Digital support and evaluation of the effectiveness of geological and technical measures based on artificial intelligence systems

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Abstract. In this paper, the authors present the approbation of an artificial intelligence algorithm for digital support and evaluation of the effectiveness of the implementation of geological and technical measures in various mining and geological conditions. The object of the study was the deposits of deposit N, characterized by significant variability of parameters reflecting the filtration and capacitance properties of productive formations and their saturating fluids. With the help of the created system, maintenance of repair and insulation works at one of the wells of the object under study was successfully carried out. The presented main stages of the algorithm are universal and can be used in other fields to solve a wide range of problems in the development of deposits. The conclusion is made about the prospects of the direction «digitalization in oil production» and the relevance of the development of this topic in the context of the need to increase the pace of extraction of reserves.

1 Introduction

At the moment, most of the fields of the Russian Federation are being developed using geological and technical measures (GTM), the purpose of which is to increase well productivity, increase oil recovery, reduce the volume of produced water, and regulate the extraction of oil reserves. As the license area is drilled and new production wells are commissioned, the problem of planning and implementing effective GTMs is largely not manifested, but taking into account the current trend of depletion of large oil production facilities and the need to extract oil located mainly within complex geological zones, one of the most important tasks of achieving design indicators and rational use of subsurface resources is to reduce risks when making decisions management decisions, including those related to the design of operations [1-6].

Taking into account the active development of digital systems in the oil and gas industry, a promising direction for improving and implementing sound and relevant

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scientific and methodological approaches is the intellectual support of GTM planning and implementation procedures.

The essence of this technology is based on processing a large amount of data by various methods in order to find patterns of parameter changes, which can be divided into two interrelated groups [7-12]:

- Statistical parameters – parameters that do not change over time or change slightly due to the manifestation of various processes in the borehole-formation system; as a rule, the time interval for determining such indicators is significant, which imposes a number of difficulties for their successful application in interpreting various results.
- Dynamic parameters – parameters whose value changes over time under the influence of natural or technological processes; each of them has a typical trend of change and, for example, deviation from it may be a signal of incorrect operation of a well or underground equipment.

The need to use basic and advanced algorithms for GTM maintenance is due not only to a significant amount of geological and field data, but also to the nonlinear nature of changes in various indicators depending on a number of conditions, the most important of which, as practice shows, is to take into account the peculiarities of the occurrence of productive formations, depending on the proximity of the object of study to a particular oil and gas province [13-17].

2 Methods and materials

For the experimental implementation of digital support and evaluation of the effectiveness of measures to increase productivity, the N field was selected, located within the highly productive West Siberian oil-bearing area, in particular, in the northwestern part of the West Siberian Plain, in the area of its junction with the peripheral part of the foothills of the Northern Trans-Urals. The formation of deposits at the field occurred under conditions of high post-sedimentation tectonic activity, which led to a unified hydrodynamic system of horizons T_1, T_2.

This is confirmed by the marks of water-oil contacts of both layers, which are close in importance, and by a multitude of small low-amplitude faults, the main of which are the faults presented on the calculation plans. These faults divide the field into 3 blocks: Northern, Central and Southern.

Analyzing the results of GTM over the past 5 years at field N, it was found:

- An increase in the number of repeated fracturing operations in connection with the development of sections of the facility characterized by an uneven distribution of reservoirs.
- A multiple increase in the number of repair and insulation works and works to limit water inflow, which is due to the wear of the operational fund of wells, the destruction of the cement ring and other factors that have a negative impact on technical and economic indicators.

The general characteristics of the operational facility of field N are presented in Table 1.

Table 1. Summary geological and physical characteristics of productive formations T_1, T_2, KV of the N deposit.

Parameters	Productive layers		
	J_2tm, T_1	J_2tm, T_2	Pz, KV
The absolute mark of the OWC, m	-1808.3 – -1900.0	-1820.0 – -1900.0	-1900.0
Type of deposit	formation-arched, lithologically, stratigraphically and tectonically shielded		vaulted, lithologically shielded
Type of collector	pore		crack-pore
Oil capacity area, thousand m^2	58401	20306	753
Average total thickness, m	22.0	29.7	60.3
Average effective oil-saturated thickness, m	1.9	3.2	0.9
Porosity coefficient, fractions of units.	0.174	0.173	0.170
The coefficient of oil saturation of the reservoir, fractions of units.	0.536	0.554	0.620
Permeability, mm^2	0.007	0.020	-
The coefficient of sandiness, fractions of units.	0.15	0.28	0.03
Dismemberment, units.	2.4	2.8	1.5
Initial reservoir temperature, ºC	79-80	-	-
Initial reservoir pressure, MPa	18.5 – 20.3	18.8 – 20.2	20.0
Viscosity of oil in reservoir conditions, MPa·s	1.35	1.12	2.10
Oil density in reservoir conditions, g/cm^3	0.739	0.746	0.726
Oil density in surface conditions, g/cm^3	0.843	0.843	0.838
The volume coefficient of oil, fractions of units.	1.19	1.20	1.22
Oil saturation pressure with gas, MPa	9.6	10.4	11.1
Gas content, m^3/t	71	85	78
Viscosity of water in reservoir conditions, MPa·s	0.4	0.4	-
Water density in surface conditions, g/cm^3	1.008	1.009	-
Displacement coefficient (by water), fractions of units.	0.413	0.427	0.479

