Research Group in Reservoir

Simulation and Management

Study Case for History Matching and Uncertainties Reduction based on UNISIM-I Field

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1. Introduction

This document provides a benchmark case for production history matching and uncertainties reduction applications (UNISIM-I-H).

The simulation model was built from UNISIM-I reservoir model (Avansi and Schiozer, 2013) in a second stage (t_2). This model assumes the same characteristics from UNISIM-I-D (until t_1), however, with a production strategy definition (after t_1), i.e., UNISIM-I-D was designed for a development phase (t_1) and UNISIM-I-H was designed for a post-development one (t_2). Avansi and Schiozer detailed the construction of the reference model (UNISIM-I). The simulation data set for IMEX 2012.10 is available for download from http://www.unisim.cepetro.unicamp.br/unisim-i/.

The study comprises two main approaches:

(1) Deterministic history matching from a base model considering the uncertain attributes;
(2) Probabilistic approach considering possible uncertainties reduction.

In the validation phase, concerning the use of the data set, any information, suggestions or problem are welcome and they can be provided by *e-mail* (unisim-adm@dep.fem.unicamp.br). Relevant information and updating will be transferred to the project subscriber users.

2. Deterministic approach

2.1 Objectives

The objectives of the deterministic approach are:

(1) Carrying out a history matching until 4018 days (t_2) from the provided base model. The base simulation file is the same supplied in the UNISIM-I-D case (selection of exploitation strategy from t_1 – 1461 days) with additional information of new wells until t_2.
(2) Carrying out production forecast until the final simulation time (t_{max}): 31/05/2043 (10957 days) without modification in the production strategy.
(3) Performing modifications in the production strategy to improve it. Changes will be allowed under project restrictions and premises defined in UNISIM-I-D.

The observed data (well rates and pressure and, field rates and average pressure) are available in the data set. A random noise was added to the observed well data.

For the production prediction (Stages 2 and 3 listed above) all the production strategy characteristics concerning operational restrictions and economic model must be used.

2.2 Uncertainties

For the history matching, the limits of the uncertain attributes descried in the UNISIM-I-D should be taken into account. Any modification outside the defined ranges or the addition of new attributes should be reported and justified.

The modifications with respect to the UNISIM-I-D are:

- A new set of petrophysical properties realizations were generated and updated the model for the post-development phase, using a new package of information as a conditioning data, i.e., new wells were perforated;
- The structural model defined as uncertainty in UNISIM-I-D was assumed known after drilling new wells in the east block.
- A new range for the attribute WOC was defined (Appendix A).

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3. Probabilistic approach

3.1 Objectives

The objectives of the probabilistic approach are:

(1) Reducing uncertainty in the production forecast;
(2) Reducing uncertainties of the attributes;
(3) Implementing probabilistic production forecast;
(4) Defining production strategy selection considering the probabilistic approach.

For the probabilistic production forecast, the same aspects described in the deterministic approach, concerning operational restrictions, should be taken into account.

4. Expected Results

The expected project results are:

4.1 History Matching and Uncertainty Reduction

4.1.1 Deterministic

a. Attribute values corresponding to the best solution;
b. Process indicator data: chosen methods, number of simulations, computational effort and objective-function evolution;
c. Plots comparing simulated and observed data;
d. Quality indicator: global objective function. Each group should report the global function chosen to measure the matching quality.
e. Matching quality indicator per well: simple (SD) and quadratic distance (QD) for oil, water and gas rate and pressure, as follows in Equations (1) and (2):
f.

$$SD = \sum_{i=1}^{n}(obs_i - sim_i) \text{ ....(1)} \qquad QD = \sum_{i=1}^{n}(obs_i - sim_i)^2 \text{..........(2)}$$

where n is the number of observed data related to each data series (oil, water and gas rate and pressure per well); obs_i e sim_i are observed and simulated data of each model, respectively.

If others indicators were chosen in the history matching process, SD and QD should be reported for comparison purposes.

4.1.2 Probabilistic

a. New likely attributes uncertainty levels indicating possible (acceptable) solutions;
b. Process indicator data: chosen methods, number of simulations and computational effort;
c. Quality indicators for the found solutions: the same one that was previously illustrated.

4.2 Production forecast

4.2.1 Deterministic

a. Production forecast until the final simulation time (t_{max}) keeping the original production strategy unchanged. Only minor modifications, such as, well operational conditions changes and well shut-in, can be done (see in Appendix B suggested conditions);
b. Indicators:

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i. Primary indicators: net present value (NPV), cumulative oil production (Np) and recovery factor (RF);
ii. Secondary indicators: cumulative gas production (Gp), cumulative water production (Wp), cumulative water injection (Winj) and average reservoir pressure (Pavg).

