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Modelling and Optimisation in BP Exploration and Production; Case Studies and Learnings

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Abstract

This paper discusses the role of modelling and optimisation in BP's FIELD OF THE FUTURE Short-Loop optimisation programme. The focus is on the short-term optimisation of oil and gas production subject to the constraints imposed by hydrocarbon reservoir management and the associated protection of reserves. Reservoir modelling itself is not discussed; rather it is assumed that an effective reservoir depletion strategy has been defined and can be used to set boundaries for the short term optimisation of production.

The primary objective of the paper is to support the case for the widespread use of mechanistic modelling in support of operational decision making. Past experience in BP, with modelling and optimisation technologies, has shown that there is a huge potential for increased production from the use of models in support of daily operations, once the quality of these models has been assured.

The paper reviews the current business drivers for optimisation in BP and summarises some of the historical experience with model based optimisation in BP's Exploration and Production segment. The paper concludes by summarizing some of the key learnings that the FIELD OF THE FUTURE programme is taking forward as the basis for the design and deployment of a new optimisation capability within BP. called Model Based Operational Support (MBOS).

Introduction

The leadership expectations for operational performance in BP are very clearly defined. At an overall company level, management systems define a set of processes, which, when implemented by the workforce, helps deliver business performance. The priority focus areas are operational safety and integrity. However, clear expectations are also expressed in the area of system optimisation with BP's producing assets challenged to continuously optimise and improve performance and value delivery.

Within the BP Exploration and Production (E&P) segment, a series of defined common processes provide the framework for effectively managing BP's operations. Each common process has been designed by a multi-disciplinary team of senior practitioners to capture best practice and ideas from the majority of BP E&P's operating locations. A number of the common processes speak directly to the concept of integrated asset modelling as a potential mechanism to support operating assets in delivering an effective optimisation process. In support of the delivery of common process, BP sponsors a strong network (community of practice) supporting the development of asset models - current modelling tools are capable of representing the full production system including producing wells, gathering system, process facilities , gas and water injection.

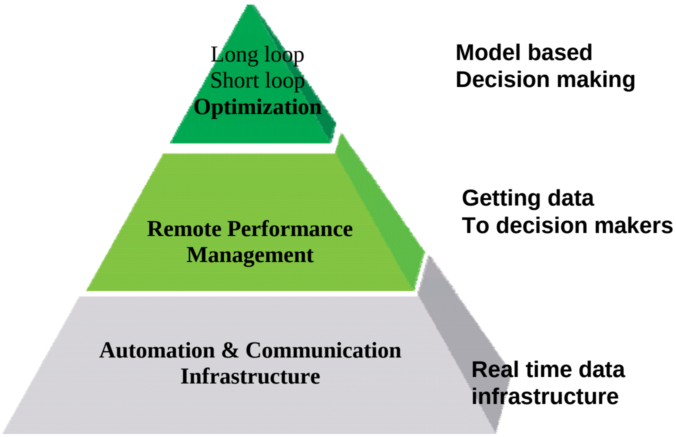

Figure 1. The Role of Optimisation within the FIELD OF THE FUTURE programme.

However, until recently, the full value of modelling has not been realised within asset operations. While individual discipline models exist for the majority of operations, a large proportion of the models are not regularly used or kept up-to-date. As the accuracy of such models begins to fall so also does the user's confidence in the model. On the majority of assets, where models are used, they are predominantly used in isolation (to study problems within a particular discipline), rather then being integrated to provide holistic system insights.

Recent successes, at a number of BP assets, has shown that there is a huge potential for increased production from using the predictive capability of existing models in daily operations, once these models have been combined with real-time data and delivered in a form that actively supports the production optimisation process. The ability to replicate this success across the whole of BP's upstream operations represents the focus of the short-loop optimisation capability of the FIELD OF THE FUTURE programme which aims to bring the use of BP's modelling software to the forefront of daily operational decision making.

Optimisation comprises the pinnacle of the FIELD OF THE FUTURE capability pyramid shown schematically in Figure 1. This simple diagram explicitly recognizes that a robust and sustainable optimisation capability can only be delivered on a platform provided by a reliable asset infrastructure together with an advanced level of remote performance management. Delivering the robust platform for optimisation is the focus of a number of the FIELD OF THE FUTURE technology programmes and will not be considered further in this paper. In addition, within the FIELD OF THE FUTURE programme, optimisation is further categorized as comprising both a short-loop and a long loop activity. The long-loop optimisation programme, which supports the recovery of reserves, is also outside the scope of this paper.

