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Influence of geometric characteristics of satellite wells in production forecast

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Introduction

According to Oliveira (1989), modeling a typical offshore production system consisting of wells and lines connected to the gathering network requires the following items:

A. Properties of the fluid produced by the well: water-cut, gas-oil ratio, densities of oil, gas and water, and stream bottom-hole temperature;

B. Geometric characteristics of the combination of pipe elements (column, flowline, manifold, choke etc.), their own characteristics (linear length, tilt angle and diameter) and their connections;

C. Correlations of multiphase flow that model each well and line segment, PVT correlations for all wells, the relative roughness of the pipe and the temperature gradient;

D. Boundary conditions for the platform (rates and pressures), manifolds and wells, treated as operational restrictions.

The characteristics of group B are obtained through standard combinations of the pipe elements, adjusted for lengths and angles obtained from a preprocessing of the coordinates of the reservoir simulation input files, which consider the position of platform and manifolds, as well as the seabed. So, the main variable to be evaluated in this group is the diameter of each pipe element.

The objective of this work is to analyze the impact of group B variables on the production forecast and on the development of field production strategy, concerning the integration between reservoirs and production systems for an offshore field.

Methodology

The study is applied to the benchmark case UNISIM-I-D, which contains economic data used for the calculation of the net present value (Gaspar et al., 2015). We use an optimized strategy (Schiozer et al, 2015) for nonintegrated base case production system, named E9, summarized in Table 1. The reservoir simulation is performed using IMEX™ from CMG.

Table 1 – E9 strategy details

New vertical producers	2
Recompleted vertical producers	1
New horizontal producers	10
New horizontal injectors	7
Max liquid production capacity (m³/day)	20,150
Max oil production capacity (m³/day)	20,150
Max water production capacity (m³/day)	9,765
Max water injection (m³/day)	28,210

The production system considered in this integrated modeling is defined by satellite wells that connect the bottom-hole to the separator on the platform of UNISIM-I field (Fig. 1). A framework based on MERO software from UNISIM incorporates the production system model within the reservoir simulator through multiphase flow tables in pipes to the producer wells, previously simulated by multiphase flow tubing simulator Ptube™ from CMG, chosen to do this calculation.

We propose the optimization of the diameter for each pipe element, to analyze the influence of geometric characteristics of satellite wells in production forecast, evaluating both Net Present Value (NPV) and oil recovery factor (RF).

Other evaluation is made by the optimization of the number of wells in the E9 production strategy.

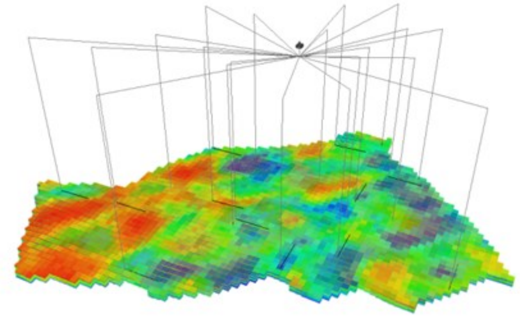

Figure 1 - *Production systems - satellite wells.*

Results

Seven combinations of pipe elements describing the production system were tested. Satellite wells are composed by riser, flowline, and production or injection column. The diameter of these elements were combined as commonly is made in offshore oil fields. We do not consider artificial lift methods in this work.

Table 2 presents the results of NPV and RF for the scenarios with a variation in the economic return of the project between US$ 1,682 and 2,542 million and RF between 53.9 and 59.1%. Scenario 5 was chosen because resulted in best NPV and RF, similar to oil recovery factor and Net Present Value from E9 strategy.

Table 2 – Indicators for the forecast scenarios

#	Riser (in)	Flowline (in)	Column (in)	NPV (Millions US$)	FR (%)
1	4	4	3	1,682	53.9
2	4	4	4	2,141	57.4
3	6	4	4	2,183	57.6
4	6	6	4	2,473	58.8
5	**6**	**6**	**5**	**2,542**	**59.1**
6	8	6	4	2,476	58.8
7	8	6	5	2,526	58.3
8	8	8	5	2,517	57.8

Figure 2 presents the oil production forecast, indicating a high variation in field oil rate. The larger the diameters, the greater the cumulative oil production and the financial return of the project, as expected due to the increased flow capacity of the production system.

