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Active Management of Five-Spot Water Flood Based on Continuous Reservoir Monitoring

B.L. Thigpen, SPE, S.A. Sakowski, SPE, X. Wang, SPE, X. Liu, SPE, J. Lee, SPE, Baker Hughes Inc.

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Abstract

Recently, the industry has seen an enormous increase in the amount of upstream data delivered with fine resolution and accuracy as provided by downhole monitoring equipment. Downhole measurements include distributed temperatures along the wellbore, wellbore pressure and temperature at discrete points, zonal flow rates, equipment performance data such as ESP operating efficiency, and downhole and surface chemical injection data. Even though the potential benefits of these measurements are recognized, practical models and processes that take full advantage of the actual data have not been well established.

Intelligent wells are gaining momentum in the oil and gas industry for production optimization, but utilization of this technology is limited to a single well or small group of wells, addressing somewhat localized optimization. Ultimate production optimization achieves higher reservoir recovery through incremental hydrocarbon production, and it needs a higher view than a well-centric approach. Considering that multiple intelligent wells comprise an intelligent field, all the data coming from each intelligent well should be brought together as input for a global optimization. This is analogous to bringing a fuzzy picture of a puzzle into focus as all the pieces fall into place. Similarly, to optimize a 5-spot waterflood, each well in the pattern should be intelligently controlled all the time and, in addition, they need to be optimized relative to each other so that the flood front movement is managed for maximum sweep efficiency. Optimization at this level is accomplished through an integrated use of reservoir/well modeling and real time data acquired through continuous downhole measurements. Measured data enables active model tuning, which in turn improves ongoing reservoir performance prediction. Sensitivity analyses find the optimal configuration of the intelligent wellbore components in injection and production wells that enables active waterflood front control.

This paper discusses methodologies used for the control mechanism, including a simplified reservoir model, continuous monitoring data, and a multi-well optimization process. Visualization and control of water flood efficiency, continuous tuning of the reservoir/well model, improved performance prediction and full utilization of real time data are some of the benefits from the process developed.

Introduction

If one were to search for publications on Smart Fields, I-Fields, Digital Oil Fields, Fields of the Future and other catch words, surely many would cover the same ground as ours with a few exceptions (Vachon et al. 2006, Saputelli et al. 2003, Sarma et al. 2005, Purves et al. 1997, Hardy et al. 1982, Going et al. 2006, Oberwinkler et al. 2004, Brouwer et al. 2004, Oberwinkler et al. 2005, Silin et al. 2005). This paper describes some of the methodologies we used and workflows which are associated with modeling, monitoring, optimizing and subsequent control of the various surface and downhole controls available in this system. Our approach goes both one step deeper by showing the exact workflows' details and also one step back by avoiding unnecessary confusion with complex software design principles. We will first describe our system approach for this inverted 5-spot water flood as it pertains to overall objectives and how the hardware system, its constraints and monitoring thereof, were used to provide relevant data based on our assumptions. Next we will describe the modeling approach and how we are performing the system optimization. Following this we will discuss the workflows that were created to capture the movement of data and information that is used for active water flood management as it pertains to several types of scenarios that are likely to occur during the lifetime of the system. These include a high level generic production workflow followed by several specific examples such as active water management and how the system reacts to an unplanned shut-in.