UNISIM ON-LINE
Year 19, Number 2 | 156th edition | April, 2024

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Model-based Petroleum Field Management in Three Stages: Life-cycle, Short-term, and Real-time

Denis José Schiozer

Introduction

The objective of this UOL is to present a summary of the work presented in OTC Asia (Schiozer, et al, 2024). The focus is the development of a new practical methodology to manage petroleum fields considering three stages (life-cycle, short-term, and real-time) that can run alongside different model fidelities and characteristics.

The model-based field management process follows the general methodology proposed by Schiozer et al. (2019) with four activities: (1) fit-for-purpose models construction, (2) data assimilation for uncertainty reduction, (3) life-cycle production optimization and (4) short-term optimization for real-time implementation.

The selection of the production strategy for field management comprehends the last two activities. Life-cycle optimization (LCO) is the first stage of the process and generates control setpoints for short-term analysis. Short-term optimization (STO) is then used to improve the quality of the solutions considering the control parameters of the next cycle (considering a closed-loop procedure - CLCO). Real-time (RTO) solution is then implemented considering operational disturbances from real operations.

The methodology was applied to a benchmark case (UNISIM-IV-2026) which is a case based on a typical carbonate field from the Brazilian Pre-salt, with light oil and submitted to Water-Alternate-Gas injection with CO_2 (WAG-CO_2).

The results show that the methodology is applicable to real and complex fields. As the three stages can run simultaneously, one can (1) use different model fidelities to improve the quality of the solutions and (2) use model-based solutions for real-time implementation. Life-cycle optimization using complex simulation models and long-term objectives can run in the background to generate control setpoints for short-term analysis in which lower fidelity models and simplified solutions can be used for the control and field revitalization parameters of each closed-loop cycle. Real-time solutions can be implemented considering operational problems and disturbances.

Motivation

The main motivations for this work are:

- The excessive time consumption of the original methodology, especially for complex fields and consequent difficulties to use simulation models for short-term decisions;
- The excessive time consumption of the LCO due to simulation times and high number of uncertainties and management variables; and
- Demand from oil companies for digital field management, where fast models are necessary to help in the decision-making process.

Objectives

The main objectives for this work are:

- Develop a methodology to support real-time decisions for field management;
- Generate petroleum field management methodology in three stages;
  - Stage 1: develop general life-cycle (LC) management rules (LCO) used as setpoints for short-term (ST) management (for each cycle: ST → CLCO) that can concentrate in the ST parameters to make better decisions;
  - Stage 2: use CLCO as management decisions that can be used as guide for production strategy implementation;
  - Stage 3: develop a methodology to rapidly adapt the CLCO solutions to real-time (RT) implementation (RTO) if operational noise occurs (operational noise is considered as any perturbation of the original scenario used for optimization, like operational failures, new information about the field, etc).

Methodology

In this methodology, we use the same structure proposed by Schiozer et al (2019), where G1 are the design variables (used for reservoir development), G2 are the control variables (used for reservoir management), and G3 are the revitalization variables (used for revitalization of petroleum fields or to account for second and third waves of wells planned for the future). For this work, the variables are divided to account for the three stages (L for life-cycle variables, C for variables of the next cycle, and R for real-time) as shown in Fig.1 (green for model construction and updating, red for data assimilation, blue for LCO, gray for CLCO, and black for RTO). The basic idea of the three-stage reservoir management is to separate the decision-making process into three parts, as shown in Fig. 2.

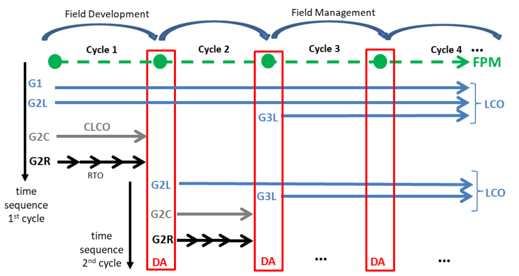

***Figure 1**: Representation of cycles of the CLFDM including: fit-for-purpose models in green, data assimilation in red (when necessary to correct models); G1, G2L and G3L in blue to represent life-cycle variables to be optimized – LCO, and short-term management in gray (closed-loop cycle optimization – CLCO), generating G2C and G3C, and real-time optimization (RTO) in black, generating G2R and G3R).*

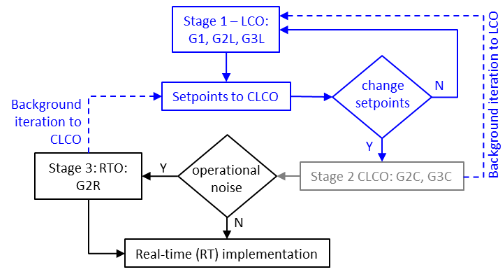

***Figure 2**: Methodology for field management: real time (RT) production strategy (PS) implementation in three stages: LCO in blue, CLCO in gray and RTO in black.*

Case Study

This study is applied to UNISIM-IV-2026, a synthetic benchmark case analogous to an offshore Brazilian pre-salt carbonate field (Botechia et al., 2022).

Results

The results are presented in Schiozer et al (2024). A complete LCO procedure would take months to run (https://www.unisim.cepetro.unicamp.br/online/UNISIM_ON_LINE_N150.PDF). A simplified LCO, described in Schiozer et al, 2024) was done in few weeks generating management rules used in the CLCO that was performed yielding results shown in Fig. 3. Results were checked in LC showing consistency of the new rules (Fig. 4).