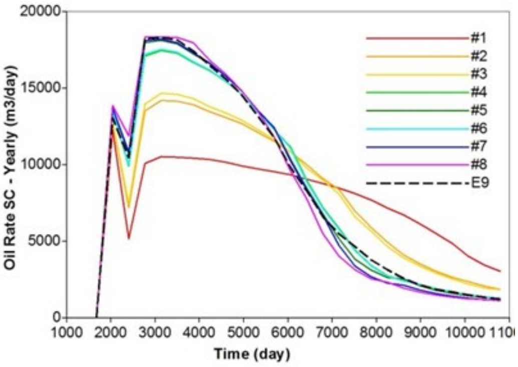

Figure 2 - *Production forecast for scenarios.*

> ***"It was verified a great impact on the pipe elements configuration of the production system, with a variation in the economic return and recovery factor of the project, dependent on the diameter setting adopted."***

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> ***"The incorporation of geometric characteristics of the production system for production optimization should be considered to properly evaluate cumulative oil production and the financial return of the project."***

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In a second step of the study we verify if the inclusion of new wells or exclusion of last wells would improve the field performance in the context of integration between reservoirs and production systems.

The region close to RJS19 was evaluated as candidate to infill drilling in this step, due to the amount of remaining oil in place (Fig. 3). The recompletion of this well was considered economically unviable for the nonintegrated base case production system.

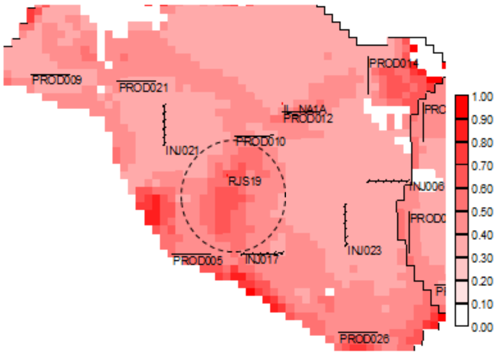

Figure 3 - Percentage of original oil net pay.

Table 3 presents the influence of the number of wells in scenario 5, with alternatives of recompleting RJS-19 (5a), infill drilling a new horizontal injector (5b), and removing last scheduled well (PROD006) in E9 Strategy (5c).

Table 3 - Influence of number of wells for scenario 5

#	Alternative	NPV (Million US$)	FR (%)
5a	RJS19 recompletion	2,534	58.5
5b	new horizontal injector	2,512	59.1
5c	PROD006 removal	2,481	57.3

Although presenting slightly worse indicators, the performance of each alternative is very close to scenario 5, indicating that the project has already achieved a local optimum number of wells for this scenario.

Table 4 shows the influence of the number of wells on scenario 1, with alternatives of recompleting RJS-19 (1a), infill drilling a new producer (1b) or a new injector (1c), evaluating if the integration of reservoir and production system would benefit a scenario with lower production and NPV.

An increase of cumulative oil production and NPV was possible, indicating that the project is in suboptimal solution for scenario 1 and the production system impacts the optimization of number of wells for this scenario.

Table 4 – Influence of number of wells for scenario 1

#	Alternative	NPV (Million US$)	FR (%)
1a	RJS19 recompletion	1,740	54.6
1b	new horizontal producer	1,738	54.8
1c	new horizontal injector	1,653	53.9

Conclusions

It was verified a large variation in economic return based on the configuration of elements that describe the production system. The field oil recovery presented a minor variation. These variations are caused by different boundary conditions imposed on reservoir by the production system, influenced by the geometric characteristics of the combination of pipe elements.

The incorporation of geometric characteristics of the production system for production optimization should be considered, within the context of integration between reservoirs and production systems, to properly evaluate oil production rate, cumulative oil production and the NPV of the project.

The number of wells previously optimized in E9 strategy was not modified, indicating that this strategy selected for the reservoir model integrated with the production system is already optimal. It is possible to conclude that in UNISIM-I-D case, the integration with production system to optimize the number of wells it is not mandatory so production strategy optimization can be considered in 2 steps, optimizing number of wells and production system separately. Further studies are necessary to fully investigate this issue in other cases.

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