The FIELD OF THE FUTURE short-loop optimisation capability is focused on maximizing production in the short to medium time frame subject to constraints arising from the prevailing reservoir depletion strategy. Work on this capability is at an advanced prototyping phase of development. The learnings that are being taken forward and used to deliver this FIELD OF THE FUTURE's capability are discussed in this paper together with a review of BP's track record of optimisation experience.

BP Exploration and Production Experience with Model Based Optimisation

BP, in common with other E&P operators [1], can reference many cases where integrated asset modelling has delivered significant value to the business through improved operation. However, although each case history is very powerful in itself, it has not been easy to sustain such examples of best practice or to transfer them to other parts of the company. Hence, the current FIELD OF THE FUTURE short-loop optimisation programme is concerned with delivering a model based optimisation capability that can be easily implemented (allowing best practice to be rapidly disseminated) and sustained. In this respect a key focus is to learn the lessons of the past and to address these as part of the new capability that is being developed.

There follows a summary of some of the optimisation projects that have been carried out at BP. The intent here is to draw out learnings relevant to the direction of the FIELD OF THE FUTURE programme in this area. The case histories do not comprise, by any means, a comprehensive summary of BP experience with integrated asset modelling and optimisation. In particular, BP has a very large community of modelling practitioners working off-line with both subsurface and surface models, who deliver significant value to their business performance. However the case studies reviewed are all concerned with putting in place a sustainable, cross-disciplinary, pseudo real-time optimisation capability of the form similar to the intent of the FIELD OF THE FUTURE programme. Hence their learnings are very relevant to future work in this area.

Wytch Farm Optimisation

Two early implementations of optimisation technology occurred at BP's Wytch Farm onshore oil field and hydrocarbon processing plant.

The first application was an optimiser for the Wytch Farm producing wells. This application used self-contained modelling software that was not part of the BP standard discipline modelling toolset. It was sponsored and owned by the assets advanced control community and used in an on-line advisory mode. Its focus was on optimizing well production against the hydraulic limitations provided by the flowlines delivering reservoir fluids to the gas processing facility. This well optimiser was maintained and used for a number of years. Some production gains were claimed. Use of the application fell away, however, after the application champion left the asset. As the asset production moved into decline the business driver for maintaining the application also weakened.

The second application at Wytch Farm was an off-line optimiser of the gas and oil processing plant. This off-line process plant optimiser was an in-house development, built with standard process modelling software. A bespoke user interface was developed to enable asset engineers to successfully run the optimisation application – the asset engineers did not have the detailed simulation expertise to use the model with its native interface. The process optimiser was used primarily in case-study mode to assess operating strategy for typical operating environments. The application was used very successfully in this respect when the asset was at high throughput and hence production constrained. Analysis, using the optimiser, identified a counter-intuitive operational mode that allowed significantly higher gas-plant throughput during the hotter summer months.

Key learnings from the optimisation work at Wytch farm included:

- Optimisation needs to be applied at the appropriate time in order to capture value. In an Upstream asset, opportunities for optimisation come and go as the asset passes through the life-cycle of ramp up, plateau operation and decline. Correspondingly, optimisation applications need to be flexible such that they can be easily reconfigured to focus on new business opportunities as they arise.
- Where feasible, optimisation applications should be built around models that are already maintained by an assets discipline engineers. Wider asset ownership of business applications is likely where the underlying models are owned within the respective disciplines
- The rigour present in the Wytch farm model was an important component that allowed counter-intuitive solutions to be identified. However, adding rigour, often reduced robustness. A challenge for any modelling project is to determine how much rigour is necessary.
- The gas and oil process optimiser was used off-line primarily to develop a deeper asset understanding of asset performance limitations. From increased knowledge, an appropriate operational strategy was determined.

The Harding Optimiser

The Harding Optimiser was an early application of model based optimisation where subsurface and surface tools were combined to deliver an operational decision support tool. Significantly, during the 6-12 month period of sustained usage, a formal optimisation team structure was in place within the asset comprising subsurface engineer, surface engineer, optimiser champion and optimiser user. A number of success stories from the optimiser were reported internally within BP. In the context of understanding the role of the tool, it is instructive to consider a typical scenario of how the value was realised:

> The asset was operating with certain wells choked back to manage gas-handling and water handling constraints. The optimiser made recommendations to change the well production profile, and in particular to open up one of the wells

that was severely choked back. These recommendations were consistent with the prevailing gas and water handling constraints as well as individual well draw-down limitations. (A drawdown limit defines how low the wellhead pressure on a particular well can be dropped. The drawdown limit is set be the asset reservoir engineer to protect long-term hydrocarbon reserves recovery).

