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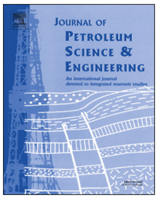

Assisted process for design optimization of oil exploitation strategy

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ABSTRACT

The decision-making processes to select an oil exploitation strategy can be complex due to many variables to be optimized and, it may be unfeasible to simultaneously evaluate multiple variables. In these cases, assisted methods involving engineering analyses and mathematical optimization algorithms may address the problem. In the literature, while several methodologies optimize specific parts of the design infrastructure of the exploitation strategy, methodologies treating the whole process are less common. Since scientific attention focuses on the solution to specific parts of this problem, methodologies that deal with the whole problem remain less clearly developed and require more tests and studies. This paper presents an assisted method to optimize a set of variables of an oil exploitation strategy in a deterministic approach. The methodology proposes to hierarchically order variables, group them according to their nature and importance and combine different optimization procedures with practical engineering analysis. The optimization variables are separated into three groups: (1) design variables group; to be decided before field development, representing the choice of configuration and equipment, (2) control variables group; these determine the operation of the oil field and (3) design future variables group, applicable at later stages such as infill drilling. It is required the estimation of a maximum number of simulation runs based on the available time, also considering interconnections between the groups. We applied the methodology to a reservoir model based on a Brazilian offshore oil field in the pre-development phase, the period before the well development drilling, when little information is available. Results indicate that this is an efficient procedure to evaluate deterministic scenarios, suggesting optimization procedures for each decision variable and achieving good quality solutions within a reasonable number of simulation runs. This is useful in many practical cases, mainly those that require long simulation time runs. Although this work considers one scenario, a deterministic approach is the first stage for optimizing uncertain scenarios in the probabilistic optimization process. In conclusion, applying an adequate assisted process can significantly reduce the number of required simulations. We also observed that the order of variables was an important aspect to be analyzed before starting the process.

1. Introduction and objectives

From a reservoir-engineering point of view, an oil exploitation strategy specifies the important characteristics of the production system (infrastructure) significantly and interactively impacting the expected profit of the whole field. These characteristics include designing many details of infrastructure that will be required in other areas. In general, different optimization processes determine the specifications to assess each element of the strategy, possibly demanding a multidisciplinary team and a complex process chain.

All evaluations and interactions follow a workflow to increase efficiency of strategy selection. The complexity of the problem and the limited time to solve it lead to the application of serial procedures that make approximations, ignore certain details, define subproblems, fix secondary design variables, and assume partial and tentative solutions based on experience (Rudd and Watson, 1968). Therefore, an important task for reservoir engineering is to organize the optimization needed to achieve a reasonable solution for the oil exploitation strategy.

Oil companies use sophisticated methods to evaluate each specification of the strategy. Despite achieving good solutions for a determined specification, combining them to solve the more global problem of strategy may be unfeasible. Adequate methodologies to organize and combine different methods of optimization for each aspect of the strategy help find better solutions efficiently. Therefore, the knowledge of the problem, the choice of appropriate optimization methods, and the way to link the methods

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Nomenclature and abbreviations

BHP	bottom hole pressure
DECE	designed exploration and controlled evolution
FEI	field economic indicator
IWEI	injection well economic indicator
N_p	total oil production
NCF	net cash flow
NPV	net present value
PWEI	producer well economic indicator
W_p	total water production
WCT	water cut
WPI	well performance indicator
AC	abandonment cost
I	investment on equipment and facilities (platform, wells, network systems, pipelines.)
I_{plat}	investment on platform (USD millions)
Inv_{well}	well investment (USD)
C_O	oil production cost (USD)
C_G	gas production cost (USD)
C_W	water production cost (USD)
CO	operational production costs (associated with oil and water production and water injection)
L^i	Cartesian coordinates of location of well i
n_w	total number of wells
n_t	total number of periods of time
$q_p^{oil,water}$	limit of platform flow rate for oil and water
q_p^l	limit of platform flow rate for liquid
q_p^{inj}	limit of platform water injection flow rate
Q_{inj}^f	field water-injection rate (L^3/T)
Q_o^f	field oil-production rate (L^3/T)
Q_w^f	field water-production rate (L^3/T)
r	discount rate
R	gross revenues from oil and gas sales
R_O	oil revenue (USD)
R_G	gas revenue (USD)
Roy	total amount paid in royalties (charged over gross revenue)
ST	total amount paid in Social Taxes (special taxes on gross revenues)
T	corporate tax rate
t_k	time in step k related to the analysis date $t_0 = 0$
t_{wo}^i	opening time of well i
t_{sd}^i	shut-in time of well i
wl^i	length of well i
x^i	x-coordinate of well i
y^i	y-coordinate of well i
z^i	z-coordinate of well i

input and output are part of the reservoir-engineering tasks to build more efficient optimization workflows.

This paper proposes a workflow to address the problem of selecting an oil exploitation strategy using optimization techniques for complex problems. This work uses an assisted process to combine both reservoir engineering evaluations and mathematical methods (more details in Section 2.3). In addition, this approach is applied to offshore oil fields in the pre-development phase defined here as the period before the well development drilling. The evaluated alternatives include: number, position and completion of wells; injection and production capacities, and opening schedules.

Although this work considers a certain scenario, the deterministic approach is one of the stages to optimize uncertain scenarios in the probabilistic optimization process. In fact, the deterministic optimization process can be applied to each scenario of a set of geological, economic and technical scenarios to achieve probabilistic evaluations. Following Schiozer et al. (2015), the methodology developed here is one of the twelve steps of a global and integrated decision analysis methodology involving; reservoir simulation, risk analysis, history matching, uncertainty reduction techniques, representative models, and production strategy selection under uncertainty. The probabilistic optimization process requires a deterministic exploitation strategy to be applied to each uncertain scenario.

2. Production system optimization review

2.1. Production system and oil exploitation strategy

To better understand the challenges involved in reservoir decision-making, we must understand the complexity of a reservoir system from the reservoir-engineering viewpoint. A reservoir system consists of the reservoir and the entire infrastructure used to bring the oil to the surface, defined as the exploitation system. The oil exploitation strategy determines the exploitation system and is included in the context of project development, where the whole exploitation strategy is considered as the product to be developed.

The complete infrastructure project needs to determine components, these can include: size, location and arrangement of surface facilities; number, position and completion of wells; platform processing capacities, wells opening schedules, use of intelligent wells, among others. There is also a certain interactive level between the different aspects. As a consequence, designing the infrastructure of an oil field can be complex and challenging due to the high number of alternatives.

Fig. 1 presents a simplified structural organization chart of reservoir systems, some of their subsystems and some required specifications for the definition of each subsystem. The full definition of the primary system only occurs once all the subsystems are defined. However, note that the number of decision variables is high and the joint selection of the system components is complex.

Some equipment has greater economic impact on use and design than others. Specifying the recovery method is crucial to define what type of surface equipment and well structure is considered. Another example is specifying the physical limits of production that is necessary for sizing up separators and storage tanks systems. On the other hand, many aspects of the infrastructure have a minimal impact on the whole exploitation strategy. In general, the type of pump may be irrelevant to defining well position, if considered the only feasible option. As a result, some pieces of equipment are more dominant than others and have a higher impact on the exploitation strategy.

2.2. Design optimization problem statement and multilevel approach

Perhaps, the distinguishing feature of design problems compared with other engineering problems is that only a fraction of the information needed to define a design problem is available from the problem statement, and all the other information needs to be generated (Douglas, 1988). To supply this missing information, we make assumptions about what types of piece of equipment to use, how the piece of equipment interconnect and the specification of process operations required. Besides this, the

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