Top-Down Modeling: A Shift in Building Full-Field Models for Mature Fields

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Description of the Technology

Models are needed to develop and operate petroleum reservoirs efficiently. Data-driven reservoir modeling [(also known as top-down modeling (TDM)] is an alternative or a complement to numerical simulation. TDM uses the so-called "big-data" solution (machine learning and data mining) to develop (train, calibrate, and validate) full-field reservoir models on the basis of measurements rather than solutions of governing equations.

Unlike other empirical technologies that forecast production, or only use production or injection data for its analysis, TDM integrates all available field measurements (well locations and trajectories, completions, stimulations, well logs, core data, well tests, seismic, and production/injection history—e.g., choke settings) into a full-field reservoir model by use of artificial-intelligence technologies. Intelligent Solutions, as the inventor of TDM, has recently released software application "IMagine" for TDM development.

TDM is a full-field model wherein production [including gas/oil ratio (GOR) and water cut] is conditioned to all measured reservoir characteristics and operational constraints. TDM matches the historical production and is validated through blind history matching, and it is capable of forecasting a field's future behavior on a well-by-well basis.

The novelty of TDM stems from the fact that it is a complete departure from traditional approaches to reservoir modeling. In this new paradigm, current understanding of physics and geology is substituted with field measurements as the foundation of the model. This characteristic of TDM makes it a viable modeling technology for unconventional assets, where the physics of hydrocarbon production is not well-understood.

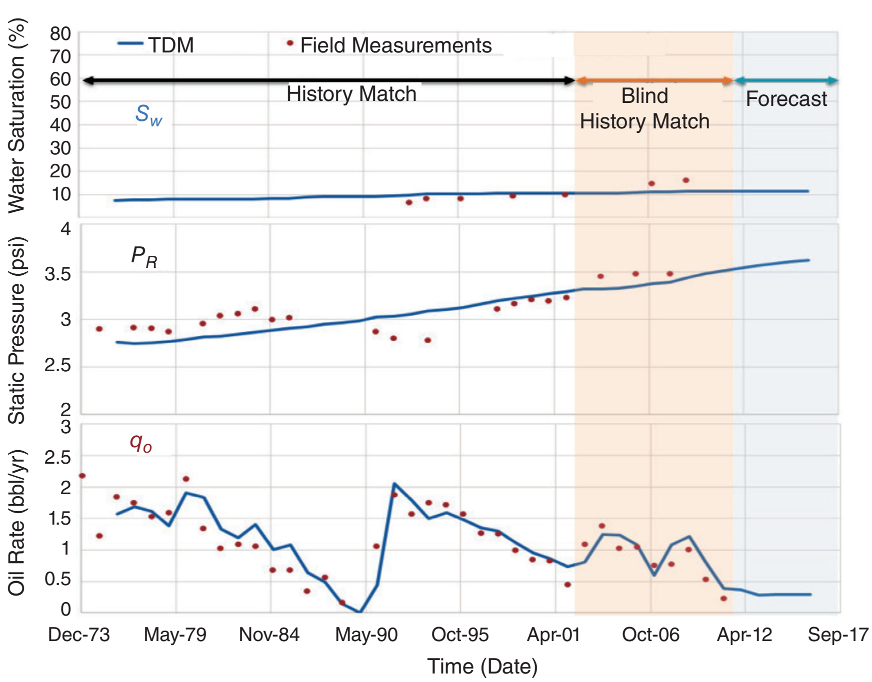

Fig. 1—TDM history match, blind simultaneous history match, and forecasting for Well #C0x41 for time-lapse water saturation (top), static reservoir pressure (middle), and oil production (bottom). Red squares in all three plots indicate field measurements, while lines indicate TDM results.

Role of Physics and Geology

First-principles physics of fluid flow is not formulated explicitly within TDM, but forms the framework for the assimilation of the spatio-temporal database as its foundation. TDM is built by correlating flow rate at each well/timestep to a set of measured static and dynamic variables. Static variables (such as porosity, thickness, initial water saturation, and formation top) are considered as follows:

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

The dynamic variables are considered at appropriate timesteps:

- Wellhead pressure, or choke size at timestep *t*
- Completion modification (inflow-control valve and squeeze-off) at timestep *t*
- Days of production at timestep *t*
- GOR, water cut, and oil production of the well at timestep t and for the offsets at timestep $t-1$
- All injections at timestep *t*

The data incorporated into TDM demonstrate its distinction from other empirically formulated models. Once the development of the TDM is completed, its deployment in forecast mode is computationally efficient (running in sec-

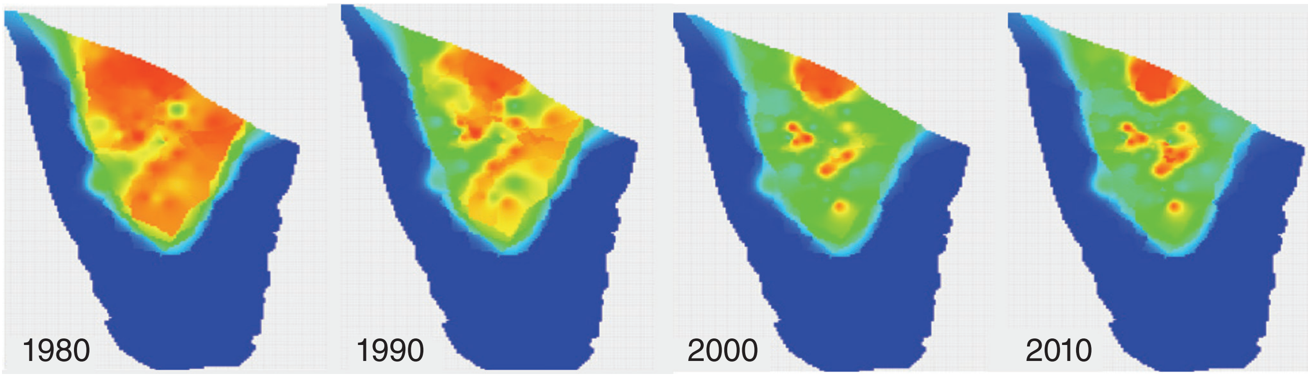

Fig. 2—Map of water saturation (blue is S_w=1.0) as a function of time in Unit A. All measured values of water saturation throughout the history of the field are honored in this map. Where and when field-measurement values were not available, TDM results have been substituted at the well locations and then geostatistics have been used to populate the map.

onds). The small computational footprint makes TDM an effective tool for reservoir management, uncertainty quantification, and field-development planning. Development and deployment costs of TDM are a small fraction of the cost of numerical simulation.

Other Considerations

TDM can accurately model a mature field and forecast its future production behavior successfully (**Fig. 1**). Its deliverables include forecast of oil production, GOR and water cut of existing wells, location of sweet spots, field-development planning, and in-fill 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 flow in the reservoir (**Fig. 2**). This is accomplished by deconvolving the effect of operational issues from reservoir characteristics on production.

TDM is applicable to fields with a certain amount of production history as long as the physics of the flow does not change dramacally. It needs to be updated (retrained) with new measurements that reflect the new fluid-displacement mechanism. **JPT**