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Optimization of integrated production system using advanced proxy based models: A new approach

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ABSTRACT

Hydrocarbon production can be elevated using gas lift especially when reservoir pressure declines throughout reservoir life. Specific amount of compressed gas distributes among wells during a gas lift operation through the orifice installed on the tubing string. Since the available gas is usually less than the amount of gas needed to obtain the maximum rate of extraction in each individual well, it is essential to determine and inject the optimal amount of gas into each well. As reservoir conditions alter over time, these optimal rates change during the life of the field; additionally, the recent and periodic fluctuation in oil price has implied a need for an economical and reliable alternative to the former discontinuous optimization methods. Therefore, to effectively increase the profit of the project and reach true potential of any hydrocarbon field, formulation of a practical dynamic optimization scheme is inevitable. Dynamic models often use integrated models of upstream and downstream systems. Since running commercial simulation software is very time-consuming, look-up tables (interpolated values) are used to reduce the laboriousness; however, the interpolations can lead to miscalculations. This study proposes a fully-dynamic novel approach to optimize a gas lift system by implementing proxy models to minimize an objective function, being the resource usage. First, machine-learning based proxy models trained with the datasets from simulation software are used. Later, the genetic algorithm GA is coupled to the model and is performed alongside the well proxy model to optimize the gas injection rate by evaluating the fitness function being net present value (NPV). The whole procedure is repeated iteratively over many time steps throughout the life of the reservoir enabling near real-time optimization. The results assert that the proposed dynamic scheme is able to fully understand the relationship between the different components of the production system. By imitating them it is thrived to optimize the gas lift operation dynamically over a specific time period. Moreover, the model is compared and verified by a semi-dynamic model reported in the literature.

1. Introduction

Gas lift, as an artificial lift technique, implements external pressurized gas to lighten the displaced oil, causing an increase in flowing fluid rate. As the total available gas is limited, the amount of gas injection in each well must be specified. Thus, there are two possible approaches to distribute the available gas and perform the operation so as to get the optimum results.

In conventional or static optimization approach, the optimizations are based on the gas lift performance curve (GLPC) for all the wells in the field. To achieve the optimal point of the curves, different tools such as genetic algorithm, sperm whale algorithm and support vector machine (SVM) are applied (Ray and Sarker, 2007; Behjoomanesh et al., 2015; Mahdiani and Khamehchi, 2015; Ebrahimi and Khamehchi, 2016a, 2016b). Nevertheless, such optimizations neglect the process facilities and the changes in reservoir and well conditions.

Considering the changes in underground and surface conditions over time, hence, updating the condition of the gas lift operation, is very essential in order to attain optimum production rate. It is possible to apply the best scenario to enhance the production rate by considering field scale conditions, and including upstream and downstream, i.e. integrating the whole production system (Gutierrez et al., 2007; Mahmudi and Sadeghi, 2013;

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Ghassemzadeh and Pourafshary, 2015).

In order to optimize a gas lift system, Gutierrez et al. (2007) introduced the integrated model including reservoir and processing components. Using results of variety of multiphase flow simulators, they built different look-up tables and applied those to a dynamic optimization scheme that greatly enhanced field planning strategies in the area of reservoir management.

Mahmudi and Sadeghi (2013) proposed their model which was a combination of genetic algorithm and the Marquardt optimization method to optimize the long-term economic of a gas lift operation. They divided the production lifetime into different number of consecutive operation intervals with different parameters and the noticeable result they came across was that increasing these intervals leads to more accurate optimization process.

Ghassemzadeh and Pourafshary (2015) studied the effect of gas lift initiation time on the reservoir life and showed that the initiation time has noticeable impact on the optimization procedure.

These studies try to incorporate the conventional criteria along with the continual consideration of reservoir and well conditions. Although the integrated method is much powerful and valuable, its accomplishment has its own drawbacks such as computational burden. In order to overcome these difficulties, there are two possible solutions: to tabulate and interpolate the necessary parameters, or use proxy models.

Proxy techniques, which their popularity has grown substantially in recent years, are simplified models of a highly complicate process. Although their high computational efficiency is proved, the use of proxy models is rarely seen in production optimization, whereas, usage of proxy models has increased recently in other fields of petroleum engineering.

Shahab D. Mohaghegh (2011), who is one of the pioneers in applying soft computing methods in oil industry, used pattern recognition proficiencies of artificial intelligence & data mining (AI&DM) so as to create connections among fluid production, reservoir characteristics and operational constraints. His proposed model was able to decrease the cost and computation time significantly.

