A METHODOLOGY FOR DEVELOPMENT SYSTEM OPTIMIZATION OF A HYDROCARBON ASSET BASED ON AN INTEGRATED ADAPTIVE GEOLOGICAL MODEL

Murodov Sadriddin Nizomiddinovich

Abstract

This paper proposes a comprehensive methodology for optimizing the development system of mature fields with high reservoir heterogeneity. The methodology is based on the sequential integration of new geological and technological data and hydrodynamic simulation results into an updated three-dimensional static model. An algorithm for model adaptation to dynamic data is considered, allowing for a reduction in uncertainty in the prediction of filtration-capacity properties. The implementation of the methodology enables a quantitative assessment of the efficiency of various development scenarios, including changes to the well pattern and operating modes. The result is a justified plan of measures aimed at increasing the oil recovery factor (ORF) and the economic efficiency of the project.

Keywords: development system optimization, adaptive geological model, reservoir model refinement, geological and technological studies, hydrodynamic simulation, oil recovery factor, reservoir heterogeneity, history matching.

The challenge of mature and complex fields. The current stage of hydrocarbon resource development is characterized by the increasing importance of mature assets, where significant portions of initial reserves have been produced, and geological complexity often exceeds initial expectations. Traditional static models, built on exploration and early production data, frequently fail to accurately predict fluid flow dynamics during prolonged exploitation. Discrepancies between predicted and actual production indicators (rates, water cut, pressure) lead to suboptimal decisions, leaving behind bypassed oil zones and reducing the ultimate recovery. Therefore, the continuous updating of reservoir models through the assimilation of new data is no longer an option but a critical necessity for effective reservoir management. This paper addresses this need by presenting a structured, cyclical methodology for model-driven development optimization.

Proposed methodology: a closed-loop optimization workflow. The core of the proposed approach is a closed-loop workflow consisting of five interconnected stages, transforming the reservoir model into a "living" digital asset.

Stage 1: Benchmarking and discrepancy analysis. The process begins with a critical audit of the existing model. A comprehensive comparison of historical production data (oil, water, gas rates, bottom-hole pressures) with the model's forecasts is conducted. Key performance indicators (KPIs) such as cumulative production, water cut trends, and pressure decline are analyzed to identify systematic mismatches. This stage pinpoints areas of maximum uncertainty, such as specific reservoir layers, fault blocks, or regions around injectors, guiding subsequent data integration efforts.

Stage 2: Systematic integration of new data streams. To reduce identified uncertainties, diverse data types are incorporated into the model:

- Geological and petrophysical data: new core analysis from infill wells, modernized log interpretations of old wells using advanced algorithms, data from sidewall cores.
- Geophysical data: results from 4D seismic surveys (if available) highlighting drainage patterns and fluid movement.
- Production and pressure data: detailed data from permanent downhole gauges, well tests (PLT, PTA), and tracer studies to understand inter-well connectivity and sweep efficiency.
- Operational data: information on pump performance, workovers, and stimulation treatments.

Stage 3: Model adaptation (history matching) and uncertainty quantification. This is the pivotal step where the static model is calibrated to dynamic reality. Using assisted or ensemble-based history matching techniques, key model parameters (permeability multipliers, fault transmissibilities, relative permeability endpoints) are adjusted within geologically plausible ranges to achieve a satisfactory match with historical data. Crucially, this process is not about achieving a perfect single match but generating multiple equiprobable realizations that capture the range of reservoir uncertainty. This ensemble of models forms the basis for robust forecasting.

Stage 4: Scenario-based forecasting and optimization. Using the ensemble of history-matched models, multiple predictive development scenarios are simulated over a long-term horizon. Scenarios may include:

- Drilling: placement and trajectory optimization of new producers or injectors (infill, horizontal, sidetrack wells).
- Recovery methods: evaluation of secondary (e.g., optimized waterflood patterns) or tertiary (EOR) methods.
- Well management: changes in production/injection rates, re-perforation, zonal isolation, conversion of producers to injectors.

Each scenario is run on all model realizations to assess technical risks and outcomes.

Stage 5: Multi-criteria decision analysis. The optimal scenario is selected based on a combination of technical and economic criteria: maximization of net present value (NPV), increase in the oil recovery factor (ORF), minimization of capital (CAPEX) and operational expenditures (OPEX), and risk exposure (e.g., probability of meeting production targets). This ensures a balanced, economically justified development plan.

Value and implementation challenges. The application of this methodology creates significant value. It moves decision-making from a reactive to a predictive and proactive mode. By quantifying uncertainty, it allows asset teams to prioritize data acquisition (e.g., drilling a pilot well in a high-uncertainty area) and de-risk major investments. The adaptive model becomes a tool for "what-if" analysis, evaluating the impact of operational changes in near real-time. However, implementation challenges exist. They include the need for specialized software and skilled personnel, the integration of data from disparate sources (data silos), and the computational cost of running ensembles of high-resolution models. Successful implementation requires strong cross-disciplinary collaboration between geologists, reservoir, production, and petroleum engineers, fostered by integrated asset team workflows.

Conclusion.

The proposed closed-loop methodology provides a systematic framework for the continuous optimization of field development. Its core principle is the iterative adaptation of the geological model to dynamically assimilate new production and surveillance data. History matching is crucial for transforming a static description into a predictive dynamic tool. Forecasting using an ensemble of models allows for risk-aware scenario evaluation and comparison. Multi-criteria optimization ensures that selected development plans are both technically sound and economically robust. This approach maximizes asset value by identifying untapped reserves and improving sweep efficiency. It facilitates the transition towards a "digital twin" of the reservoir for real-time management. Future advancements lie in accelerating the workflow through machine learning-based proxy models and full-loop ensemble-based optimization.

References.

1. Aziz, K., Settari, A. Petroleum Reservoir Simulation. – London: Applied Science Publishers, 1979. – 476 p.
2. Oliver, D.S., Chen, Y. Recent progress on reservoir history matching: a review // Computational Geosciences. – 2011. – Vol. 15(1). – P. 185–221.
3. Sarma, P., Durlofsky, L.J., Aziz, K. Efficient Closed-Loop Production Optimization under Uncertainty // SPE Journal. – 2006. – Vol. 11(2). – P. 227-239.
4. Tavassoli, Z., Carter, J.N., King, P.R. Errors in History Matching // SPE Journal. – 2004. – Vol. 9(3). – P. 352–361.
5. Williams, G.J.J., Mansfield, M., MacDonald, D.G., Bush, M.D. Top-Down Reservoir Modelling // SPE Annual Technical Conference and Exhibition. – SPE 89974, 2004.