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A Workflow to Quantify Uncertainty in a Gas Field Development to Optimize the Number of Producing Wells With Hydraulic Fracturing

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SUMMARY

A complete workflow including stochastic geological modelling, history matching and risked production forecasting has been designed. The impact of hydraulic fracturing through the variability of well productivity has been studied.

Introduction

Hydraulic fracturing is a practice to increase well productivity of a producing well which, in turn, reduces the number of infill wells, and so also reduces the capital and operating cost needed for a specific production scenario. Whilst successful design and implementation of hydraulic fractures will increase the recovery, the degree of well productivity index enhancement depends on many factors. It is, therefore, desirable to study the impact of different productivity indexes on individual wells as well as its effect on the field total recovery. Having quantified these uncertainties, it is then possible to make the optimum field development plan or any other decision making regarding the number and location of infill wells.

Methodology

In this study, a workflow is designed to optimize the number of producing wells in a gas field both with and without hydraulic fracturing, allowing us to quantify uncertainty in a more robust approach. The workflow starts with generation of initial geological realizations and calculation of gas in-place percentiles (P10, P50 and P90). The next step was to choose the P50 case based on initial gas in-place and take it to flow simulation. In a screening exercise, a limited number of static model realizations, all within a narrow range of in-place around the P50 case, were simulated. A performance indicator was then defined based on historical production data to calculate the P50 case of the dynamic simulation model. A realization which was the closest to the P50 of both static and dynamic criteria was then selected for history matching. This model was history matched using global changes of some of the properties to make it more valid in the prediction phase.

Using optimization techniques, it was possible to find the range of uncertainty parameters which satisfied the objective function. The objective function was defined as a least square type function quantifying the discrepancies between the historical and simulated data. Having found the solution range of the uncertainty parameters, they were then applied to an ensemble of static realizations and those within a defined tolerance of history match criteria were selected to be taken to the prediction phase.

A number of field development scenarios were designed with different number of new in-fill wells with and without hydraulic fracturing. The impact of hydraulic fracturing was represented by varying the well productivity indexes. Running simulations for various scenarios on all history matched realizations made it possible to investigate the impact of the number of wells with and without hydraulic fracturing on recovery factor. Hence a quantified uncertainty envelope for different plateau rates and durations could be achieved.

Examples

Figure 1 shows the cumulative density function of the plateau rate for two scenarios with the same number of wells but different well productivity factors. The red distribution has no hydraulic fracturing well, and the green one shows the density function for the case where all new wells are hydraulically fractured. A comparison of the percentiles for these two cases clearly indicates the range of uncertainties. In this example, the P90 of the case with no hydraulic fracturing is exactly the same as P15 case for the scenario where we hydraulic fractures were introduced.

Figure 1 Probability density functions and their percentiles for two different development scenarios with the same number of wells with and without hydraulic fractures.

Conclusions

A complete workflow from stochastic geological modelling to history matching and risked production forecasting has been designed. The approach highlights the impact of hydraulic fracturing performance on field recovery as well as its significant role in the capital and operating cost. Successful design and implementation of hydraulic fractures could reduce the number of wells for a specific development scenario by up to 30%. The workflow allows us to examine a wide range of well placement scenarios taking into account well productivity, well patterns as well as plateau rate and duration resulting in quantification of uncertainty to reduce the risk of every single development scenario.