Research on an optimization of uncertainty in oilfield development planning

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Abstract: In the development of extra-high water cut in the oil field, uncertainties in key indicators of potential, new technologies, and benefits are increasing in the development planning optimization process of influencing factors, such as the variety of displacement methods, the deterioration of development targets, the increase in the development field, the fluctuation of international oil prices, and so on. In the analysis of many uncertainties in the oilfield development planning, an integrated platform on oilfield data mining and an analysis method are established on the based on the optimization idea. Multi-objective uncertainty analysis method for development planning was established on the base of technical optimization, economic optimization and integrated optimization. Using an improved intelligent optimization algorithm, the optimal algorithm of the multi-objective programming optimization model is studied, which can solve the difficult problem of multi-objective, multi-stage, multi-parameter optimization simulation. By applying the uncertainty analysis method, it is possible to predict changes in oilfield production under different probability. These methods can provide scientific decision-making basis for oilfield development and production management, which can formulate oilfield optimization plans for reserves, production, investment, cost, and benefits.

1. Introduction

Oilfield development planning is a series of comprehensive plans for technical decision-making and production and business decision-making in oilfield development. It is a complex system engineering that integrates multiple disciplines and technologies[1]. During the planning period, rational optimization of the workload of oilfield production and production-increasing measures is an important part of oilfield development planning, which will affect the long-term development of oilfields and the success or failure of oilfield development. After the oilfield enters the ultra-high water cut period, due
to the influence of diverse displacement methods, poor development targets, increased development areas, and fluctuations in international oil prices, the uncertainty of core indicators such as the potential for planning optimization, new technologies, and benefits has increased. Due to factors such as geological characteristics and development methods[2], the understanding of oil reservoirs is vague and uncertain, which causes many uncertain factors in the process of oil field development planning. This makes the increase in oil production in the oilfield development planning plan very uncertain.

By analyzing the many uncertain factors in oilfield development, researching and establishing the quantitative representation method of uncertainty planning indicators, and establishing the uncertainty optimization model of zoning planning. Use this model to solve artificial intelligence based on a hybrid algorithm of genetic algorithm and Monte Carlo simulation theory, and quantify the risk probability of the solution. It solves the complex problems of large simulation calculation of multi-structure, multi-stage, and multi-parameter optimization model in oilfield development[3]. By carrying out research on optimization methods for oilfield development planning based on uncertainty, more reliable and robust optimal design results can be obtained. The purpose is to introduce uncertainty planning design ideas and methods into oilfield development planning and improve the level of oilfield development.

2. Uncertainty prediction methods of development planning indicators

2.1. Determination of key indicators affecting planned output
Considering that the uncertainty in the development plan is objective, random variables are used to describe the value of the index, and its characterization is given by means of mathematical statistical analysis[4]. First, for uncertain indicators with data, the type of random variable distribution is known, and the parameters of the distribution need to be determined by the observation data; determine the probability distribution type of a random variable from the observation data, and determine its parameters on this basis; it is difficult to determine the theoretical distribution form of the random variable from the existing observation data, so define an experimental distribution[5]. The second is that there are no indicators, or the sample of indicator data is small, and the distribution type cannot be accurately determined by quantitative methods. The distribution type and its parameters can be given by experts.

2.2. Quantification of uncertain indicators
The decline rate of old wells follows the method of “split well pattern and production wells of the year”. Statistic changes in the decline rate over the years according to branch plants, well patterns, and annual production wells. According to the four methods of basic well pattern, primary well pattern, secondary well pattern and tertiary well pattern. Based on the production well of the year, the historical development data of batch wells of the year is traced forward in the development database. Then, the West Pachev water drive law curve (according to the fixed fluid method) is used to predict the development indicators such as the decline rate of production wells in different years under different well patterns. Through the above steps, a two-dimensional matrix of decline rates can be obtained, that is, data samples in the time dimension and the dimension of the number of times of the same well in different well patterns and years. Combining expert experience and the research results of decline rate, using the uncertainty measurement theory and expert experience, it is comprehensively determined that the type of distribution function is a normal function, and the decline rate range is 6-8%.
3. The establishment of an optimization model for uncertain planning