Analyzing the dynamics of falling oil flow rates, increasing water content and liquid flow rates since the beginning of industrial development of the field, the following has been established: anhydrous oil production was carried out only in the first year of operation of the field and amounted to 15 thousand tons or 0.8% of the accumulated. Since 2005, there has been a gradual increase in the share of water in the extracted products. At the time of the study, the water content in the Northern Block of field N is 91.6%, in the Central Block – 92.4%. The extraction from the initial recoverable reserves achieved at the field is 75%, which is high enough for low–productive Tyumen deposits. The oil-saturated reservoir of the deposit has a lenticular structure, a thin-layered structure (69% of interlayers up to 1 m) and is characterized by high zonal and layered heterogeneity. In such conditions, the forcing of liquid withdrawals, widely used at field N, is a justified method of intensifying oil production, allowing the stagnant zones of the formation to be put into operation, but requiring, however, careful control in order to avoid cone formation and breakthrough of

the injected waters. In addition, the development of a low-permeability reservoir is impossible without the use of hydraulic fracturing, cracks from which are periodically opened by previously unidentified water-saturated lenses in the inter-well space. Another factor that inevitably leads to faster rates of flooding is the presence of a small number of thin, highly permeable interlayers in the section of the layers of the Tyumen formation (with an overall low permeability), which quickly become channels for active water filtration from injection wells to production faces, this fact is confirmed by numerous tracer studies at analog deposits of the district. The tightening (breakthrough) of the injected waters at field N is in some cases confirmed by field and geophysical studies.

For example, the flooding of the T_2 formation in well XX38 was confirmed by repeated registration of gamma logging, which shows a positive increment due to the influence of the radiogeochemical effect against the washed intervals (Figure 1).
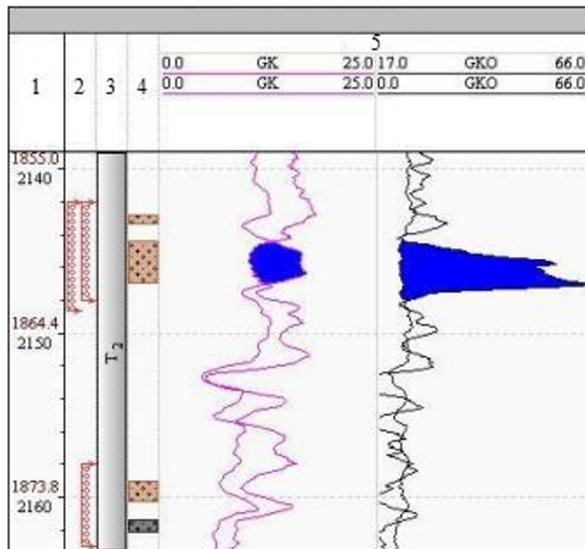
Fig. 1. An example of registration of a breakthrough of injected waters based on the results of the PGI. Well XX 38: 1- depth; 2- perforation; 3- formation; 4- saturation; 5- logging.

This effect consists in the fact that during the displacement of oil by water in the front part of the displacement front, the concentration increases and the isotopic composition of natural radioactive elements changes. The approach of radioactive fringing of reservoir waters to the faces of oil wells and the adsorption of radium salts on the cement ring of wells is accompanied by an increase in the natural radioactivity of flooded formations. The washed intervals are located in the upper, most permeable part of the T_2 formation.

It should be noted that the above-mentioned water supply factors are complex in connection with the traditional support of the development of deposits in the Tyumen formation (geological factors) and the irrationality of approaches to planning and further implementation of the RIW (technical and technological factor).

3 Results and Discussion

The share of inefficient GTMs in this area in 2022 at the Mansingyan field is almost a third of the total number of completed well operations (9 units). The increase in this indicator compared to 2021 was 5%. Repair and insulation work was considered unsuccessful under the following circumstances:

- The well did not work out the guaranteed period.
- According to the results of repeated PGI, partial isolation of the water supply was established (the marked interval works less intensively).
- The insulating screen is broken due to various reasons.
- After the PGI and RIW, the impossibility of further operation of the well was established due to the achievement of the maximum water content of the products.

