Public Summary

A challenging task for operators of gas fields is to operate wells and platform equipment and to optimize their (gas production) performance. This can be a complex job due to phenomena such as salt precipitation, liquid loading and compressor degradation. These phenomena involve physically complex processes that make it difficult to predict well and equipment performance. Therefore, it is difficult to assess how to operate optimally, since it requires an optimal scheduling of remediation treatments such as washing of wells due to deposited salt or scheduling of maintenance in case of degradation of compression equipment.
The goal of the project is to develop and demonstrate technology that can assist the operator in their demanding task by providing strategies to optimize well and equipment performance. As some of the aforementioned phenomena can take place on short time scales (hours to days), real time monitoring of the platform units (wells, turbines, compressors etc.) is a necessity. Furthermore, to be able to assess optimal strategies for production performance, physical-mathematical models of the platform units are required that exhibit predictive capabilities. At TNO several projects have been executed in the past to develop Real Time Production Optimization (RTPO) systems. The project addressed in this report builds further on the earlier developed RTPO framework at TNO and extends in particular on the optimization aspects and associated modelling.
For proper optimization performance the physical models used should be able to make reliable predictions of future behavior. An important aspect of the project is to introduce a feedback mechanism into the optimization algorithms that is capable of detecting a growing mismatch of predictions of the models used with real time monitored data and to adjust the models (model update) to correct for these mismatches if the deviations become too large.
A number of RTPO demonstration cases have been defined at the start of the project using the producing gas asset F16_E18 of Wintershall as illustrative underlying real field case. F16_E18 is a mature gas field of which wells are known to suffer from salt precipitation and is therefore a good candidate for demonstration of the developed technology. The four demonstration cases that have been set up to validate the newly developed optimization and modelling concepts are:

- Case 1: Optimization of washing times of gas wells suffering from salt precipitation,
- Case 2: Turbine performance monitoring,
- Case 3: Compressor performance monitoring
- Case 4: Prediction of short term cumulative gas production of the asset.

A major activity in the project was to prepare the real time monitoring environment at Wintershall such that it is aligned with the research environment at TNO and can be used for the demonstration cases intended. For the latter special attention was needed to the databases used at Wintershall and the sample rate of the measured data available in the databases. A second main activity was to find data in the databases that has sufficient quality (e.g. no data gaps) to perform the demonstrations on and to smoothen the data such that it can be used for the optimization algorithms. A third major task was to develop models for each case (e.g. a salt model for case 1) that, through history matching describe degradation

(e.g. performance decline due to salt precipitation) as monitored and is able to predict performance degradation in a reliable and accurate way.

For Case 1, a workflow has been developed and implemented in the RTPO framework that enables optimization of washing times for individual wells experiencing performance decline due to salt precipitation. We note that the washing remediation process needs to be repeated cyclically so that the optimization process is repeated over and over in time. For this, a model was developed to predict the well's inflow reduction caused by salt precipitation. This so-called *salt model* is calibrated using historical data of a predefined number of washing cycles to ensure predictive capabilities. Important aspect of the developed workflow is the incorporation of a feedback procedure for calibrating the salt model in case a well's behavior deviates significantly from modelling results. This makes the workflow a closed loop optimization workflow.

For Case 2 and 3 the goal was to develop and implement a workflow for monitoring and predicting performance decline of turbines and compressors, in order to assist operators to optimally schedule the maintenance. It was found that thermal efficiency is the best parameter to monitor degradation of the turbines. The isentropic efficiency is found to be the best parameter to monitor degradation of the compressors. A full-blown closed loop optimization workflow as developed for Case 1 was not found practical for these two cases as degradation appears to be modest and is occurring on a much larger time scale, typically in the order of months. In fact, for our field case, degradation was not widely observed in the F16_E18 turbines.
Workflows have been formulated for equipment performance monitoring. In addition, for Case 3, the effect of maintenance scheduling of the compressor on production gain was investigated, showing a significant impact on production.

The RTPO framework connects the units, among them the wells, turbines and compressors according to the platform configuration. Given human controllable settings such as choke positions, rpm's of compressors and the export pressure, the framework can calculate, using nodal analysis methods, the cumulative platform gas production. In Case 4, the RTPO framework is used to demonstrate its capability for short term prediction (typically 1 to 3 months) of the full platform cumulative gas production given a future scenario for the human controllable settings. This capability has been tested on a historical time frame to be able to compare the prediction results with field measurements. It was found that the prediction matches well with the measured data corroborating the short term predictive capabilities of the RTPO framework. This capability can be used to explore future production scenarios to enhance production or ultimately and more systematically through optimization of the controllable settings. This was however outside the scope of this project.

Part of the work described in this report was presented at the SPE workshop Gas Well Deliquification in Amsterdam, 10-11 October 2016. For 2017 Wintershall has the intention to implement the results of the project as a "beta version" into the monitoring systems of its gas production assets in the North Sea.

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