- The asset reservoir engineer challenged the optimiser recommendations on the basis that the well targeted to be opened up would, in reality, incur an effect called gas-coning which would result in the process plant receiving much more gas than the optimiser had predicted – the well models in the optimiser did not model this gas-coning mechanism, rather they assumed a constant gas load on each well with drawdown. On the basis of the significant added value predicted by the optimiser, the optimisation team worked to review the basis of the gas-coning theory. This exercise was able to demonstrate that the conclusion that the well would cone gas was a result of a faulty gas measurement on recent well tests giving a much higher gas load to the well than was actually the case. With a revised well test with an accurate gas measurement, the well was concluded to be not gas-coning. The well was opened up as predicted by the optimiser and a significant production prize delivered.

Key learnings from this work included:

- The existence of an Optimisation team within the asset, with clear roles associated with the use and maintenance of the optimiser, contributed significantly to the sustainability of the model based optimisation process in the asset.
- A key role for the optimiser was to be a catalyst for a robust cross–disciplinary conversation around best operating strategy. Recommendations from the model needed to be challenged and sense-checked against the more complete operational understanding present in the wider operational support team.

Alaska, Prudhoe Bay Optimisation

BP Alaska were one of the early pioneers in BP for model based optimisation with two significant applications being developed.

The first application was a production optimisation tool developed from the Prudhoe full field reservoir model. The scope of the underlying model was from well-bore through the gathering system to the primary separation. The application was fully data-enabled allowing rapid whole asset data reconciliation and model parameter estimation together with what-if model runs and optimisation studies. Although never used extensively for optimisation runs, the application added significantly to operational understanding by providing a self-consistent view of well and facilities operation across the very large Prudhoe system. Particular challenges around the optimisation usage related to the large number of degrees of freedom involved and developing an implementation plan that was tractable to the operations team in the time window available for action. In recent years the optimser has not been widely used due to resource constraints on the asset. However, an effort is currently in place to provide a more comprehensive user interface for operations. This is designed to reduce issues associated with the quality assurance and understanding of input data and results which are in files associated with a commercial reservoir simulator. Typically production engineers do not have sufficient exposure to reservoir modelling software to be able to adequately interpret the model output.

A second, separate, application was focused on the Prudhoe field gas handling and compression system. This was used, in conjunction with the field optimiser, to identify the best operating pressures for the gas-oil separation facilities. Although very powerful, and significantly more advanced than commercial systems available at the time, it was not possible to take this model from a pilot to a production due to the lack of an adequate data historian to train the model. As with the first model, lack of local resources also delayed further development.

Key learnings from this work:

- If models to support optimisation are complex and hence expensive and difficult to maintain, it is likely that such models will not be maintained and will fall into disuse.
- Upstream asset optimisation problems can sometimes be effectively de-coupled into separate sub-problems, allowing each component application to be simpler and easier to maintain.
- For large systems, implementing a significant number of set-point changes may not be practicable in the timeframe available for implementation (before the basic operational conditions have changed). Hence the focus should be on using model runs to derive improved operational understanding and by seeking to implement this knowledge via improved operating strategies and operator guidelines.

The Valhall Optimiser.

The story of the BP Valhall optimiser has been summarised earlier in a previous SPE paper [2]. The Valhall optimiser was a very powerful technology that successfully identified significant benefits. Implementation was supported by a detailed analysis of the optimisation business process at Valhall to identify the people and organizational requirements for sustainable usage. However, the benefits delivered by the Valhall optimiser were lower than the theoretical potential due to the high variability of the Valhall process.

Key learnings from the Valhall work include:

- Optimisation technology needs to be owned by an accountable person in the asset organization and should be introduced gradually, with developments and enhancements planned on the basis of identified value.
- Optimisers for Upstream plants need to be designed to help user interpretation of optimiser advice. As an example, it is much easier to engage an operator in the need for change using a graphical display rather than a table of numbers..
- System models will always comprise only a simplified representation of the actual physics taking place. Hence, optimiser output, in the form of control setpoints, will normally require the assessment and verification of a cross-disciplinary asset team prior to any advice being implemented.
- A high degree of plant variability will reduce the scope of benefits achievable from the use of steady-state optimisation technologies. Where high variability exists the initial optimisation focus should be on approaches to stabilise the process. This is likely to be of high value in itself and also provides an improved platform for set point optimisation.
- For an Upstream topsides process plant, the operating strategies derived from model-based optimiser runs, are, typically, straightforward to encode within an advanced multivariable controller.