The selection of candidate wells for repair and insulation work includes a set of various studies aimed at registering deviations in the operation of the well due to the ingress of third-party waters into the extracted products, unforeseen by the mode of its operation.

It consists in determining the discrepancy between the oil flow rate and the water content in the well's products (the degree of its flooding), assessing the discrepancy between productivity and the saturation of the exploited reservoir, the results of which ultimately lead to a feasibility study of the RIR.

An integral part of RIR planning in field conditions is the conduct of a number of field geophysical studies in order to identify violations in the operation of wells (profile and composition of fluid inflow from the reservoir in non-resonant wells, water flow intervals, etc.).

In addition, PGI is used to assess the quality of the conducted RIWs,

which allows us to say the following: the results of field geophysical surveys of wells determine the need for insulation work and are the final stage of monitoring the technical condition of the well after repair work. The successful determination of the nature of the water inflow guarantees the accurate selection of the necessary techniques and technologies to eliminate it. The correctness of the selection of candidate wells is assessed by geological and technological success.

Geological success is expressed by the following formula:

$$G_1 = \frac{\Delta q_1}{\Delta q_2} \cdot 100\% \qquad (1)$$

Where Δq_1 – the actual increase in oil obtained after putting the well into operation, t/day; Δq_2 – estimated increase in oil, t/day.

Technological success is determined by the formula:

$$T_{1.} = \frac{N_1 - (N_2 + N_3)}{N_1 - N_3} \cdot 100\% \qquad (2)$$

Where N_1 – the number of RIWs performed, borehole operations; N_2 – the number of unsuccessful RIWs, well operations; N_3 – wells that are being withdrawn.

Let's consider the results of digital support and evaluation of the effectiveness of GTM on the example of the producing fund of wells of the N field. As of 01.01.2023, 47 production wells are in operation (90% of the production fund). To reduce the information processing time, historical data on wells were taken for the last 5 years of their operation (2018-2022). The 1st stage of the algorithm was to download historical data on the operation of wells of the producing fund of the object under study and calculate the dynamics of oil drop and increased water content of products. After that, the parameters were compared with critical indicators and an array of data was created with wells that could potentially become candidates for RIW (there may be a defect).

Based on the results of the algorithm, the system identified 12 wells. The second stage of the algorithm is to prepare the array for loading into the created artificial intelligence (AI) model and implement forecasts of oil and water flow rates taking into account 7 basic scenarios. The results of forecasting the oil flow rate for one of the scenarios using the example of well 113 are shown in Figure 2.
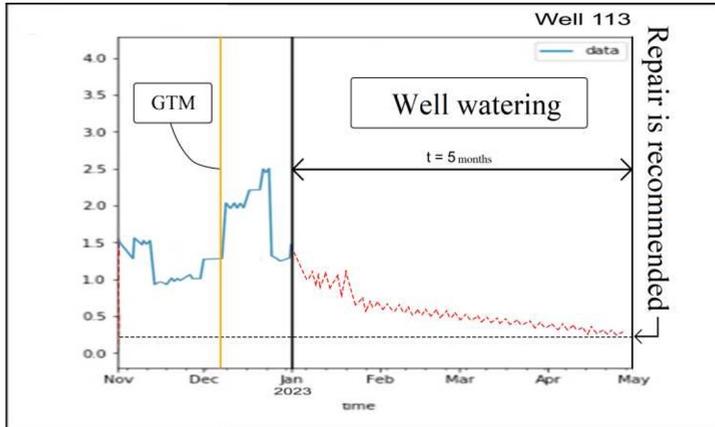
Fig. 2. Forecast of oil flow rate for well 113 using the developed AI model.

The output data of the algorithm in the conditions of the producing well fund of field N is a list of potential candidates for the RIR, ranked by the average success rate of the work.

4 Conclusion

Wells of the first group have the highest percentage of RIW success in various production processes. Wells belonging to the first and second groups are recommended for planning and further implementation of the RIW. Wells belonging to the third group are recommended for RIW planning with additional studies, after which it is possible to conduct RIW. For wells belonging to the fourth group, it is recommended to monitor the further dynamics of changes in oil and water flow rates over time and recommended studies to establish the inflow profile. The obtained qualitative and quantitative results of testing the algorithm for selecting candidate wells for RIR allow us to judge the following.

Thus, digitalization of the well selection process, implemented at the junction of a machine learning system for processing field data and forecasting, together with increasing the efficiency of field operation, is an important area for further research. The created algorithm for monitoring wells for conducting RIWs will allow subsoil users to make management decisions correctly in conditions of a limited amount of information. Due to the possibility of remote analysis of the producing well stock, the developed system opens up new opportunities and technologies for effective GTM planning.

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