N441: Data-Driven Reservoir Modeling: Top-Down Modeling

Instructor(s): Shahab Mohaghegh

Format and Duration

Classroom - 2 Days

Summary

This course covers the fundamentals of data-driven analytics and predictive modeling. It explains how to build, history match and validate data-driven reservoir models. Instead of using first principle physics, and geological interpretations, the data-driven reservoir model is developed using field measurements such as well construction details, reservoir characteristics, completion parameters, operational constraints, and production and injection volumes. Data-driven reservoir models have small and highly efficient computational footprints that make them ideal reservoir management tools for the purposes of field development planning and uncertainty quantification.

Learning Outcomes

Participants will learn to:

1. Explain the theoretical background of Artificial Intelligence, Machine Learning and Data Mining,
2. Assess artificial neural networks.
3. Apply genetic optimization.
4. Assess fuzzy set theory.
5. Characterize the different philosophies behind data-driven solutions versus traditional engineering.
6. Conduct data preparation for machine learning purposes using principles of fluid flow through porous media.
7. Apply history matching in the context of data driven reservoir modeling (TDM).
8. Validate data-driven reservoir models (TDM).
9. Apply TDM as a reservoir management tool for field development planning and uncertainty quantification.

Training Method

This is a classroom course comprised of lectures with case studies and discussion.

Who Should Attend

The course is designed for reservoir engineers, reservoir modelers, reservoir managers, and geoscientists.

Course Content

To efficiently develop and operate a petroleum reservoir, it is important to have a model. Currently, numerical reservoir simulation is the accepted and widely used technology for this purpose. Data-Driven Reservoir Modeling (also known as Top-Down Modeling or TDM) is an alternative (or a complement) to numerical simulation. TDM uses the “Big Data” solution (Machine Learning and Data Mining) to develop (train, calibrate, and validate) full field reservoir models based on measurements (facts) rather than mathematical formulation of our current understanding of the physics of fluid flow through porous media.

Unlike other empirical technologies that forecast production (Decline Curve Analysis - DCA), or only use production/injection data for its analysis (Capacitance Resistance Model - CRM), TDM integrates all available field measurements such as well locations and trajectories, completions and stimulations, well logs, core data, well tests, seismic, as well as production/injection history (including wellhead pressure and choke setting) into a cohesive, comprehensive, full filed reservoir model using artificial intelligence technologies. TDM is defined as a full field model where production (including GOR and WC) is conditioned to all measured reservoir characteristics and operational constraints. TDM matches the historical production (and is validated through blind history matching) and is capable of forecasting field's future behavior.

The novelty of Data-Driven Reservoir Modeling stems from the fact that it is a complete departure from traditional approaches to reservoir modeling. The Fact-Based, Data-Driven Reservoir Modeling manifests a paradigm shift in how reservoir engineers and geoscientists model fluid flow through porous media. In this new paradigm current understanding of physics and geology in a given reservoir is substituted with facts (data/field measurements), as the foundation of the model. This characteristics of TDM makes it a viable modeling technology for unconventional (shale) assets where the physics of the hydrocarbon production (in the presence of massive hydraulic fractures) is not yet, well understood.

Role of Physical Geology

Although it does not start from the first principles physics, a TDM is a physics-based reservoir model. The incorporation of the physics in TDM is quite nontraditional. Reservoir and geological characteristics to the extent they can be measured. Interpretations are intentionally left out during the model development, but are extensively utilized during the analysis of model results. Although fluid flow through porous media is not explicitly (mathematically) formulated during the development of Data-Driven Reservoir Models, successful development of such models is unlikely without a solid understanding of reservoir engineering and geoscience. Physics and geology are the foundation and the framework for the assimilation of the data set that is used to develop the TDM.

Formulation and Computational Footprint

A Top-Down Model is built by correlating flow rate, reservoir pressure and fluid saturation at each well and at each time step to a set of measured static and dynamic variables. The static variables include reservoir characteristics such as well logs (gamma ray, sonic, density, resistivity, etc.), porosity, formation tops and thickness, etc. at the following locations:

- At and around the well,
- The average from the drainage area,
- The average from the drainage area of the offset producers,

- The average from the drainage area of the offset injectors.

