Fundamentals

Reservoir Simulation | Fundamental

Basic concepts

Reservoir simulation is an area of reservoir engineering that, combining physics, mathematics, and computer programming to a reservoir model allows the analysis and the prediction of the fluid behavior in the reservoir over time.

It can be simply considered as the process of mimicking the behavior of fluid flow in a

petroleum reservoir system(including reservoir rock and fluids, aquifer,surface and subsurface facilities) through the use of either physical or mathematical models.

It’s a valuable tool to understand the oil and gas reservoir performance under various operating strategies.

Basically, reservoir simulation consists of:

1. a geological model in the form of a volumetric grid with cell/face properties that describes the given porous rock formation
2. a flow model that describes how fluids flow in a porous medium, typically given as a set of partial differential equations expressing conservation of mass or volumes together with appropriate closure relations
3. a well model that describes the flow in and out of the reservoir, including a model for flow within the well bore and any coupling to flow control devices or surface

facilities

Reservoir simulation is used for two main purposes:

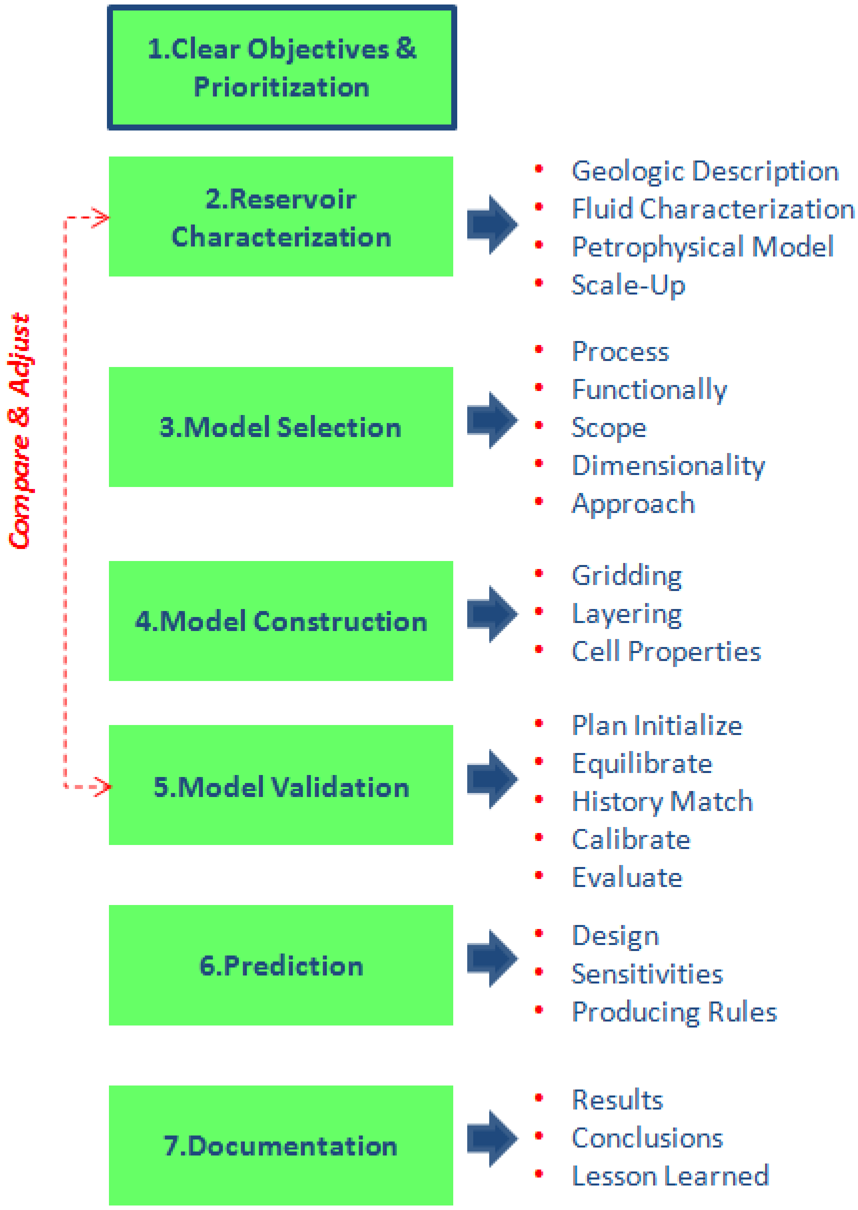
1. to optimize development plans for new fields
2. to assist with operational and investment decisions.

To carry out reservoir simulation, it is necessary to perform several and complex studies which are normally made by teams of specialists from different disciplines – due to the large amount of data required for the preparation of the simulation input data set.

The main elements of a simulation study include

- matching field history
- making predictions (including a forecast based on the existing operating strategy)
- evaluating alternative operating scenarios

A description of the steps to undertake during a simulation study is presented in the table below



Main steps in a reservoir simulation study

Numerical techniques and approaches

Traditional finite difference simulators dominate both theoretical and practical work in reservoir simulation. Conventional Fluid Dynamics (FD) simulation is underpinned by three physical concepts: conservation of mass, isothermal fluid phase behavior, and the Darcy approximation of fluid flow through porous media. Thermal simulators (most commonly used for heavy crude oil applications) add conservation of energy to this list, allowing temperatures to change within the reservoir.

Numerical techniques and approaches that are common in modern simulators:

- Most modern FD simulation programs allow for construction of 3-D representations for use in either full-field or single-well models.2-D approximations are also used in various conceptual models, such as cross-sections and 2-D radial grid models.
- Theoretically, finite difference models permit discretization of the reservoir using both structured and more complex unstructured grids to accurately represent the geometry of the reservoir. Local grid refinements are also a feature provided by many simulators to more accurately represent the near wellbore multi-phase flow effects. This “refined meshing” near wellbores is extremely important when analyzing issues such as water and gas coning in reservoirs.
- Representation of faults and their transmissibilities are advanced features provided in many simulators. In these models, inter-cell flow transmissibilities must be computed for non-adjacent layers outside of conventional neighbor-to-neighbor connections.
- Natural fracture simulation (known as dual-porosity and dual-permeability) is an advanced feature which model hydrocarbons in tight matrix blocks. Flow occurs from the tight matrix blocks to the more permeable fracture networks that surround the blocks, and to the wells.
- A black oil simulator does not consider changes in composition of the hydrocarbons as the field is produced. The compositional model, is a more complex model, where the PVT properties of oil and gas phases have been fitted to an equation of state (EOS), as a mixture of components. The simulator then uses the fitted EOS equation to dynamically track the movement of

both phases and components in field.

The simulation model computes the saturation change of three phases (oil, water and gas) and pressure of each phase in each cell at each time step. As a result of declining pressure as in a reservoir depletion study, gas will be liberated from the oil. If pressures increase as a result of water or gas injection, the gas is re-dissolved into the oil phase.

A simulation project of a developed field, usually requires “history matching” where historical field production and pressures are compared to calculated values. The model’s parameters are adjusted until a reasonable match is achieved on a field basis and usually for all wells. Commonly, producing water cuts or water-oil ratios and gas-oil ratios are matched.