The Azerbaijan Field Optimiser

The scope of the Azerbaijan Field Optimser (AFO) is multi platform covering the East Azeri, West Azeri and Central Azeri platforms together with gas processing and power generation on the Compression and Water Injection platform, and oil and gas processing in the shore based Sangachal terminal.

Due to the large number of platforms and units, model validation against plant data is a major challenge for the asset team. Hence, the software has been explicitly enhanced to support the user in this process leading to optimisation. The design of the AFO explicitly recognizes that the workflow of the engineer within the AFO, as he/she carries out an optimiser run, is complex. Hence the tool provides a high level of workflow guidance to ensure the application can be applied correctly and valid advice obtained.

At current production levels, oil and gas processing constraints are starting to contribute to production losses in Azerbaijan. Hence the optimisation technology has become a key component of the assets daily optimisation process. Recent case studies with the AFO have shown that a significant optimisation prize is available from regular daily optimisation in support of operational decision making.

Key additional learnings from this work include:

- For a large, multi-asset, optimisation application, the optimisation workflow is complex. Hence the user interface should be designed to support the user's workflow, from data input though analysis to results, in such a way that assurance is provided, to the end users, on the validity of the insights being developed.
- The interpretation of output from large optimisation runs is a challenging aspect of model based optimisation. The technology focus needs to be on developing new capabilities to support the derivation of operational insights that will lead to value when implemented.
- As expected, the implementation of optimisation technology within a large multi-asset system is significantly more complex than for a single asset. The role of the technology within the overall optimisation process needs to be fully understood and supported by key stakeholders representing the individual operating assets.

Schiehallion gas-Lift optimisation

During 2007 BP's Schiehallion asset has been successfully piloting FIELD OF THE FUTURE's new approach to short-loop optimisation called Model Based Operational Support (MBOS). At Schiehallion, MBOS is focused on gas-lift allocation and optimisation. The Schiehallion production system comprises approximately 20 gas-lifted producing wells with sub-sea manifolding into up to nine risers. Flow regimes in the risers are often unstable. Flow stability in risers can be influenced by individual well and gas-lift rates. There is a significant optimisation prize for Schiehallion from the mixed-integer optimisation of wells to risers subject to constraints defining regions of stable operation..

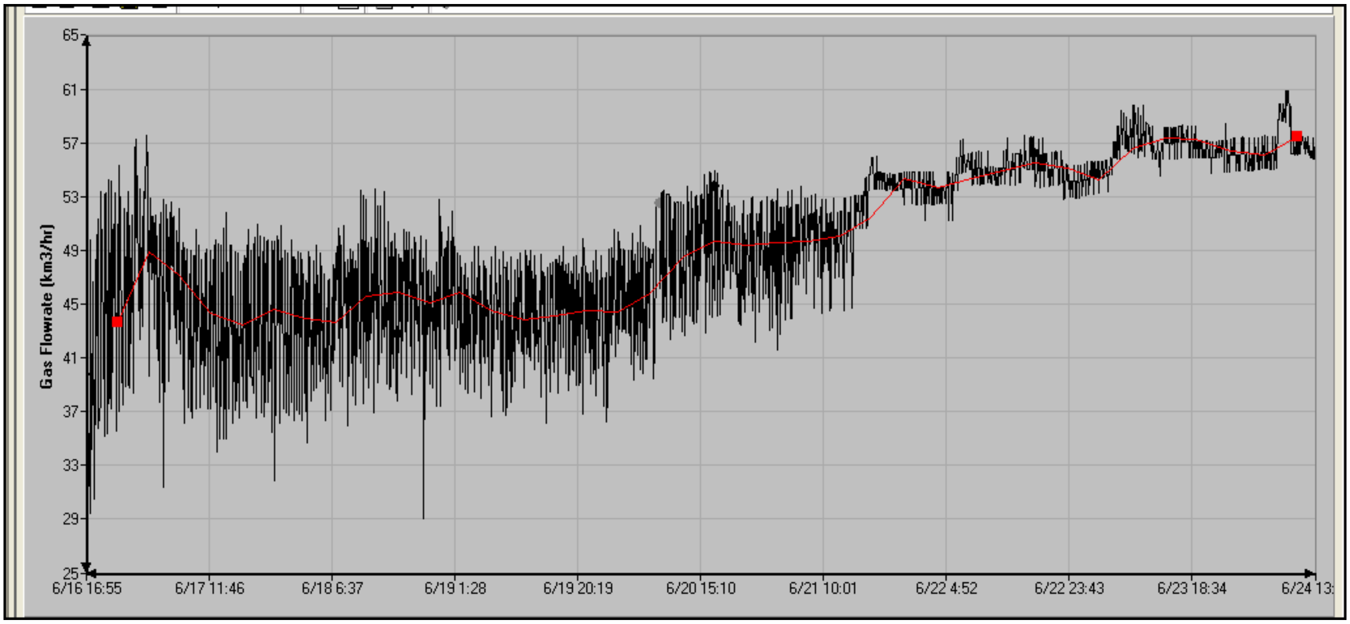

Figure 2. Reduced process variability and optimiseed gas throughput at Schiehallion