The dynamic variables include operational constrains and production/injection characteristics at appropriate time steps, such as:

- Well-head or bottom-hole pressure, or choke size, at time step t,
- Completion modification (operation of ICV, squeeze off, etc.), at time step t,
- Number of days of production, at time step t,
- GOR, Water cut and oil production, at time step t-1,
- GOR, Water cut and oil production, of the offset wells at time step t-1,
- Water and/or gas injections, at time step t,
- Well stimulation details.

The data (enumerated above) that is incorporated into TDM shows its distinction from other empirically formulated models. Once the development of the TDM is completed, its deployment in forecast mode is computationally efficient. A single run of the TDM is usually measured in seconds or in some cases in minutes. The small computational footprint, makes TDM an ideal tool for reservoir management, uncertainty quantification, and field development planning. Development and deployment costs of TDM is a small fraction of numerical simulation.

Expected Outcome of Top-Down Models

Data-Driven Reservoir Modeling can accurately model a mature hydrocarbon field and successfully forecast its future production behavior. Outcomes of Top-Down Modeling are forecast of oil production, GOR and WC of existing wells as well as static reservoir pressure and fluid saturation, all of which are used for field development planning and infill drilling. When TDM is used to identify the communication between wells, it generates a map of reservoir conductivity that is defined as a composite variable that includes multiple geologic features and rock characteristics contributing to fluid flow in the reservoir. This is accomplished by de-convolving the impact of operational issues from reservoir characteristics on production.

Limitations of the Technology

Data-Driven Reservoir Modeling is applicable to fields with a certain amount of production history, and so is not applicable to green fields and fields with a small number of wells and short production history. Another limitation of TDM is that it is not valid once the physics completely change. For example, when a field under primary recovery moves to an enhanced recovery phase, retraining of the model is required.

Itinerary

- Introduction
  - Reservoir Models for Reservoir Management

    - What Is Top-Down Modeling?
    - Paradigm Shift
    - Mature Fields
    - Reservoir Simulation Models
- Pitfalls of using Machine Learning in Reservoir Modeling
    - Fact-Based Reservoir Management
    - Empirical Models in the E&P Industry
    - Decline Curve Analysis
    - Capacitance-Resistance Modeling
- Top-Down Modeling – TDM
    - Components of a Top-Down Model
    - Formulation & Computational Footprint of TDM
    - Curse of Dimensionality
    - Correlation is not the same as Causation
    - Quality Control and Quality Assurance of the Data
    - Inspecting the Quality of the Data
    - Quality Control of the Production Data
- The Spatio-Temporal Database
    - Static Data
    - Dynamic Data
    - Well Trajectory and Completion Data
    - Two versus Three Dimensional Reservoir Modeling
    - Resolution in Time and Space
    - Role of Offset Wells
    - Structure of the Spatio-Temporal Database
    - Required Quantity and Quality of Data
- History Matching the Top-Down Model
    - Practical Considerations during the Training of a Neural Network
    - Selection of Input Parameters
    - Partitioning the dataset
    - Structure and Topology
    - The Training process
    - Convergence
    - History Matching Schemes in Top-Down Modeling
        - Sequential History Matching
        - Random History Matching
        - Mixed History Matching
    - Validation of the Top-Down Model
    - Material Balance Check
- Post-Modeling Analysis of the Top-Down Model
    - Forecasting Oil Production, GOR and WC

    - Production Optimization
    - Choke Setting Optimization
    - Artificial Lift Optimization
    - Water Injection Optimization
    - Reservoir Characterization
    - Determination of Infill Locations
    - Recovery Optimization
    - Type Curves
    - Uncertainty Analysis
    - Updating the Top-Down Model
- Examples and Case Studies
    - Mature Onshore Field in Central America
    - Mature Offshore Field in the North Sea
    - Mature Onshore Field in the Middle East
    - Data Used During the TDM Development
    - TDM Training and History Matching
    - Post-Modeling Analysis
    - Performing a “Stress Test” on the Top-Down Model
- Limitations of Data-Driven Reservoir Modeling
- Future of Data-Driven Reservoir Modeling