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Review article

Infill well placement optimization in coal bed methane reservoirs using genetic algorithm

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ABSTRACT

The unprecedented growth of coal bed methane drilling, expensive coal bed water treatment, and low gas rates urge the integration of petroleum engineering and optimization disciplines to meet production goals. An integrated framework is constructed to attain best-obtained optimal locations of infill wells in coal bed methane reservoirs. This framework consists of a flow simulator (ECLIPSE E100), an optimization method (genetic algorithm), and an economic objective function. The objective function is the net present value of the infill project based on an annual discount rate. Best obtained optimal well locations are attained using the integrated framework when net present value is maximized. In this study, a semi synthetic model is constructed based on the Tiffany unit coal bed data in the San Juan basin. The number of infill wells in reservoir resulting in peak production profit is selected as an optimum number of the infill drilling plan. Cost of water treatment and disposal is a key economical parameter which controls infill well locations across the reservoir. When cost of water treatment is low, infill wells are mostly located in virgin section of the reservoir where reservoir pressure is high and fracture porosity is low. Water content in fractures does not play a significant role on infill wells selection when water treatment and disposal is a cheap operation. When cost of water treatment is high, infill wells are mostly located on the transition section between virgin and depleted sections of the reservoir to minimize water production.

Contents

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1. Introduction

Coal bed methane (CBM) reservoirs contribute to a considerable proportion of the gas supply in countries having large reserves of coal. In the United States, coal bed methane production is almost 10% of the total gas production. In Australia, CBM activities are young however it has been a fast growing industry. Liquefied natural gas (LNG) plants projects for gas export to China and Japan has raised the CBM gas price in Australia [1].

Water residing in cleats maintains reservoir pressure and keeps methane in adsorbed phase. To produce gas, it is required to pump the water out to create sufficient pressure gradient in the reservoir. Produced water is brought to surface along with gas and a decision should be made for the fate of the water. The management decision on the water depends on the volume of the water and the water composition. Generally coal bed wells produce more water than conventional gas wells. The average water rate production from coal wells in Queensland, Australia, is 20,000 L of water per day per well and can significantly vary from only a few hundreds of litres up to hundreds of thousands of litres per day per well [2]. Over time, the area around wellbore is drained from water and the volume of the water coproduced with methane at surface is reduced. When coal bed (having a permeability more than 100 mD) is hydraulically connected to a strong aquifer, the water discharged from the coal bed can be easily replaced with aquifer water making dewatering operation inefficient [3]. This can result in premature field development failure. Generally coal water possesses a better quality compared to the produced water from conventional oil and gas wells [4]. Normally the total dissolved solids (TDS) in coal bed water ranges from 200 (mg/L) up to 170,000 (mg/L) and changes from one basin to another one. The coal bed water with 200 (mg/L) and 170,000 (mg/L) of solids concentration are classified as fresh and saline respectively.

Prior to making any decision on the fate of the produced water, the water should pass adequate treatment to make sure that it meets all the environmental and governmental requirements for reuse or disposal purposes. The choice to reuse or dispose the water largely depends on the water composition and the treatment cost. Treatment cost can vary from 0.04 $/STB to 2 $/STB [5]. If the produced water is fresh, it can be used for the water supply after careful treatment. Also the water can be used for irrigation in local areas. When the treatment cost and water salinity are high, the coal water is reinjected into underground formations where formation water is compatible with injected water. Tough environmental regulations prohibit water disposal in surface pits which was previously a normal practice.

The gas production performance of coal bed methane reservoirs is different from conventional gas reservoirs in terms of the dewatering period at the early life of the reservoir. Dewatering period results in significant water production while gas rate is negligible. Gradually the gas rate is built up and reached to the peak production rate. The peak gas rate and the time required to reach the peak gas rate play important roles in economics of CBM plays. Both gas rate and ultimate gas recovery can be improved using the enhanced techniques. Carbon dioxide injection, nitrogen injection and thermal gas recovery techniques have been introduced to increase the gas rate from coal beds [6–8]. The term infill drilling is referred to drilling new wells in the reservoir to boost gas production rate. Infill drilling can be viewed as an option to produce gas more quickly and therefore shorten the production time of the reserve. Shortening the production time is beneficial in terms of time value of the money even if the ultimate recovery remains unchanged. The additional cost associated with drilling new wells in the coal bed might be justified when the time value of the money is calculated on a discounted rate. An ideal development plan for CBM reservoirs is to maximize gas production while water production is minimized [9]. Unlike conventional oil and gas reservoirs, well interference in coal bed methane reservoirs has a constructive impact on the production response of the reservoir. In coal bed methane reservoirs, wells help each other by the interference and drain fractures from water more efficiently and consequently gas desorption from coal matrix is facilitated.

To implement a successful infill drilling program in a CBM play, it is required to investigate the production performance of the coal bed, geological description of the coal bed, infill drilling design, and the economical feasibility of drilling new wells [3]. Having an accurate geological picture of the reservoir and a comprehensive infill program enable the operators to economically evaluate the success or failure of the project. Since the infill project increases the gas recovery and also accelerates the reserve production, the economic analysis should be carefully performed on a discounted rate [10]. Once the profit associated with infill project justifies drilling new wells in the reservoir, the infill project comes from the design phase to the operational phase.

In this study, a reservoir flow simulator (ECLIPSE E100), an economic objective function, and an optimization technique (genetic algorithm) are integrated to develop an economic assessment tool to design an optimal infill drilling program. The coal bed methane simulator (ECLIPSE E100) is coupled with MATLAB while the objective function is the net present value of infill project. The best-obtained optimal infill well locations and also the optimum number of the wells are determined using this framework. Infill well locations correspond to the maximum net present value are selected as optimum locations. Then the role of water treatment cost on infill wells distribution is investigated.

2. Methodology

An optimal CBM drilling plan can be achieved through intelligent use of a flow simulator in an integrated framework updating well locations to maximize project profitability. Fig. 1 is the schematic of the integrated framework consisting of three main components; the reservoir model, the optimization model, and the economic model. This framework should contain predictive information about the key operational parameters including production data, well locations, and project's profit. The geological map of the coal bed and reservoir data are incorporated into a flow simulator as input data and production data are generated using a simulator while well locations are distributed across the coal bed using an optimization tool for discrete reservoir models. The project's profit and the quality of infill well locations are evaluated using an economic objective function.

2.1. Reservoir model

The reservoir model in this study is created based on the available data from the Tiffany Unit ECBM N_2 pilot study operated by Advanced Resources International Unit [11]. The Tiffany unit is a pilot study of enhanced coal bed methane recovery using nitrogen injection. The Tiffany unit is located in San Juan basin in Southwest Colorado and Northwest New Mexico which in 2000 accounted for 80% of CBM activities in the United States [12]. Primary gas production is from the Fruitland formation and coal rank is described as medium volatile bituminous with an average thickness of 47 ft with an average depth of 3040 ft.

We constructed the ECLIPSE model from the available topographical map of the area [13]. The created ECLIPSE reservoir model for the Tiffany area is shown in Fig. 2. There are 45 wells drilled in this section of the coal bed and all wells placement are based on standard five-spot pattern. The model is made of $73 \times 37 \times 4$ grid