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Introduction to Simulation Grid Design and Upscaling Methods

Kevin Zhang*
Roxar Canada Ltd., Calgary, Canada
Kevin.Zhang@roxar.com
Sasan Ghanbari
Roxar Canada Ltd., Calgary, Canada
Sasan.Ghanbari@roxar.com
and
Robert Chelak
Roxar, Inc., Houston, USA
Robert.Chelak@roxar.com

Summary

With the availability of high-end PCs and workstations (high-frequency CPUs, 10s-GB RAM, TBs-hard drive, and 64-bit operating system), geological reservoir models with tens million cells can be routinely built. Vertical resolutions of the geological grid can be as fine as 0.5 feet (0.1524 meter) or even finer. Meanwhile, the acceptable total number of cells of a simulation grid has not been changed much. The main reason for this is that reservoir simulation algorithms are complex and have expensive computational run times. Simulation technology has advanced but not at the same rate as geological models. The explosion in geological reservoir details presents great challenges for model upscaling. This paper discusses common approaches in simulation grid design and introduces common reservoir property upscaling algorithms, which result in an optimized simulation grid and maximum geological details may be kept for numerical reservoir simulation.

To reduce the total number of cells used for numerical reservoir simulation, a simulation grid is generated instead of using the geological grid directly. Simulation grid design is still commonly done by hand nowadays, where a reservoir engineer needs to generate a coarser scale simulation model. A uniform simulation grid is used often for simplicity. The drawback is that reservoir heterogeneity cannot be maintained, which could eventually lead to poor history matching. The key ideas of simulation grid design include: (1) volume preservation; (2) similarity between geological grid and simulation grid; and (3) geological details preservation. Corner-point grid is used for both geologic and simulation grids building; therefore, areal grid size selection is important to preserve reservoir bulk volume constrained by bounding surfaces. Besides of the areal grid size, both grids should honor fault surfaces well. Only when two grids are similar, tensor-based upscaling approaches can be applied. Another common challenge is layering scheme definition. The common concern is that a simulation grid must keep maximum geological details that a geological grid captured as possible. In other words, only homogeneous geological grid cells should be combined. There are many ways to quantify reservoir heterogeneity / variation and optimization algorithms are often applied to simplify the workflow. For example, Li et al. (2000) used a displacing front conductivity to quantify reservoir heterogeneity, which is a combination of porosity, permeability and facies (in terms of relative permeability, endpoint saturation, and various facies rules). Ates et al. (2003) applied the streamline simulation-based ranking and upscaling approach in a field case study.

There are many upscaling algorithms available. This paper discusses some commonly-applied algorithms. There are some rules must be followed by all algorithms. For example, pore volume and water volume must be reproduced for porosity and water saturation upscaling. The upscaling of permeability is a big challenge. Diagonal tensor, full tensor and facies-based upscaling approaches are commonly used for permeability upscaling.

References

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