Benefits of Detailed Compressor Modelling in Optimising Production from Gas-Lifted Fields

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THE IMPORTANCE OF COMPRESSOR PERFORMANCE IN GAS-LIFT OPTIMISATION

Gas-lift is one of the major artificial lift methods employed for oil production. In implementations where there is no external source of high pressure lift-gas (eg, a gas field nearby), compressors are used to provide the lift-gas supply by recycling the low pressure associated gas produced with the oil. Figure1. shows a schematic of a typical gas-lifted production system. Lift-gas leaving the discharge side of the compressors travels through a distribution network to the individual wells, and returns to the production separators along with the fluids (oil, gas and water) produced from the reservoir. The gas is separated from the liquids, and passes to the compressors and from there back to the wells.

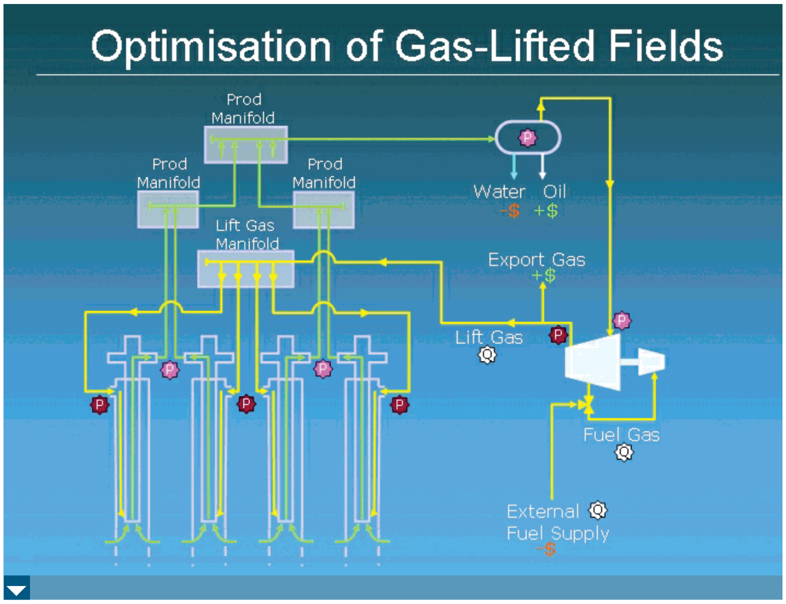

Optimisation of Gas-Lifted Fields

Figure 1

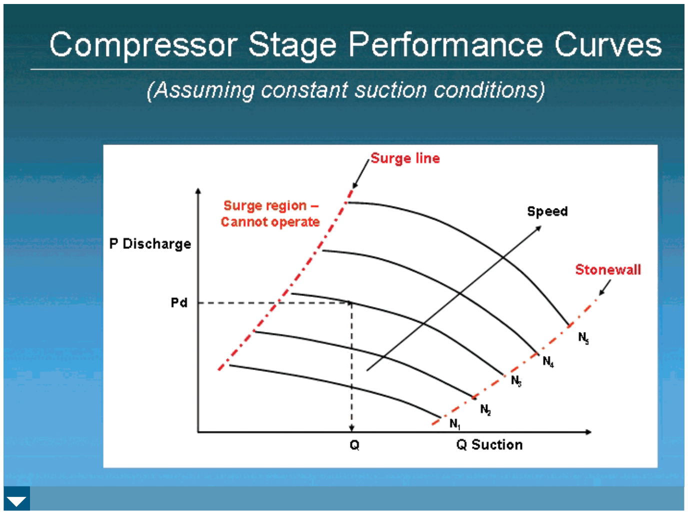
Traditional optimisation methods have focused on the combined performance of the production side of the system: ie, the wells and the pipe network that carries the produced fluids to the separators. However in order to fully optimise the total system, it is necessary to also consider the lift-gas side, including the compressors.

The most important behaviour characteristic for compressors with regards to total system optimisation is that the power required to drive the compressor increases with flowrate and pressure rise. Therefore for a given amount of power available, increasing the flowrate reduces the pressure rise that can be achieved, and vice-versa. This leads to the following dependencies with other parts of the system:

- Compressor flowrate controls the total lift-gas available. For each well, there will be an optimal lift-gas rate which maximises its production rate or net revenue contribution at the prevailing conditions. Ideally, the total lift-gas available should be equal to the sum of the optimal lift-gas rates to all of the wells. If it is lower than this, the lift-gas rate allocated to some of the wells will need to be lower than the optimum.
- Compressor suction pressure controls the minimum allowable separator pressure. In general, there is a trade-off between lowering the separator pressure to reduce wellhead pressures and increase well deliverability, and reducing the total lift-gas available due to the increased pressure rise.
- Compressor discharge pressure controls the maximum lift-gas pressure available at the individual wells. This in turn controls the maximum lift-gas rate into the well, and also the maximum depth at which the gas can enter the tubing to reduce the density of the fluid column: in general, this should be as deep as possible. There is therefore a trade-off between maintaining a compressor discharge pressure which is sufficiently high to provide the desired lift-gas pressure at the wells, and the effect of the increased pressure rise on the total lift-gas available.

