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Integrated Production Optimization from a Mature Oil Field Using Artificial Gas Lift by Considering Nonlinear Operational Constraints

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Abstract

Production optimization is one of the most complex activities from the operational point of view due to the effect of the uncertainty of physical rock and fluid properties, errors, and the lack of measurement tools. Production optimization is defined based on a set of activities that measure and collect data to make optimized management decisions. The purpose of this study is to optimize the production of a mature hydrocarbon field located in the south of Iran with consideration operational nonlinear constrains, and by defining four different scenarios. Cumulative oil production and net present value were used to select the best production scenario from this oil field. The results of simulation and optimization showed that in the current situation of the field, gas injection is prioritized with respect to artificial gas lift with gas due to the reduction of cost and time, as well as an increase in current net present value. Although, using an artificial gas lift method, the amount of cumulative oil production is higher than the gas injection method, but due to increased costs, it will have less net present value.

Keywords: Hydrocarbon Field, Nonlinear Constrains, Optimized Production, Artificial Gas Lift, Optimization.

Introduction

Production optimization is one of the most complex activities from the operational point of view due to the effect of the uncertainty of physical rock and fluid properties, errors and the lack of measurement tools. Production optimization is defined based on a set of activities that measure and collect data to make optimized management decisions. There are many effective factors which determine the ultimate recovery of the hydrocarbon from the oil field including production rate, number of production wells, gas or water injection rate, number of injection wells, location of production and injection wells, and individual wells tubing head pressure, just to name a few. As time progresses, the production rate of field declines as a consequence of reservoir energy depletion. In this situation, it is crucial to determine the optimum production criteria from the reservoir in such a way to result in maximum oil production, and minimum water production during lifetime of the field [1-11].

Methodology

The purpose of this study is to optimize oil production of a mature hydrocarbon field located in south of Iran with consideration operational nonlinear constrains, and by defining four different scenarios. The studied scenarios are as follow: 1) continue the production from the field with gas injection and without considering operational constrains, 2) continue the production from the field by considering operational constrains and the gas injection through gas injection wells, 3) continue the production from the field without gas injection and by considering operational constrains, 4) continue the production by applying artificial gas lift and stopping the gas injection through gas injection wells by considering operational constrains. The nonlinear constrains considered to optimize the production are minimum individual well production rate, maximum tubing head pressure and maximum surface facility capacity to separate produced fluids. The simulation of integrated model is done for 16 years in order to be able to obtain optimum production rate of existing wells to maximize the net present value. In this regard, cumulative oil production and net present value were used to select the best production scenario from this oil field. In order to perform the required reservoir simulations to optimize the oil production by considering net present value as an objective function, an actual carbonate reservoir in south of Iran was selected. The field has been produced over 17 years and currently its production has been reduced due to nonoptimum production conditions. The geometry of the field has been modeled using corner-point geometry. This model contains 28×115×83 grid blocks, of which 156631 blocks are active. Figure 1 shows the simulated reservoir model for this study. The field contains 27 production and injection wells that are completed in the oil column and are active. The production wells operate under constant-rate production constraints. After falling below a limiting bottom hole pressure, they will switch to a BHP-constraint. The detailed information about the field 3D model and its rock and fluid properties is given in the paper. surface facility is simulated using GAP software.

