Revolutionising History Matching and Uncertainty Assessment

When planning future production, new technology that replaces manual history matching of reservoir models represents a key advance for reservoir engineering.

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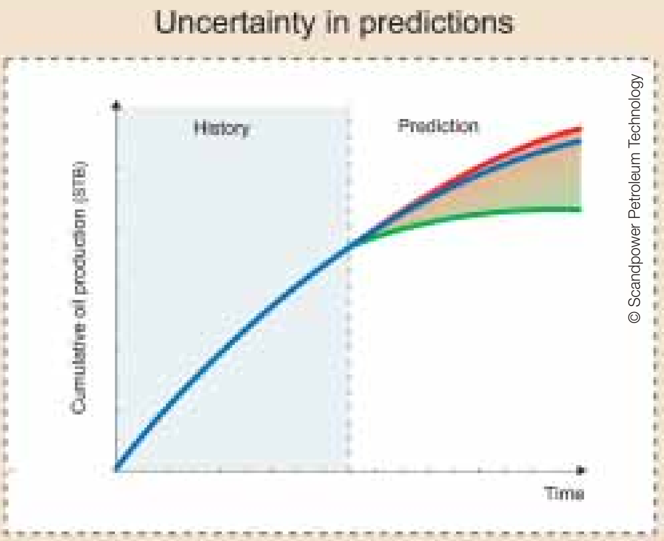


The blue line shows the manual match. The area between the red and the green line indicate possible future production based on results from MEPO. This chart clearly shows that the manual match is quite optimistic and not well suited as a P50 case.

Traditionally, history matching of the reservoir model has been done manually and methods from the 1980's are still widely used. Runs are usually launched sequentially, all files are prepared manually and the evaluation is done by visually comparing line plots. This is time consuming and it is difficult to absorb all the information available, inevitably, such an approach is very subjective. Being constrained by a time frame, the engineer frequently has to finish after finding only one single match.

Through the history matching process we aim to calibrate the model to reproduce historical observations such as production rates or formation pressure in a reservoir simulator. When calibrated, the model can be used for predictions and decision making for future field development.

In order to history match the model we need to adjust parameters like permeability, porosity, fault transmissibility and PVT within a given uncertainty range. Similar to a mathematical problem with more unknowns than equations, there will multiple solutions. This means that it is possible for several combinations of parameters or models to give a good match. Typically, we end up having a handful of new, calibrated models, all of which are as likely as each other. These models give quite different dynamic results. Using only one single model for prediction and decision-making purposes will result in increasing risk.

Leading oil and gas companies are now experimenting with assisted history matching because of the shortcomings of the manual method. Companies that have applied these methods report very successful results which have directly impacted on financial performance.

A Question of Philosophy

History matching is as much a question of philosophy as technology since there are different workflows to follow. Three of these are discussed below.

As previously mentioned, a common workflow method is *manual history matching*. This usually results in only one solution and is very time consuming.

Another approach is to run a number of models - for example 100 dynamic simulations - and use approximations to generate *proxy models* in an attempt to find all possible solutions. Proxy models are polynomial representations of the full dynamic simulation model. The advantage of this approach is speed, since calculations are done using the simple proxy model, not the reservoir simulator. With 100 simulations this can be expensive, while the quali-

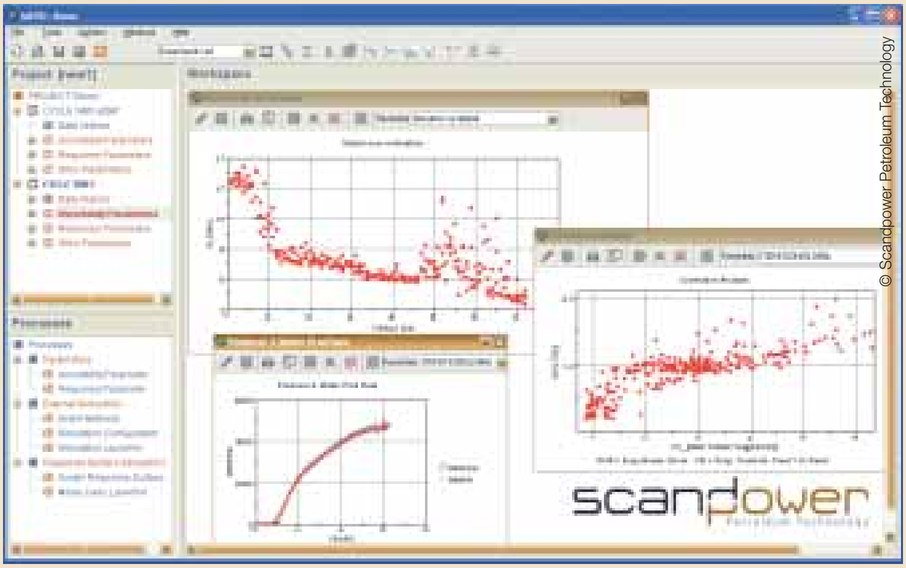
Evolutionary Algorithms

Evolutionary algorithms in particular have proved to be well suited for history matching. Genetic Algorithms and Evolution Strategy are two sub-groups of Evolutionary Algorithms. The Evolution Strategy has been proven successful to complex optimisation problems in the oil and gas and other industries.

