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Model-Based Decision Analysis Applied to Petroleum Field Development and Management

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Introduction

In the 100th edition of UNISIM ON-LINE (https://www.unisim.cepetro.unicamp.br/online/UNISIM_ON_LINE_N100.PDF), May-2016, we have presented our methodology "Integrated Model Based Decision Analysis in Twelve Steps Applied to Petroleum Fields Development and Management".

Since then, UNISIM has dedicated a strong effort to improve the methodology based on several tests published in the last 3 years and we have published recently an updated version in Schiozer et al. (2019).

The main topics are the same and we tried to keep it in 12 Steps but several advances were accomplished, starting from the workflow (Figure 1) which is now divided into four colors and includes a short-term decision loop.

The colors represent:

- Green: gathering of all data and uncertainties and model construction; multiple simulation models are used in the process so model fidelity (Avansi and Schiozer, 2017) is adapted to balance quality of the results and computational time.
- Blue: model-based, long-term decisions under uncertainties; the best alternative is implemented in the field (with operational noise due to delays, fails, etc.) generating measured dynamic data (production, pressure, 4D seismic, etc.).
- Red: data assimilation; all dynamic data must be within a tolerance range to select models that will be used in the blue part; data assimilation may directly change the simulation models or the high fidelity geologic models (big loop).
- Black: (1) implementation of long-term decisions (normally model-based) and short-term decisions (normally data-driven); (2) definition of study objective; and (3) selection of the type of study (past – data assimilation; or future – decision analysis).

The twelve steps are described below:

Green Steps

1. Reservoir characterization under uncertainties (to build models, develop scenarios, and estimate probabilities) (Correia et al., 2015, 2018a, 2018b; Mahjour et al., 2019). This crucial step requires a multidisciplinary approach to consider all possible uncertainties: reservoir, fluid, economic, and operational attributes.
2. Build and calibrate the simulation model: accurate risk quantification requires reliable responses; therefore, the simulation model must be calibrated to have a fast and yet robust response to avoid biased evaluations (Avansi et al., 2019). Decision makers define the degree of model precision according to the objective. We believe that a high-fidelity model should be preferred over low-fidelity or proxy models because of the high nonlinearity between the reservoir model and the production strategy performance. The calibration is normally done with a Base Case (in this work, called Base0).

Red Steps

3. Verify inconsistencies in the Base Case and dynamic well data (fluid rates and BHP measurements) to be used in the data assimilation procedures. This step is often simplified or skipped but it is crucial as it can identify inconsistencies in the simulation model and the real data.
4. Generate scenarios considering reservoir uncertainties. In this work, a scenario is a particular combination of all possible uncertainties. Several sampling techniques are available in the literature, but we recommend the efficient DLHG (Schiozer et al., 2017).
5. Data assimilation: history match and reduce the number of scenarios with dynamic and seismic data. Several techniques are available (Avansi and Schiozer, 2015a; Bertolini et al., 2015; Maschio and Schiozer, 2008, 2015, 2016; Costa et al., 2018; Davolio and Schiozer,

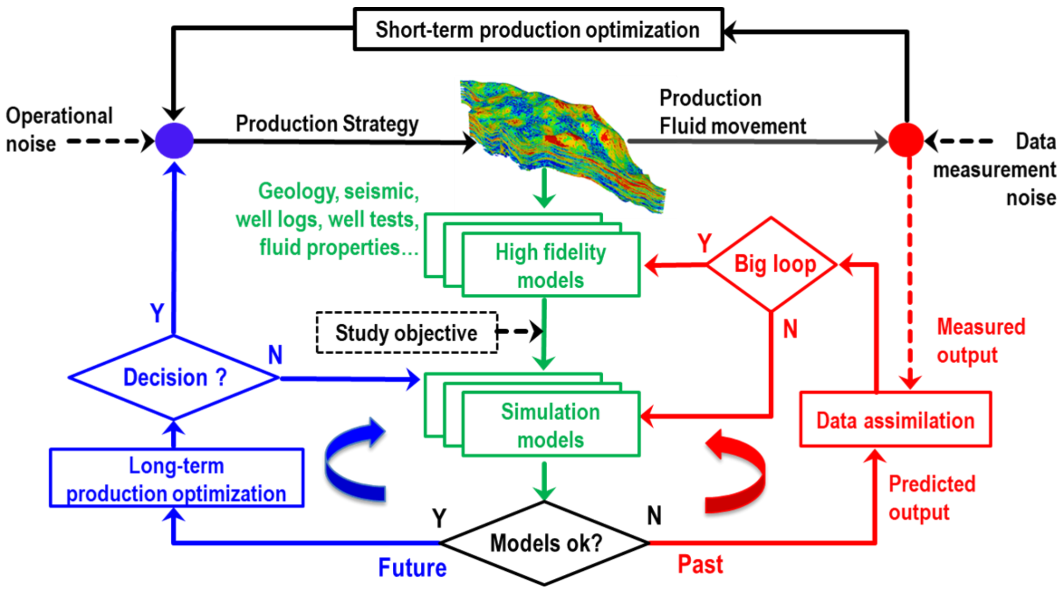

Figure 1: Closed-Loop Field Development and Management (Schiozer et al., 2019)