Most large-scale implementations of gas-lift use centrifugal compressors, and these are further constrained by the surge and stonewall aerodynamic limits (see Figure 2). The compressor cannot be operated to the left of the surge line, or to the right of the stonewall line.

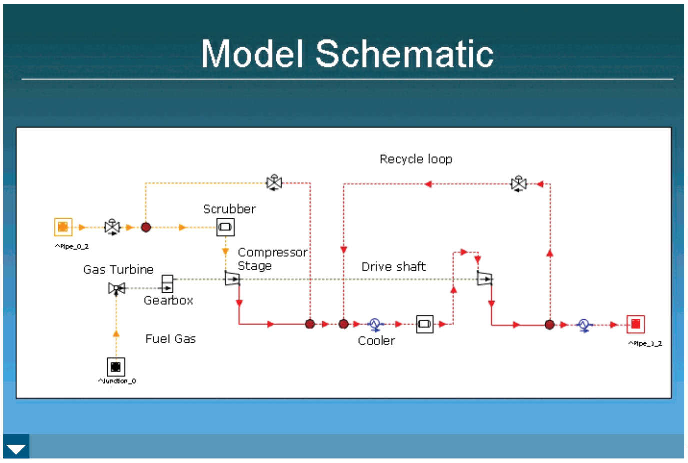
If gas turbines are used to drive the compressors, then the power available cannot be assumed to be constant. The power available from a gas turbine is dependent upon ambient temperature, and in a region such as the Gulf where there is a large seasonal fluctuation in air


Compressor Stage Performance Curves

(Assuming constant suction conditions)

Figure 2

temperature, the power available in the summer can be 15 per cent lower than in the winter. The power available may also reduce between overhauls.



Model Schematic

Figure 3

THE DETAILED COMPRESSOR MODEL

ReO, the Resource Optimiser software from Edinburgh Petroleum Services Ltd, has the ability to optimise large and complex gas-lifted fields, while taking into account the interactions between the various elements of the total system. The detailed compressor model incorporated in this software has the ability to represent the key features of compressor performance described previously. A schematic of a detailed compressor model in ReO is shown in Figure 3. The engineer is able to construct a model representing the configuration of his particular multi-stage compressor system, using objects such as gas turbines, compressor stages, inter-stage coolers and scrubbers, and control valves.

The gas turbine object contains a performance map which defines the maximum power available as a function of power turbine speed, and also the variation of efficiency with operating conditions, allowing the calculation of fuel-gas consumption. A correction can be applied to the performance map to account for changes in ambient temperature. The compressor stage object contains the performance map shown in Figure 2; it is expressed in dimensionless form, allowing the complete performance surface to be represented by just two curves.

BENEFITS OF DETAILED COMPRESSOR MODELLING

Applications of ReO's compressor model to gas-lifted fields worldwide have shown the following benefits:

- Separator pressures have been lowered, resulting in increased production. The model allows the optimum separator pressure to be quickly calculated for current field conditions. Without such a model, the calculation is complex and time-consuming, and is therefore performed infrequently, if at all. In addition, field production staff are rightly concerned about minimising downtime, and may be tempted to set the separator pressure higher than strictly necessary, to avoid trips.
- Discharge pressures have been lowered, increasing total lift-gas availability. The model allows direct calculation of the discharge pressure which gives the best compromise between the minimum pressure required at the wells and compressor throughput. Once again, in the absence of such a model the calculation is complex and time-consuming, and is therefore rarely performed.
- Compressor operating costs have been reduced and availability has been increased. In some cases, the optimiser has recommended that whole compressor trains are surplus to requirements, allowing them to be shut down. This results in reduced maintenance costs and increased availability since the stopped machine becomes reserve capacity. Even where a train cannot be shut down, it may be possible to run it at a lower percentage of rated power, which increases the run-life between overhauls.

Interestingly, although there appears to be potential for saving operating costs by reducing fuel gas consumption if compressor power is reduced, experience suggests that the savings are negligible, even in cases where the fuel gas is purchased from an external source such as a utility. The main reason for this is that the variation in a gas turbine's fuel consumption with power output is too small to play a significant part in the optimisation.

- The model results in a superior shared understanding of total system behaviour between staff from the various engineering disciplines involved in field operations, particularly petroleum engineers and compressor operating and maintenance staff.

In conclusion, gas-lifting remains an important technique to enhance the production of mature oil fields. In many fields the current practice is to optimise individual wells, or occasionally to include the production gathering network in the optimisation process. Recent developments such as EPS's ReO software allow a more holistic approach to be taken, enabling the optimisation of the total system including the compressors. This approach delivers increased net revenue, and also provides operational benefits ■

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ABOUT THE AUTHORS

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