4.2.2 Probabilistic

The same indicators corresponding to the deterministic approach should be presented. In addition, a probabilistic analysis, including expected monetary value (EMV) and risk indicators, should be showed.

4.3 Production strategy modifications

Following the production forecasting indicators, changes in the production strategy, including new wells, should be proposed from t_2, presenting:

a. Production forecast until the end of the simulation (t_{max});
b. Process indicator data: chosen methods, number of simulations and computational effort;
c. Indicators:
    i. Primary indicators: net present value (NPV), cumulative oil production (Np) and recovery factor (RF);
    ii. Secondary indicators: cumulative gas production (Gp), cumulative water production (Wp), cumulative water injection (Winj) and average reservoir pressure (Pavg).

5. References

1. Avansi, G. D., Schiozer, D. J., "UNISIM-I: Synthetic Model for Reservoir Development and Management Applications", International Journal of Modeling and Simulation for the Petroleum Industry, 9 (1), p. 21-30, April, 2015.

2. UNISIM-I-D (http://www.unisim.cepetro.unicamp.br/benchmarks/br/unisim-i/unisim-i-d).

6. Provided Files

Table 1 contains the description of the files:

Table 1: Description of the provided files

File	Description
UNISIM-I-H.zip • UNISIM-I-H.dat • im0.inc • mst2u_corners.inc • mst2u_null.inc • mst2u_pinchoutarray.inc • mst2u_sectorarray.inc • mst2u_transfc.inc	Simulation data set
UNISIM-I-H_HistoryData_t2.zip • UNISIM-I-H_Well_ProdHist_t2.fhf • UNISIM-I-H_Well_InjHist_t2.fhf • UNISIM-I-H_FieldProdHist_t2.fhf • UNISIM-I-H_FieldPressHist_t2.fhf • UNISIM-I-H_FieldInjeHist_t2.fhf	Observed data set: • Producer wells • Injector wells • Field rate • Average field pressure • Field injection
UNISIM-I-H-WellLogs.xlsx	Well log data

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7. Next step

An additional part of the project, related to 4D seismic data, will be released in the near future.

8. Appendix A - Attribute WOC

The uncertainty in attribute WOC was reduced to a small range compared with UNISIM-I-D (Table 2).

Table 2 – Attribute WOC

Attribute	Unity	PDF**
WOC Region 2	(m)	$\begin{cases} 0, & x < 3169 \\ \frac{x-3169}{25}, & 3169 \le x < 3174 \\ \frac{3179-x}{25}, & 3174 \le x \le 3179 \\ 0, & x > 3179 \end{cases}$

** *Probability Density Function*

9. Appendix B - Conditions for prediction

The following tables show wells and group controls for the prediction period.

Table 3 - Producer wells controls

Wells	Minimum BHP (kgf/cm^2)	Maximum Q_L (m^3/d)	Maximum wcut	Maximum GOR (m^3/m^3)	Minimum Q_o (m^3/d)
NA1A	228	2000	0.90	200	20
NA2	267	2000	0.90	200	20
NA3D	190	2000	0.90	200	20
RJS19	195	2000	0.90	200	20
PROD005	258	2000	0.90	200	20
PROD008	289	2000	0.90	200	20
PROD009	239	2000	0.90	200	20
PROD010	300	2000	0.90	200	20
PROD012	314	2000	0.90	200	20
PROD014	217	2000	0.90	200	20
PROD021	292	2000	0.90	200	20
PROD023A	185	2000	0.90	200	20
PROD024A	246	2000	0.90	200	20
PROD025A	314	2000	0.90	200	20

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Table 4 - Injector wells controls

Wells	Maximum BHP (kgf/cm^2)	Maximum Q_w (m^3/d)
INJ003	351	5000
INJ005	351	5000
INJ006	347	5000
INJ007	351	5000
INJ010	352	5000
INJ015	352	5000
INJ017	340	5000
INJ019	352	5000
INJ021	352	5000
INJ022	350	5000
INJ023	350	5000

Table 5 - Group controls

Group name	Maximum Q_L (m^3/d)	Maximum Q_o (m^3/d)	Maximum Q_w (m^3/d)
‘Producao’	15500	15500	13950
‘Injecao’	-	-	21700

Nomenclature:

Q_L = Liquid rate
Q_o = Oil rate
Q_w = Water rate
BHP = Bottom-hole pressure
GOR = Gas-oil ratio
wcut = water cut

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