Optimal Field Development and Control Yields Accelerated, More Reliable, Production: A Case Study

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Outline

- Introduction to Intelligent Wells (I-wells)
  - I-wells control
    - Reactive
    - Proactive

- Challenges in Proactive Control
  - Developed framework for proactive optimisation under reservoir description uncertainties

- Intelligent field development case study

- Conclusions

- Extensions

- Acknowledgements
Introduction
Intelligent Wells (I-wells)

- Equipped with down-hole monitoring and control devices
  - ICD (Inflow Control Devices) – Single, fixed position
  - AICD (Autonomous Inflow Control Device) – self-adjusting position, providing a pre-designed, fluid-dependent flow control
  - ICV (Interval Control Valve) – Multiple positions, surface control
  - ICV provides a flexible production control, BUT maximum “Added Value” depends on identifying the optimal ICV control strategy

From SPE-107676 with modification
Introduction
Reactive Control Strategy of ICVs

Reactive

- Decisions are based on the system’s current condition
- Considers Short-term (current) objectives → Production Improvement
- Fast reaction to recognised situations
- Potentially can be done using well intervention
Introduction
Proactive Control Strategy of ICVs

Proactive
• Starts earlier
  ➢ Mitigates future undesired problems and/or states.
• Long-term objectives
  ➔ increased Oil Recovery
• Requires a reservoir model to forecast production
Objective: Find the control scenario of ICVs that maximises the objective function.

Challenges:
- Large number of control variables
- Computationally expensive objective function evaluations (i.e. reservoir simulator)
- Uncertain objective function

\[
\text{No. of control variables} = \text{No. ICVs} \times \frac{\text{Total Control period}}{\text{length of control steps}}
\]
Proactive Optimisation
Developed Robust Optimisation Framework

- A fast and efficient optimisation algorithm is developed which can handle large number of control variables with minimum obj. fun. evaluations
  - SPE-167453, SPE-178918
- Accounting for reservoir description uncertainty

Modified Objective function
- Mean optimisation: Search for a control scenario which improve all realisations (to some extent)
Case Study
Model Description & Development Plan

A full-field, consists of two overlaying heterogeneous reservoirs, each divided into two layers → 4 zones, 4 ICVs & 4 Packers to separate zones

Conventional Development Plan:
- 14 producers (single zone)
- 7 injectors

Alternative I-well development plan:
- 3 intelligent producers (commingled)
- 8 conventional producers (single zone)
- 7 injectors
Case Study
Reservoir Description Uncertainty

- Formation porosity and permeability, faults (locations and transmissibility), initial water saturation and reservoir net-to-gross were the major uncertainties.

- 3 realisations known as P10 (optimistic), P50 (base) and P90 (pessimistic) are employed to capture this uncertainty.

- Enough to capture the underlying uncertainty?!
The developed framework is capable of performing proactive optimisation of ICVs in a reasonable time for this relatively large, full-field model.
Robust Proactive Optimisation
Added-Value

Improved mean → higher expected added-value

Reduced variance → higher reliability (lower risk) by applying the best ICV control scenario

An extended oil plateau was observed for all realisations.
Conventional Vs. I-well Development Plan
Impact of Robust Proactive Optimisation

- Conventional Development plan → 14 conventional producers
- I-well development plan → 8 conventional & 3 intelligent producers

Extended plateau by robust proactive opt.

I-wells lead to loss → mitigated by optimum control

Lower number of wells drilled

Accelerated field development

P90 realisation
Robust Vs. Single realisation Proactive Optimisation

- Proactive control must be applied early, during the plateau period, to achieve the highest gain
  - the reservoir model is most uncertain during the early period.
- The importance of robust optimisation is shown by considering a non-robust optimisation performed using a single realisation (here P50).

<table>
<thead>
<tr>
<th>% Change</th>
<th>P10</th>
<th>P50</th>
<th>P90</th>
<th>Mean</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robust optimisation</td>
<td>+0.2</td>
<td>+1.3</td>
<td>+4.3</td>
<td>+1.6</td>
<td>-12</td>
</tr>
<tr>
<td>Single-realisation (P50)</td>
<td>+0.05</td>
<td>+2</td>
<td>+0.3</td>
<td>+0.8</td>
<td>+2.8</td>
</tr>
</tbody>
</table>

- Higher Added-value
- Reduced uncertainty

Max improvement for P50 but non-optimum performance for other realisations, lower added value, increased uncertainty
Conclusions

- Reservoir-model-based proactive control should be applied early, during the plateau period → greatest uncertainty in the model
  - Single realisation optimisation → sub-optimal performance, high risk.
    - One of the main reasons why the operators are often unwilling to control the ICVs/wells proactively. Although a no-control scenario may diminish the I-well gain!
  - Robust proactive optimisation is the solution.

- Developed robust optimisation framework can efficiently handle large number of control variables, high computation time and reservoir description uncertainty
  - The whole process was performed using a single, high-end PC in a reasonable time for this relatively large, full-field model
Conclusions

- (Partial) 1-well development scenario
  - Increased, early-time, NPV by reducing the number of wells to be drilled
  - May accelerates field development by speeding up the drilling process
  - state-of-the-art, proactive optimisation extended the oil production plateau, ensuring that the early NPV gain was maintained.

- Robust proactive optimisation allows the production operators to confidently control their I-wells to achieve
  - maximum expected added-value
  - lower uncertainty in the operation
Reservoir description uncertainty is quantified by hundreds of model realisations.

How to select a small ensemble of realisations as the representative of all realisations:
- P10, P50 & P90 are not always good enough representatives.
- **Developed realisation selection algorithm**: smartly select an ensemble of realisations. Tailored to the subsequent application.
  - A. Visualisation
  - B. Clustering

Each circle is one model realisation.

The developed robust optimisation framework can be extended to advanced completion design.

Control Variables
(Completion design parameters)
- Type of Flow Control Devices (FCDs): ICV, ICD, AICD(V)
- Location, Number (& strength) of FCDs
- Autonomous, fluid dependent performance of AFCDs

To be presented in Inflow Control Technology (ICT) Forum, 12th & 13th October 2017, San Antonio, USA.
New Phase of “Value from Advanced Wells” JIP (2018-2021)

Theme A: Maximum “Added value” from downhole flow control completions
- Modelling
  - AFCDs
  - AFCD completions
  - TIFs
- Design
  - Robust Prod./Inj. with AFCDs considering
    - Uncertainties
    - TIF
- Control
  - Robust ICV control
    - Large fields
    - Uncertainties

Theme B: In-well monitoring and data interpretation in advanced wells
- Analysis
  - PTTA
- Interpretation
  - DTS oil and gas wells
- Data mining
  - Test design
  - Missing data

- Other topics….
- Sponsor steered
Thanks For Your Attention.

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