Research Group in Reservoir Simulation and Management

UNICAMP

UNISIM-I-M: Study Case for Management Variables Optimization of Reservoir Exploitation Strategy

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Campinas, October 15, 2015

Summary

1. Introduction

The aim of this document is to present a reservoir study case to be submitted to decision analysis regarding reservoir management, **UNISIM-I-M.**

The simulation model is based on information from a reference model **UNISIM-I-R** (Avansi and Schiozer, 2015a). Data for simulation is available for download to research groups interested in the cases (http://www.unisim.cepetro.unicamp.br/unisim-i/). The base simulation model and the operating conditions of the exploitation strategy have the same assumptions of **UNISIM-I-D**.

UNISIM-I-D simulation model was created for t_D (1461 days), the initial stage of field development. UNISIM-I-M considers an exploitation strategy of 14 producers (4 vertical and 10 horizontal) and 11 horizontal injectors that are already used in the water flooding project (Avansi and Schiozer, 2015a). A history production for 2618 days is provided. The goal of this project is to optimize the future design and control variables of the provided exploitation strategy after t_M (2618 days) until the maximum final time t_F (10957 days).

The study should consider two approaches:

- Deterministic (without uncertainties);
- Probabilistic (including geological, economic and operational uncertainties).

From 2000 possible scenarios generated using HLDG, combining all the uncertainties including 500 different realizations (Schiozer et al, 2015b), a set of 48 models representing the case was obtained after being submitted to parameterization procedures and reduction of scenarios with dynamic data process (as suggested in steps 4 and 5 in Schiozer et al, 2015). These models were selected after a model filtering step (Avansi and Schiozer, 2015b) considering all the objective functions simultaneously, with values between -2 and 2 represent low deviation from history data.

Among the models honoring the dynamic data, a model close to P50 in all main indicators for the given exploitation strategy was selected as base case. Details about the process of generation, reduction and selection of scenarios can be seen in Gaspar et al (2015b).

It is important to highlight that the objective-functions and approaches are the same of the UNISIM-I-D proposal available in the website. The only difference is the date regarding the stage of field management.

Any information, suggestions, problems or comments should be sent by e-mail to unisim-benchmark@dep.fem.unicamp.br. Relevant information will be transferred to the project subscribers.

2. Deterministic approach

The objective of the UNISIM-I-M deterministic approach is to optimize the design and control variables of the provided exploitation strategy between t_M (after the strategy implantation in development phase) until the maximum final time t_F.

This project considers the management phase, the period after the strategy implantation. In this phase, design and/or control variables should be optimized, such as infill drilling, recompletion, well conversion and conditions for wells shut-in, among others. The costs associated can be seen in UNISIM-I-D proposal.

2.1 Important Date/Times

- 05/31/2013 (t_0) – 0 day:
  - Simulation initial time.
  - Production starting time.
- 06/30/2020 - 2587 days:
  - The last well is opened (implanted in the development phase).
- 07/31/2020 (t_M)– 2618 days:
  - End of history production.
  - Starting date analysis (for updating cash flow).
  - Starting date for operating the petroleum field.
- 05/31/2043 (t_F) – 10957 days:
  - Maximum simulation time.
  - Maximum date of field abandonment.

2.2 Premises and data

Some premises and information have to be considered:

- The project variables related to the infrastructure of the strategy already defined in the development phase, as for example, drilled wells and platform provided in UNISIM-I-M simulation files, must not be modified.

- The well operating conditions for the management phase are presented in Table 1 of UNISIM-I-D project proposal.

- Production and pressure history of 14 producers and 11 injectors: UNISIM-I_HistoryData_t_M.zip file.

- Fiscal assumptions and the economic scenarios are the same adopted in UNISIM-I-D proposal.

- The equation for calculating the net cash flow presented in UNISIM-I-D project proposal (Equation 3) should be adapted to be used in the management phase. Note that the investments in the infrastructure had already been made in the development phase. Additional investments regarding the management phase must be taken into account if design variables are considered.

3. Probabilistic approach

We present here details about the uncertainties considered to generate all possible scenarios submitted to the reduction process resulting in the 48 models given in this proposal.

3.1 Geologic uncertainties

For this project, new uncertainty levels are considered for the attributes. A history matching process was used to reduce uncertainties (Step 5 of Schiozer et al 2015).

A new set of reservoir properties were generated and the model was updated for the post-development phase, using a new set of information as a conditioning data, i.e., wells were perforated after 1461 days (Avansi and Schiozer, 2015b). The structural model defined as uncertainty in UNISIM-I-D is now assumed known after drilling wells in the east block. In addition, local modifications in the region of PROD010 and PROD025A were necessary requiring the generation of new attributes.