Artun et al. (2011) developed a dynamic scheme in the cyclic pressure pulsing process with CO2 and N2 in naturally fractured reservoirs. They combined neural networks and genetic algorithm to build a proxy model that is capable of predicting desirable parameters such as cumulative oil production, and oil flow rates to high levels of accuracy.

Kalantari-Dahaghi et al. (2015a) proposed a pattern recognition-based proxy model to overcome the challenges during the model development of the hydraulically fractured shale reservoirs. Their proposed proxy model can be paired with a numerical simulation model to, effectively, be applied as a reservoir management tool.

Later, they (Kalantari-Dahaghi et al., 2015b) developed a shale proxy model at the hydraulic fracture cluster level, as a replica of a reservoir simulation model, instead of applying the explicit hydraulic fracture modeling technique (EHF), which is long and laborious, and its implementation is computationally expensive. They used a history-matched hydraulic fractured Marcellus shale pad with multiple stages/clusters as a base-case for their study.

Knudsen and Foss (2015) created a dynamic shale well proxy model based on the first principles for gas flow in dry shale-gas reservoirs, representation of semi-physical modeling approach between proposed black-box models and reference numerical models. To tune proxy models, they recommended a parameter-estimation scheme that integrates pre-filtering of errors between the proxy model and simulation results.

Goodwin (2015) combined proxy models with Hamiltonian Markov chain Monte Carlo (MCMC) to create a suitable deterministic reservoir models. Besides, he described the disadvantages of random walk MCMC techniques being currently used for reservoir prediction studies.

Besides, Cheng et al. (2009) and Nasrabadi et al. (2012) used similar approaches in well placement optimization.

To practically optimize a production system, many combinations of the input variables are required to be calculated over many time steps. As indicated in Fig. 1, limited time steps in oil field optimization process cause significant loss in oil total production rate and its final net profit (Forero et al., 1993). In order to reduce the gap between true potential and oil production of the field and enhance its optimization scheme, more iterations are needed which implies a large number of simulation runs; however, limitations in CPU time forces the optimization process to have less iterations and use interpolation, instead; as a result, because of highly non-linear dependency of variables, there is a possibility that an impractical or imprecise solution will be achieved causing considerable loss in total revenue.

There are various methods to construct a proxy model. In this study, developed proxy models were built using artificial neural networks (ANN). ANN which mimics the brain neural networks is able to learn and understand the dependency and interdependency of any non-linear relationship among variables. Full datasets of input and output parameters are introduced to ANN and after several iterations, having learnt the dependencies, they are able to predict the outputs of similar datasets with reasonable accuracy (Zangl et al., 2006; Lu and Fleming, 2012; Ranjan et al., 2015).

In this paper, an integrated model is proposed which contains proxy models of reference gas lift system. By using a limited number of simulation runs, the developed models' predictions are in agreement with the actual outputs and are approved to be used for production optimization. Instead of discontinuous usage of simulators in distant time steps, the proposed model provides continuous and near real-time calculation throughout the reservoir life so as to obtain the highest possible NPV.

2. Solution approach

In this section, the developed representative model, which can be used to optimize any production system for specific operation time, is described in brief. The proposed production network in this

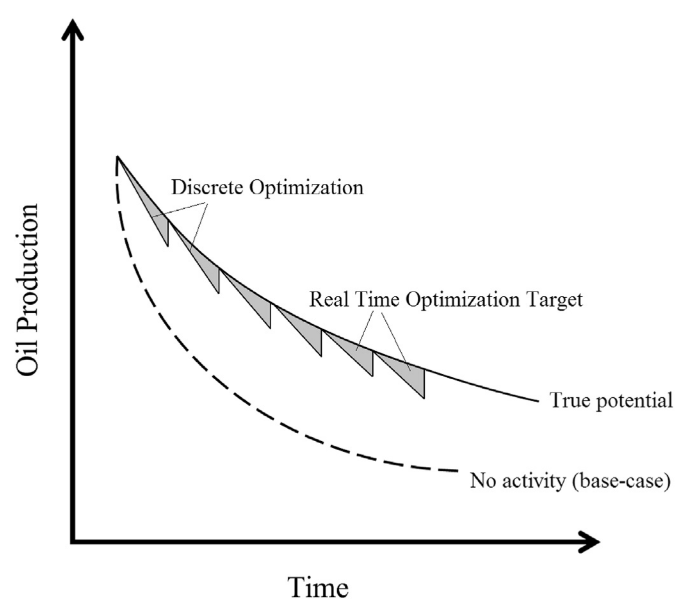

Fig. 1. Comparing continuous and discontinuous optimization in oil reservoir.