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*"This methodology can be applied to other fields where the subsea technologies are being evaluated, considering a reservoir-engineering approach."*

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# Assessing the Use of Subsea Technologies for Produced Water Management in Offshore Fields Using Integrated Asset Modeling

Oscar Julian Peña Piraneque

## Introduction

The production and treatment of large volumes of water during the exploitation of oil fields affect the operating expenditures (OPEX), especially in offshore fields where operations are more complex and the discharge of produced water to the sea is controlled by environmental agencies. Subsea technologies for oil-water (O-W) separation and produced water re-injection (PWRI) can mitigate this problem. Flow from a producer well is separated into two streams: (1) hydrocarbons, produced at the platform, and (2) water, directly re-injected into the reservoir to sustain pressure or for secondary recovery purposes.

The implementation of these technologies have shown interesting results worldwide. The best assessing alternative is the Integrated Asset Modeling (IAM). Silveira et al. (2016) and Abelsson et al. (2016) noted the importance of using IAM to analyze the feasibility of implementing these technologies, as it allows the fast and accurate analysis of complex scenarios.

This work presents a methodology to evaluate these technologies in offshore fields estimating the benefits for the reservoir performance using economic indicators.

## Methodology

The following methodology permitted evaluating the installation of the subsea technologies from a point of view of reservoir-engineering. The purpose is to quantify the effect of installing subsea technologies on field production rather than model the processes carried out by the devices involved in the separation and re-injection. Figure 1 summarizes the adopted methodology for this study.

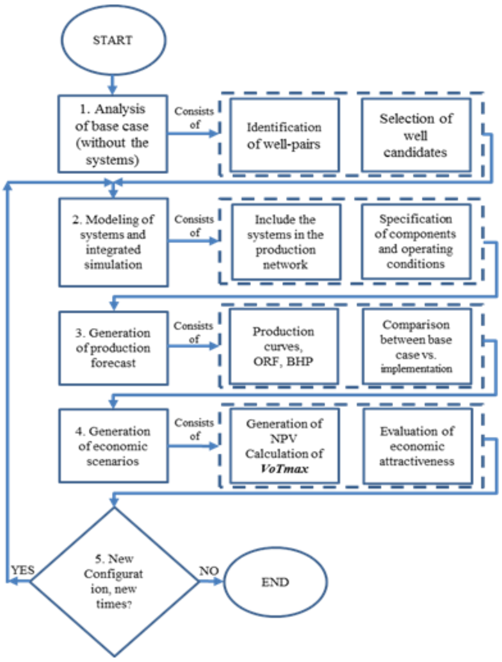


***Figure 1:*** *Methodology to evaluate the economic attractiveness of implementing subsea technologies.*

## Analysis of Base Case

It is composed of two steps: *Identification of well-pairs* and *selection of well candidates*. The first one considers the use of the allocation criterion to quantify the influence of each injector to the producers of the strategy. Knowing the total amount of water injected, it is possible through allocations, knowing the proportion of that water being injected in each producer ($Wi_p$). Using tools of multivariable statistical analysis, the best candidates for implementing the systems were selected through basic information of the production parameters in the base case.

## Modeling O-W Separation, PWRI and Integrated simulation

The modeling of components was simplified but it appropriately represents the processes during separation and subsequent PWRI. In this step, the subsea technologies and components are included and modeled in the production network. After defining the equipment to be modeled, the integrated simulation begins. Two types of arrangements were studied in this work, single-well and multi-well. In the case of single-well, we adopted a satellite well approach and it consists of a dedicated O-W subsea separator and a subsea pump. For multi-well arrangements, several producers can be linked and gathering the production using manifolds. Each producer well has a dedicated O-W subsea separator and can be linked to a dedicated re-injection pump or share a pump. The subsea separator is located on the producer wellhead to minimize pressure drops. Analogously, the subsea pump is located at the injector wellhead.

Besides the reduction of water produced in the platform, installing subsea technologies relieves liquid platform capacity, reduces the amount of water required from injection coming from the platform, increases the oil production associated with great amounts of water (increasing oil recovery factor, ORF), and decreases pressure drops along the production network.