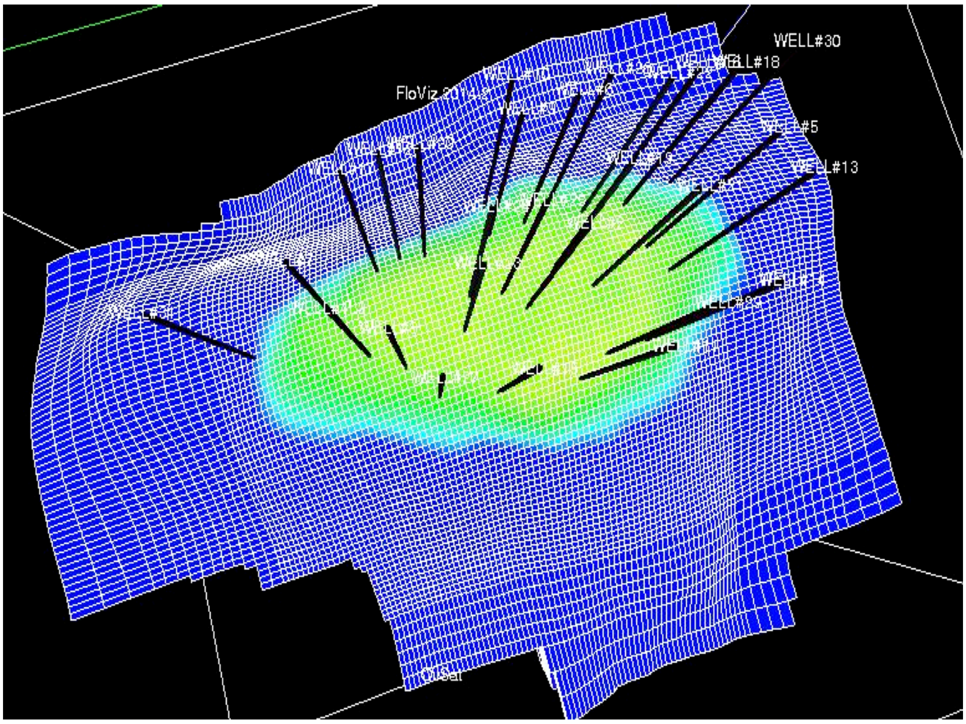

Figure 1. Simulated Model

In this study, the reservoir section of the integrated model is simulated using Eclipse software; moreover, the wells are modeled using Prosper, and the surface facility is simulated using GAP software.

Due to complex nature and existence of nonlinear constrains, it is required to apply a robust method in order to be able to maximize the objective function. In this regard, sequential quadratic programming (SQP) is used due to its capability to solve the optimization problems with nonlinear constrains. Sequential quadratic programming is a powerful and an iterative methodology to optimize nonlinear constrained problems. SQP is used on mathematical problems in which the objective function and the constraints are differentiable. The algorithm solves the optimization problem by constructing a sequence of quadratic optimization subproblems of the objective function subject to a linear system of the linearized constraints. The SQP method reduces to Newton's method for an optimization problem without constrains. For the problem with only equality constraints, the method is equivalent to applying Lagrangian method. However, for the problems with inequality constraints in addition to equality constraints, the methodology is equivalent to apply Newton's method to the Lagrangian function or, in general, Karush–Kuhn–Tucker optimality conditions. After performing required simulations and optimization, the optimum condition of production from the field under given nonlinear constrains could be obtained [12-15].

Results and Discussion

An integrated model of the field made for this case study was simulated for 16 years. Cumulative oil production for the first case scenario after simulation is 810 million barrels of oil eventually withdrawal from the field. After one year of production, a sharp drop in the rate of production of each well is visible to the end of simulation period. This reduced production is a result of not applying appropriate control conditions on operating wells during production.

The cumulative oil production for the second scenario after simulation is 865 million barrels of oil which is 55 million barrels of production more than first case. This increased production is due to applying operational limits on production.

The cumulative oil production from field during the 16 years reached to 660 million barrels in third scenario. This reduction could be due to stopping gas injection and reducing the energy available for oil production.

Finally, the cumulative oil production from field with artificial gas lift is estimated 870 million barrels.

The current net present value of each of the scenarios 1 to 4 respectively is equal to 718.98, 850.65, 558.62, and 837.92 million which is obtained for 16 years of simulation. So the second and fourth scenario is the best option. It is noteworthy that although applying artificial gas lift increases the field production, it needs to spend more time and money, the second scenario compared to the relatively better profit of the fourth scenario, this scenario will be the primary choice of scenario.

Conclusions

The results of simulation and optimization showed that in the current situation of the field, gas injection is prioritized with respect to artificial gas lift with gas due to the reduction of cost and time, as well as the increase of current net present value. Although, using an artificial gas lift method, the amount of cumulative oil production is higher than the gas injection method, but due to increased costs, it will have less net present value. In addition, the results of optimization shows that by applying appropriate constrains during production, the rate of production decline could be reduced, and consequently the total oil production could be increased over lifetime of the field. Although oil production without applying constrains maybe useful in short time, it is not optimum over the life of the field due to reduced net present value.

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