The Evolution Strategy (ES) generally imitates the biological principals of evolution, 'survival of the fittest'. This means that the algorithm will continue the search around the best combinations of parameters to further improve the match and reject the bad ones. During every iteration the software analyses the results, trends and correlations to further adjust the parameters to improve the match. This is done in a matter of seconds.

The ES contains a destabilisation feature that will force the algorithm to try out totally different combinations when the match cannot be improved further. By doing this the algorithm will find more possible matches in the solution space.

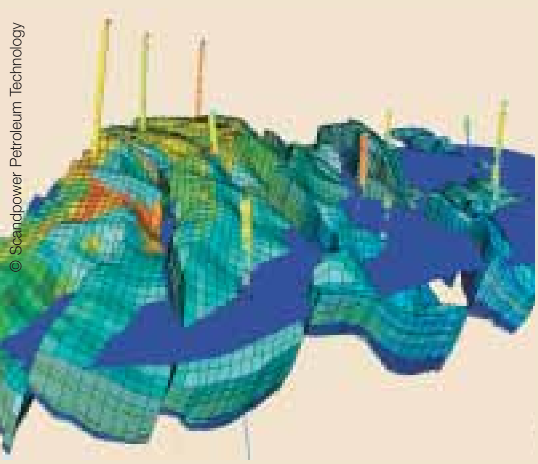
This approach is very pragmatic, but the artificial intelligence in MEPO makes the search for acceptable matches extremely efficient. This means that the engineer can cover the whole solution space finding the possible matches and have much more confidence in the final result.



The MEPO user interface makes the analysis easy and efficient. The engineer gets the full overview by looking at the global match error and can at the same time investigate all the important details.

ty of the proxy model decreases with the increasing number of parameters and the degree of complexity. As a result, proxy models are not well suited for complex models or cases where there are several parameters that need adjusting.

A third option is to run *multiple dynamic simulations in parallel* and efficiently search the solution space. This approach has proved to be very successful. It copes with hundreds of parameters as well as the nonlinear variable interactions and dependencies that proxy models fail to include. There is no doubt that this approach can provide valuable information about the reservoir behaviour if the information is extracted and presented in a proper way.



The same algorithms that find history matches can also easily find optimal well position or well length for infill drilling. It also accounts for the uncertainties in the model so that the potential risk is reduced.

The Technology is Available

MEPO, an example of this third option, was made commercially available in 2004 (GEO ExPro No. 1, 2006). The software utilises cheap and fast CPU's and modern cluster technology.

The software prepares all the files, executes all runs, analyses all the data and searches to obtain as many good matches as possible. This frees the engineer from time-consuming file handling and allows more time to be spent analysing and evaluating results. Based on knowledge and experience, the engineer can steer the process as desired.

Running 2,000 simulations in 2 weeks has no value unless it is possible to efficiently extract information of importance. Therefore, a variety of sophisticated analysis techniques are included. Plots showing trends, correlations and match quality provide the engineer with much more information than can usually be seen from normal line plots. The information helps the engineer to fully understand the model behaviour.

MEPO has been shown to speed up the history matching process by up to 10 times. History matching projects that used to take months can now be done in weeks or days and can even generate alternative match realisations within that time frame.

Uncertainty Assessment

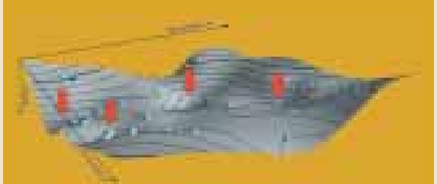
History matching is often done in order to calibrate the model so it can be used for predictions, but there is normally a large degree of uncertainty attached to these.

Many different methods are used today

The Solution Space

To illustrate the complexity of history matching, a simple model with only two parameters is used. Different parameter combinations of X and Y will result in a match quality seen on the vertical axis. Each simulation case is shown as a dot in the solution space. A surface is displayed to better see the vertical position or quality of each case.

With manual history matching there is not time to do a large number of simulations. The red arrow indicates the lowest mismatch error found. This single model is then used for future predictions.



Using MEPO you have time to do a large number of simulations and efficiently search the solution space. In this way you can find the possible solutions and make reliable predictions.

to assess uncertainty. Running thousands of Monte Carlo simulations in order to find the P10, P50 and P90 case is probably well known. However, all of these methods have one thing in common; they imply that the single match realisation is a sound basis for the uncertainty assessment. Assisted history matching studies have, however, shown the pitfall of assuming that a single match realisation is a reliable P50 (base) model. A traditional uncertainty description will generally deliver an uncertainty range surrounding the base model, but since the base model is seldom suited for such use, it would appear pointless to use such false descriptions of reservoir uncertainty in the decision process.

The new approach through MEPO makes it feasible to explore the solution space and find several possible resolutions. These multiple solutions are run in prediction mode to find a more realistic uncertainty range. The result will help visualise both the up and down side potential associated with drilling decisions such as well placement.