## Generation of production forecast and economic scenarios

Curves of production, water injection and re-injected water are generated and compared with those of the base case (without installation). This comparison is essential to analyze the response of the reservoir, in terms of production, to the inclusion of the subsea technologies.

Once the production for each time step until the end of the simulation is determined, the next step is to generate economic scenarios, specifying the investments required to install the systems.

Due to the variability in costs and lack of information in the literature about capital expenditures (CAPEX) and OPEX associated with the installation and operation of the subsea technologies, the indicator *Maximum-Theoretical Value of Technology* (*VoTmax*) was created and adopted to quantify the economic attractiveness of each installation. *VoTmax* is defined as

$$VoT_{max} = NPV_{with} - NPV_{without}$$

*VoTmax* represents is the maximum affordable investment for installing the subsea technologies. This parameter does not include both CAPEX and OPEX for operation and maintenance during all the time of the project. Therefore, the *Value of Technology* (*VoT*) can be calculated by the following equation

$$VoT = VoT_{max} - (CAPEX+OPEX)_{with}$$

This proposed methodology can be applied to other fields where the installation of subsea Technologies is being evaluated.

## Application

The methodology was tested on the benchmark case UNISIM-I-D showing promising results. Table 1 shows the submodels that were considered during the building of the integrated model. Figure 2 presents a general scheme of a single-well application considering the project specifications of UNISIM-I-D.

***Table 1:*** *Submodels and features considered in the integrated model.*

| SUBMODEL | DESCRIPTION |
|---|---|
| Reservoir and components | UNISIM-I-D (Gaspar et al., 2015) RM9 (Schiozer et al., 2015). Black oil formulation |
| Wells | Empirical correlation for multiphase flow (Beggs and Brill, 1973) for producer wells |
| Production Network | Single and multi-well arrangements considering the features of the production network in UNISIM-I-D |
| Economic | Economic and fiscal assumptions in UNISIM-I-D |

*"The results of the installation showed promising values of VoTmax to include the technologies as a revitalization strategy for mature offshore fields."*

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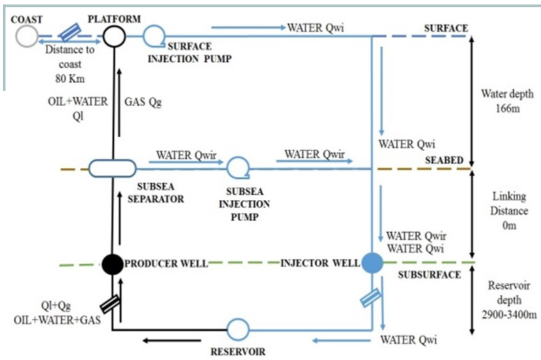


***Figure 2:*** *Final production network for single-well application.*

**Case Studies**

Base case (*OPT PLAT*) incorporates RM9-S9 with optimized platform capacities using integration. *Revitalization of field shows* the installation at later production stages to mitigate the problem of water management. Installation is at the beginning of declining oil production. *New field* assumes that the systems are implemented at the beginning of well production. Results of *revitalization of field* are going to be presented below.

**Results and Discussion**

Table 2 shows the results of the identification of well pairs and the influence of injectors quantified in terms of $Wi_p$, as well as showing the ranking following the *well candidate criteria* based on cumulative water production ($W_p$) and time of breakthrough (TB). INJ023 was not considered because of low value of allocation.

***Table 2:*** *Producers in OPT PLAT and their most influential injectors.*

| PRODUCER | INJECTOR | Wip (m3 thousands) TO THE PRODUCER | RANKING (well candidates) |
|---|---|---|---|
| IL_NA1A | INJ019 | 416.15 | 13 |
| PROD005 | INJ021 | 236.02 | 9 |
| PROD006 | INJ017 | 38.54 | 12 |
| PROD007 | INJ022 | 143.18 | 4 |
| PROD009 | INJ019 | 691.51 | 6 |
| PROD010 | INJ017 | 1.58 | 11 |
| PROD012 | INJ006 | 174.40 | 3 |
| PROD014 | INJ006 | 512.31 | 1 |
| PROD021 | INJ021 | 444.99 | 8 |
| PROD023A | INJ022 | 284.00 | 2 |
| PROD024A | INJ010 | 489.10 | 5 |
| PROD025A | INJ010 | 94.06 | 7 |
| PROD026 | INJ006 | 189.31 | 10 |

