of deposits. The numerical experiments carried out have confirmed the high computational and economic efficiency of the proposed approach and method. Conclusions. The proposed method and its software implementation are an effective computational tool for justifying the route and parameters at all stages of management of the development and conservation of field gas-oil pipelines and is recommended for use in the practice of designing the corresponding pipeline systems.
Keywords. Field gas-oil pipelines. Redundant design scheme, methodology for indicative and adaptive management of field development and conservation.

1 Introduction

Management of oil and gas field development is a complex and multi-stage process, depending on the structural, geological, geophysical, hydrological and other features of the field, its remoteness from urbanized areas and geographical location [1-5]. Field development can be conditionally divided into two large blocks: a technological one, which deals with all issues of location of production and injection wells, their period of operation, productivity, stages of conservation; and the project itself, which deals with the placement of all gathering, separation, and preparation facilities for oil and gas for their further transportation through main pipelines, the organization of a reservoir pressure maintenance system, a network of main roads and access roads, the structure of energy and power facilities and cable lines.

Each oil and gas field has its own life cycle, which can be conditionally divided into four stages:
1. The stage of intensive development of the field, at which production wells are built up and put into operation for the extraction of oil products, injection wells for waterflooding and increasing the interstratal pressure of the field.
2. Stage of maximum production of oil products. At the same time, the volumes of water injected into the reservoir layers increase.
3. Stage of decline in oil production. At the same time, the volumes of injected water increase significantly and its pressure rises due to high-pressure injection pumping units (about 30 and above MPa).
4. The final stage. Production wells and flow pipelines are being mothballed. At the same time, more water is injected into the interstratal space of the fields.

Distinguishing the main of the field pipelines systems for transporting crude oil products and systems for supplying water to injection wells, one can graphically represent the life cycle of the field in the form of Figure 1. It is obvious that the time of the maximum production of oil products and the water used in this case does not coincide [6,7]. Peaks can occur with a difference of 30-50 years. And these systems could be considered and designed separately. At the same time, it is a single complex consisting of hydraulic circuits for supplying water, its movement through oil-containing soil layers, pipelines for a mixture of water, oil and gas. This factor is taken into account at all stages of the design, construction and operation of the field [8]. At the same time, the parameters of pipeline systems do not always correspond in time to the loads on water and oil products [7], which leads to a violation of the hydraulic stability of their work and to unnecessary deadening of capital investments. Obviously, designing field pipelines for maximum loads and then implementing them in stages, as well as preserving, is one of the ways to solve the problem.

Another option is to design and build pipelines in stages, first at the first stage of development, and then, as the load grows, to reconstruct them, increasing their capacities, and, if suspended, to phase them out of operation. The first option leads to a significant deadening of capital investments, the second - to continuous reconstruction. Although the reconstruction can be arranged in parallel before laying the pipelines. But this option is still costly. The optimal solution lies between the indicated options.

2 Methods

According to this scheme, the entire life cycle is divided into stages of development management and conservation of the field (for example, four stages) and conditionally optimal solutions of possible development options are increased.

Possible development options are formed on the basis of a field development plan, and take into account possible deviations of a technical and economic nature due to the uncertainty of forecasts [9, 10]. At this stage, the theory of fuzzy sets is applied and a fuzzy idea is formed not only about the volumes of produced oil products and water requirements, but also about others, including the cost indicators of construction and operation of field pipeline systems [20].

At the same time, the important and complex issues are the tracing of the listed PTNG and at the same time they are among the most difficult tasks of their design [7]. At the same time, in the current practice, these tasks are reduced to the analysis of one or two options for routes. However, it is not difficult to make sure that even these two options, when overlaid, generate a redundant diagram that already contains hundreds or more options for routing pipelines. It should be noted that all technological pipelines are laid along roads on one side, energy facilities on the other. This rule is enshrined in law and specified in the regulatory framework [1,2].