Stage 3 was not the focus of this work but to test the methodology, operational problems were created (described in the article) and RT implementation was performed to improve the solution, generating ST (Fig. 5) and LC results (Fig. 6).

"This work presents a novel procedure to integrate three stages for production optimization that can run in parallel, allowing the integration of life-cycle and real-time solutions."

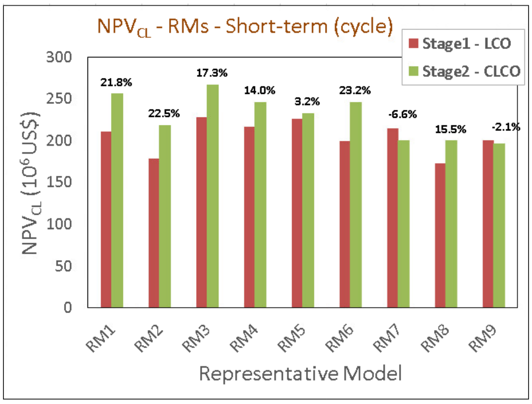

***Figure 3**: Short-term NPV for each representative model (RM) after Stages 1 and 2. The percentages indicate the variation in Stage 2 in relation to Stage 1.*

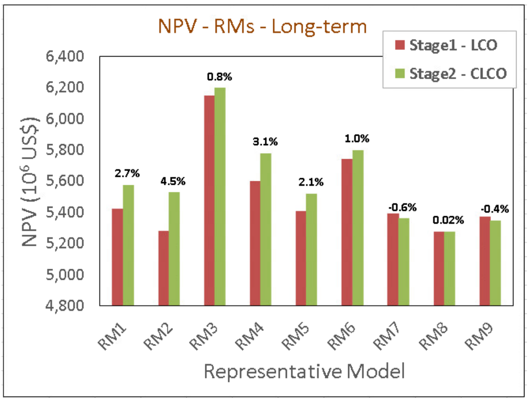

***Figure 4**: Life-cycle NPV for each representative model (RM) after Stages 1 and 2.*

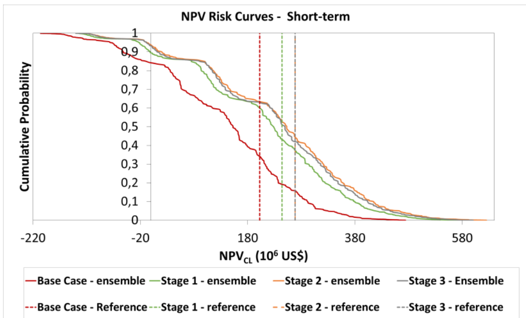

***Figure 5**: NPV risk curves for the ensemble of 48 models and the solution in the reference case in short-term. (NPV$_{CL}$ is the NPV considering only ST results).*

Concluding Remarks

This work presents a novel procedure to integrate three stages for production optimization that can run in parallel, allowing the integration of life-cycle and real-time solutions.

The methodology (1) allows the use of complex reservoir simulation models from the life-cycle production strategy optimization, (2) focuses short-term control parameters that improve the quality of the short-term solution, and (3) guides real-time implementation, so it can be the basis to a digital field management.

Stage 1 can be a simplified LCO to generate a fast solution to be updated if necessary. A LCO can run in background (in parallel to implementation), so new operation rules can be updated as setpoints for short-term operation

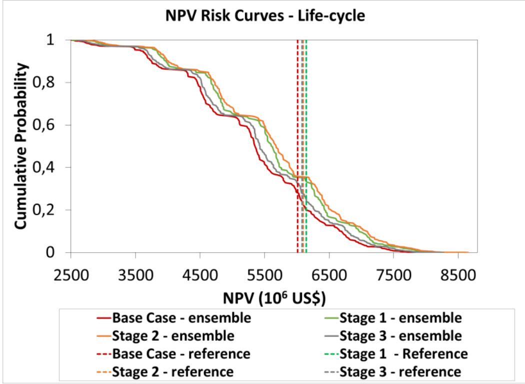

***Figure 6**: NPV risk curves for the ensemble of 48 models and the solution in the reference case in life-cycle.*

if necessary.

Stage 2 is useful for a fast optimization process related to the variables of the next cycle of decisions only. The LCO can be very complex because of the number of variables and many uncertainties to be treated. In the CLCO (short-term optimization) there are less variables and the effect of uncertainties is smaller, so it can be much faster and more efficient allowing faster update of operations.

Current simulation models must be modified and corrected to improve the quality of short-term forecast. Productivities and injectivities have to be corrected and boundary conditions for forecast must be carefully treated to reflect the real field. Otherwise, forecast is not representative and the decisions can yield bad results.

Stage 3 is the implementation of decisions in real field and it is important to have a faster model (considered here a digital twin) to react to operational noise (problems in the implementation). Another advantage of the third stage is that Stages 1 and 2 can allow some flexibility in the restrictions to be corrected later as in the example of the need for full gas recycling. The methodology was tested in a benchmark case with initial focus in Stages 1 and 2. Further research is necessary to: (1) test in other examples, (2) improve Step 3, (3) integrate with machine learning techniques to build a digital-twin model for real time optimization.

Acknowledgments

Vinicius E. Botechia and Luis C. O. Pires.

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About the author:

Denis José Schiozer is a full professor at UNICAMP, a chair of Energi Simulation, the director of EPIC, coordinator of UNISIM and researcher 1A from CNPq.

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unisim@cepetro.unicamp.br