Figure 3 shows the *VoTmax* for single-well installation in each producer well and the base case. The best values were observed in wells with upper positions in the ranking. Figure 4 shows the *VoTmax* for multi-well installations. New wells included in the final configuration positively impacted *VoTmax* until reaching the highest value for 12 producer wells and respective influencing injectors, excluding well IL_NA1A. Nevertheless, this value for 12 producer wells requires a further analysis taking into account the required investment for installation in each well.

Increases in *VoTmax in both cases* were obtained due to decreased OPEX because of water production mitigation and revenues due to increased ORF.

For further information about the results and case studies, see Peña (2018).

**Conclusions**

This work demonstrated the use of IAM to evaluate subsea installations. The methodology is suitable for applications in other fields. The results of the installation cases showed promising values of *VoTmax* and the potential of including the technologies as a revitalization strategy for mature offshore fields.

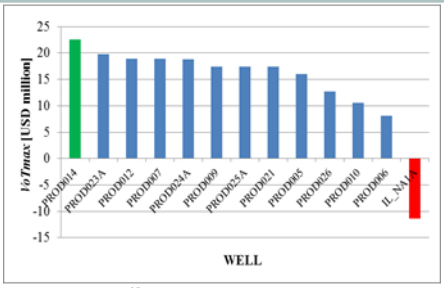


***Figure 3:*** *Difference between single-well applications*

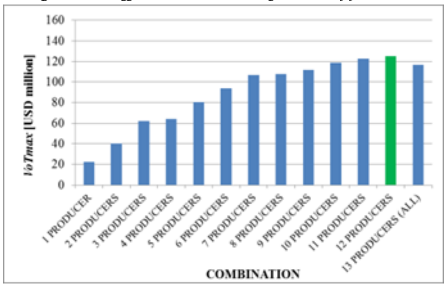


***Figure 4:*** *Difference between multi-well applications*

**References**

Abelsson, C., Hofstad, Å., Rønning, P., B. De Souza, V.H., Hauge, S.H. 2016. Subsea Pump System Technology. Rio Oil & Gas. Expo and Conference. Rio de Janeiro, 1-10. IBP 2120_16.

Gaspar, A. T., Avansi, G. D., Santos, A. A., Hohendorff Filho, J. C. V., Schiozer, D. J. 2015. UNISIM-I-D: Benchmark Studies for Oil Field Development and Production Strategy Selection. International Journal of Modeling and Simulation for the Petroleum Industry, 9 (1), 21-30. https://www.unisim.cepetro.unicamp.br/publicacoes/2015_04_IJMSPI_GASPAR_AVANSI_SANTOS_HOHENDORFF_SCHIOZER.pdf

Schiozer, D. J., Santos, A. A. S., Drumond, P. S. 2015. Integrated Model Based Decision Analysis in Twelve Steps Applied to Petroleum Fields Development and Management. Society of Petroleum Engineers, 3-10. doi:10.2118/174370-MS. https://www.unisim.cepetro.unicamp.br/publicacoes/2015_EUROPEC_SCHIOZER_SANTOS_DRUMOND.pdf

Peña, O. 2018. Use of Subsea Technologies for Produced Water Management in Offshore Fields Using Integrated Asset Modeling. Universidade Estadual de Campinas, Faculdade de Engenharia Mecânica. Dissertação (Mestrado). 125 p. https://www.unisim.cepetro.unicamp.br/publicacoes/OSCAR_JULIAN_PENA_PIRANEQUE.pdf

Silveira, A. N. Bampi, D. Brasil, T. E. Carvalho, K. G. Ferreira, M. N. Guarda, M. Moreira, D.C. 2016. Revitalização de Campos Maduros Offshore: Marlim e o Novo Desafio. Rio Oil & Gas. Expo and Conference. Rio de Janeiro, 2-5. IBP 2204_16

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