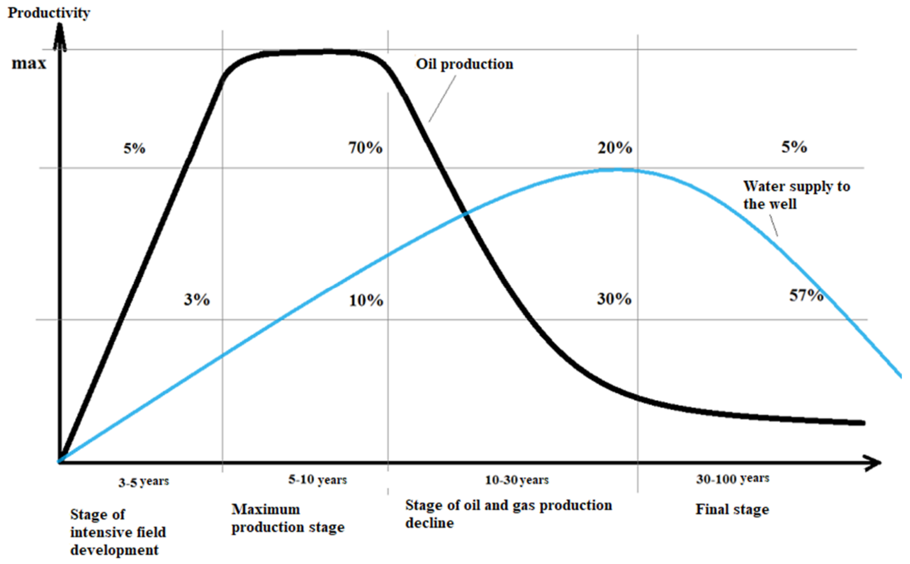

Fig. 1. Life cycle of oil and gas field

For each option and stage of development, the schematic-structural and schematic-parametric problems of substantiating the parameters of field pipelines are solved. When moving to the second stage of the system life cycle, it is considered that the first stage has been implemented and its reconstruction and construction of new pipelines are required in order to increase their productivity. It is also carried out for the third and fourth stages, taking into account the development and conservation of pipelines. After increasing the possible options for the development of the field, the best one is selected and the construction of its first stage is carried out. At this stage, on the basis of the obtained set of options for the life cycle of the system, a matrix of risks is formed and the option with the lowest technical and economic risks is selected for the construction of the first stage. As the first stage of construction progresses, target and planned indicators (indicators) are assessed, the costs of new equipment and structures are specified, the actual volume of oil products produced is determined and the intervals of their possible values are formed in the future. All these procedures are repeated. As a result, the principle of indicative and adaptive management of field development and conservation is implemented.

Among the first works on automating the selection of the pipeline route were the works of Professor P.P. Wart. and others [11], which formulated the criteria for the optimal choice of pipeline routes, and related mathematical problems of finding the optimal pipeline route between two points. On the basis of the Steiner-Weber problem [12], methods for finding the optimal route of a pipeline with branches are proposed. However, in such a setting, it was practically difficult to avoid possible restrictions on the terrain and other subjective factors.

The problem of choosing the optimal configuration and parameters of field systems of gas-oil pipelines according to the criterion of life cycle costs is proposed to be formulated as follows. Let a redundant scheme be given, including all kinds of connections between existing and new fields, clusters of wells, gas storage tanks, possible water intakes, and other structures. It is necessary to single out a subnetwork in the form of a tree in this diagram, which would meet the minimum total costs for the construction and operation of the PTG over the entire life cycle of the field. To solve this problem, a new approach is proposed, consisting of a complex iterative process, in which the implementation of each of the external (large) iterations is carried out in two stages. At the first stage, one of the possible trees of the initial approximation is built and the life cycle costs for this variant of the scheme are calculated. At the second stage, this solution is improved by sequentially replacing the branches of the resulting tree with chords (a chord is a section that is not included in the tree). After that, the transition to the next iteration is carried out, for which the best variant of the scheme obtained at the previous iteration is taken as an initial approximation, etc. until the condition of convergence of the computational process is met [13-17].

3 Numerical examples

As an example, consider the already existing "Verkhnechenskoye commercial field", which is located in the Katansky district of the Irkutsk region, 130 km to the South-East from the district center of Erbogachen. Figure 2 shows the main route of the crude oil and gas transportation system from the cluster wells to the oil and gas treatment point. Through flow pipelines, production from each production well is directed to an automated group of metering units, after which crude oil and free petroleum gas are combined into a manifold and sent to the transport system to the oil treatment unit. There are booster pumping stations with an outlet pressure of 3-3.6 MPa. High-pressure water conduits from distribution manifold blocks to injection wells are laid above the ground in thermal insulation.

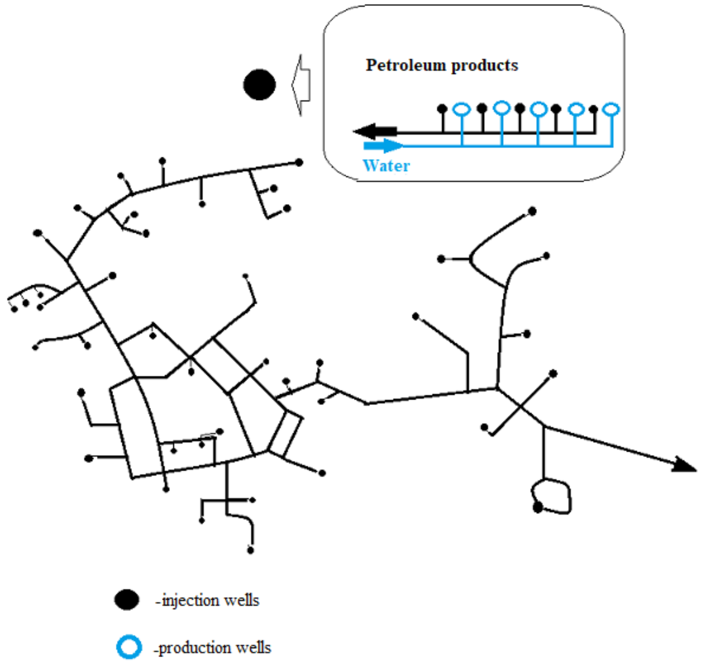

Fig. 2. Scheme of the field pipelines of the Verkhnechenskoye oil and gas condensate field