"The methodology is flexible enough to be applied to reservoirs in different stages of their lifetime."

2018; Oliveira et al., 2018) depending on the complexity of the case and the available data. From the accepted models, a Base Case is selected for the following steps (Base1). The usual recommendation is to use a model close to P50 in all indicators to optimize the initial production strategy, representing an intermediate case. A new Base Case must be selected only when Base0 fails to honor the dynamic data or is too optimistic or pessimistic.

Blue Steps

6. Selection of a deterministic production strategy for the Base Case. As the production strategy selection strongly affects the risk quantification, an iterative technique is best to select the production strategy. The first production strategy is selected using an optimization procedure (Ravagnani et al., 2011; Gaspar et al., 2014, 2016a; von Hohendorff Filho et al., 2016).
7. Initial risk estimate of the first production strategy with all possible scenarios (from Step 5). This risk curve is often used in projects. Here, we propose additional analyses (Steps 8 to 12) to further improve decisions and reduce risk, showing that the final risk curve can be very different.
8. Selection of Representative Models (RMs) (Schiozer, 2004; Costa et al., 2008; Meira et al., 2016, 2017) based on multiple system inputs (probability distribution and range of uncertain attributes) and outputs (production, injection, and economic forecasts).
9. Selection of a specialized production strategy for each RM, as in Step 6, to provide different solutions for field development.
10. Production strategy selection under uncertainty including reservoir, economic, and other uncertainties. A Robust Optimization procedure (Silva et al., 2016) can be used, or a risk-return analysis (Santos et al., 2017a) to select the best strategy from the candidates obtained in Step 9. If the simulation runtime for the number of scenarios is unfeasible, the RMs can be used to represent them.
11. Identification of potential changes in the production strategy (obtained in Step 10) to manage uncertainty and improve the chance of success based on the value of information (Santos et al., 2017b; Botechia et al., 2018b) and value of flexibility analyses (Silva et al., 2017; Santos et al., 2018a), and integration with production facilities (Hohendorff and Schiozer, 2017, 2018). If the simulation runtime for the number of scenarios is unfeasible, the RMs can be used to represent them.

Black Step

12. The black step is dedicated to the decision analysis. Technical and economic indicators support long-term, model-based decisions as well as short-term, data-driven decisions. The objective guides the process: model quality, need for further data assimilation (history matching), objective function selection, etc.

Discussion

We have presented new details of the model-based, closed-loop methodology based on twelve steps to be used in decision analysis for petroleum reservoir development and management under uncertainties, covering both model updating and production optimization.

Results for one of our benchmark case are presented in Schiozer et al. (2019) and several other results are listed theses, dissertations and articles in our webpage (https://www.unisim.cepetro.unicamp.br/en/component/publicacoes).

It is common to skip several steps to expedite projects but we believe that, with the simplification presented here, the methodology is applicable to real cases, including complex cases with long simulation times, and still ensure reliable decisions. In such a case, it is possible to decrease the number of simulation in Steps 6, 7 and 9 and select a smaller number of representative models (Step 8).

Note that further simplifications can yield suboptimal decisions. The level of detail of each step is a function of the importance of the study, the complexity of the case, and the available resources and time. The most time-consuming part is the optimization of the production strategy and the results are a function of the quality of this process; therefore, it is important to use computationally efficient optimization processes.

The methodology is flexible enough to be applied to reservoirs in different stages of their lifetime. We presented a case in the development phase but it can be used at other stages. It is also simple enough to be used in practical applications because it does not require proxy models or complex tools.

Final Comments

Based on the concept of closed-loop reservoir management, we improved a decision structure of twelve steps to assist engineers in reservoir development and management.

By providing a comprehensive decision structure that integrates reservoir characterization, data assimilation, and production optimization, our method works as the core basis for specialized methodologies for each of these domains, as our results have shown.

Acknowledgments

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Main Reference (other references are in the original paper)

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