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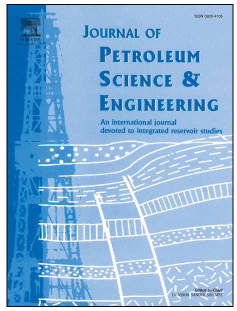

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Short-Term Model-Based Production Optimization of a Surface Production Network with Electric Submersible Pumps Using Piecewise-Linear Functions☆

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Abstract

This paper describes the development details and results of a model-based production optimization scheme to advice how to set frequencies of electric submersible pumps to maximize total oil production in a surface network. Furthermore, the effect of model fidelity and modifications to enforce high ESP efficiency are studied. The particular system targeted is surface networks with ESP-lifted wells, high water cut, low API gravity and gas oil ratio where wells require regular updates to their frequencies and there are multiple operational constraints.

The model employed for the optimization is a steady-state synthetic surface network with 15 wells. The optimization is formulated as a Mixed-Integer Linear Problem by approximating the network model using piecewise linear functions (tables). Well opening and ESP frequency are the two controllable variables. Monte Carlo simulations were performed varying randomly the predicted pressure drop in each pipe section within 20%. The operational envelope of the ESP was reduced to enforce high pump efficiency.

For the cases tested the optimization methodology has low runtime (13 s avg.), reproduces with an acceptable accuracy (average 0.6%, maximum 5%) the original network model, it handles successfully multiple operational constraints and guarantees global optimality. Additionally, it can be easily updated to reflect depletion changes by generating new tables. Monte Carlo simulations show that model fidelity has a minimal effect in the variation of the optimal conditions found. The modifications to enforce high ESP efficiency reduce significantly the maximum oil production predicted (37%).

Keywords: Model-Based Production Optimization, Linear Programming, ESP, Production Network, Uncertainty

1. Introduction

This paper focuses on production systems that consist of a surface network where wells are grouped in clusters and their production commingled in manifolds near to the wellheads (Fig. 1). Flowlines and pipelines transverse the field collecting the production from each cluster and transporting it further to the processing facilities. Therefore, flow conditions in each individual well are dependent, to some extent, on the operating conditions of other wells in the network. The description that follows is based on the Rubiales field in Colombia (Anaya et al., 2012).

Wellhead chokes are either fully open or non-existent. The wells produce mainly oil and water and the water cuts typically increase steadily from 0 to 98% during the life of the field. The producing gas oil ratio (GOR) and the bubble point pressure of the crude are low (GOR = 5 scf/stb) and gas liberation occurs only during the last pipe sections in the main trunkline.

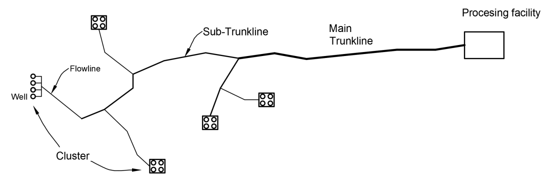

Figure 1: Surface network layout of the production system under study in this work.

Wells are equipped with downhole electric submersible pumps (ESPs).The downhole ESPs are powered either by in-situ diesel generators or using electricity from the national grid. Each well has its own variable speed drive unit that allows changing the frequency of the current to modify the rotational speed of the pump and control the output rate. ESP frequencies are often increased to compensate for the loss in oil production due to increased well water cut. The typical allowed operational range of frequency is between 30-70 Hz.

The lifting cost of this type of production systems is usually high (∼16 USD/bbl for the Rubiales field for Q3 2013, according to Serfinco (2014)). Some cost contributors might be the water disposal and ESP operating and maintenance expenses.

☆This document is a collaborative effort between Petrostreamz, a Norwegian service and software company specialized in Integrated Asset Modeling (IAM) & Optimization, and the Department of Geoscience and Petroleum at NTNU, Trondheim.

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