Taking into account the possible paths for the passage of oil and gas pipelines, a redundant scheme was outlined, which is shown in Figure 3

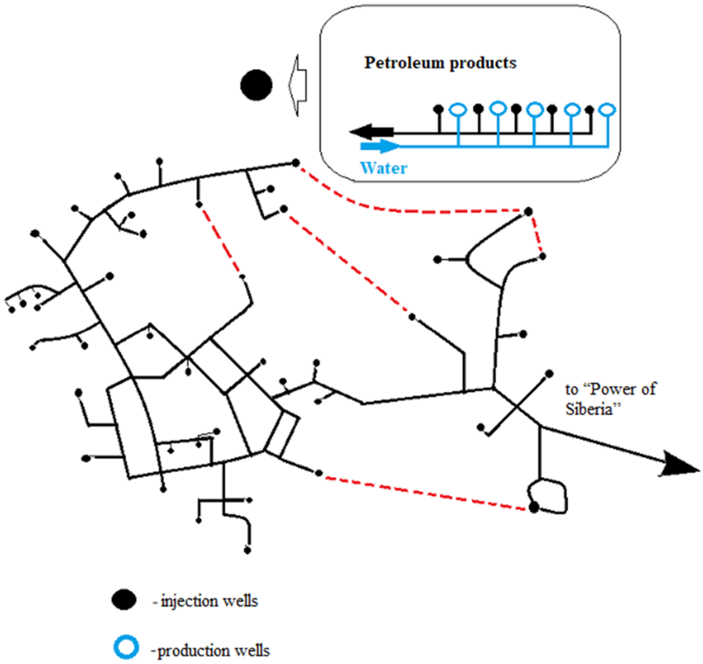

Fig. 3. Redundant layout of the field pipelines of the Verkhnechenskoye oil and gas condensate field

Applying the technique of finding the best trace in the form of a tree on a redundant graph [19], a variant was obtained, which is shown in Figure 4. This variant is 26% more economical in terms of life cycle costs than the existing one.

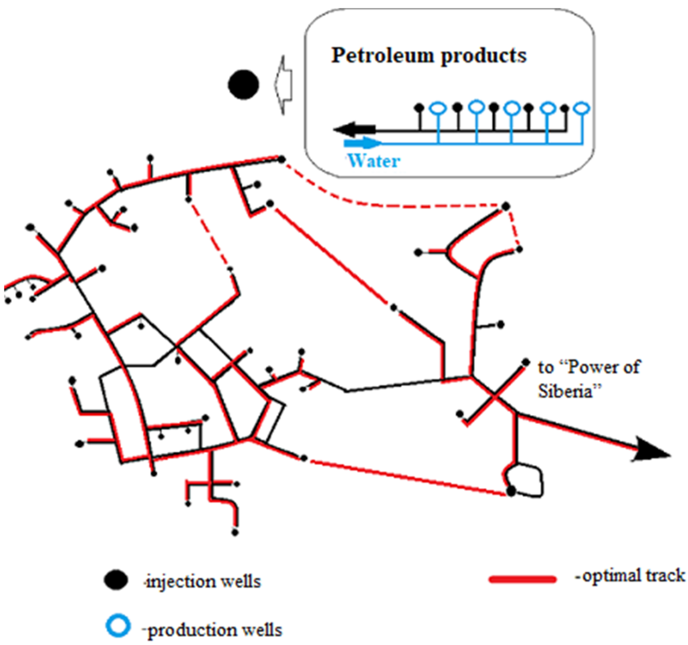

Fig. 3. Optimal layout of the field pipelines of the Verkhnechenskoye oil and gas condensate field

4 Conclusions and discussion

Optimization of development, reconstruction and conservation of oil and gas fields require special attention and should be considered at all stages of the life cycle. For optimal control of these processes, a methodology for indicative and adaptive management of the development and conservation of the field is proposed. At each stage of this technique, it is proposed to carry out a comprehensive optimization of the main field pipelines and use the technique of redundant design schemes with the solution of circuit-structural and circuit-parametric optimization problems, including the stages of conservation of deposits.

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