The uncertainties considered are:

- por/permi/permj/permk/ntg: 500 images of reservoir properties including porosity, horizontal and vertical permeabilities and net-gross.
- cpor: rock compressibility.
- krw: water relative permeability.
- kxa: horizontal permeability (permi) multiplier (local – PROD025A).
- kxb: horizontal permeability (permi) multiplier (local - PROD010).
- kz: vertical permeability (permk) multiplier (global).
- kza: vertical permeability (permk) multiplier (local – PROD025A).
- kzb: vertical permeability (permk) multiplier ((local – PROD010).
- mp: porosity (por) multiplier (local – PROD025A).
- pvt: region 2 PVT data (east block).
- woc: region 2 oil-water contact (east block).

Tables 1 and 2 present, respectively, the levels and the probability density functions (pdf) of the geological uncertainties for each attribute. We can see in Table 1 that some levels were eliminated when compared to UNISIM-I-D case.

Table 1: Uncertainty levels and probabilities of the discrete geological attributes

Attribute (Probability)	Levels				
	-2	-1	0	+1	+2
por / permi / permj/ permk / ntg	500 equiprobable petropysical images				
krw*	-	-	krw0 (0.33)	krw+1 (0.34)	krw+2 (0.33)
PVT* Region 2	-	-	pvt0 (0.50)	pvt+1 (0.50)	

* Krw and PVT tables are provided. Files: *krw_alpha.inc* and *pvt_beta.inc*, given that *alpha* and *beta* correspond to the levels.

Table 2: Uncertainty levels of the continuous geological attributes*

Attribute	Unit	Probability Density Function
woc Region 2	(m)	$\begin{cases} 0, & woc < 3169 \\ \frac{woc-3169}{25}, & 3169 \le woc \le 3174 \\ \frac{3174-woc}{25}, & 3174 \le woc \le 3179 \\ 0, & woc > 3179 \end{cases}$
cpor / (10^{-6})	$1/kgf/cm^2$	$\begin{cases} 0, & cpor < 10 \\ \frac{x-10}{1849}, & 10 \le cpor \le 53 \\ \frac{96-x}{1849}, & 53 \le cpor \le 96 \\ 0, & cpor > 96 \end{cases}$
kz	dimensionless	$\begin{cases} 0, & kz < 0 \\ \frac{2x}{2.101}, & 0 \le kz \le 1.025 \\ \frac{4.100-2x}{2.101}, & 1.025 \le kz \le 2.050 \\ 0, & kz > 2.050 \end{cases}$
kza/1.5	dimensionless	$\begin{cases} 0, & kza < 1 \\ \frac{kza-1}{4}, & 1 \le kza \le 3 \\ \frac{5-kza}{4}, & 3 \le kza \le 5 \\ 0, & kza > 5 \end{cases}$
kzb	dimensionless	$\begin{cases} 0, & kzb < 0.60 \\ \frac{kzb-0.60}{0.04}, & 0.60 \le kzb \le 0.80 \\ \frac{1.00-kzb}{0.04}, & 0.80 \le kzb \le 1.00 \\ 0, & kzb > 1.00 \end{cases}$
kxa/1.1	dimensionless	$\begin{cases} 0, & kxa < 2.00 \\ 0.17, & 2.00 \le kxa \le 8.00 \\ 0, & kxa > 8.00 \end{cases}$
kxb	dimensionless	$\begin{cases} 0, & kxb < 0.73 \\ 2.27, & 0.73 \le kxb \le 1.17 \\ 0, & kxb > 1.17 \end{cases}$
mp	dimensionless	$\begin{cases} 0, & mp < 0.38 \\ 7.14, & 0.38 \le mp \le 0.52 \\ 0, & mp > 0.52 \end{cases}$

* Modified SI system.

3.2 Economic and Technical Uncertainties

The optimistic and pessimistic economic scenarios and their probabilities of occurrence are defined for each uncertain geological model shown in Tables 11 and 12 and the scenarios and probabilities for technical attributes are highlighted in Table 13 of the UNISIM-I-D proposal.

4. Expected Results

After the decision regarding the new design and control variables optimization, a report should be generated including:

1. Strategy configuration and operational conditions of each well and group constraints.
2. Process indicator data: chosen methods, number of simulation runs and computational cost, objective-function evolution.
3. Selected strategy indicator data:
    a. Main indicators: NPV, cumulative oil production (Np), recovery factor (RF).
    b. Secondary indicators: cumulative gas production (Gp), cumulative water production (Wp), cumulative water injection (Winj) and average field pressure (Pavg).
4. Producers indicators: oil rate (Qo), gas rate (Qg), water rate (Qw) and costs.
5. Injectors indicators: injected water rate (Qwi) and costs.

5. References

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3. Gaspar, A.T.F.S., Avansi, G.D., Maschio, C., Santos, A.A.S., Schiozer, D.J., “UNISIM-I-M: Benchmark Studies for Decision Analysis regarding Reservoir Management”. In preparation, 2015, Brazil.

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5. Schiozer, D.J., Avansi, G. D., Santos, A.A.S.. “Risk Quantification Combining Geoestatistical Realizations and Discretized Latin Hypercube”. Submetido para publicação (SPE Reservoir and Evaluation), 2015.