The Schiehallion operations support team has many challenges to address on a daily basis, in particular maximizing the availability of plant whilst seeking opportunities to increase production. In practice, operational improvements can be readily achieved by, firstly, making operational changes to improve stability and, secondly, by making changes to reduce back pressure in the common manifolds and risers. These improvements can often be identified, without recourse to formal optimisation, by simple what-if model runs supported by visualisation aids to identify stable and unstable operating regimes.

As operating performance improves and operation more closely approaches optimum conditions, then the formal optimisation techniques become necessary to allow additional benefit to be obtained Figure 2 illustrates the operational improvements that have been achieved at Scheihallion with MBOS – firstly a signifiant reduction in process variability followed by an increased gas throughput as operators push closer to gas handling constraints.Overall, the sustained production gain has been around 1-2% and the approach is being taken up by other similar North Sea assets.

Key additional learnings include:

- All assets will vary in the degree to which they approach optimum conditions in day-to-day operation. Where operation is a long way from optimum, the use of models for simple what-if simulation can deliver significant operational improvements.
- The environment in which the optimisation technology is housed can contribute significantly to the success of the implementation and the perception of the technology within the asset.

The way forward – A summary of high-level learnings from BP's Optimisation Experience

BP's Field of he Future R&D programme is focused on delivering a robust optimisation capability that can be applied at scale and pace to appropriate operating assets in the BP federation. In order to achieve this, the FIELD OF THE FUTURE Technology unit is learning the key lessons from past experience and addressing these in the design of the future product. As a direct result, 2007 has seen a new approach to model based optimisation being prototyped successfully on a number of assets in the North Sea. It is possible to summarise here some of the key learnings that are underpinning the development of this new capability. These can be summarised under the headings of technology, people and process:

Technology

- Upstream asset optimisation tools need to be as simple as possible, robust and easy to learn and use.
- Tools need to provide advice on stabilizing operations (reducing variability) as well as pushing constraints.
- The scope and limitations of the modelling tools need to be well understood by the asset teams.
- Tools needs to easily adaptable and rapidly configurable. The window of opportunity for optimisation can be quite short as an asset moves rapidly though the life-cycle from ramp-up to later life decline.
- Optimisation technologies need to be able to formally assess the impact of data and other uncertainties on the advice provided to operations.
- Advanced Control is likely to be the appropriate technology for deploying closed-loop optimisation on most upstream plants.

People

- Operating knowledge is inherently more sustainable than set-points. Given the challenges faced on an upstream plant, the current focus of optimisation technology should be on off-line usage to develop operator knowledge and understanding of the plant.
- The skills to develop, deploy and use optimisation tools are in short supply.. Hence organizational capability needs to provide a career path for engineers such that optimisation discipline health can be sustained and new recruits attracted to the opportunities.

Process

- Optimisation technology should be introduced gradually, starting simple and adding complexity as required with a value-driven approach.
- The primary role of an optimisation tool is to act as a catalyst for a strong cross-disciplinary conversation, the result of which is a more complete understanding within each discipline team of the full impact of decisions made within the discipline.
- With current technologies, it is better to introduce model based optimisation technology within an onshore support team rather than, within an off-shore (troubleshooting) environment. Optimisation technology should not distract offshore operators from their primary role of ensuring safety and integrity.
- There are a limited number of optimisation workflows that are common to many upstream operations. A toolkit designed to support these workflows can be rapidly reconfigured and re-deployed.
- Snapshots of data can be unreliable when used to verify asset models as the basis for optimisation. Typically models need to be analysed and verified against time dependent data such that trends in model parameters can be understood.

Conclusions

BP has a long case history associate with model-based optimisation. Most of these projects have delivered significant benefit but have proven difficult to sustain. Learnings from these experiences are being captured to define a new model based optimisation capability to fulfill the short-loop optimisation capability within the FIELD OF THE FUTURE programme. BP is already starting to benefit from this technology in the form of an early prototype deployed on a small number of North Sea assets. Looking ahead, 2008 will be a critical year for this new approach as *BP* seeks to demonstrate that the capability can be rolled out across a significant proportion of BP's operating portfolio.

References

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