For a complex decision-making problem such as oilfield development planning, after the oilfield’s production task target is determined, the mathematical model of output optimization is established for each planning unit through the method of output decomposition. This can simplify the complexity of oilfield development planning to a certain extent[6, 7]. The oil production composition of the third production is mainly divided into five major parts: oil production in the polymer injection block, oil production in new wells, blank water flooding oil production, production in the test area and oil production in the new investment block. Among them, the oil production from the polymer-injected blocks, the oil production from new wells, the blank water flooding oil production and the test production are given as known in the knowledge base. The part that can be adjusted each year is the oil production of the new betting block. The oil production of the new betting block can be arranged through different injection times and different displacement methods (ASP or polymer flooding). How to optimize the injection time of the block and which displacement method to adopt is the main problem of optimization. For this kind of block investment non-investment, upper polymer flooding or ternary, and when to invest, select the 0-1 plan to analyze it[8]. The planning optimization model is as follows:
The completion is 1, there is also a risk of output completion. The content of each part is organically combined to form a complete set of algorithms, which can effectively solve the multi-objective optimization model with uncertain parameters.

4. Model solving based on artificial intelligence algorithms
Aiming at such a problem, we plan to use a combination of random search and Monte Carlo simulation to find a feasible solution for the model. The specific search ideas are: starting from an initial solution, each step finds a better solution in the current neighborhood, so that the objective function is gradually optimized until no further improvement is possible.

The content of each part is organically combined to form a complete set of algorithms, which can effectively solve the multi-objective optimization model with uncertain parameters.

5. Optimization results and analysis of the planning scheme
Apply the above research methods to plan and optimize the design of T oilfield, among them, tertiary oil recovery planning uses a combination of random search and Monte Carlo simulation to find feasible solutions to the model. In order to ensure that the chances of random sampling in the new blocks of each plant are relatively balanced, the number of random simulations is set to 10000. The production targets of 20, 40, and 60 are optimized on an annual basis.

From the results of optimization of different output targets, the increase rate of 20 is the most likely to complete the target, and the probability of completion during the planning period is 0.991. The production plan with an incremental scale of 40 can basically complete the target from 2013 to 2015, and the probability of completion in 2016 and after is 0, and the risk of completing the production target is very high. The plan of increasing the scale by 60 was basically completed from 2013 to 2014, and the production target requirements were not met in other years, and the risk is very high. According to the results of the production probability analysis of the program in the incremental oil recovery scale 40, the production variance and risk index of each year of the program increase year by year, and the risk of the program also increases year by year. It shows that although the probability of project output completion is 1, there is also a risk of output completion.
Figure 2. Planning and optimization uncertain solution algorithm flow

Table 2. Optimization results of different production targets for tertiary oil recovery

| Increment | Probability of completion of production in each year (%) | Planning period | Probability of completion |
|-----------|----------------------------------------------------------|-----------------|----------------------------|
|           | Probability of completion                                  | Max             | Min                         |
| 20        | 2015 2016 2017 2018 2019                                  | 1 1 1 0.996 0.994 0.991 | 1 0.999 0.244 0 0           |
| 40        | 2015 2016 2017 2018 2019                                  | 1 1 0.971 0 0 | 1 0 0 0 0                   |
| 60        | 2015 2016 2017 2018 2019                                  | 1 0.826 0 0 0 | 0.014 0 0 0 0               |

Figure. 3 The distribution frequency of tertiary oil production by year

6. Conclusion
(1) The fluctuation of development indicators in the later stage of oilfield development has great uncertainty. The prediction method established based on the uncertain research of development indicators and related influencing factors can provide a probabilistic basis for planning, decision-making and optimization.
(2) For the multi-structure, multi-stage, risk and multi-objective in the later stage of development, the uncertainty development planning optimization model can provide a solution set and probabilistic decision-making basis for planning and decision-making. At the same time, for the planning model of "multiple input parameters, multiple constraints, and multiple output results", a hybrid solution of artificial intelligence algorithms such as stochastic programming, genetic algorithms, and neural networks is required.

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